



Radio Technology and Systems Assessment

Final Report

PREPARED DECEMBER 2017 FOR
STORY COUNTY, IOWA

Table of Contents

Executive Summary.....	1
1 Introduction	4
2 Methodology.....	5
2.1 Historical Reports and Documentation	5
2.2 Stakeholder Interviews and Focus Group Interviews.....	5
2.3 Frequency Analysis.....	5
2.4 Site Evaluations	5
2.5 Report Development	6
3 Findings and Analysis	6
3.1 Existing Radio and Paging System	6
3.2 Coverage	8
3.2.1 Existing Radio Coverage.....	8
3.2.2 Existing Paging Coverage	9
3.3 Capacity.....	9
3.3.1 Loading for Trunking Systems	11
3.4 Tower Sites.....	12
3.5 Interoperability	14
3.5.1 Inter-County.....	14
3.5.2 Neighboring Counties and State Agencies	15
3.6 Backhaul.....	16
3.7 Frequency Considerations	16
3.7.1 Current Frequency Band 800 MHz	16
3.7.2 VHF	17
3.7.3 UHF	18
3.7.4 700 MHz	18
3.7.5 800 MHz	20
3.8 Subscriber Radios and Dispatch Consoles	21
3.9 Paging	22
3.9.1 Tone and Voice	22
3.9.2 Alphanumeric	22
3.9.3 P25 Trunked Paging (Unification)	23
3.10 Stakeholder Operational and Performance Needs Interviews.....	23
3.10.1 System Concerns	23
3.10.2 Coverage Concerns	24
3.10.3 Future System Requirements	25
3.10.4 Subscribers	25
3.10.5 Summary of User and Stakeholder Requirements	26
3.11 System Lifecycle	26
3.12 Radio System Technologies	28

3.12.1	Non-Public Safety Radio Systems	28
3.12.2	Multicast Trunking	28
3.12.3	Simulcast Trunking.....	29
3.12.4	Project P25.....	30
3.12.5	Phase I (FDMA).....	32
3.12.6	Phase II (TDMA).....	33
3.12.7	FirstNet and Long-Term Evolution	33
3.12.7.1	LMR over LTE	34
3.12.8	Push-to-talk over Cellular	34
3.13	Shared Systems/Regional Systems.....	35
3.14	Summary of Findings and Analysis.....	36
4	Recommendations	37
4.1	System Technology	37
4.1.1	Option 1 – Build County-Owned P25 Phase II Radio and Paging Systems	37
4.1.2	Option 2 – Join a Regional Radio System	38
4.1.2.1	Option 2a – Iowa Statewide Interoperability Communications System (ISICS) (Motorola)	38
4.1.2.2	Option 2b – RACOM SARA Radio Network (Harris).....	39
4.1.3	Conceptual Radio System Design	40
4.2	Recommended Paging Solution.....	41
4.2.1	Describe the Methodology	41
4.2.2	Conceptual Paging System Coverage	41
4.3	Recommended Radio and Paging Sites.....	41
4.3.1	Department of Transportation – Ames, Iowa	41
4.3.2	Colo, Iowa – Radio and Paging Site	42
4.4	Frequency Band	43
4.5	Backhaul.....	43
4.6	Subscriber Radios and Features.....	44
4.6.1	Encryption	45
4.6.2	Over-the-Air Programming	46
4.6.3	Over-the-Air Rekeying.....	46
4.6.4	Global Positioning System	46
4.7	Radio Dispatch Console.....	46
4.8	Logging Recorder	47
4.9	Bidirectional Amplifiers.....	47
4.10	Budgetary Cost Estimates	48
4.10.1	Option 1 – Story County-Owned, 800 MHz, P25 Phase II, Trunked Simulcast System.....	48
4.10.1.1	Capital Investment.....	48
4.10.2	Option 2a – Join ISCIS (Motorola)	50
4.10.2.1	Capital Investment Option 2a.....	50
4.10.3	Option 2b – Join SARA (RACOM/Harris).....	52
4.10.3.1	Capital Investment Option 2b.....	52
4.11	Lifecycle, Maintenance, and Sustainment Costs.....	55
4.12	Next Steps.....	56
4.12.1	Competitive Procurement.....	56

4.12.2 RFP with Multiple Awards	57
4.12.3 RFP Competitive Procurement with Existing Contracts	57
4.12.4 Schedule	58
5 Conclusions.....	58
Appendix A – Existing 3 site Composite Coverage Map	60
Appendix B – Properly Engineered and Licensed Paging System	64
Appendix C – County Owned System Maps	67
Appendix D – RACOM Maps	72
Appendix E – ISICS Maps	82

Executive Summary

Mission Critical Partners, Inc. (MCP) respectfully submits this Radio Technology and Systems report to Story County 911 Service Board (the Board). The Board contracted with MCP to assess its existing 800 megahertz (MHz) Motorola Privacy Plus radio communications system and very-high frequency (VHF) paging system, to provide a thorough analysis of alternative solutions, and to determine the best approach for replacing the systems and improving radio communications within Story County (County).

MCP confirmed that the radio system is based on an architecture and equipment that is no longer supported by the manufacturer and the system is not public-safety grade. The paging system is operational but was not designed for its intended use, and lacks coverage and reliability.

Based on deficiencies identified by system users and the data collected, MCP recommends implementation of new radio and paging systems consisting of standards-based, public safety-grade equipment, which will provide cost savings while enhancing coverage, capacity, reliability, backhaul capabilities, and subscriber devices. Given the age of the legacy equipment, and the recent failures that County's radio and paging systems have endured, MCP recommends immediate replacement of both systems.

Story County is in an unusually unique position in that it currently has two regional radio systems from which to choose: the Statewide Interoperable Communications System (ISICS), which is operated by Motorola Solutions, and the Shared Area Radio Agreement (SARA) network—operated by RACOM Corporation, a Harris channel partner—which interconnects dozens of Project 25 (P25) radio towers across the state.

MCP recommends joining a regional system, which provides a significant opportunity for cost savings, both in terms of capital investment and long-term sustainment. Each of these regional radio systems has similar features and offerings, and each is more than adequate to meet the requirements of Story County. Both vendors want to earn the County's business. Because both vendors equally can provide a viable solution that will meet the County's needs, MCP recommends conducting separate negotiations with each vendor. Doing so will bring more options and features at the lowest competitive price, with Story County getting the most benefit in terms of cost savings and feature and functionality enhancements.

MCP recommends the following activities to begin immediately to replace the current radio and paging systems.

1. Budget appropriate funds based on cost estimates provided
2. Begin negotiating with RACOM (Harris) and Motorola based on a minimum set of requirements
3. Select a vendor and a regional system partner
4. Execute agreements to join the chosen regional radio system

MCP recommends an 800 MHz, Project 25 (P25) Phase II public safety radio system. Based on MCP's calculations, eight talk paths or five channels are needed to provide a sufficient level of capacity for Phase

II subscribers. MCP recommends a procurement method that allows for the option of sharing system technology, either by joining ISICS or the SARA network. An IP-based, loop-protected microwave system providing minimum throughput of 150 megabits per second (Mbps), and connecting all radio sites and dispatch centers, is the ideal backhaul solution. A replacement paging system operating in the general public safety frequency pool is the optimal paging solution to allow users to reuse their existing pagers.

All of the evaluated options would provide improved coverage through the addition of radio sites with a delivered audio quality (DAQ) score of 3.4 and 12 dB in-building coverage throughout 95 percent of the County. MCP recommends an in-building coverage requirement for dense structures throughout the heavily built-up areas of the City of Ames (Ames) and Iowa State University (ISU). To accomplish this level of coverage, MCP has identified the Department of Transportation (DOT) Site in Ames, and a site in the town of Colo. Most of the total cost of ownership is in leasing sites. Site leases for vertical space on towers average \$4,000 per month with a 3 percent escalator year over year. For a single site, this could result in paying more than \$1.3 million over 20 years to lease a site. This cost estimate does not include possible modifications to existing towers, which would be the responsibility of the County. MCP thus recommends that, in lieu of paying for long-term site-lease costs, the County should own its sites. The return on investment is realized within seven years, or less, when building a new tower site.

Cost estimates, based on budgetary pricing, have been developed for each option. These costs are inclusive of radio site electronics equipment, backhaul network, tower site facilities (i.e., tower and shelter modifications), paging system, and vendor services. The cost estimates are intended to be conservative to account for variability during procurement. The table below summarizes the estimated costs for each system option prior to negotiations, discounts or incentives from potential awarded vendors. Typical industry discounts are in the 30 percent range depending on the size and system proposed. The price for a 35 percent discount is included to account for any discounts negotiated during the procurement phase of the project as well as prices realized by leveraging state or county contracts.

Table 1: Estimated Budgetary Cost Overview

	Option 1	Option 2a	Option 2b
System Description	Standalone 800 MHz P25 Phase II	Join ISICS 800 MHz P25 Phase II	Join RACOM SARA 800 MHz P25 Phase II
*Radio System	\$3,527,708	\$1,954,578	\$1,801,457
Backhaul	\$450,544	\$450,544	\$591,672
Paging	\$84,228	\$84,228	\$84,228
Facilities	\$708,043	\$708,043	\$739,322
**Dispatch Consoles	\$697,836	\$697,836	\$697,836

	Option 1	Option 2a	Option 2b
Subscriber Equipment	\$5,076,345	\$5,076,345	\$5,076,345
PM, Engineering & Implementation***	\$3,074,053	\$2,426,771	\$2,413,669
Total	\$13,618,757	\$11,398,345	\$11,404,529
30% Discount	\$9,533,130	\$7,978,842	\$7,983,170
* Includes FCC licensing and system options (OTAR, OTAP, P25 over cellular, logging recorder) ** Assumes 12 dispatch positions and four dispatch consoles at each site. *** Includes 5 percent contingency of system costs			

The typical implementation period for a radio system is 18 to 24 months. Consequently, given the necessary planning and procurement tasks, it may be two years before a new system is implemented and operational. With the challenges faced by the existing system, time is of the essence. The estimated completion date for all users migrated to the new system is the first quarter of 2020.

MCP fully understands the challenges faced by the Board and what must be accomplished to provide a long-term communications solution that will satisfy the needs of first responders in Story County. MCP is available to assist the County with its planning, procurement and implementation needs.

1 Introduction

Story County (County), City of Ames, Iowa State University (ISU) and all agencies within the County currently operate on a three-site, 800 megahertz (MHz) Motorola Privacy Plus radio communications system. The system consists of non-public safety technology, has reached end of life (EOL), is no longer supported by the manufacturer and is not Project 25 (P25) compatible. Fire and emergency medical services (EMS) agencies use a countywide, very-high frequency (VHF), analog tone-and-voice paging system located at three sites, which has demonstrated reliability issues. The system is faced with critical component failures and is operating with equipment that is far beyond the EOL projections. Plagued with degradation in reliability, numerous coverage gaps, and limited capabilities, the Story County 911 Board (Board) has determined that a substantial investment for system replacement is necessary. The Board tasked Mission Critical Partners (MCP) to assess its current radio and paging systems, and to provide cost-effective recommendations for replacing them.

The County is located in the center of Iowa approximately 30 miles due north of Des Moines. The County has an approximate population of 96,000 and is home to ISU. Ames is the largest city, with an approximate population of 66,191 people. The Board is the coordinating entity that provides voice and data communications that serve both public safety and non-public safety agencies within the County's geographic boundary. This includes providing emergency and non-emergency response voice communications to Story County, City of Ames, ISU, law enforcement, fire, emergency medical services (EMS), hospitals, local schools, County road departments, and public works. The Board expects the current level of interoperability to be maintained with any options proposed for the new radio and paging systems.

For the purposes of this report, the terms "Story County" and "County" reference all public safety and non-public safety entities, users, supervisors, and stakeholders that are within the county's geographic boundary and have an involvement with the radio and paging systems. This report also will reference the radio system as "the County's radio system," with the preface that Electronic Engineering (EE), the commercial vendor that owns the radio system, rents the infrastructure on a fee basis to the users within the County. The paging system is owned by the Board.

The Board tasked MCP to assist with the replacement of the radio and paging systems. This included reviewing past reports, conducting stakeholder and user interviews, and evaluating frequency bands. Specifically, through a collaborative approach with the Board, MCP assessed the existing radio system, evaluated user needs regarding the new systems, and proposed options for a new, standards-based P25 system to replace the County's existing radio system, to improve coverage, capacity and reliability, and to maintain direct interoperability within the County. In addition, MCP assisted in reviewing the condition of the existing countywide paging system, and developed recommendations for improving or replacing it.

2 Methodology

2.1 Historical Reports and Documentation

MCP conducted a comprehensive review and analysis of two previous reports titled “Story County Paging System Assessment Report,” dated January 30, 2017, and “Story County, Iowa, Radio Communications Study,” dated November 3, 2010. The information contained within these reports was used when compiling current radio and paging information for this report. The information within the reports was verified during our discussions with Story County personnel.

2.2 Stakeholder Interviews and Focus Group Interviews

Stakeholder and user interviews with the County, City of Ames, and ISU personnel were conducted from October 10 –12, 2017. The interviews were held with various focus groups with a cross-sampling of stakeholders, users, and key personnel from law enforcement, fire, EMS, emergency management, public works, transportation, and other agencies as requested by the County. The purpose of the focus group interviews was to capture an understanding of the current radio and paging systems, and to document user concerns, from both technological and operational perspectives. MCP focused on current system deficiencies and future requirements that impact coverage, capacity, interoperability, equipment features and system operations.

2.3 Frequency Analysis

MCP used the Federal Communications Commission’s (FCC) Universal Licensing Service (ULS), Spectrum Watch database and Antenna Registration System, as well as the Computer Assisted Pre-Coordination Resource and Database (CAPRAD), to perform a thorough review of available radio spectrum. The FCC ULS (<http://wireless.fcc.gov/uls>) is an online tool that simplifies the application and licensing process, and enables research of applications and licenses. Spectrum Watch (<http://www.spectrumwatch.com/>) is an online planning and licensing software application used to find and apply for available licenses in various frequency bands. CAPRAD (<http://caprad.org/>) is a nationwide database for public safety professionals to coordinate the application and licensing of frequencies in the 700 MHz band. MCP compiled a list of available radio channels for Story County. Searches performed were limited to the VHF, ultra-high frequency (UHF), 700 MHz, and 800 MHz bands, to determine what public safety frequency pools have sufficient available spectrum in the area to support a new land mobile radio (LMR) system.

2.4 Site Evaluations

MCP visited a cross sample of sites that comprise the radio communications and paging system, to evaluate user concerns and document the existing systems’ infrastructure, assess the condition of existing facilities, record deficiencies, and evaluate the sites’ ability to support new or upgraded equipment in the future. Story County personnel had detailed knowledge of the radio and paging sites and reported that the

sites were similar in configuration and condition. In addition, MCP surveyed two dispatch centers to document the current console features and how the consoles are used operationally.

2.5 Report Development

Based on the information gathered, MCP documented critical issues affecting the current radio and paging systems, and formulated conceptual options that are available to the County. MCP used information collected from the stakeholder interviews, spectrum research, and vendor meetings to develop solutions that would address the issues affecting users of the radio and paging systems, in terms of coverage, capacity, interoperability, system features, and long-term sustainability.

MCP accounted for the County's needs and priorities shared during the stakeholder interviews to migrate from the existing radio and paging systems to new radio and paging systems. The recommended design for these systems focused on improving coverage and reliability, and maintaining interoperability, to public safety-grade standards. For each option, MCP has provided cost estimates and a comparison of advantages and disadvantages. Recommendations have been provided based on the solutions MCP believes best satisfy the requirements for Story County, City of Ames, and ISU users.

3 Findings and Analysis

3.1 Existing Radio and Paging System

The County currently uses a three-site, 800 MHz, Motorola Privacy Plus specialized mobile relay (SMR) system for public safety communications. The system originally was installed in the early 1980s by Electronic Engineering (EE) in Des Moines, Iowa, to provide trunked repeater service to commercial entities. Story County leases the infrastructure and pays for radio service, similar to a utility, paying a monthly recurring fee of approximately \$13.50 per subscriber based upon the number of subscriber radios operating on the system. Three sites are operational: the primary site in the City of Alleman; a secondary site in Ames; and a third that was added specifically to provide coverage on the ISU campus. Each site consists of a site controller, multiple repeater stations and an antenna system. Each radio site works independently of each other, a configuration known as site trunking; this configuration requires the user to select the radio site to operate on, and does not offer the capacity or coverage that would be provided by three interconnected multicast or simulcast sites.

The analog system previously was evaluated in 2010 by Elert and Associates, an information technology (IT) consulting firm based in Libertyville, Illinois. Since then, no system upgrades or refreshes have been implemented. The system in the early 1990s reached end of life, and no longer is supported by Motorola. Further, system components not only are aging but also are becoming increasingly unavailable. While the County appears to have an adequate supply of radios capable of operating on the system, these too are getting old. The previous assessment indicated that the system was operating on "borrowed time." Since then, no spare parts are available from the manufacturer and the system is at significant risk of failure that, depending on the type, might not be rectifiable. Indeed, it previously was noted that most system users

have experienced an outage at some point. While it is advantageous to have two backup sites to guard against failure of the primary site, the method for switching to them reportedly is cumbersome, requiring users to know how and when to change channels and sites. Further, an instance was observed when one user group was told to change to a backup site, but it did not appear that any other users were given notice to change to the backup system.

As reported by the users, the system provides less-than-adequate performance for day-to-day operations and interoperable voice communications. There are areas within Ames and throughout the County where public safety users know the system will not provide radio coverage, features, or interoperability, and that they cannot rely on the radio system or the backup system. Users also uniformly shared, in different interviews, that the radio and paging systems lacked capacity and that system busies were frequent. During our interview with EE, MCP requested radio system data on capacity performance; however, EE determined that this is competitive information regarding its commercial system, and the information was not provided.

Coverage has been an issue over the years at times, primarily because the system was designed for commercial operators, and not public safety communications. If the number of users increases, additional channels are added to accommodate the increased traffic. During interviews with the current service provider, they shared that channels have been turned off since the 2010 radio assessment to support their latest generation, commercial two-way radio system. Alleman is the primary system site, because it has the best coverage. However, that site is more than 10 miles outside Story County; this site location was chosen because the majority of coverage and users are located in Polk County. With most of the coverage in Polk County, Story County is lacking targeted coverage tailored specifically for the users in the County, the City of Ames, and the ISU campus.

The County's multisite, VHF paging system is used to dispatch fire/rescue and EMS response. A UHF link is used to relay the paging tones generated by the console equipment from three UHF transceivers to the VHF transmitter.

Elert and Associates assessed the paging system in January 2017. This assessment found that some rural fire departments consider the paging system to be unreliable. Most users interviewed shared that the system performance between pages was inconsistent and unreliable. The current paging system is set up like a simulcast system. However, there is no simulcast equipment controller for broadcasting, nor is the current equipment within specifications to allow for stable simulcast operation.

The simulcast problem is that the paging system transmits simultaneously from three sites on the same frequency, but the equipment needed to control frequency, phase and amplitude is lacking; the consequence is that interference from the system itself can occur in areas where coverage overlaps, resulting in pages regularly not being received. Even if simulcast equipment was added, the current repeaters cannot utilize the simulcast controllers. Ultimately, the current paging system cannot be modified to address this limitation.

As with the County's radio system, however, the critical issue affecting the paging system is age. It has reached end of life and no longer is receiving manufacturer support. While components still are available

through aftermarket and used-equipment suppliers, the availability will continue to diminish over time, which increases the risk of a system failure that, again, may not be rectifiable.

In its review of the previous Story County radio and paging system assessments, MCP found that little, if anything, has changed regarding these systems in the ensuing time period. As such, we concur with the findings and the recommendation to replace the legacy systems with a P25 digital radio system and an analog simulcast paging system, respectively.

The current radio system and paging systems are not usable for public safety operations and a replacement system should be considered immediately. Based on user interviews, previous consultant reports, and site inspections, these systems should be abandoned as soon as possible, for numerous reasons, which are summarized below:

- No spare parts are available for the radio system
- Radio system utilizes proprietary technology
- Voice channels are being shared with other commercial radio systems, diminishing capacity
- No interoperability with other P25 users
- Frequent radio and paging system failure
- Lack of coverage throughout the County
- No wide-area coverage capabilities between backup sites
- Inflexible fleet map
- No public safety features, e.g., emergency button, unit identification (ID), Global Positioning System (GPS), over-the-air programming (OTAP), and priority and preemption
- Competing with other public customers for resources without reserved channels
- Lack of integrated console
- Encryption for secure communications is not available

Further, the current paging system cannot properly or consistently operate in its quasi simulcast configuration, nor is coverage acceptable for any one site alone. This system requires a complete redesign, relicensing from the FCC, and new equipment to become an effective, reliable public safety-grade paging system. It is understood that a technical team optimized the system in May 2017, and that the system works as designed. However, the system is not engineered properly for simulcast, nor are the components capable of simulcast operation.

3.2 Coverage

3.2.1 Existing Radio Coverage

Although the current system was state of the art 30 years ago, modern public safety communications has evolved dramatically since the adoption of these systems. When Story County was a rural community, coverage requirements would have been 95 percent mobile coverage. Please see Appendix A for existing coverage. The map shown is a composite map of the three individual systems that are not connected. This coverage is inadequate for Story County.

Now that Story County has grown into a more urban area with more growth coming, public safety coverage requirements should be greater than 95 percent within buildings, accounting for a 12-decibels signal loss, which is equivalent to a medium-density building.

3.2.2 Existing Paging Coverage

There is a history of the paging system not working to the needs and expectations of the County. There were two different documents that MCP reviewed to determine the issues with this system:

1. Story County Paging Report (2016)
2. Story County, Iowa, Paging System Evaluation (May 2017)

Appendix B shows the potential of the paging system. These maps depict what the coverage would be if the system was engineered properly and if the proper licenses were provided. Because the system is not engineered properly and is interfering with itself, this coverage is not realistic; further, consistent with user observations, the coverage is degraded severely beyond reliable usage.

3.3 Capacity

The capacity of a radio system is the system's ability to provide an effective communications path for all users at any time. When a system reaches capacity, the ability of radio users to communicate is inhibited. On a trunking system, a talkgroup may be denied service because all frequencies are currently in use by active talkgroups. Capacity on a system is directly related to the number of radio channels in the system. A trunking system dynamically allocates a pool of frequencies to a pool of user groups as needed, which results in more communications capacity than that provided by a non-trunked (conventional) system.

Capacity on a radio system can be quantified on several levels. The lowest capacity level pertains to how the system accommodates day-to-day radio traffic. Day-to-day traffic coincides with the number of emergencies, which are typically higher during nights and weekends. While these incidents do not necessarily occur on a day-to-day basis, they are common enough that systems should be designed to accommodate the higher traffic loads of multiple incidents.

The next capacity level relates to planned events—such as parades, holidays, and sporting events—for which increased radio traffic will be planned. During these events, it is expected that radio usage will be higher. Story County and the City of Ames are home to ISU, whose football games can draw more than 60,000 fans from all over the region. College basketball, concerts, and other large university events all have the potential to increase radio traffic compared with normal day-to-day operations. Planned events demanding high radio usage can be accommodated by proper event planning. Radio channels can be assigned ahead of time so that users can properly manage the capacity on the radio system.

The highest capacity level relates to unplanned events—such as natural disasters—that demand a high level of radio capacity. During these events, it is likely that a radio system must accommodate both the primary users and traffic for mutual-aid response arriving from other jurisdictions to support the local

emergency response. System capacity in these events is the hardest to manage, yet can be the most critical.

As with coverage, it is important to design a radio system with sufficient capacity to meet the needs of the users. FCC guidelines recommend one radio channel for every 70 to 100 users. This is a rough estimate because actual usage depends on the operational requirements of each individual agency. A more accurate estimate of loading for trunking systems is based on Erlang calculations, which take into consideration the type of users, the frequency of radio calls, and the duration of radio calls. Ideally, coverage is designed to meet the capacity needs during the worst-case situation, not just everyday use. The issue with the current radio system in terms of capacity is that the system currently serves approximately 1,400 users in Story County, but also any user that EE allows on the system, which can include commercial users—this further diminishes system capacity. The reports from users interviewed stated several instances of system busies, which indicates the system does not have adequate capacity for Story County.

Trunking systems provide far more capabilities than conventional systems for managing system capacity. First and foremost, trunking systems are inherently more spectrally efficient than conventional systems, because the dynamic allocations of talkgroups provide a higher rate of channel reuse. Second, priority can be set on trunking systems so that access is denied to less-critical user groups when capacity is reached. Third, features such as dynamic allocation enable radio managers to remotely alter the composition of user groups and their access to the radio system. The current system does not have the capability to provide priority to public safety users over non-public safety users, or dynamic allocation; this contributes significantly to the system busies and denied access experienced by all radio system users.

Agencies within Story County operate approximately 1,470 subscriber radios. Story County does not have an accurate inventory of subscriber radios but has provided the estimated number to vendors for costing. MCP added a +/- five percent factor to account for subscriber radios that are not accounted for in the estimated inventory, for a total of 1,544 units.

Typically, growth in terms of the number of users on a radio system is a concern of local public safety agencies. During discussions with the County and user group interviews, concerns were raised regarding the County's system being unavailable due to channels becoming overloaded. MCP performed calculations to ensure that the County's next radio system has an adequate number of channels to handle both current and anticipated future capacity needs.

Using the U.S. Census data for Story County published online,¹ MCP analyzed the growth rate from 2000–2016 and found that Story County's population grew at a rate of 21.40 percent over this period. Using the historical growth rate over a 20-year period, the County potentially could add an additional 330 subscriber radios, if the projected growth trends reflect a similar increase in subscriber radios, resulting in a total of 1,874 radios. The FCC recommends 70 to 100 radios per channel, although various factors exist that may shift this range higher or lower. Specific considerations include whether the channel is used for

¹ <https://www.census.gov/quickfacts/fact/table/storycountyiowa/PST045216>.

conventional or trunked operation, the number of disciplines sharing the channel, the number of agencies sharing the channel, whether the channel is used exclusively for dispatch or also is used for tactical purposes, the average number of push-to-talk transmissions per hour per user, and the average call duration. Assuming Story County users are distributed evenly across the ten operational channels, the current County loading is approximately 180 radios per channel, well above typical FCC-recommended limits. However, based on geographic separation and user populations, it is likely that traffic is concentrated on a small subset of the channels. A minimum of one dispatch channel and one tactical channel per discipline per site is typically the minimum required to accommodate existing users.

3.3.1 Loading for Trunking Systems

Because trunking systems dynamically assign frequencies to active channels, capacity is defined as the probability that the system will not have an available frequency to accommodate a talkgroup request, resulting in the subsequent queuing of the call. Erlang C calculations can be made to determine the appropriate number of channels for a trunking system based on the number of active users, the average number of calls per hour, and the average duration of each call.

The County's current system has three individual trunking sites, operating independently of each other. The Alleman site uses 15 channels, the Ames EE site uses ten channels, and the ISU site uses five channels. It is believed that the current system is shared with other non-public safety agencies and commercial entities, which would further reduce the capacity of each site. The first channel is known as a control channel and is the "traffic director," which would give the Alleman site 14 channels for radio traffic, the Ames EE site nine channels, and the ISU site four channels.

MCP performed Erlang C calculations to determine the appropriate number of trunking channels to support Story County if a trunking system ultimately is implemented. There are approximately 1,470 subscriber radios programmed on the system. MCP performed the analysis using a total of 468 active users, with an average of five calls per hour and an average call duration of four seconds, which are industry standards. It is assumed that of approximately 1,874 subscribers (users) that are assigned a radio (given the growth estimates described above), roughly 25 percent would be actively communicating concurrently on the system at any given time during the busiest activity periods.

Table 2 below summarizes the results of the Erlang C calculations.

Table 2: Erlang C Calculations

System Erlangs	# Of Active Users	Average Call Duration	# of Calls per Hour	Acceptable Queued Call Delay (in seconds)	Maximum # of Voice Paths	
2.6	468	4.0	5.0	1.0	8	
Number of Voice Paths	Probability Call Request Blocked	Average Queue Depth	Average Call Delay	Queued Call Delay (in seconds)	Arbitrary Call Delay	% Calls Exceeding Acceptable Queued Call Delay
7	0.02	0.01	0.02	0.33	0.01	0.6%
6	0.06	0.04	0.07	0.43	0.02	2.4%
5	0.15	0.16	0.25	0.55	0.08	8.2%
4	0.35	0.66	1.01	0.70	0.25	25.0%
3	0.76	4.93	7.59	0.90	0.69	68.7%

Based on these results, a trunking system with seven voice paths is necessary to provide an adequate level of capacity for Story County. One additional channel is required for the control channel, necessitating a total of eight channels for a P25 Phase I radio system. Should the County choose to implement or join a P25 Phase II system which provides two talk paths on each frequency, five channels would be required, providing eight total voice paths.

3.4 Tower Sites

Radio sites are a vital extension of the radio system in that they provide a secure space to house the equipment that provides communications to first responders. They also provide protection from natural and manmade threats to allow communications equipment to run at optimum performance. Radio sites are also an important factor when designing a new communications system, as it relates to site reliability, availability and function.

Story County does not currently own or operate its own tower sites for radio and paging. The sites have severe deficiencies. The deficiencies include inadequate grounding of equipment, improper cooling, space limitations, and no backup power. During the interviews, MCP learned that when Science Hall II lost power, the radio site located at the top of the building also would lose power. This site is the main site that

services the area of Ames and ISU, putting a majority of first responders at high risk without reliable communications.

Motorola R56® *Standards and Guidelines for Communication Sites*² generally has been adopted throughout the public safety sector as the standards for site construction and radio installation. All vendors have guidelines that comply with the R56 standards, or which at least track very closely to it. Non-compliance with R56 standards does not make the installation wrong, but it may place the site at an increased risk of downtime or significant site/equipment damage. Consequently, MCP recommends adherence to the R56 standards when deploying radio equipment.

Using the R56 standards as a resource, MCP evaluated the equipment installation and site maintenance practices regarding the County's radio system to determine the level of reliability based on the site configuration. MCP found that the radio sites were not installed or maintained to the minimum standards referenced in the R56 standards. The County has suffered interruptions in communications that may be attributed to non-standard configurations, such as insufficient grounding, power surges, and equipment damaged as the result of environmental conditions.

A typical public safety site should include battery backup, generators, air-conditioning, and other civil hardware supporting the system. New sites should include environmentally controlled spaces. Such enclosures will be sufficient to handle robust public safety equipment and ensure that each piece of equipment is hardened so that towers can provide an adequate amount of countywide coverage. Other key elements that must be considered to ensure a reliable radio site and reduce system downtime from potential failures include:

- Grounding – Most deficiencies found at radio sites are related to external and internal grounding systems. MCP recommends that site grounding follow industry standards when procuring a system. Equipment warranties sometimes will not apply if the equipment is not grounded according to industry standards.
- Climate Control – Air-conditioning sufficient to support the building size and thermal load present; monitoring for low-, medium- and high-temperature alarms; installation of a thermostatically controlled fan-and-ventilation system.
- Connectivity – Two avenues of connectivity should be present. Reverse loop or multipath microwave, microwave with fiber or copper backup, hot standby microwave, and multiple copper or fiber circuits all are acceptable in meeting this requirement.
- Power – Commercial power backed up by a generator, fixed or portable, and sufficient direct current (DC) power via a DC plant or uninterruptible power supply (UPS) system capable of running the site for no less than six hours for transmitter sites is required. The ability to monitor power alarms—such as

² Motorola R56 is a body of standards developed to outline the requirements and guidelines for site design, development, grounding, and installation of communications equipment.

alternating current (AC) power fail, DC power fail, rectifier fail, generator start, generator run, generator fail, and low battery—should be evaluated. A DC power plant is required for the microwave system, so the plant easily could be expanded to accommodate additional radio equipment. DC power eliminates a single point of failure, and is less expensive to maintain due to the ability to purchase off-the-shelf batteries.

- Physical site – Availability of temporary resources—such as mobile command posts and cells on wheels (COW) in the event of a system outage—and other site support, such as snow removal and other methods of improving road conditions to facilitate site access, are a must.

Most of these conditions did not exist at the sites that MCP visited, or reviewed based on photographic evidence. The ISU site required a fan to ventilate the equipment room. The backup paging sites did not have environmental controls, nor did they have backup power supplies.

Based on the deficiencies found at the existing sites that MCP visited, we strongly recommend that any new or upgraded tower sites resulting from this project adhere to the Motorola R56® standards, Harris grounding guidelines, or equivalent standards/guidelines governing communications towers.

3.5 Interoperability

Interoperability refers to the ability of users to communicate with agencies that fall outside of their primary response group. Interoperability may be between different law enforcement and firefighting agencies within the same county, across disciplines, with agencies in neighboring counties, or with any other agency with which communication may be required. Interoperability also applies to any non-public safety agency that may need to communicate with a public safety agency. Below is a description of technological solutions utilized to establish interoperability within Story County and neighboring counties. When more than one system is involved, certain hardware and procedures are required to achieve interoperable communications between systems.

3.5.1 Inter-County

Within the county, the following entities are expected to be on the same regional system:

- ISU personnel
- Public works (utilities)
- Transportation and road crews
- Hospitals
- City of Ames
- Countywide law enforcement agencies and police departments
- Countywide fire/rescue agencies
- EMS agencies

Story County users have direct interoperability on EE's communications system, but interoperability is hindered because the system lacks the required capacity and coverage. Specific talkgroups have been defined for interoperable events, and are the primary talkgroups utilized for events involving multiple jurisdictions. In some instances, agency-specific talkgroups are utilized for multiagency response. These units will be a part of a local fleet map plan and will not require special hardware. As the new system is rolled out, direct interoperability with these users will be available.

Dispatchers in certain circumstances may patch together two talkgroups. This typically occurs when two agencies that normally do not talk with each other need to do so during an event, and their respective fleet maps do not include the other agency. Dispatchers also can patch together users on the same system in a talkgroup.

3.5.2 Neighboring Counties and State Agencies

Most of the counties surrounding Story County will be joining a regional radio system, whether it is the SARA network or ISICS. In either case, Story County users will have two options available to them regarding interoperability once the County decides how to proceed with replacing its current radio system. If the County elects to join either SARA or ISICS, its users will have direct interoperability with the users in the surrounding counties that are operating on whichever network it selects. Story County users will have indirect interoperability with users in surrounding counties that are operating on the other regional network, either via the Inter-RF Subsystem Interface (ISSI), which is a component of the P25 standards suite, or gateways. (Indirect interoperability with all users in surrounding counties will be the result if Story County opts to implement a standalone radio system.)

Most users of P25 systems equate disparate systems with a lack of interoperability. Systems provide coverage to the users who operate in that coverage footprint. When a user roams to another network, they will switch to a channel that operates with those users. It may be on the SARA system or on ISICS. In either case, the user will have the ability to talk locally and even have their ID display within that system.

The options explained above allow users in one county to communicate, i.e., roam, in the other county while still talking with their assigned dispatcher. With the required hardware in place, users simply will select the local talkgroup on their radio.

The reciprocal is expected. When users come into Story County from other counties, they will need to be able to talk with local Story County agencies. If they are not on the same regional network, memorandums of understanding (MOU) will need to be executed between the counties, in addition to implementation of the necessary interfaces and hardware, to enable such interoperability.

There will be interoperable opportunities that are not in the fleet map. If a radio's fleetmap had every talkgroup in both systems in it, then the radio would be unmanageable. Only the common talkgroups should be in the radio. To facilitate the less-frequent interoperability events when they arise, common mutual-aid talkgroups can be programmed into the radios. These regional mutual-aid channels would be the primary talkgroups shared with neighboring agencies outside of Story County for interoperability

purposes. Although these talkgroups do not currently exist, both ISICS and RACOM agreed that they would allow this solution on their networks.

Whether Story County joins ISICS or the SARA network, the P25 nature of these solutions will elevate interoperability for Story County throughout the state.

3.6 Backhaul

Typically, connectivity for a public safety communications network is comprised of one or a combination of the following:

- Leased telephone lines
- Fiber-optic cables
- Wireless links (e.g., microwave or radio frequency [RF] links)

In most situations, connectivity is a combination of analog and digital circuits that carry voice, data and control tones between the radio consoles and the network of radio communication sites.

For Story County, there are currently no leased lines, fiber-optic cables, or microwave links in use to provide interconnection for the radio system equipment. There is however, fiber between the dispatch center in the City of Ames, Story County's dispatch center in Nevada, and the ISU dispatch center. All communications from the three dispatch centers with repeater sites is accomplished through the use of control stations, which utilize a wireless link between the dispatcher and the site location.

Backhaul connectivity is a critical component of multisite radio systems. Modern P25 networks operate on IP-based platforms. A robust and reliable backhaul network is required to ensure reliable communications. MCP finds it necessary for the County to implement an IP backhaul network capable of supporting both voice and data communications. Communications centers and radio sites are the lifeline of emergency response organizations, and it is vital that they can communicate at all times.

3.7 Frequency Considerations

3.7.1 Current Frequency Band 800 MHz

Story County's radio system currently operates in the 800 MHz frequency band using the general industrial business pool of frequencies. Although it is a public safety entity, Story County does not own its own licenses—EE holds the licenses for the current 800 MHz system—and the frequencies it uses are being shared with other non-public safety organizations. The risk of this is that the County does not have control over its frequencies and other entities could interfere with the licenses without the County being aware of such issues. Regardless of the frequency band on which its replacement radio system will operate, Story County will be required to license its own public safety frequency licenses.

Frequency acquisition is one of the most challenging, time consuming, and uncertain aspects of any radio system implementation. In many cases, the availability of frequencies can dictate the frequency band in which a system is constructed. The next biggest driver of determining the frequency band is the characteristics and type of coverage that is needed from a new system, which can be the deciding factor in choosing one frequency band over another. For instance, not all frequency bands are the same in terms of in-building coverage versus mobile in-street coverage. For ISU and the City of Ames, in-building coverage is the top priority, so a higher frequency band where in-building penetration is a key attribute would yield better results compared with a VHF system. The following sections below address the strengths and weaknesses of each available public safety frequency band, as well as the frequency availability in each band.

3.7.2 VHF

The VHF high-band frequency range is the oldest of the available public safety frequency bands that is still widely utilized today. VHF is utilized by several agencies including the State of Iowa for the Law Enforcement Assistance Channel, known as the LEA system. The VHF band is widely desired because of beneficial radio propagation characteristics. VHF signals have a longer wavelength, so they can travel over terrain farther than signals in other bands. As such, systems constructed in the VHF band require less radio sites than systems constructed in other frequency bands. The VHF band is very crowded due to its popularity. This can create a higher noise floor and risk of interference. However, the VHF band is rarely utilized for systems requiring a large number of frequencies, such as trunked networks.

The VHF band was not originally designed for the use of repeater systems, so repeater pairs must be constructed using individual frequencies located throughout the 150–160 MHz range. The combination of multiple repeater pairs at individual radio sites introduces numerous challenges because of system design constraints. Spacing frequencies so that they do not interfere with each other and can be combined into single combiner units significantly restricts the frequencies that can be used.

There are also strict licensing restrictions for the use of VHF channels in the trunking mode. Acquisition of VHF trunking frequencies requires stringent frequency coordination criteria. While conventional systems are permitted to coexist at closer spacing based on the discretion of frequency coordinators, trunking systems must satisfy strict interference protection criteria.

Radio spectrum is licensed according to the placement of a site relative to existing co-channel and adjacent-channel license holders. The distance from existing license holders provides a good reference for whether a frequency can be obtained.

Because of the many disadvantages of VHF in urban areas, MCP does not recommend that Story County transitions to the VHF band for a trunking radio system. Although VHF is not recommended for radio systems, paging could make best use for the VHF frequency band. The County currently uses the VHF frequency band for paging and it would be prudent to remain on a single, public safety-licensed paging channel if the County elects not to replace the paging devices. MCP researched and found some frequencies available, 151.3850 for example, that could be licensed for paging.

3.7.3 UHF

The UHF frequency band covers the range from 450–470 MHz. This portion of the band includes general public safety and industrial/business pools. The UHF band provides fixed offsets between transmit and receive frequencies, thus supporting the use of repeater systems. UHF radio waves are shorter than VHF radio waves, and as a result, UHF signals have a shorter range than VHF signals. Buildings, trees and even human bodies can interfere with UHF signals. Further, UHF signals have limited in-building penetration, though not to the extent of 700/800 MHz signals.

The other area where UHF channels could be identified is in the Part 22 paging pool. These frequencies primarily are assigned to commercial paging systems. Entities wishing to operate on these frequencies purchase the channels through FCC auctions. Public safety agencies may acquire these channels by buying rights to the channels from the current license holders and filing a major waiver with the FCC. The cost associated with these channels varies greatly depending on the specific market demand and license holder. MCP has seen Part 22 channels given away and sold for as much as \$1 million for one channel.

3.7.4 700 MHz

The 700 MHz band is available for both commercial and public safety communications. Taken from the FCC website, the following figure illustrates the available public safety spectrum in the 700 MHz band.

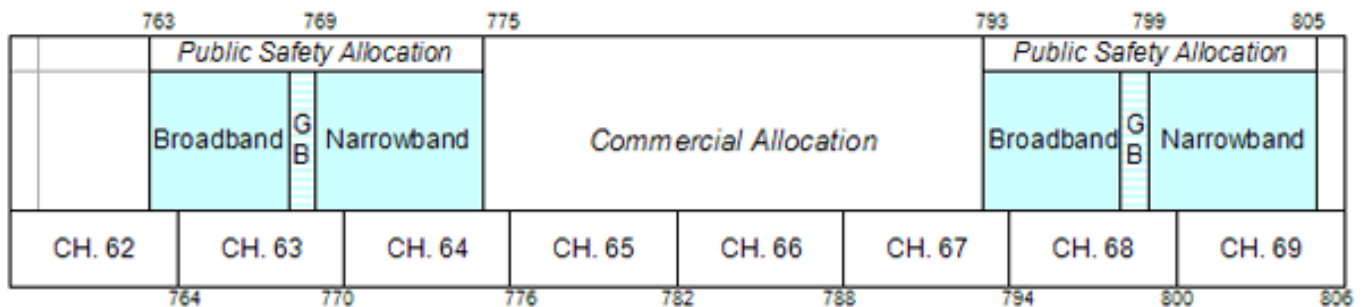


Figure 1: 700 MHz Frequency Chart

The FCC has allocated protected spectrum in the 700 MHz band specifically for public safety operations. Frequencies in the 700 MHz band are pre-paired for repeater operations, with mobile frequencies 30 MHz above the base frequencies. The 700 MHz frequency band provides an alternate source of spectrum for Story County. The band is not heavily encumbered and frequency assignments already have been made to Story County. Twenty-five 12.5 kilohertz (kHz) channel blocks are assigned for usage within the county. Table 3 summarizes these frequencies.

Table 3: Region 15 – 700 MHz Assignments for Story County

Channel Number	Base Frequency	Mobile Frequency
15-16	769.09375	799.09375
43-44	769.26875	799.26875
81-82	769.50625	799.50625
121-122	769.75625	799.75625
161-162	770.00625	800.00625
203-204	770.26875	800.26875
241-242	770.50625	800.50625
281-282	770.75625	800.75625
335-336	771.09375	801.09375
357-358	771.23125	801.23125
379-380	771.36875	801.36875
401-402	771.50625	801.50625
423-424	771.64375	801.64375
445-446	771.78125	801.78125
467-468	771.91875	801.91875
489-490	772.05625	802.05625
511-512	772.19375	802.19375
533-534	772.33125	802.33125
555-556	772.46875	802.46875
607-608	772.79375	802.79375
635-636	772.96875	802.96875
673-674	773.20625	803.20625

Channel Number	Base Frequency	Mobile Frequency
717-718	773.48125	803.48125
751-752	773.69375	803.69375
787-788	773.91875	803.91875

Obtaining these frequencies will require authorization from the Region 15 – 700 MHz Planning Committee. Several technical constraints regarding the use of the 700 MHz frequencies will limit the types of systems that Story County can construct in this band. The system must be digital and must permit subscriber operation on conventional interoperability channels in the P25 mode. Most current production subscriber radios are capable of operating in both the 700 MHz and 800 MHz frequency bands; thus, the frequencies can be used interchangeably.

Radio signals in this spectrum have better propagation characteristics than higher frequency signals, and require less power to achieve the same range. The 700 MHz frequency can penetrate obstacles and foliage with a higher level of success, even in the worst environmental conditions. This spectrum also is ideal for rural and dispersed applications as it is less dependent on line of sight. The FCC also allows higher power limits for operations in the 700 MHz band compared with other spectrum. The 700 MHz licensed frequencies also are not prone to interference from other equipment or broadcasts, are more resilient to changes in weather conditions, and as managed frequencies are unlikely to cause self-interference.

3.7.5 800 MHz

Frequencies in the 800 MHz band are pre-paired for repeater operations, with mobile frequencies 45 MHz below the base frequencies. The frequencies are assigned in licensing pools: the interleaved band, which is governed by frequency coordination rules (854–860 MHz); and the National Public Safety Planning Advisory Committee (NPSPAC) band, which is governed by Regional Planning Committees (851–854 MHz).

Much like 700 MHz frequencies, 800 MHz frequencies are known to propagate shorter distances than UHF frequencies and thus require more radio sites than UHF or VHF to cover the same geographical area. The advantage of 800 MHz systems is improved building penetration compared with UHF and VHF systems; however, the 800 MHz signal is weaker, which can diminish or even negate this advantage, and which can result in higher implementation and operational costs due to the increased site requirements. To mitigate the loss of coverage, 800 MHz frequencies can be licensed for higher wattage output compared with the restrictions placed on the 700 MHz band by the FCC.

Much of the 800 MHz interleaved spectrum has been vacated by Sprint/Nextel as a result of the effort to reconfigure the band, i.e., “rebanding.” These channels will be available to Story County until another entity

licenses them, and they are expected to be available for the foreseeable future. If Story County decides to remain on the 800 MHz band, it would need to license its own frequencies for public safety use. Based on channel availability within the middle section of Iowa, MCP feels it is likely that 800 MHz channels could be acquired in Story County. MCP found ample frequencies available with a small listing of these in Table 4 below. The “Co-channel from Center” column shows the distance in kilometers from the next transmitter using the same frequency. The greater the distance, the less interference County users would encounter. Generally, MCP recommends frequency spacing in excess of 100 kilometers (km). The 800 MHz band is a good option compared with VHF and UHF, and given the superior in-building penetration and higher output power allowed by the FCC. However, the 700 MHz channels are still a viable option due to the pre-coordination of channels for Story County.

Table 4: Sample List of Available 800 MHz Frequencies

Frequency	Co-channel from Center (km)
859.9875	119
859.8625	122
859.6875	133
858.9875	119
858.7625	99
858.4875	123
858.2375	114
857.9875	131

3.8 Subscriber Radios and Dispatch Consoles

Subscriber radios (mobiles, portables, and consoles) within the county are owned by each operating agency. The subscriber radios are manufactured by Motorola. Each of the radios is proprietary and cannot interoperate with ISICS or the SARA network, even via a gateway or the ISSI, because they are not P25 compliant. The radios only can transmit and receive on the current network and lack public safety features such as an emergency button, GPS, and OTAP. Approximately 1,400 radios currently are in use on the County’s system. When the County migrates to the P25 design platform, every subscriber radio will need to be replaced.

Each of the three consoles are Zetron dispatch solutions. Each of the consoles used for public safety operations in Story County are connected to the system via control stations. In this configuration, the

control stations are not providing basic services for dispatch operators to be effective in supporting their field personnel. For example, the dispatch operator often cannot tell which radio is on the air. More detrimental to first responder safety is that not all of the IDs display on the console when an emergency button is pressed. This is not a deficiency in the console, but rather a deficiency in the selection of the control station and the information that the control station passes. It is possible that the Zetron dispatch solution can pass this data if it is engineered properly.

It is possible to reuse the Zetron dispatch consoles. Each radio system vendor will require an interface to these consoles. The vendors obviously charge for this interface. MCP recommends that the County shares with the vendors a desire to reuse and interface the consoles, and requests a cost for doing so. However, the County also should explore with the vendors the advantages and costs associated with implementing new consoles.

3.9 Paging

There was a lot of discussion on what type of paging the users wanted. MCP covered the technologies below with the users. The users were fairly split in whether they wanted to keep the current tone-and-voice pagers or migrate to an alphanumeric-type pager. In the end, a fire committee was established to consider these options, and the committee decided to keep the existing format.

3.9.1 Tone and Voice

The current paging system is tone-and-voice. We already have discussed the issue of poor coverage caused by the simulcast issues. Users also have complained about their pager receiving other pagers' messages. This is due to the out-of-phase transmitters that cause the pagers to misinterpret tones. The pager looks for two specific tones from the system. When it identifies those tones, the pager allows the audio to pass to the speaker. In the event of out-of-phase transmitters, tones can either mix or pass four separate tones. Any pager that identifies the correct sequence of these tones will open its speaker. Therefore, pagers are accessing pages unintended for them.

In the new design, the system will be engineered properly and will not have these problems. Because the fire committee decided on maintaining the tone-and-voice capability—something that MCP also recommends—all of the current pagers will operate on the new tone-and-voice paging system.

3.9.2 Alphanumeric

Another potential solution is alphanumeric paging. This solution would use the same transmitters. However, instead of the information arriving in audio format, the information would be text, like a current Short Message Service (SMS) message on a cell phone. This functionality can be added to the system. It would require an interface from the computer-aided dispatch (CAD) system and a message switch. (A message switch takes the CAD information and acts as a traffic cop, sending the message at the right time to the transmitters.)

Another benefit of the message switch is that it actually can send the page to a cell phone. Once the message arrives at the message switch, it looks at the message and how the user wants it sent. It can send it to a paging system, an SMS cell phone, or even an email at that point.

A common request from the fire users is the ability to hear the message, as they do with their current tone-and-voice pagers. Some pager vendors offer that option. Anytime you want to hear the message, the user presses a button and the message will be provided audibly. This can happen as many times as one wants to hear the message, unlike the traditional tone-and-voice pager, which offers a single chance to hear the message.

Although the fire committee decided to use tone-and-voice pagers, the alphanumeric solution also can be used in the future by implementing the CAD system interface and adding the correct messaging switch. While both solutions can be implemented at the same time, doing so will result in additional support costs borne of operating and maintaining separate solutions.

3.9.3 P25 Trunked Paging (Unification)

Unification is a brand of pager that uses the P25 system instead of a separate infrastructure to deliver pages. It can operate in tone-and-voice mode and alphanumeric mode. Instead of the interface going to a separate paging system, the interface goes to the trunked radio system. A benefit of this configuration is that the P25 system has multiple channels and provides great coverage. The downside is that if the P25 system goes down, so does the paging system.

3.10 Stakeholder Operational and Performance Needs Interviews

The stakeholder operational and performance needs interviews describe various user groups and feedback regarding the system. The purpose of the interviews is to determine the needs that the current communications system satisfies and those that it does not. Using this information, a set of requirements is established that defines what features the new communications system must provide.

This section includes a summary of feedback from the agencies that utilize the Story County radio system, feedback from interviews with end-users and interoperability partners, feedback collected regarding the system from User Questionnaires and MCP's assessment of the most-critical system concerns that should be addressed in an improved or new communications and paging system.

3.10.1 System Concerns

An overwhelming response from users from every organization interviewed simply stated, "we want a reliable radio system that works". The users have lost confidence that when they push to transmit a voice message on the radio that the radio will work, and the message gets to dispatch. Many stated that radio system outages are routine, and the radio vendor, Electronics Engineering (EE), would take several days to respond. During one interview session, MCP was provided with an email that indicated a critical radio channel was down and would not be repaired until the following week. This system only had two talk paths

during the outage. Many users stated that the radio vendor did not provide an adequate level of support. Some users stated that they would like to see a P25 radio system implemented.

Each group interviewed mentioned that there have been several occasions when the radio transmissions were filled with static, sounded scratchy or weak, and the messages were unclear. Many users stated that they were denied access to the radio system during busy times or for being out of coverage. Dispatchers interviewed unanimously agreed that the system is overloaded with busies, and they are unable to communicate or take control of the radio channel. ISU law enforcement had an issue where a student was in a life-threatening situation and the officer was not able to reach medical or dispatch personnel using their radio, which placed the student at high risk. Cell phones are being used instead to contact dispatch during emergencies. The problems with cell phones are they do not take priority or have preemption over the normal day-to-day traffic from consumers.

Both dispatchers and first responders do not know who is speaking on the radio. The capability does not exist on the current system to allow radio IDs or “aliases” to be programmed and pass through to dispatchers. The dispatchers have mentioned that this is a concern when trying to communicate or determine who is communicating on the radio system. Users had issues with inconsistencies concerning the talkgroup labels and no standard fleet maps for radio programming. When radios are assigned, two radios assigned to two individuals in the same law enforcement squad could be programmed completely different, frustrating officers when using the portables in day-to-day operations. Some users stated that they would like to see a channel structure that is expandable and adaptable for large-scale disasters.

MCP heard from a few users from various agencies that had concerns with training. Users indicated additional training would help with some of the newer patrol officers and volunteer firefighters.

3.10.2 Coverage Concerns

The majority of users interviewed stated that the existing system does not adequately penetrate dense buildings in the City of Ames, ISU buildings, and area hospitals and schools. The ISU football stadium is a big concern in terms of coverage, as law enforcement has described several areas surrounding the stadium that are without coverage. The university has many high-rise buildings and is ever expanding with new buildings being constructed. In-building coverage is a concern in many of the campus buildings, given the rise in mass-shooting and other emergency events. Others stated that coverage is lacking inside of homes, even when standing by the window. The County jails are a main concern where coverage is needed; today, officers are forced to use a cellphone for emergency communications. The power plant is a main concern where coverage is required. One area specifically called out during the interviews was the College of Veterinary Medicine at ISU. There is very little coverage and this is an area where officers frequently are responding to emergency calls. There is also an FBI Tier 1 Critical Infrastructure facility and reliable radio coverage is mandatory in case of an emergency. Through the questions, MCP learned there were low-lying areas within the City of Ames that have no coverage. City Hall was mentioned as an area of concern along with other city buildings. Other areas included the water pump house, the water plant, and water towers. For ISU, the residence halls are another area where coverage is a key requirement.

3.10.3 Future System Requirements

Law enforcement personnel indicated that encryption is a must. One agency spoke of a situation where news agencies would listen to the police channel and report tragic events, such as suicides, before law enforcement personnel could arrive on scene or notify the victim's parents.

Both dispatchers and users from all agencies would like the ability to see radio aliases on the radio and dispatch console. Law enforcement likes the idea of GPS and tracking resources in the field in real time. The dispatchers use a system called locution, a text-to-speech application used to send text pages over the paging network. The dispatchers expressed their desire to keep this ability and integrate into the next radio and paging systems, as well as any future dispatch console system. Dispatchers also agreed that if a new console system is selected, they would like to keep the feature where the phone and radio traffic uses the same headset. For functionality, dynamic regrouping was requested by several to allow emergency personnel responding to an incident to be organized or "regrouped" into a dedicated talkgroup. This would be a capability of the new system; however, the current system does not have that capability. The public safety organizations, such as law enforcement, would like the new system to prioritize their radio traffic over that of public works.

In terms of interoperability, one of the law enforcement agencies in Story County has a dive team that is part of a regional resource for the state. The dive team has a requirement to interoperate with the State of Iowa and would need the State's talkgroups for direct communications. Others mentioned the ability to interoperate with bordering counties and with both ISICS and the SARA network. During the firefighters meeting, many stated that they want the ability to interoperate with the State of Iowa. The Department of Conservation would like the new radios they use to have the State channels for direct interoperability. It was a common statement amongst all agencies—law enforcement, public works, fire, EMS, and others—that direct interoperability within the County is a mandatory requirement and a useful feature that enhanced their operational capabilities. As an example, law enforcement personnel found it useful to speak directly with road crews during an emergency or weather-related event. Some law enforcement personnel expressed the need to communicate with the Department of Natural Resources.

Users of the paging system want a system that "just works." They would like the new paging system to bring back the basic concept of paging in terms of receiving the page regardless of their location, and to be reliable, where a missed page is something out of the ordinary rather than the current normal. Currently, users are relaying on their cellphones with an application called "I Am Responding," and would like to migrate away from cell phone use and use the paging system as the primary means of alerting, with the cellphone as a secondary device.

3.10.4 Subscribers

A popular feature among many, requested by both the law enforcement and firefighting agencies, was the use of the "man down" button. The dispatchers would like the capability to know who initiated the man-down call and the location of the radio, which would increase the safety of the first responder. From a subscriber functionality standpoint, users have indicated that the batteries on the portables typically do not last a full shift. Mobile radio users were very dissatisfied with car installation, with reports regarding

installation issues that resulted in leaks and radio performance problems. Other requests heard were the need for a more simpler radio, with an easy-to-use interface, and a radio that does not require users to change zones continually. A select few agencies would require a radio to be intrinsically safe and submersion capable due to the nature of the work performed, such as power plant users and the emergency response dive team. For law enforcement officers and many firefighters, the wired lapel microphone is the preferred method of communicating on the radio, though some speak directly into the device. MCP did not find any users that use the wireless microphone configuration. Most users provided feedback where bigger buttons, durability, and ease of use were the top priorities concerning the mobiles and portables.

3.10.5 Summary of User and Stakeholder Requirements

Every single user of the radio system echoed the same simple message: “We just want the radio system to work.” One user said that a system is needed that is highly resilient to nature, manmade, and technical threats, one that will survive and provide reliable communications no matter the time, place or emergency. The radio system needs to have clear communications and have the coverage throughout the County, with a focus on in-building coverage on the ISU campus and in the City of Ames. Users want the ability to see who is talking on the radio with aliases, proper radio programming, and consistent talkgroup names. The subscriber radios should be simple and easy to use, able to operate on battery for an entire shift, and durable. Finally, users need to maintain current interoperability within the County but also outside with the State of Iowa and neighboring counties, such as Boone and Marshall.

Further analysis shows the clear need for law enforcement agencies to have encryption, with the ability to change the encryption keys through over-the-air rekeying, to prevent unwanted information and criminals from listening to the radio traffic. Law enforcement agencies want the use of GPS functionality. For paging, firefighters desired improved reliability, improved coverage, and compatibility of their pagers. User training is necessary in the new system for both end users and dispatch personnel, to review available and new interoperability capabilities and functionality of the new radio system.

3.11 System Lifecycle

Two-way radio equipment always has had a replacement lifecycle. The lifecycles of today’s robust, feature-rich radio systems particularly have been impacted by rapidly advancing and changing technologies. Replacement cycles may vary (+/- 25 percent) and also may vary based on factors such as the need for new technology and general wear and tear. Once equipment reaches end of life, it is time to upgrade that equipment. Based on the typical lifespan of each type of equipment, a general schedule of replacement is shown below in Table 5.

Table 5: Equipment Lifecycles

Facility Equipment	Lifespan
Building	20-30 Years
Towers	30-50 Years
Generators and Transfer Switches	10-15 Years
HVAC and Shelter Components	7-10 Years
UPS	7-10 Years
UPS Batteries	2-4 Years
Microwave Equipment	Lifespan
Digital Microwave Equipment and Antennas	10-15 Years
Radio Equipment	Lifespan
Base Stations and Antennas	10-15 Years
Network and Control Equipment	10-15 Years
System Software	2-3 Years
IP-Based Operation Equipment	5-7 Years
Subscriber Equipment	Lifespan
Mobile Radios	6-8 Years
Portable Radios	5-7 Years
Pager Units	5-7 Years
Consoles	10-12 Years

All of the radio infrastructure and paging equipment in use within Story County is approximately 30 years old, which far exceeds the end of typical lifecycle replacement periods. Consequently, the equipment suffers from high failure rates and has reached obsolescence, as the vendors no longer support the equipment. Subscriber radios vary in age greatly, depending on the replacement cycles of the various user agencies. Subscriber unit obsolescence is driven primarily by vendor lifecycles and compatibility with modern systems. While mobile and portable radios in use in Story County already may be seven to 10

years old or older (toward end of life), these units are not public safety grade and not compatible to operate on the new system if a P25 Phase II solution is implemented. In contrast, the County's dispatch consoles are approximately six years old, well within their recommended lifespan with vendor support; however, given a timeline of up to 24 months to implement the new radio system, the consoles would be within two years of requiring a hardware refresh when the new radio system goes live.

3.12 Radio System Technologies

3.12.1 Non-Public Safety Radio Systems

Proprietary shared systems refer to the use of a common technology among multiple agencies that is proprietary to a specific vendor. Examples of proprietary systems include the Motorola Privacy Plus system currently used by Story County. Multiple users operating with a proprietary technology have the ability, with proper permission, to access the talkgroups and features of the system. This has been the common mode of achieving interoperability for agencies within Story County for many years. Seamless interoperability is available provided that all users are using the same proprietary technology in the same frequency band.

Proprietary systems have the inherent limitation of being specific to an individual vendor. Use of proprietary systems as a regional interoperability solution requires the consensus of all stakeholders on the vendor and technology to implement. Individual agencies that choose to operate proprietary solutions without the consensus of interoperability partners within the region create an interoperability scenario that is limited to a gateway solution. Even if that consensus is achieved, regional proprietary systems limit the capabilities of users from outside the region to communicate. Lastly, only interoperable P25 systems are eligible for grants. For these reasons, proprietary systems rarely are used for public safety today, and new systems are based on the P25 standards.

As mentioned, the current system is a proprietary system. Other examples of popular proprietary systems are EDACS, DMR, MOTOTRBO, NEXEDGE, and OpenSky to name a few. Interoperability has been limited between users of Motorola and Harris systems in Story County for many years due to proprietary technologies, which require the use of gateways at the dispatch centers. In the current public safety radio market, proprietary systems are not recommended as an interoperability solution. Proprietary systems became popular during the advent of trunking systems in the 1980s and 1990s. However, with the development of P25-compliant technology, proprietary systems are less desirable given their inherent interoperability limitations and vendor restrictions. Most of these proprietary systems already have been replaced or will be replaced in the near future with standards-based P25 systems for public safety radio communications.

3.12.2 Multicast Trunking

A multicast trunking system utilizes a trunking architecture whereby different frequencies are utilized at each radio site. In general, a trunking system has a larger pool of user groups than radio channels. When a specific user group needs to communicate, the radio system assigns the group to a specific channel. Because each user group is not talking all the time, the system is able to better manage spectral efficiency

by only assigning active groups to a specific frequency. With a multicast trunking system, different frequencies are utilized at each radio site.

Trunking systems typically provide a multisite, wide-area coverage solution. A multicast system allows users to roam from site to site without switching channels. While the actual radio frequencies change, the radio system is able to “handshake” traffic between sites and channels so that communication on a specific talkgroup is seamless to the user.

Trunking systems have numerous additional features that are alluring to public safety users. These include encryption, system keys, system IDs, telephone interconnect, private call, group calls, dynamic talkgroup allocations, over-the-air rekeying, OTAP, low-bandwidth mobile data, and other features that are not available with conventional radio systems.

Trunking systems have a significantly larger hardware requirement than conventional systems. Above and beyond a conventional simulcast system, trunking systems require a central core to serve as the brain of the system, managing users, radio traffic, site affiliations, and other aspects that are seamless to the end-user. Trunking controllers are needed at radio sites to assign repeaters to specific talkgroups. Trunking systems are very complex and require stringent conditions to function properly. Due to the complexity of these systems and the associated cost, a much higher value is placed on assuring site conditions are optimal and system alarming tools are utilized.

Compared with a simulcast trunking system, multicast systems are less spectrally efficient because different frequency groups are needed at each radio site. For high-density areas, this can amount to a dramatic number of frequencies in a very small area. Multicast systems, however, are beneficial in the event that connectivity is lost. If site connectivity is lost, each site will continue to operate in site trunking mode. Wide-area coverage and site-to-site communications will be lost, but communications around any one given site will continue.

Subscriber equipment for trunking systems is generally more expensive than equipment for analog systems. Radios capable of both modes require an expensive firmware upgrade to perform trunking operation. Inexpensive business-model radios typically are not capable of operating on public safety-grade trunking systems.

Multicast trunking systems are available in the VHF, UHF, 700 MHz, and 800 MHz bands, although trunking systems typically are implemented in 700 MHz or 800 MHz due to frequency availability. VHF presents challenges with locating spectrum sufficient for trunking operation. Trunking systems may operate in analog or digital modes; however, today’s market is primarily based on digital P25 systems.

3.12.3 Simulcast Trunking

Simulcast trunking systems operate much like multicast trunking systems. The primary difference is that the same frequencies are reused at multiple radio sites in simulcast trunking systems. Implementation of simulcast circuits requires the introduction of timing circuits. The feature sets provided by simulcast trunking systems are similar to those provided by multicast trunking systems.

With the introduction of timing circuits, the opportunity exists for interference in simulcast overlap areas. In addition, loss of backhaul connectivity can result in a catastrophic failure. Because sites operate on the same frequencies, a loss of coordination between the sites will limit the ability of the sites to function as independent systems, as the sites will interfere with each other. Typically, simulcast systems are designed to fall back to a more limited number of radio sites that do not share overlapping coverage. Due to this reason, it is especially important that backhaul networks be designed to a very high fault-tolerant design, with high reliability levels, when accommodating simulcast systems.

Simulcast trunking systems are available in the VHF, UHF, 700 MHz, and 800 MHz bands, although typically these systems are implemented in 700 MHz or 800 MHz. VHF presents challenges with locating spectrum sufficient for trunking operation. Trunking systems may operate in analog or digital modes; however, today's market is primarily based on digital P25 systems.

A simulcast trunked network will satisfy the coverage and capacity requirements of Story County. All subscriber radios utilized within Story County will need to be replaced, and there are minimal opportunities for reuse of any existing equipment. Obtaining frequencies for a simulcast trunked network is feasible if 700 MHz or 800 MHz channels are used. Obtaining clear VHF or UHF spectrum will prove very challenging, and may not be possible.

3.12.4 Project P25

The Association of Public-Safety Communications Officials International (APCO) P25 standards for public safety digital radio were established under the guidance of APCO and developed under the governance of the Telecommunications Industry Association (TIA). The development of P25 standards involved representatives from local, state, and federal government agencies, in conjunction with industry representatives, who evaluated basic technologies to develop common standards for advanced digital LMR service. P25 is an industry-wide effort to establish recommended voluntary standards to foster uniform digital two-way radio technology for public safety organizations.

P25 is a suite of eight standards intended to help produce equipment that is interoperable and compatible regardless of manufacturer. The P25 standards suite involves digital LMR services and includes the following standard interfaces:

- Common air interface (CAI)
- Fixed/base station subsystem interface (FSSI)
- Inter-RF subsystem interface (ISSI)
- Console subsystem interface (CSSI)
- Data network interface
- Network management interface
- Telephone interconnect interface
- Subscriber data peripheral interface

P25 has four key objectives:

- Provide enhanced functionality with equipment and capabilities focused on public safety needs
- Improve spectrum efficiency
- Assure competition among multiple vendors through an open systems architecture
- Allow effective, efficient, and reliable intra-agency and interagency communications

P25 is intended to make informed decisions easier for users when planning to convert an existing system to digital. Using the P25 standards, vendors' systems can be more readily compared because they use an agreed-upon baseline set of specifications. This allows users to more accurately compare the direct features and benefits of both entire systems and individual radio products. It is intended to make bidding processes more competitive among prospective vendors. In addition, users should have the opportunity to mix and match equipment among P25-compliant suppliers because all compliant equipment will use the same standards and work on any P25-compliant system.

The Department of Homeland Security (DHS), in its 2007 Federal Grant Guidance for Emergency Response Communications and Interoperability Grants, indicated a strong preference for P25-compliant radio equipment, stating:

“When procuring equipment for communication system development and expansion, a standards-based approach should be used to begin migration to multi-jurisdictional and multi-disciplinary interoperability. Specifically, all new digital voice systems should be compliant with the P25 suite of standards. This recommendation is intended for government-owned or -leased digital land mobile public safety radio equipment. Its purpose is to make sure that such equipment or systems are capable of interoperating with other digital emergency response land mobile equipment or systems. It is not intended to apply to commercial services that offer other types of interoperability solutions.

Further, it does not exclude any application if the application demonstrates that the system or equipment being proposed will lead to enhanced interoperability. With input from the user community, these standards have been developed to allow for backward compatibility with existing digital and analog systems and to provide for interoperability in future systems. The FCC has chosen the P25 suite of standards for voice and low-to-moderate-speed data interoperability in the new nationwide 700 MHz frequency band and the integrated wireless network (IWN) of the United States Homeland Security, Justice and Treasury Departments has chosen the P25 suite of standards for their new radio equipment. The United States Department of Defense has also endorsed P25 for new LMR systems.”

Only where there are compelling reasons to do so will the federal government fund the procurement of non-P25-compliant radio equipment.

The final documents establishing the P25 standard were approved and signed in August 1995 at the APCO International Conference and Exposition in Detroit, Michigan. These are referred to as the P25

Phase I standards; however, P25 is an ongoing project. The current effort, referred to as P25 Phase II, is to develop standards for narrowband operations using 6.25 kilohertz (kHz) channel spacing. This will require the use of time division multiple access (TDMA) technology. In April 2007, the majority of the P25 steering committee selected what is referred to as the 12 kilobits per second (kbps), two-slot TDMA solution for Phase II technology.

According to APCO, this selection not only will allow for a graceful migration to Phase II and backward compatibility with Phase I systems, but it offers advanced capabilities that will result in an even more robust P25 system. This solution was chosen to accommodate ever-increasing needs for spectral efficiency and user capacity in public safety wireless voice and data radio systems, while ensuring full-feature functionality and improved audio quality. The P25 Phase II standard is currently complete and equipment is being sold today that is Phase II-compliant. However, while many vendors have P25 Phase I compliant systems and subscribers, there is a growing number of vendors currently providing Phase II compliant systems and subscribers.

Based on the current market for trunked public safety radio system technologies, a P25 standards-based system is the only reasonable technology available for implementation by Story County.

3.12.5 Phase I (FDMA)

P25 Phase I leverages frequency division multiple access (FDMA) technology, which provides one talk path or conversation per radio channel. Each channel designed in the radio system would be associated with one voice path. Most system manufacturers will offer Phase I systems given that there are available frequencies to accommodate current and future capacity needs of the users.

The primary advantages of P25 Phase I systems concern availability and cost. More vendors offer available equipment that is designed for P25 Phase I operation, and FDMA network equipment and subscriber radios typically are less expensive, compared with Phase II gear. Another benefit of a Phase I system is the flexibility for end users to flash upgrade non-P25 subscriber radios to Phase I operation, depending on the model. This ability helps agencies avoid forklift radio replacements.

Phase I systems offer seamless compatibility with subscriber radios from other agencies that also are operating Phase I systems. In addition, a Phase I system would offer additional fallback capacity if the system were to revert to failsoft mode, resulting in the loss of only one channel if only a repeater failure were to occur.

The main disadvantage of Phase I radios is their inability to interoperate with Phase II radios; in contrast, a properly configured Phase II system can have backward capability with Phase I radios. Also, compared with Phase II systems, Phase I systems require more frequencies and base stations.

Despite these limitations, P25 Phase I FDMA would be a viable option when the County elects to replace or upgrade its current radio system.

3.12.6 Phase II (TDMA)

P25 Phase II leverages TDMA technology, which permits a single radio channel to be split into two distinct voice paths, thus doubling system capacity and enabling more efficient use of radio spectrum. The latter benefit is especially important because radio spectrum is a limited resource and, in high population regions, there typically is not enough spectrum to satisfy the needs of all agencies.

In addition, P25 Phase II TDMA is designed to be backwards compatible with P25 Phase I systems and subscriber radios. The backwards compatibility mandated by the standard requires repeaters to be capable of both Phase I and Phase II operation, which in turn requires repeaters to be partitioned; this results in trunking resources being split between Phase I FDMA, which has one voice path per channel, and Phase II TDMA, which has two voice paths per channel. However, the major equipment vendors have taken Phase I backwards compatibility beyond the standard by providing repeater systems that can switch dynamically between FDMA and TDMA, thus eliminating the need to partition channels. Talkgroups also may be configured in a dynamic fashion so that the system will initiate a TDMA call of all active radios on the talkgroup operating in the TDMA mode, and initiate an FDMA call if there are any FDMA-only radios active on the talkgroup.

Major P25 equipment vendors are now selling P25 Phase II-compliant systems and subscriber radios. The smaller vendors that do not yet have a fully developed product are marketing P25 Phase I systems with a guaranteed upgrade to Phase II. Therefore, a competitive environment exists in today's market for Phase II systems. There are many Phase II systems already deployed or in the process of being deployed.

TDMA is a viable option for the County if it elects to replace its current trunking system. However, TDMA systems have a more limited pool of compatible subscriber radios, with costs typically about \$500 more per radio to provide TDMA capability, compared with Phase I gear. In addition, system infrastructure costs can be more expensive when comparing repeater to repeater; however, through a competitive procurement process, these costs often are lower when providing an equivalent number of talk paths.

3.12.7 FirstNet and Long-Term Evolution

Long-Term Evolution (LTE) is a commercial wireless broadband standard. The standard has been adopted by the public safety community for implementation on mission-critical, public safety-grade broadband networks. While commercial cellular networks are deploying this technology across the country, implementation of private public safety LTE networks has yet to take hold. Public safety agencies today largely depend on commercial broadband 3G networks for their data needs, using wireless air cards.

In 2012, public safety was awarded access to the 700 MHz D Block, which accounts for 10 MHz of broadband spectrum. The allocation is immediately adjacent to the 10 MHz of broadband spectrum already allocated to public safety. Congress has committed to funding a nationwide broadband LTE network for first responders, under the auspices of the First Responder Network Authority (FirstNet). Much of the details behind the FirstNet build-out have yet to be defined, including costs to end-user agencies.

LTE itself is a wireless network providing high-speed data to subscriber devices. The benefit to public safety concerns the potential applications that can be run over an LTE network. Today, only a handful of these applications exist. There has been discussion that voice over LTE will take the place of narrowband voice radio systems. However, the LTE standard does not provide the equivalent quality of service (reliability) provided by current public safety voice systems, and does not provide direct unit-to-unit simplex operation. If LTE is ever able to take the place of narrowband voice systems, it certainly will not be any time soon.

While there would be benefits to an LTE broadband system within Story County, the decision is distinct from the radio system procurement. LTE is not yet mature enough to serve as a viable voice radio system alternative for public safety.

3.12.7.1 LMR over LTE

LMR over LTE is an emerging technology for public safety. Largely driven by the advancements of the commercial cellular industry, the FirstNet network is in the early stages of planning. It is possible that public safety-grade LTE devices (subscriber units) may be available by 2018. The larger question concerns the network to support it. LTE requires more system command, control, and traffic routing than a traditional LMR system. Currently, public safety LTE network developers are exploring options of partnering with commercial cellular providers, building local LTE networks, or building a national dedicated public safety LTE network. For public safety communications, LMR is the industry's preferred mode of communications. An LMR-over-LTE solution could be a backup or secondary system, but until proven in real-world scenarios, would not be preferred as the County's primary means of public safety radio communications.

3.12.8 Push-to-talk over Cellular

Push-to-talk over Cellular (PTToC) has been around for many years, with the Nextel iDEN network being the most widely utilized at one time. With FirstNet's network on the horizon, there has been a renewed push to develop public safety-grade applications that can provide push-to-talk (PTT) service over LTE networks.

The Third Generation Partnership (3GPP) has published Mission Critical Communications Push to Talk standards (MCCPTT). It will be at least two years before the vendors will have acceptable products using the MCCPTT standards. Even though FirstNet has not arrived yet, many solutions are available that leverage PTT service on current cellular networks. A subset of these have established interfaces to LMR systems to extend channel and talkgroup audio to cellular applications. Examples include radio vendor-hosted solutions such as Harris BeOn and Motorola WAVE, carrier-hosted services such as AT&T Enhanced PTT, and other solutions such as ESChat.

Each of the services has its own competitive values that enhance push to talk. BeOn and Wave integrate directly to the radio system. Cisco brings radio talkgroups to Cisco desk phones. Some applications specialize in public works features and bring GPS or video for on-scene awareness.

These solutions provide a cost-effective alternative for radio operators with limited or non-mission-critical needs, such as management personnel or school resource officers. Further, because range when operating these devices is extended to commercial networks, first responders can operate these devices outside of their jurisdiction or in buildings where commercial coverage may be present, but LMR coverage is not.

The primary means of connecting the P25 system with a commercial carrier is ISSI. The ISSI solution is more expensive than conventional interfaces, but enables connectivity between a large number of talkgroups, and extends identification and emergency information to the PTTToC device, making operation with these users more operationally equivalent to radio users. The ISSI solution is usually cost prohibitive for smaller agencies, and there is no plan for the regional operators to implement the advanced features that ISSI provides across networks.

Providers of these services also may integrate with an LMR system through a conventional interface. The conventional interface is cost-effective and scalable for smaller conventional systems. However, this interface does not permit unit identifications or emergencies to be extended to operators of the PTTToC devices. Currently these systems are not used in areas where the public safety functions are required. Therefore, this method is attractive to smaller agencies that just want to have wide-area audio between P25 and their cellular system.

PTTToC is being adopted first by the public works and education sectors. Public works requires phones to call their customers and vendors. They require a camera to show status of projects and GPS for closed unit response. PTTToC offers these features. Another potential candidate would be the executive staff of the public safety departments. They do not have to carry a radio and do not need the P25 features or robustness. Instead they choose to use their PTTToC service to monitor large fires or events.

PTTToC is migrating to MCCPTT, but until this technology is ready for public safety, users should vet this technology for features and coverage around Story County.

3.13 Shared Systems/Regional Systems

Shared systems provide a way for multiple agencies to share common system components to reduce costs and increase operational effectiveness. Typically, agencies that share a common response area or border each other receive the greatest benefit from system sharing. System sharing can range in degree from one common system serving many agencies to separate systems sharing a single radio site that lies on the border between two systems.

P25 trunking systems provide the greatest opportunity for system sharing because central control equipment used on P25 systems often can accommodate a far greater level of users than is typically required for a single agency. Sharing of this control equipment can result in savings of \$300,000 to \$2,000,000, depending on control equipment capacity.

Agencies that share control equipment have the added benefit of improved interoperability with other agencies interconnected with the control equipment. In this scenario, subscriber radios can be configured

to roam to any interconnected radio site if the frequency band of the site and the subscriber are compatible.

A successful example of a shared radio system started by Armstrong County, located in western Pennsylvania, is the P25 Phase II Inter-County Regional Radio System (ICORRS). ICORRS is a similar setup to the SARA radio system, with the major difference being that ICORRS is owned by Region 13 (a cooperative consisting of 14 counties), while SARA is a private commercial radio system owned by RACOM (Harris). ICORRS started with two counties and as of today, has grown to six counties with a seventh county joining in spring 2018. The regional radio network allows first responders to communicate directly with each other across county lines. As more counties join ICORRS, the cost of the annual upgrades and maintenance drop significantly. Capital investment also is reduced when a county joins the system. The individual county looking to join could save costs, with the vendor often offering discounts when a radio core is not needed, due to sharing the existing core of the regional radio system.

A second example was implemented in the state of Texas and is called the Greater Area Texas Radio System (GAToRS). The City of Austin purchased the original core for this network, and since then state and local government agencies have been allowed on the system. Some agencies bring infrastructure with them, similar to how Story County will add sites to its network. In South Carolina, the 800 MHz, P25 Palmetto radio system is similar to ISICS in that it is governed by an elected advisory board comprised of representatives from local law enforcement, fire, emergency management, EMS, local and state government, and utility companies. The joint shared radio system allows agencies, such as those in Story County, interested in 800 MHz trunked radio technology to participate in a state-of-the-art system for approximately half the cost of purchasing and maintaining an independent private system. This allows agencies to take advantage of cutting-edge technology at a fraction of the cost to build and maintain similar systems on their own.

Shared systems come with the task of developing agreements with the sharing agencies to establish equipment ownership and responsibilities. Additional planning is required in advance of installation to work through these details and establish usage criteria that is acceptable to all parties involved. Governance and standard operating procedures (SOPs) are equally important to ensure consistent usage of the shared system and its resources following implementation.

During discussions with Story County, it was noted that two options exist for joining a regional or shared system, ISICS and the SARA network. By joining a regional or statewide radio system within Iowa, Story County would improve interoperable communications, both with bordering counties and other counties within the State of Iowa, and would share maintenance costs, so that one county does not have to struggle to solely maintain the system through its lifecycle.

3.14 Summary of Findings and Analysis

Concerning the current voice radio system, MCP echoes the findings in the previous consultant's reports. In the 2009 report, Story County was to "take the necessary steps to replace the existing systems with a countywide portable-based P25 platform." Based on recent user feedback regarding the current system's

subpar performance, the slow decommissioning of the current sites, and the regularity of system busies or failures, MCP recommends that Story County pursue the new radio system with a sense of urgency.

Regarding the paging system, MCP also agrees with the 2017 assessment of the paging system. The current system should be abandoned, and a new paging system should be pursued. Once again, due to the substantial number of pages that go missing because of the current system design, MCP recommends that Story County pursue a new paging system with a sense of urgency.

4 Recommendations

4.1 System Technology

4.1.1 Option 1 – Build County-Owned P25 Phase II Radio and Paging Systems

The County always has had the option to build its own radio system. Owning one's system has advantages. As the owner of the system, the County would have complete control of the system. It could add users when needed. It could add partner counties' users and sites. It would have all of the working knowledge of its own system. When a site goes down, the County would be alerted, and as first responders require resources from that site, workarounds can be pre-planned.

The disadvantage is that there is a tremendous cost associated with keeping a radio system up to date on its firmware. Current radio vendors only support their software for less than a year. And then all of the bug fixes and features are developed into the next release. To provide this added support, the County would have to hire more personnel. Even though there is a new system release once a year, vendors release bug fixes throughout the year. There can be from a dozen to more than 100 software patches for which a user may be responsible.

Because of the critical nature of these systems, the core requires a highly specialized skillset to maintain it. All vendors offer service programs, but they come at a price. Also, each problem in the network is owned by the system owner. Service providers cannot work on the system if they do not know exactly what is wrong, and it often is difficult to identify the problems in modern P25 systems.

When you build your own system, the only coverage available is what your system provides. Therefore, only the Story County sites can provide coverage for County users. In contrast, a regional network can have other sites assist in providing coverage. See Appendix C for County-owned system coverage, which illustrates the following scenarios.

1. 2 sites on street
2. 2 sites on street with surrounding counties
3. 2 sites with 12 dB in-building Story County view
4. 2 sites with 12 dB in-building with surrounding counties
5. 2 sites with 20 dB in-building Story County view

6. 2 sites with 20 dB in-building with surrounding counties
7. 2 sites with 30 dB around Ames

The greatest risk in owning a system is the cost commitment. Owning a system generates significantly more operational costs. Often, a change in leadership means that funding for proactive preventative maintenance gets reallocated. The result is a system that is trusted from an operational perspective to one that breaks down due to the lack of maintenance until it fails and requires a significant overhaul to update or replace the system.

4.1.2 Option 2 – Join a Regional Radio System

During the review and analysis of the 2009 radio system assessment report, owning the system was the only available option. This was not an oversight from the original report. This option only has become viable over the past couple of years, with the ISICS and SARA network build-outs.

Story County is in a unique position that allows it to choose between these two regional networks. Joining a regional system compared with owning the system will save the County millions of dollars in standalone hardware, maintenance, and personnel to support the system. The core of these networks can be cost-prohibitive. And during the past couple of years, the cost of these cores, with the features needed by Story County, have risen. Being able to utilize a regional core allows savings by avoiding duplicative hardware, maintenance, and personnel support. Further, having the ability to select between two networks is a rare opportunity for a county.

This approach also enhances interoperability, as the MOUs needed to enable interoperable communications already will be in place with every entity that has joined the regional network.

Although full system control is lost when joining a regional network, this is more than offset by not having the responsibility of operating and maintaining the regional system.

4.1.2.1 Option 2a – Iowa Statewide Interoperability Communications System (ISICS) (Motorola)

The Iowa Statewide Interoperable Communications System (ISICS) is a system purchased and funded by the State of Iowa that provides P25-standard digital communications to public safety agencies, first responders, schools, and utility workers. ISICS is built on a Motorola platform that is P25 Phase II-compliant with three geo-redundant cores. The system has encryption and OTAR capabilities. ISICS is managed by an ISICS user group committee. It currently offers to all agencies within the state its extra capacity. A small agency usually can be added to the system, and the system allows sites outside of the County's primary footprint to be used to ensure coverage. The system was designed for the State of Iowa agencies first and foremost, and it was designed to provide 95 percent mobile coverage throughout the state, not the individual counties.

The State currently is building a tower at the Ames Department of Transportation compound that will provide mobile coverage to the majority of Story County. Iowa has presented an opportunity to allow the Story County Board to use the State radio sites and add capacity to the system, while sharing the benefits

of a shared core along with the capabilities the core brings. This allows Story County to customize the radio solution to best fit the needs of the County in terms of features, functionality, coverage, and capacity. The State maintains that the County will have local agency control and management of its own assets. The State also maintains there is a “no-fee” structure to utilize and access the ISICS platform.

Each of the systems will allow interoperability with the other vendor’s radio system. Again, even though P25 guarantees operability on other vendor networks, Story County will need to execute MOUs to gain permission to join talkgroups on the other network for interoperability purposes. If the ISICS network is chosen then an application needs to go to the ISICS board for review. The board will review capacity, coverage, and need to determine if the permission will be allowed.

Regarding Story County users on ISICS, a site exists in Ames that offers great mobile coverage for most of the county, but it does not provide the mobile and portable coverage and capacity that the County requires. So, joining ISICS will mean that Story County will have to purchase sites for coverage and repeaters for capacity—as it would have to do if it joins the SARA network. Please see Appendix E for maps showing the coverage for Story County with augmented coverage by ISICS.

4.1.2.2 Option 2b – RACOM SARA Radio Network (Harris)

The Shared Area Radio Agreement (SARA) network, operated by RACOM, a Harris channel partner, consists of independent owners that allow direct interoperability across their networks. The network can be tailored to each county’s needs regarding coverage, capacity, and features. Each system owner has its own core device for reliability and redundancy. Although each core operates each owner’s system, the core has the capability to load share any part of the rest of the network. SARA has core-sharing, also called switch-sharing, capability with other counties. Connectivity would be required to connect Story County to a nearby RACOM site to connect to the core, either by fiber or microwave. SARA allows for interoperability with most users. Most of the populated counties in the eastern region of Iowa have chosen SARA as their primary network. These counties include Blackhawk, Marshall, Johnson, Dubuque, and Linn, with Scott and Warren soon to follow.

Each of the systems that comprise SARA will allow interoperability with the other vendor’s (Motorola) radio system. However, even though P25 guarantees operability on other vendor networks, Story County will need to execute MOUs to gain permission to join talkgroups on the other network for interoperability purposes. So, if the SARA network is chosen, then each system owner will need to be contacted for an independent MOU or similar agreement.

Regarding Story County users on the SARA system, there currently is not enough coverage to meet Story County’s needs. Joining the SARA system will require Story County to purchase sites for coverage and repeaters for capacity. Please see Appendix D for different maps showing the coverage for Story County with augmented coverage from the Harris SARA network.

The table below provides a comparison of the pros and cons between owning a standalone system, joining ISICS, or joining SARA.

Table 6: Option Comparisons

Solution	Pros	Cons
Owning	• Full system control	• Higher capital and sustainment costs • Lack of direct interoperability • System administrator required
Joining ISICS	• Currently no fees required³ • Core maintained by state⁴ • Can add sites and capacity • Use of surrounding layer of sites • ISICS radios operate on SARA • Statewide 95% mobile coverage	• All decisions go to ISICS Board • Global settings in system
Joining SARA	• MOUs with other agencies • Typically free or at low cost with agreement • Can share neighboring cores • Can add sites and capacity • Use of all RACOM sites with MOU • SARA radios operate on ISICS	• Decisions are between individual county owners • Settings are based on personality area

4.1.3 Conceptual Radio System Design

Both Motorola and RACOM/Harris offer the solutions requested by the users. The only variable in the design was the coverage. Several options were investigated for coverage and capacity. Several previous designs showed tower heights of about 200 feet. At 200 feet, the County requires four sites to provide coverage to the County and its critical areas. Raising towers to 400 feet provides much more coverage throughout the County. Appendix D and Appendix E shows two simulcast sites at 400 feet. With 400-foot towers, the conceptual hardware components design includes:

- Prime site controller capable of Phase II P25
- Simulcast equipment local to the Ames site, with two remote sites
- Remote site equipment with five repeaters at Ames and Colo (eight talk paths)
- Dispatch console positions at Ames Police Department, Story County Sheriff, and ISU dispatch.
- Concurrent network management positions at each dispatch location
- Microwave backhaul to each of the sites not connected by microwave
- 95% coverage with a 12-dB margin in buildings

³ Subject to change

⁴ Prepaid for 10 years

- Paging transmitters operating in simulcast mode at Ames and Colo

4.2 Recommended Paging Solution

From the interviews, the fire community has a road map for fire alerting, which will continue to be an analog simulcast tone-and-voice paging system. This is the same architecture as the current system. However, the new system will be enabled for simulcast, and the sites will be different from the current design.

4.2.1 Describe the Methodology

Each dispatch console will have the ability to transmit a fire alert. A dispatch operator will select the paging icon and transmit the message. This will go across the microwave network to the prime paging site. The system can add a CAD analog input if a CAD solution in the future can read the message. This is becoming a standard function on the fire side of CAD interfaces.

The two sites—DOT Ames and Colo—would be simulcasted together. These sites would require relicensing from the FCC. But because the hardware is colocated with the radio system, maintenance will be more cost-effective without sacrificing coverage. And because the sites have redundant hardware, any single point of failure will be eliminated.

4.2.2 Conceptual Paging System Coverage

The current site does not offer radio equipment protection. Although the current prime site is in the middle of the county, there are more advantageous sites when incorporated into a working simulcast design. The new paging system should be colocated with the new radio equipment to achieve maintenance economies of scale. Coverage using the DOT Ames and Colo sites for the analog paging system can be found in Appendix B. The recommended coverage will be 95 percent countywide, with a 12-dB margin for in-building coverage that also can be achieved by these sites.

4.3 Recommended Radio and Paging Sites

Story County's existing radio sites are not owned by the Board and are not properly maintained to Motorola R56® guidelines. The Board will have the opportunity to take advantage of colocating the paging equipment on a tall tower structure with improved antenna heights, thus potentially improving coverage in the service region. A second site will be required in the County's eastern region, and budgetary estimates have been provided for the tower, compound development, and shelter that will be necessary to build a new radio site.

4.3.1 Department of Transportation – Ames, Iowa

The Department of Transportation site at Ames, also known as DOT Ames, is a State-owned, 375-foot tower being constructed on the eastern border of the city. The tower is located at 42° 0' 41.09" N, 93° 33'

32.45" W and is projected to provide ample coverage to the city and the western half of Story County. Currently the site is under construction with tower steel being delivered and site development underway. It is anticipated that the site will be constructed to industry-standard specifications and will include ample space for additional radio and microwave equipment. Completion of the site is projected to occur in spring 2018. During our discussions with the State, it has agreed to allow Story County to colocate at the DOT Ames site if joining the ISICS system or the SARA system.

The opportunity to colocate on the State-owned tower is advantageous to Story County as the State has indicated there would be no lease costs. MCP recommends using the DOT Ames tower, as it provides a suitable location providing coverage throughout the City of Ames, the ISU campus, and the County's western region, and would save the Board a monthly lease cost or the cost to build a tower—a capital cost savings of more than \$700,000 dollars, and more than \$1.3 million in recurring payments over 20 years.

4.3.2 Colo, Iowa – Radio and Paging Site

MCP identified the need for a radio site in the east-central portion of the County, in the Town of Colo, for improved coverage regardless of whether the Board opts to join a regional shared system or build its own system. If the Board chooses the regional shared system, the Colo site still would be required regardless of whether the Board joins ISICS or SARA.

A property is located at 42° 1'3.77"N, 93°18'46.91"W, adjacent to the Colo Volunteer Fire Department, which should provide adequate coverage with a 380-foot tower. Alternate properties may be evaluated if this site cannot be secured. No existing structures were found in the immediate area of Colo. Even if one existed, MCP does recommend leasing a tower from an existing owner, as lease fees are \$4,000 per month, or more, depending on the amount of equipment and vertical spaced requested. Leasing two vertical spaces on towers at \$4,000 with a 3 percent escalator over a 20-year period would cost the Board \$1.3 million. Greenfield sites clearly are the better option when a new tower is required to improve coverage.

Greenfield sites are constructed from the ground up and usually are built to stringent specifications such as Motorola R56®. They have the benefit of being purchased, constructed and owned by the operating agency, thus reducing recurring lease payments. Assuming land is available, site locations can be identified that provide optimal coverage for the system for which they are being constructed. However, construction requires potentially costly land acquisition and timely completion of zoning requirements; adherence to the National Environmental Protection Act (NEPA), approvals from the State Historic Preservation Office (SHPO) and the Federal Aviation Administration (FAA); and various other approvals. In some cases, land access still may require a monthly site lease; however, if the land is acquired from a local agency, such as a fire department, that cost is substantially lower.

Strategically placed greenfield radio sites may interest other wireless carriers that may seek tower usage for a monthly fee, revenue that can offset construction or land-use fees. It has been MCP's experience that the typical return on investment (ROI) for a new-build site has been seven years, with a cost savings of more than \$1 million dollars. The ROI is much quicker if the Board leases space to commercial carriers or other businesses desiring space on the tower.

4.4 Frequency Band

Story County's radio system operates in the 800 MHz frequency band; however the licenses are in the commercial pool. The 800 MHz frequency band is a good choice for the County, but it would need to obtain its own licenses in the public safety pool for the next radio system. The 800 MHz frequency band offers a low noise floor, good building penetration, less interference, and higher output power. At the time of MCP's research, an ample amount of 800 MHz frequencies were available. Subscriber radios operating in the 800 MHz frequency band are interoperable with ISICS, which operates in the 700 MHz frequency band. If Story County chooses, the 700 MHz band would be a suitable alternative to the 800 MHz band, as preassigned channels are ready to be licensed through coordination with Region 15. The 700 MHz band shares the same common characteristics with the 800 MHz band, with the exception of output power. The FCC imposes regulatory limitations on the 700 MHz band that reduce the transmit output power, resulting in more radio sites required compared with 800 MHz band. The 800 MHz band can provide similar coverage but with less sites, resulting in an overall reduction of capital investment, and lower infrastructure and maintenance costs, giving the County a better overall value.

The paging system currently operates in the VHF frequency band with licenses assigned to Story County in the public safety pool. However, the County will need to perform modifications to the existing paging license to reflect the configuration of the new paging system. MCP recommends VHF as the optimal frequency band for continued paging operations, because it allows the reuse of existing pagers. This offers a significant cost savings for the Board and the local fire and EMS agencies by avoiding the purchase of new pagers.

4.5 Backhaul

Backhaul connectivity is a critical component of multisite radio systems. A robust and reliable backhaul network is required to ensure reliable communications.

The current three-site radio system is not interconnected and there is no backhaul between the sites. Modern public safety communications systems require multiple sites to have connectivity with each other. This means that the sites cannot talk to each other until there is connectivity. As the current radio system demonstrated, the lack of such connectivity creates a potentially dangerous situation for first responders, because they do not have wide-area communications. Modern public safety communications also require all sites to have access to all talkgroups, which currently is not the case in Story County. In addition, users often are unaware when a site becomes unavailable. This is a common occurrence with the current system that was witnessed during our interviews with users.

Modern public safety communications systems have a reliable means of connecting the sites, which typically takes the form of fiber-optic cable or microwave.

Reliability is one of the most coveted traits of any public safety system. There are several methods to achieve reliability. One method is to design the microwave backhaul in a ring configuration. In the event a hop fails due to a maintenance issue or weather-related event, the network will reroute itself in the other direction. However, sometimes a loop is not feasible, and the path needs to have redundant components in

a hot-standby configuration, and extra margin on the radio signal. Ultimately the microwave connections are designed to have a minimum connectivity of 99.999 percent per hop.

Based on the Board's desire for a reliable backhaul network to support a P25 operations, MCP recommends that the Board implement a microwave network in a ring or hot-standby configuration, with a designed reliability of 99.999 percent.

Backhaul routing should be installed that supports IP-packet Ethernet traffic and operates on the multiprotocol label switching (MPLS) platform. This will allow dynamic routing of voice and data traffic over multiple physical mediums (fiber, copper, microwave). The microwave network should provide a minimum of 150 Mbps of throughput on each link to support future capabilities, such as data applications and video. This will provide the Board with a backhaul network with increased redundancy and greater reliability.

Communications centers and radio sites are the lifeline of emergency response organizations, and it is vital to ensure that they are able to communicate at all times. MCP estimates microwave implementation costs at \$148,000 per hop, with the potential for reductions depending on the level of competition and vendor discounts.

4.6 Subscriber Radios and Features

Subscriber radio equipment needs to be compatible with the infrastructure technology implemented by the County, and should meet public safety standards for durability and reliability. Subscriber radios currently utilized within the county are not capable of P25 operation. Therefore, all subscriber radios will need to be replaced if a P25 Phase II system is implemented.

Subscriber equipment also is past end of life, driven by the day-to-day abuse mobiles and portables endure, the natural evolution of technology, and manufacturer discontinuation notices. Most subscriber units average seven to ten years, as these units operate in a more rugged environment compared with fixed equipment assets, which leads to a shorter lifespan. The majority of radios in operation in Story County are not designed for public safety operations. They are commercial grade and are not designed for the rigorous environment in which first responders operate.

MCP recommends a complete and full replacement of the current radios with P25-capable public safety-grade radios. The current Motorola XPR series of mobiles and portables showcased during MCP's evaluation will not support P25 operations, nor are they rated for the rigorous standards designed for public safety. In addition to P25 operation, MCP recommends replacing the current fleet of subscriber radios with public safety-grade radios designed to withstand the abuse stemming from the daily operations of law enforcement, fire, and EMS users.

MCP further recommends that the County consider the following guidelines when determining the appropriate number of subscriber radios:

1. A one-for-one replacement of all existing 800 MHz mobile radios and control stations.
2. A one-for-one replacement of all existing 800 MHz law enforcement portables.

3. A one-for-one replacement of all existing 800 MHz emergency medical services (EMS) portables.
4. One portable radio in each operator position for each fire engine, or the current number of portable radios, whichever is lower.
5. A one-for-one replacement of all existing 800 MHz public works mobiles and portables, with a lower-tiered public safety grade radio.

A P25 radio system allows the subscriber units to be purchased from one or more vendors, which can provide the County with the benefit of competition. Conservative pricing for portable and mobile trunked P25 radios is approximately \$3,700 per unit on average. The estimated cost then to replace all subscriber devices, at list cost, is \$5,076,345, based on the current number of mobiles, portables, and control stations in use today. MCP divided the subscriber count into two public safety tiers. For budgetary purposes, we estimated 300 mid-tier mobiles, 750 mid-tier portables and 250 low-tier portables. The low-tier and mid-tier devices are both public-safety grade, but the difference is in features. The low-tier may not have a keypad, whereas the mid-tier may have a color screen and a full-function keypad. Low-tier radios are typically for users in a non-public safety role but who still require a public safety-grade radio, such as public works or road crews. Typically, with system procurements, the vendor often will provide a bulk purchase discount of at least 20 percent, and further negotiations often can result in substantial additional cost savings.

MCP thus encourages the Board to engage in a competitive procurement for replacement of its user fleet, to stimulate competition and obtain the best possible pricing.

4.6.1 Encryption

Encryption, which currently is unavailable, has been identified as a requirement by many law enforcement agencies in Story County, City of Ames, and Iowa State University. The Advanced Encryption Standard (AES) is the most secure encryption available for public safety radios and is the standard encryption per P25 specifications. AES is available on P25 trunking systems and is the only encryption that meets the P25 type 3 encryption standards for interoperable communications.⁵ The majority of vendors support the AES algorithms. While there are other encryption methods available, they are proprietary to the vendor that offers them or are not as secure as AES.

MCP recommends that all law enforcement agency radios be equipped with AES. Encryption then could be implemented on specific talkgroups for use on an as-needed basis. If law enforcement elects to encrypt primary talkgroups, special considerations must be made for interoperating agencies that may not have encryption-capable radios, or access to the County's encryption keys

⁵ http://www.twoway.net/sites/default/files/documents/p25_encryption_and_interoperability.pdf.

4.6.2 Over-the-Air Programming

Over-the-air programming (OTAP) is an optional feature that permits remote programming of subscriber radios utilizing the P25 data network. OTAP can reduce programming time and effort significantly compared with the typical manual programming efforts.

OTAP also is a proprietary feature available on systems that do not conform to the P25 standard. When proprietary features are implemented, the subscriber radio manufacturer must be the same as the system manufacturer for these features to work.

MCP cautions that the adoption of proprietary features may lock agencies within the county into a single vendor from which to purchase subscriber radios to maintain use of any proprietary feature. Consequently, MCP recommends that the vendor price OTAP as an option; however, it should be noted that vendors are offering Wi-Fi capabilities in mobiles and portables in lieu of OTAP.

4.6.3 Over-the-Air Rekeying

Over-the-air rekeying (OTAR) enables mobiles and portables to be rekeyed using digital data transmitted over RF links. This allows each subscriber radio to be rekeyed without having to bring it to a radio service shop to be physically programmed. It is similar to OTAP, with the difference being that OTAR involves changing the encryption keys the subscriber device uses to refresh the keys, or due to an encryption key becoming compromised. This is a significant time-saving tool that would allow a radio manager to quickly change the keys on a radio through a simplified process. OTAR provides a stronger security position and gives the County complete control of subscriber devices that have encryption. As a best practice, MCP recommends requesting OTAR as an option for the subscriber radios planned to operate with encryption, typically those used by law enforcement agencies.

4.6.4 Global Positioning System

Certain P25-compliant radios are equipped with Global Positioning System (GPS) receivers that are capable of transmitting a subscriber unit's coordinates to a communications center utilizing the P25 data backbone. This feature can be used for unit tracking of both portable and mobile radios. The feature costs approximately \$400 per radio, plus additional costs for GPS monitoring equipment and CAD system integration. GPS-equipped systems and radios are available from multiple manufacturers. However, subscriber radios must match the system vendor, which limits competition for subscriber radios if all radios are to be equipped with GPS. Consequently, MCP recommends that the vendor provide this as an option on mobiles and portables. Typically, the GPS option is used for law enforcement, but not for fire, EMS, or public works agencies.

4.7 Radio Dispatch Console

The existing Zetron dispatch consoles are P25 capable and were installed approximately six years ago. The current consoles are well within their typical lifespan of 12 years. Our expectation would be that the

vendor provides an option to reuse the existing consoles, or proposes new consoles that integrate seamlessly with the radio system and fit the dispatchers' needs.

For P25 systems, the interface between the system and the console remains proprietary for the largest system vendors. Because of this interface, the dispatch console manufacturer will be required to match the radio system vendor. P25 systems permit a direct IP connection between the system and console units, significantly reducing the amount of backroom equipment necessary to provide channel audio to the consoles.

If the Board elects to implement an 800 MHz P25 trunked system, consoles may be selected from almost any console vendor available. All LMR consoles support narrowband analog connectivity, as well.

The current console system supports an interface with the CAD system that allows the CAD system to automatically select the appropriate paging tones for fire and EMS dispatch. This feature should be included as a mandatory requirement in any developed console specifications document, to ensure that the console product will permit the continued use of this feature.

4.8 Logging Recorder

P25 systems provide a significant amount of information along with call audio. This information includes unit ID, affiliated radio sites, talkgroup information, and other data that may be useful if the call needs to be recalled and reviewed in the future. Only certain model logging recorders are capable of recording this data. Certain model recorders also are capable of directly interfacing with P25 systems, while others only can support four-wire audio through a control station interface. Control station interfaces can be costly if a significant number of channels are to be recorded, as each channel requires a separate mobile radio to provide the four-wire audio.

If a P25 system is implemented, the Eventide logging recorder system used by Story County at the three dispatch centers likely will need to be upgraded for a direct system interface to be implemented, to allow P25 trunked audio to be recorded. This determination ultimately will be identified by the selected vendor.

4.9 Bidirectional Amplifiers

During the interviews, it was determined that one bidirectional amplifier (BDA) is in operation to make up for poor in-building coverage. There may be more because this system has been in operation for more than 30 years, and other BDAs might have been forgotten. However, any BDAs in play will not be operating on the frequencies of the recommended system; this is not an issue because significant coverage enhancements will be provided by the new system, so these legacy BDAs most likely will not be required, a determination that will be made once the new system is implemented.

The new radios offer technology that offers in-building coverage from the concurrent P25-over-cellular devices. This may be advantageous to ISU and the City of Ames. Because most of the dense buildings are in these jurisdictions, the new radios can be ordered with Wi-Fi to provide coverage in large, dense structures via the campus-wide Wi-Fi system.

4.10 Budgetary Cost Estimates

MCP has developed preliminary budgetary estimates based on the system options identified. These estimates will be further refined during the design phase once specific design considerations are finalized. Estimates have been provided should Story County choose to build its own system, join ISICS, or join the SARA network. Estimated costs in the following tables show the list costs and a potential 30 percent discount off list price which reflects an industry typical discount depending on size and scope of the system.

4.10.1 Option 1 – Story County-Owned, 800 MHz, P25 Phase II, Trunked Simulcast System

The following capital investment is for the Board to procure a standalone radio system that includes geodiversity and optimum redundancy and replacement of all subscriber radios, as well as the implementation costs associated with installation and engineering. The paging cost assumes the use of existing pagers. Other assumptions are as follows:

1. Two-site simulcast transmit/receive locations
 - a. One existing site at the Department of Transportation facility in Ames, east of Interstate 35
 - b. Construction of a 400-foot tower in Colo, to include shelter, generator, and site development
2. Total of eight talk paths across two simulcast sites
3. Story County-owned geographically diverse, redundant system controllers and prime sites
4. Twelve new console positions for three dispatch centers—ISU, Ames, Story County, with four at each center
5. Microwave system with MPLS in a ring or hot-standby configuration; three hops
6. Replacement of the tone-and-voice paging system with a standalone, two-site simulcast paging system
7. All subscriber radios replaced—estimated 750 mid-tier portables, 250 low-tier portables and 300 mobiles; 70 control stations; 273 AES encryption and OTAR licenses; and 1,370 OTAP licenses

4.10.1.1 Capital Investment

Table 7: Standalone Radio and Paging System Budget

Item	Assumptions	Total Cost
System Core and RF Infrastructure	P25 Phase II Trunked Simulcast – 2 Sites, 5 Talk Paths	\$3,199,160
Backhaul Network	166 Mbps, Ring Topology	\$450,544
Paging	2-site Simulcast	\$84,228
Facilities	Site Upgrades, New Tower Site at Colo	\$708,043

Item	Assumptions	Total Cost
Radio Dispatch Consoles	12 positions	\$697,836
Radio System Options	Logging Recorder, OTAP, OTAR, P25 over Cellular, GPS	\$304,048
FCC Licensing	Frequencies for 800 MHz, Paging	\$24,500
Subscribers	Portables, Mobiles, Control Stations	\$5,076,345
PM, Engineering & Implementation	Project Management, Spares, Freight, Test Equipment, Training	\$2,800,635
Contingency	5%	\$273,418
Total		\$13,618,757
30% Discount		\$9,533,130

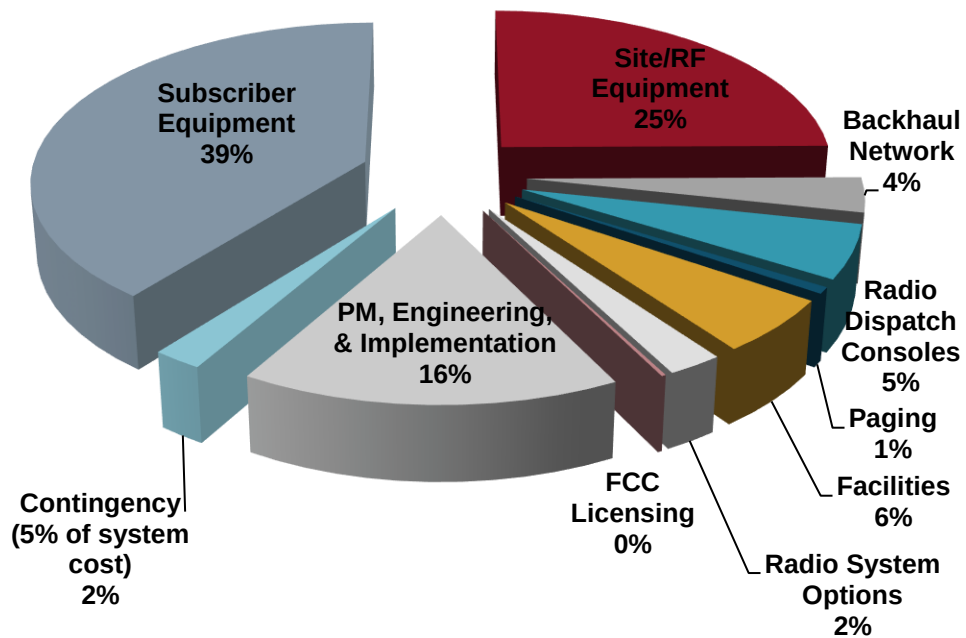


Figure 2: Standalone Radio and Paging System Capital Investment

4.10.2 Option 2a – Join ISCIS (Motorola)

The following capital investment details the costs should the Board choose to join ISCIS system, which inherently would provide geo-diverse, redundant core equipment at no cost to the Board. The cost includes the required infrastructure for capacity tailored specifically to Story County users, required backhaul to connect two sites for coverage specific to the needs of the County, replacement of all subscriber radios, and the implementation costs associated with installation and engineering. The paging cost assumes the use of existing pagers. Other assumptions are as follows:

1. Two simulcast transmit/receive locations
 - a. One existing site at the Department of Transportation facility in Ames, east of I-35
 - b. Construction of a 400-foot tower in the town of Colo to include shelter, generator, and site development
2. Total of eight talk paths across two simulcast sites
3. Pricing includes sharing the network core with ISICS, and simulcast equipment at DOT Ames
4. Microwave system with MPLS in a ring or hot-standby configuration; three hops
5. Replacement of the tone-and-voice paging system with a standalone, two-site simulcast paging system
6. Twelve new console positions for three dispatch centers—ISU, Ames, Story County, with four at each center
7. All subscriber radios replaced—estimated 750 mid-tier portables, 250 low-tier portables and 300 mobiles; 70 control stations; 273 AES encryption and OTAR licenses; and 1,370 OTAP licenses
8. Other implementation costs include items such as permitting, site acquisition, lease agreements, engineering, and project management

4.10.2.1 Capital Investment Option 2a

Table 8: Option 2a—ISICS Budget

Item	Assumptions	Total Cost
P25 Phase II RF Infrastructure	2 Sites, 5 Channels	\$1,629,028
Backhaul Network	166 Mbps, Ring Topology, 3 hops	\$450,544
Paging	2-site Simulcast	\$84,228
Facilities	Site Upgrades, New Tower Site at Colo	\$708,043
Radio Dispatch Consoles	12 positions	\$697,836
Radio System Options	Logging Recorder, OTAP, OTAR, P25 over Cellular, GPS	\$301,050
FCC Licensing	Frequency for 800 MHz, Paging	\$24,500

Item	Assumptions	Total Cost
Subscribers	Portables, Mobiles, Control Stations	\$5,076,345
PM, Engineering & Implementation	Project Management, Spares, Freight, Test Equipment, Training	\$2,229,504
Contingency	5%	\$197,267
Total		\$11,398,345
30% Discount		\$7,978,842

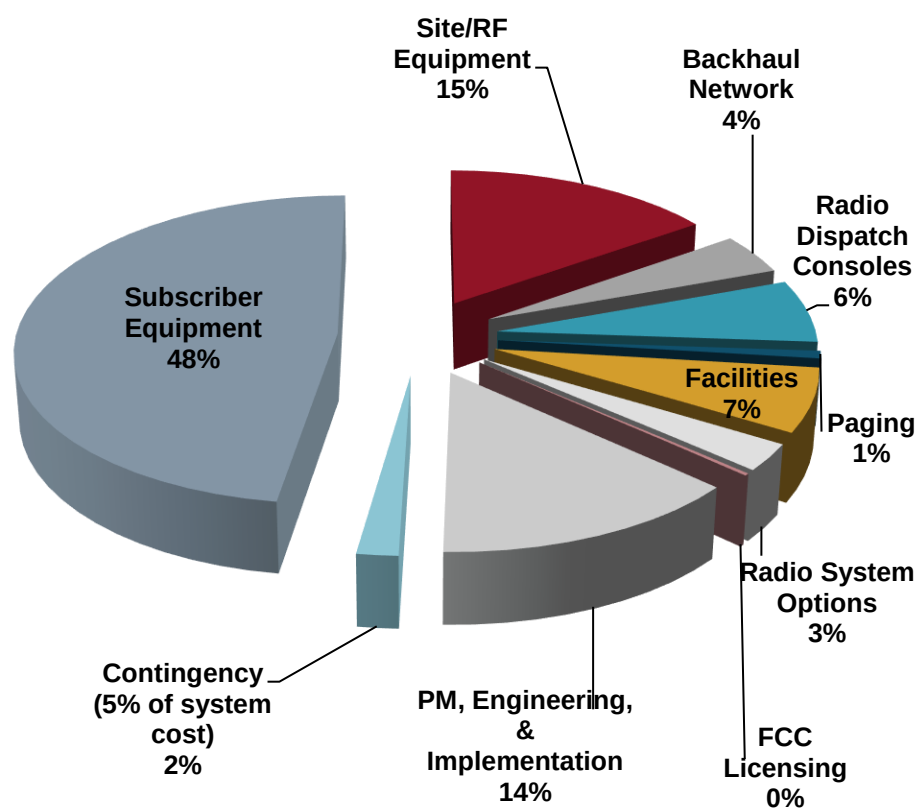


Figure 3: Option 2a Capital Investment

4.10.3 Option 2b – Join SARA (RACOM/Harris)

The following capital investment details the costs should the Board choose to join the SARA system. Joining SARA provides a cost-savings opportunity to share core equipment at Marshalltown and Polk County. Required connectivity by microwave to the switching equipment would be between Colo and Jasper. The cost includes the required infrastructure for capacity tailored specifically for Story County users, new subscriber radios, and the implementation costs associated with installation, project management and engineering. The paging cost assumes the use of existing pagers. The following cost assumes that the State of Iowa will allow the Board to use the DOT Ames site to house Harris's equipment. Other assumptions are as follows:

1. Two simulcast transmit/receive locations
 - a. One existing site at the Department of Transportation facility in Ames, east of I-35
 - b. Construction of a 400-foot tower in Colo to include shelter, generator, and site development
2. Total of eight talk paths across two simulcast sites
3. Pricing includes sharing the SARA network core with one of the existing network partners
4. Microwave system with MPLS in a ring or hot-standby configuration; four hops
5. Replacement of the tone-and-voice paging system with a standalone, two-site, simulcast paging system
6. Twelve new console positions for three dispatch centers—ISU, Ames, Story County; four at each center
7. All subscriber radios replaced—estimated 750 mid-tier portables, 250 low-tier portables and 300 mobiles; 70 control stations; 273 AES encryption and OTAR licenses; and 1,370 OTAP licenses
8. Other implementation costs include items such as permitting, site acquisition, lease agreements, engineering, and project management

4.10.3.1 Capital Investment Option 2b

Table 9: Option 2b—SARA Budget

Item	Assumptions	Total Cost
P25 Phase II RF Infrastructure	2 Sites, 5 Channels	\$1,475,907
Backhaul Network	166 Mbps, Ring Topology	\$591,672
Paging	2-site Simulcast	\$84,228
Facilities	Site Upgrades at DOT Ames; New Tower Site at Colo	\$739,322
Radio Dispatch Consoles	12 positions	\$697,836

Item	Assumptions	Total Cost
Radio System Options	Logging Recorder, OTAP, OTAR, P25 over Cellular, GPS	\$301,050
FCC Licensing	Frequency Coordination for 800 MHz, VHF Paging	\$24,500
Subscribers	Portables, Mobiles, Control Stations	\$5,076,345
PM, Engineering & Implementation	Project Management, Spares, Freight, Test Equipment, Training	\$2,217,943
Contingency	5%	\$195,726
Total		\$11,404,529
30% Discount		\$7,983,170

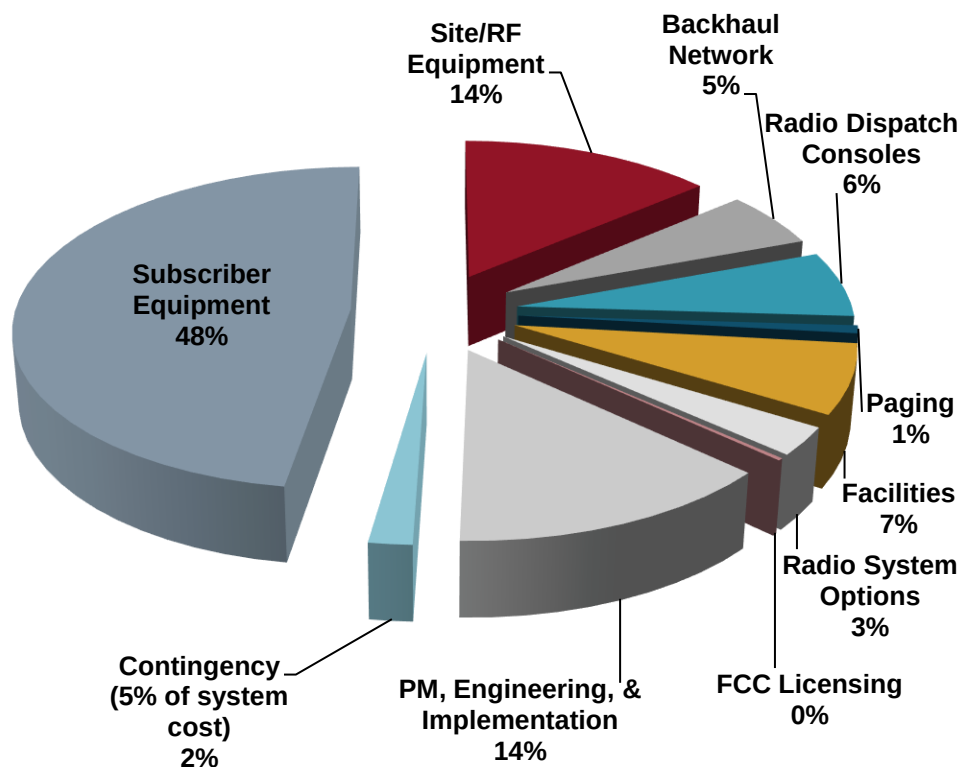


Figure 4: Option 2b Capital Investment

If the State of Iowa does not allow the Board to use the DOT Ames site in the SARA design, there would be an additional cost of \$871,231 to build a second site with a 400-foot tower. This includes the tower, site acquisition and development, a shelter, generator, DC power, regulatory work, engineering, and project management. The radio infrastructure, backhaul network, paging, and all other costs would remain the same.

Table 10: SARA with Two New Sites Budget

Item	Assumptions	Total Cost
P25 Phase II RF Infrastructure, Backhaul, Paging, Dispatch Consoles, FCC Licensing, Subscriber Radios, PM & Engineering	2 Sites, 5 Channels	\$10,350,995
*Facilities	New Tower Site in Ames; New Tower Site in Colo	\$1,883,837
Total		\$12,234,832
30% Discount		\$8,564,382
*Includes a 5% contingency, PM, engineering and implementation costs for two new greenfield sites		

It should be noted that it is common to expect actual competitive prices to be discounted below the budgetary cost estimates provided above. However, these levels are recommended for budgeting purposes to ensure that sufficient contingency funds are available.

Regardless of whether the County selects ISICS or SARA, one of the many benefits of joining another system is the ability to share costs. When joining another system, the costs are spread among the users and the agency hosting the core equipment. Both the Motorola and the Harris technology lend themselves to this architecture. The system itself becomes more redundant. Because the Harris technology allows for other controllers on the wide-area network (WAN) to share loading, if a Story County core were to fail, another core in the system would pick up the load and alert technicians that a repair is necessary. With the ISICS system, there are three cores that provide triple redundancy. Sharing of this control equipment can result in savings of \$300,000 to \$2,000,000, depending on control equipment capacity and configuration. The Board should leverage any existing resources, such as sharing core equipment, to reduce the capital investment and establish redundancy for the users in Story County.

4.11 Lifecycle, Maintenance, and Sustainment Costs

Story County currently uses Electronic Engineering as its local service shop for the subscriber radios, paging system and radio system; however, during our discussions with the Board and stakeholders, the support received has been less than adequate. MCP recommends a preventive maintenance program with a reputable local service shop that the Board and County trusts, to put the needs of the users first. Any of the options selected will include additional system components, which result in higher maintenance costs.

System lifecycle costs include site maintenance, heating/ventilation/air-conditioning (HVAC), generator, microwave, preventive maintenance, unlimited radio programming, parts and labor repairs, active network monitoring, and 24 x 7 x 365 response on emergency repairs. P25 systems specifically include numerous hardware and software components that must be maintained. Additional maintenance services are available, such as remote monitoring of system alarms and remote technical support, which significantly can reduce the amount of time needed to correct system failures. The regular update of system software permits bug fixes, the addition of features, and a regular refresh of technology to extend the life of the system.

With any of the identified options, the Board can anticipate system sustainment costs anywhere between 3 percent and 12 percent depending on negotiations, services required, and system bundling options. The first year of maintenance typically is included with any system purchase. The Board will have the option to purchase additional maintenance for subsequent years. This maintenance may be contracted with the system vendor directly or with a local radio shop that the Board chooses. The Board does have the option to prescribe a vendor based on preference.

The maintenance vendor will depend on the option and vendor the Board ultimately chooses. Maintenance vendors are trained and certified for certain systems; the maintenance vendor will need to be qualified to work on the installed system. Training of Board or County personnel on maintenance is also a recommended option. Most organizations of this size have at least one person on staff to assist in programming, interoperability, and keeping track of vendors' maintenance performance. Without this individual, scope and costs tend to creep upwards with maintenance vendors. Training sometimes will be included in the system cost, although additional test equipment may need to be purchased for the new system. The County would need to secure optional pricing for test equipment and training.

MCP recommends that optional pricing be secured for system maintenance for years two through ten following system implementation. Maintenance costs can be lumped into a capital expenditure if it is anticipated that the County will not receive a large-enough budget to maintain recurring yearly payments. With more advanced systems, such as trunking systems, additional software-update fees are required to keep the system at current release. If the Board chooses to join ISICS, it is a requirement that the radio infrastructure be on the same release version. Table 11 summarizes, on average, the estimated lifecycle costs for each of the identified options.

Table 11: Proposed Lifecycle Costs

	Option 1 Standalone	Option 2a Joining ISICS	Option 2b Joining RACOM
Year 1	\$3,420	\$3,420	\$3,420
Year 2	\$154,478	\$98,770	\$76,784
Year 3	\$159,112	\$101,733	\$79,087
Year 4	\$189,643	\$164,804	\$131,693
Year 5	\$195,332	\$169,748	\$135,644

The above includes software updates and maintenance fees. Utilizing a shared system has additional cost-saving potential, as the cost for the system core is shared across multiple agencies or counties.

4.12 Next Steps

MCP recommends that the County take the steps detailed below to move forward with the radio system procurement. MCP understands that there are multiple options available to the County, including some that may involve waiting a significant period of time before any action is taken. MCP has found that system purchase costs are at an all-time low. This is a reflection of the current radio equipment market and current competition levels. There is no guarantee that the deals available today still will be available several years from now. In a nutshell, now is the time to act.

4.12.1 Competitive Procurement

This is usually the primary means of procurement when competition is desired between vendors that do not have a contract for procurement. Competitive procurements typically yield the best overall system value when multiple vendors are capable of offering equivalent or near-equivalent products. In this example, at least one vendor can reasonably offer a shared-switch option with a contract vehicle. And the introduction of competition may lead to additional savings that surpass the benefit of a shared central controller.

Several components of a radio system may be offered by different vendors. These components include the following:

- Radio system infrastructure
- Radio system subscriber radios
- Microwave backhaul network
- Radio site construction

Requests for proposals (RFPs) may be developed that contract all of these components into a single vendor or to separate vendors.

4.12.2 RFP with Multiple Awards

An RFP designed for multiple awards permits vendors to bid separately on the different system components. More often than not, system infrastructure and subscriber radios are bid together. However, significant cost savings may be recognized through the separate procurement of microwave and site-development components. Separately procuring microwave and site-development services is an available option even if infrastructure and subscriber components are procured through an existing contract source, shared-switch option. The drawback to multiple awards is the increased project management responsibility for coordinating the different entities. However, project management services typically can be contracted for far less than the added cost of a single-vendor contract.

Multiple awards may be accomplished through either a single RFP that permits vendors to independently bid on different sections, and through multiple RFPs. If an RFP route is selected, MCP recommends a single RFP that permits vendors to bid the system as either a single-award or multiple-award. This type of RFP will provide the Board with comparative prices for single-award and multiple-award options, thus providing the greatest level of pricing options.

4.12.3 RFP Competitive Procurement with Existing Contracts

MCP recommends a competitive procurement with an RFP between existing contract sources. If the Board wishes to procure from either Motorola or Harris, there are established contracts in the state that allows for existing contract source procurement. The State of Iowa allows single-source procurement off its contract with Motorola. The director of the radio system has confirmed and forwarded the contract to MCP. RACOM executives have forwarded a similar contract from Blackhawk County that allows an existing source procurement from that contract for Harris equipment.

This allows for some economies of scale between the customer and its potential vendor. Because there is an existing contract vehicle for each of the major vendors and both of those vendors have a regional system that can provide adequate coverage for Story County, a value proposal can be started with each vendor. Each regional system has strengths and weaknesses. Instead of a uniform and blank approach to a solution, each vendor can present a proposal that plays to their strengths and shores up their weaknesses, while allowing for system discounts higher than the current contract pricing. Through this process, each vendor can have a chance to provide more features and lower costs until the best solution and value is reached for the County.

An RFP is written to minimally qualify vendors and provide a baseline set of requirements that the vendor must meet. After a thorough review of the vendors' proposals is completed, an award is made. During the negotiations after the award, features and options above and beyond the minimally required usually receive less discount than before the award was made.

MCP recommends beginning dual negotiations with existing contract sources at the end. This will ensure both vendors will bring ALL of their options and features at the lowest competitive price.

4.12.4 Schedule

Given the current state of public safety communications in Story County, time is of the essence to proceed with procurement. Project implementation for radio systems that have subscriber radio, microwave, and paging components typically follows the progression below:

- Contract execution (Month 1)
- Coordination of MOU for joining regional system (Months 1–3)
- Frequency coordination (Month 3)
- Contract design review (Month 5)
- Shipment of microwave equipment from factory staging (Month 10)
- Shipment of radio equipment from factory staging (Month 12)
- Site development completion (Month 14)
- Subscriber equipment and accessories (Month 16)
- Installation completed at all sites (Month 18)
- System acceptance and ready for cutover (Month 20)
- Cutover and final acceptance (Month 24)

The anticipated project schedule is approximately 24 months, including RFP development if chosen, with all users transitioned to the new system at the end of the second quarter of 2020.

5 Conclusions

Mission Critical Partners (MCP) completed a comprehensive assessment of the Motorola Privacy Plus radio system used by the Story County 911 Board and its VHF paging system. MCP confirmed that the radio system is based on architecture and equipment that no longer is supported by the manufacturer and is not public safety grade. Based on deficiencies identified by system users and the information collected, we have presented recommendations for replacement of the radio and paging systems, with cost savings opportunities that will provide improvements in areas of coverage, capacity, reliability, and backhaul capabilities, as well as subscriber radios with standards-based, public safety-grade solutions. Based on the age of the current equipment, and the recent failures Story County has endured, MCP recommends replacement of both systems immediately.

Stakeholders and users interviewed just want the system to work; they have been too accustomed to system downtime and failures. Reliability, coverage, and capacity are the most requested areas of improvement stated by users

The Board should maintain the current momentum by progressing directly into the planning, procurement, negotiation, and implementation phases. The success of these phases and their individual components will

have a direct impact on the success of any initiative. The County's radio communications and paging systems are failing and putting police officers and firefighters at an elevated risk of danger. The typical implementation period for a radio system, including system design and planning, is approximately 18-24 months. With the necessary planning and procurement tasks, it may be two years before a new system is implemented and operational. With the challenges faced by the existing systems, time is of the essence.

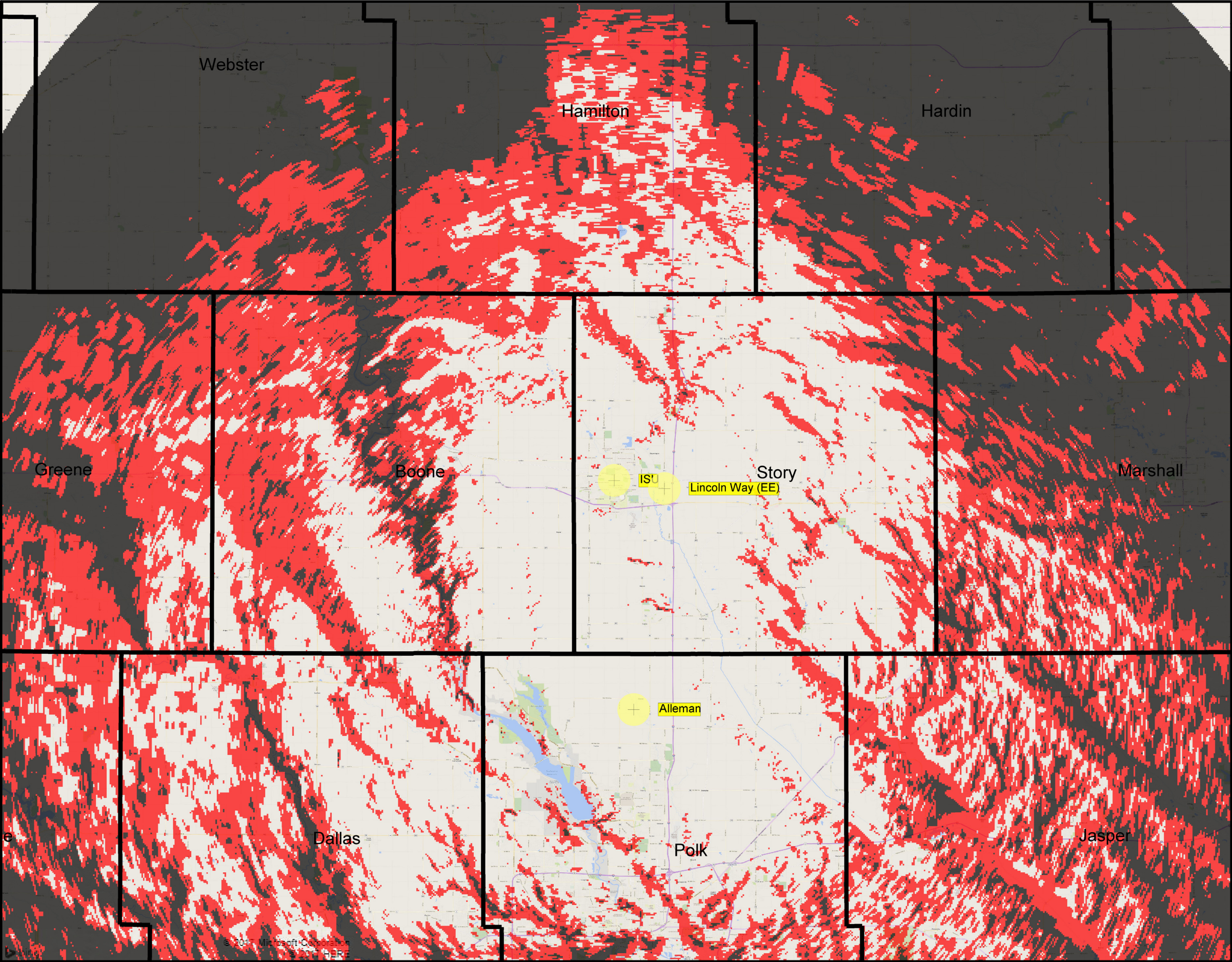
Both the ISICS and SARA regional systems meet the requirements of the users. Both vendors (Motorola and RACOM/Harris) have proven products and systems operating in Iowa. It is recommended that Story County utilize one of the current regional systems, ISICS or SARA. This will allow for the most improvements in terms of coverage, capacity and interoperability, at the best value price. It is further recommended that Story County discusses site and talkgroup interoperability options with both regional system owners.

There are a few other immediate tasks that Story County should pursue. A sample of P25 radios from each vendor on similar talkgroups should be tested on the DOT site in Ames. Because the current Ames site is one of the main sites of interest, Story County should start evaluating the coverage and features of ISICS. A site should be acquired in Colo for the other simulcast site. When each of these topics has been investigated, dual negotiations with both vendors should begin.

MCP fully understands the challenges faced by the Board and what must be accomplished to provide a long-term communications solution that will satisfy the needs of first responders in Story County for the years to come. MCP stands ready to assist the Board in the next phase of the project with planning, procurement, and implementation, upon review and approval of the presented options.

Appendix A – Existing 3 site Composite Coverage Map

1. Existing 3 Sites on Street
2. Existing in building 12 dB
3. Existing in building 20 dB



EDX® SignalPro®: Story County V.3

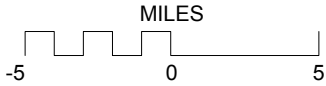
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

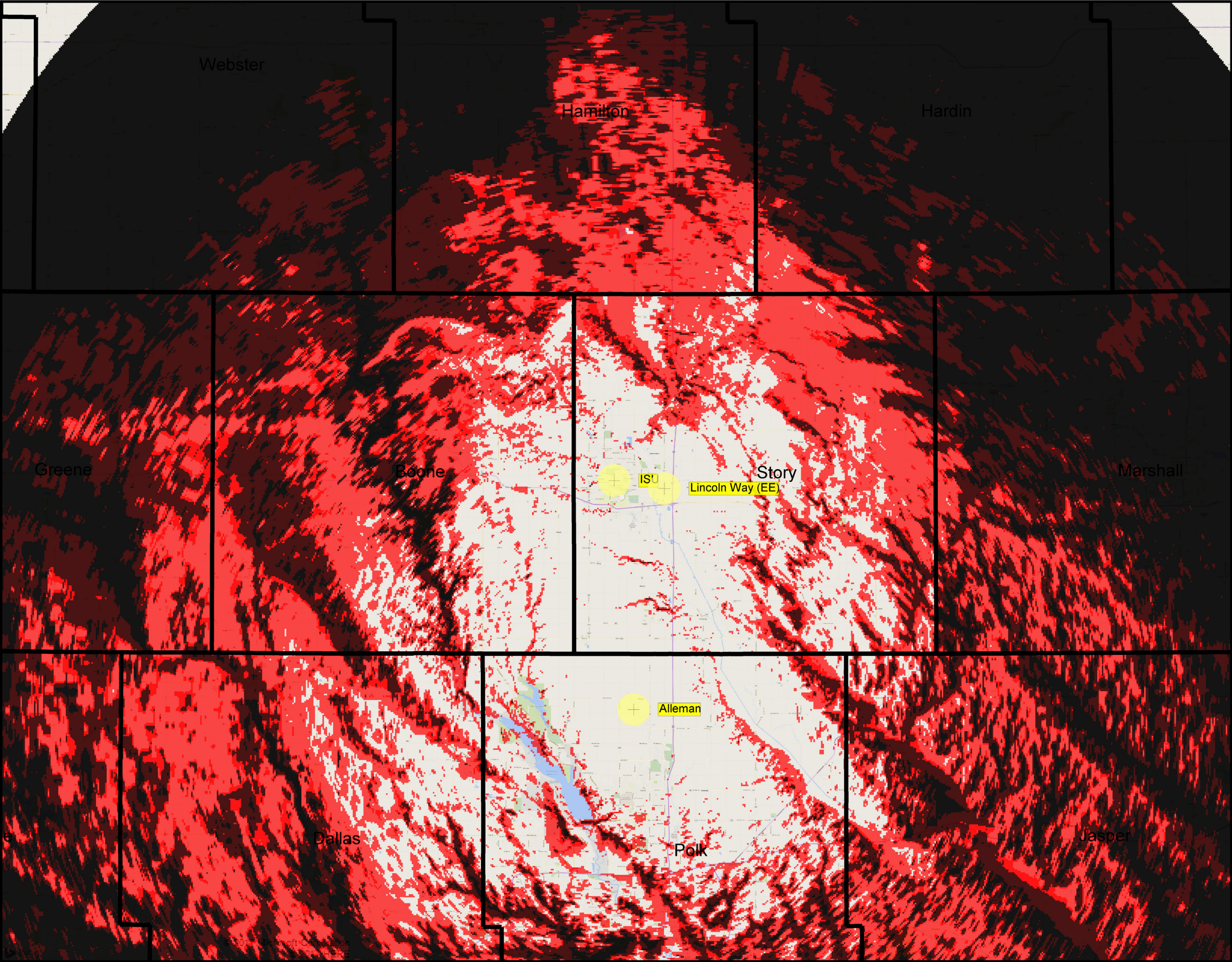
Existing System

>=	-95.6 dBmW	DAQ 3.4 or Better
	-111.6 to -95.6 dBmW	DAQ 2.0 to 3.4
<	-111.6 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story County, IA
Existing 800 MHz Composite Map
On Street Mon Nov 27 13:07:07 2017



EDX® SignalPro®: Story County V.3

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

800 MHz 12 dB

>=

-83.6 dBmW

DAQ 3.4 or Better

-99.6 to -83.6 dBmW

DAQ 2.0 to DAQ 3.4

< -99.6 dBmW

Less than 2.0

Display threshold level: -250.0 dBmW

MILES

-5

0

5

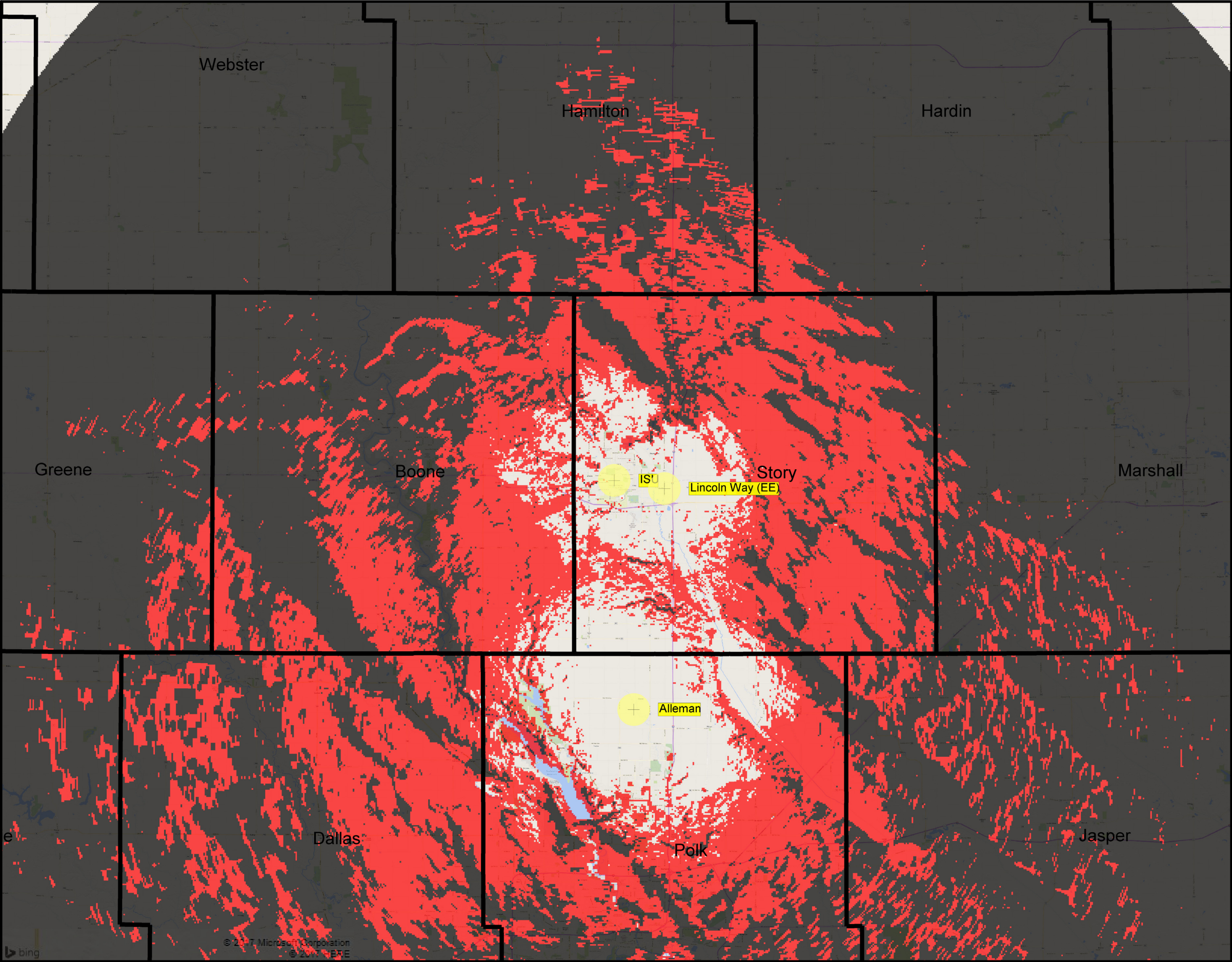
MissionCriticalPartners

Story County, IA

Existing 800 MHz Composite Map

12 dB in building

Mon Nov 27 13:04:38 2017



EDX® SignalPro®: Story County V.3

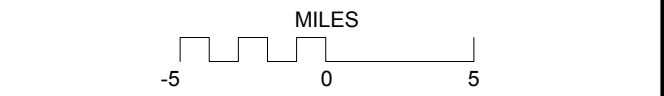
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

800 MHz Existing 20 dB

>=	-75.6 dBmW	DAQ 3.4
>=	-91.6 to -75.6 dBmW	DAQ 2.0 to DAQ 3.4
<	-91.6 dBmW	Less than DAQ 2.0

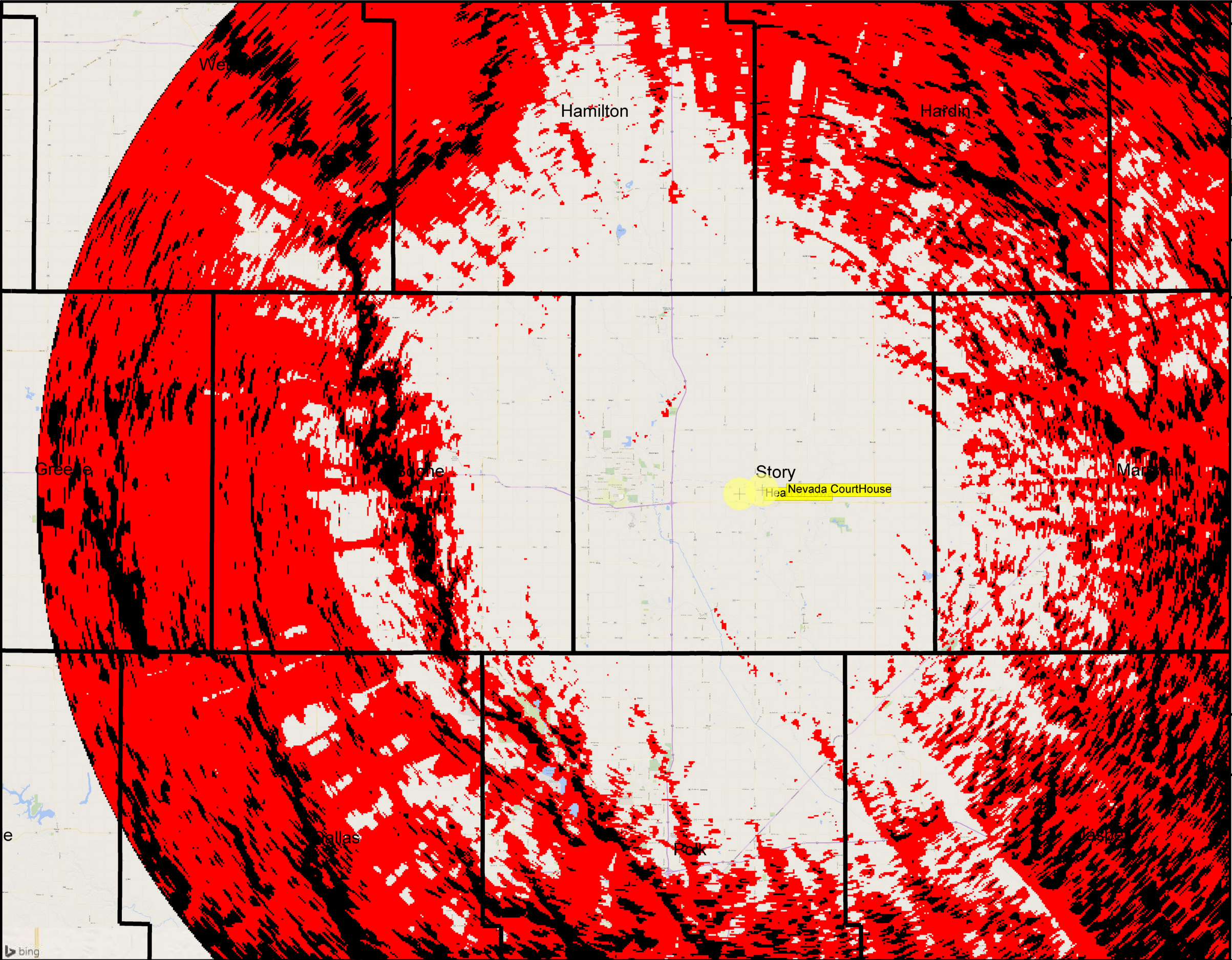
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story County, IA
Existing 800 MHz Composite Map
20 dB in building Mon Nov 27 13:00:36 2017

Appendix B – Properly Engineered and Licensed Paging System

1. Existing Ideal VHF Paging 12 dB building and On Street
2. Proposed VHF Paging 12 dB building and On Street



EDX® SignalPro®: Story County V.3

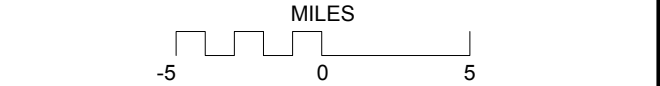
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

Paging System

>=	-93.7 dBmW	12 dB Buildings
	-105.7 to -93.7 dBmW	On Street
<	-105.7 dBmW	Low success of pages

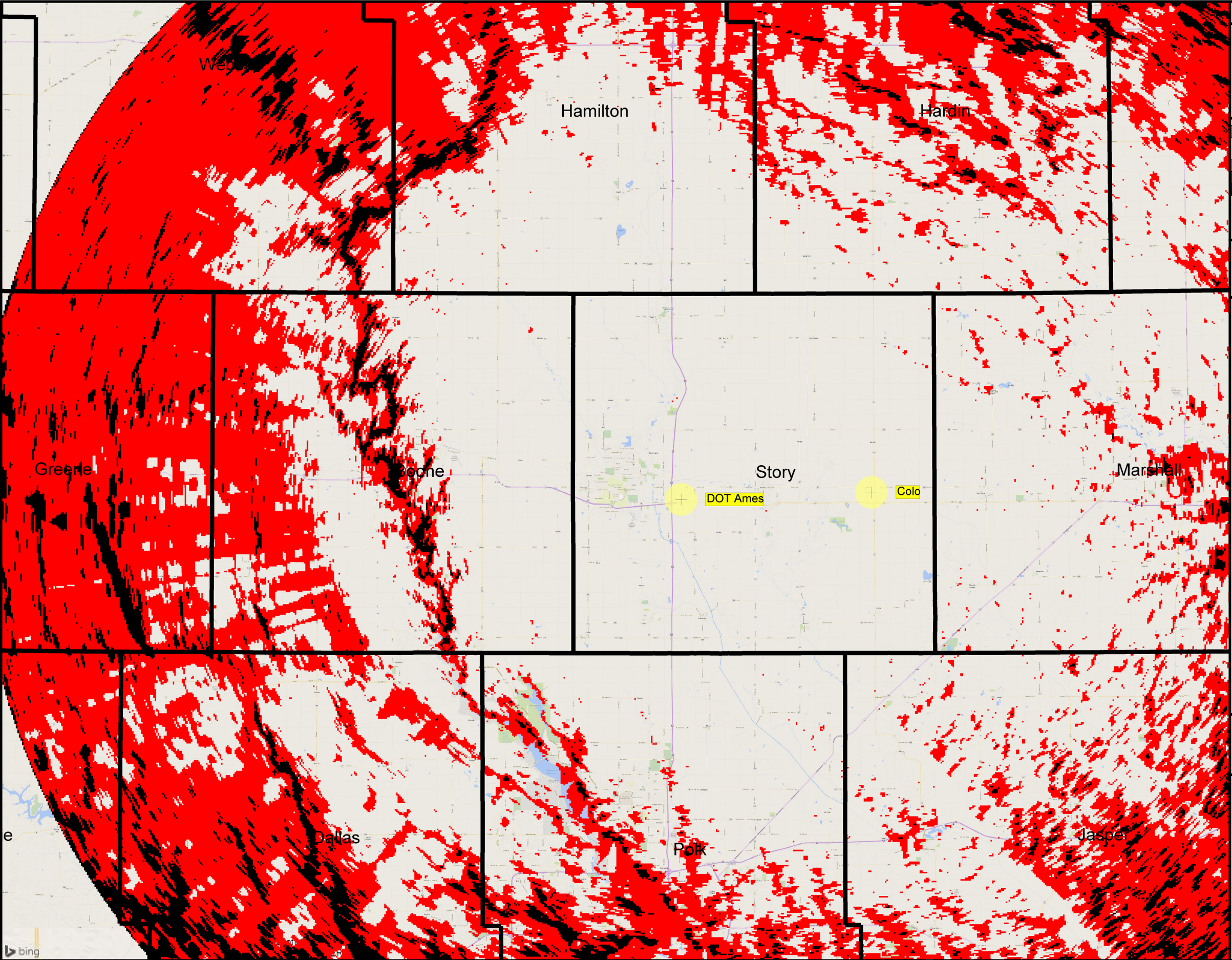
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: -2.15 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing Ideal VHF Paging Composite Map
12 dB Building and on street in RED Mon Nov 27 13:57:26 2017



EDX® SignalPro®: Story County V.3

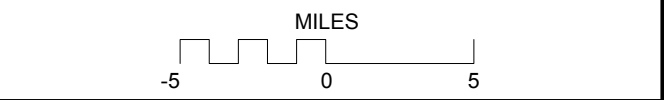
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

Paging System

>=	-93.7 dBmW	12 dB Buildings
	-105.7 to -93.7 dBmW	On Street
<	-105.7 dBmW	Low success of pages

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: -2.15 dBd



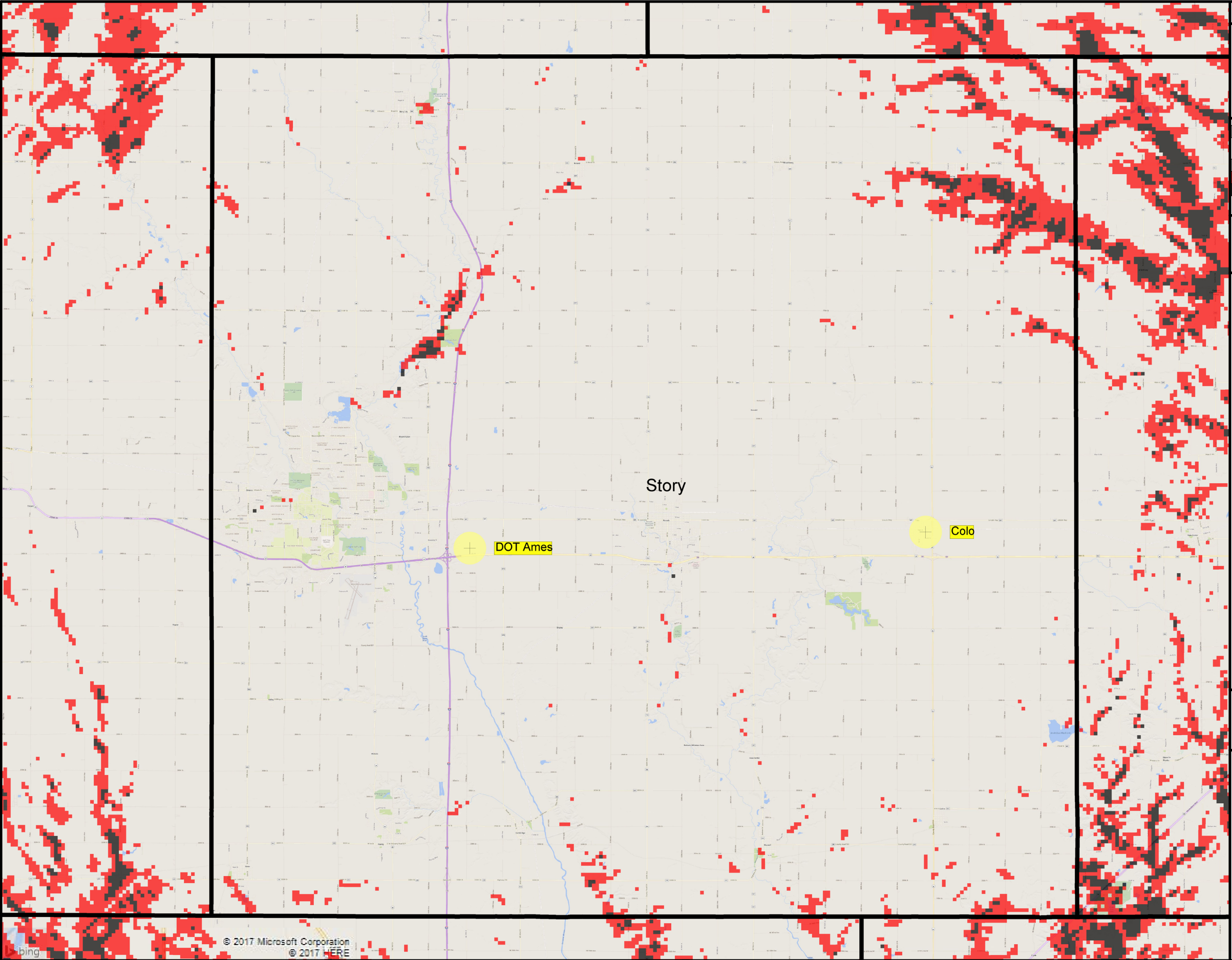
Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Proposed VHF Paging Composite Map
12 dB Building and on street in RED Mon Nov 27 14:50:37 2017

Appendix C – County Owned System Maps

1. 2 Sites on Street
2. 2 Sites with 12 dB in building Story County view
3. 2 Sites with 20 dB in Building Story County view
4. 2 Sites with 30 dB around Ames



EDX® SignalPro®: Story County Zoom In

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

Story County Owned

>= -100.7 dBmW	DAQ 3.4 or Better
-109.8 to -100.7 dBmW	DAQ 2.0 to DAQ 3.4
< -109.8 dBmW	Less than 2.0

Display threshold level: -250.0 dBmW

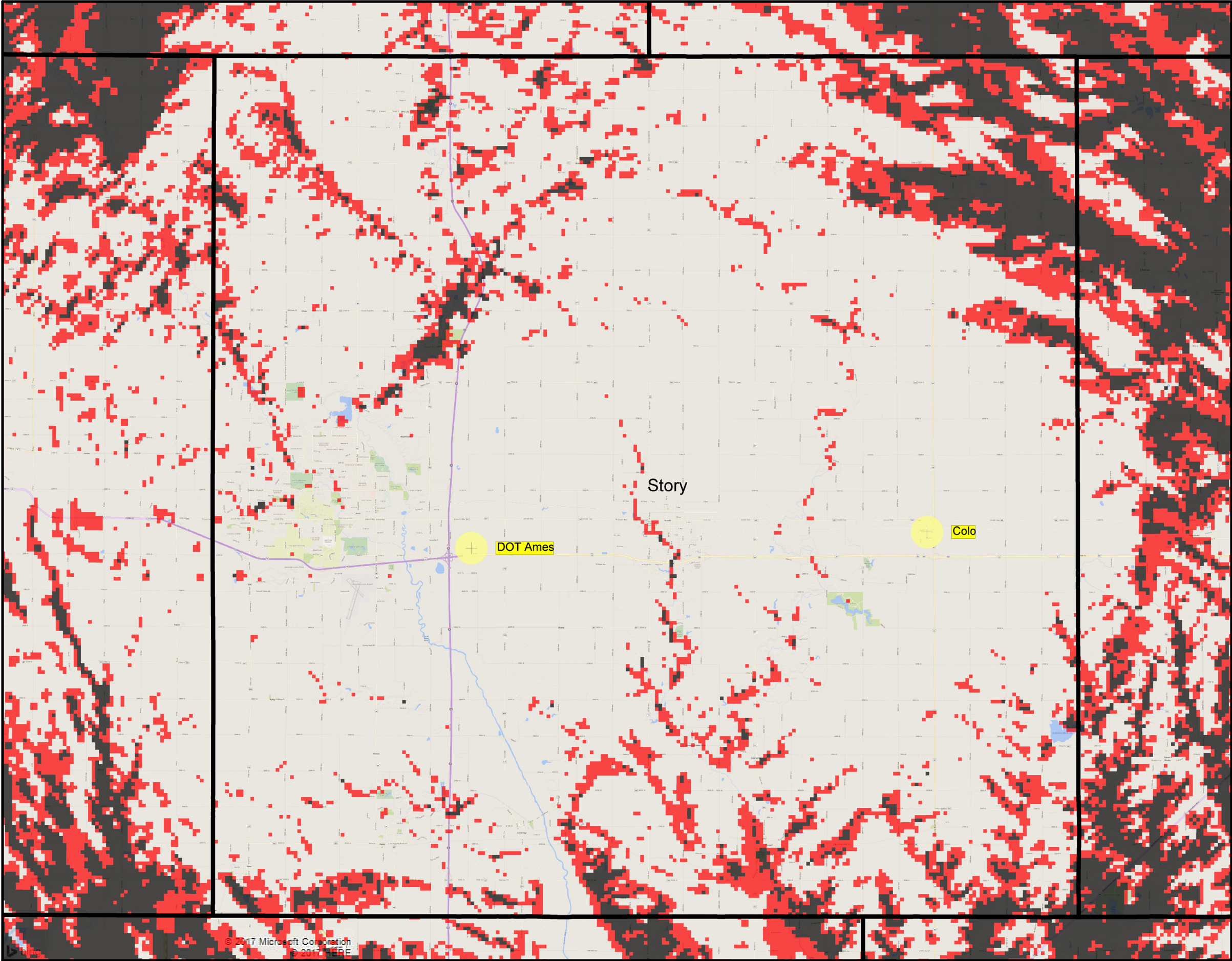
MILES

-1 0 4

Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Story County Owned System-Ames and Colo
On Street Fri Dec 01 09:38:54 2017



EDX® SignalPro®: Story County Zoom In

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

Story County Owned

>= -88.7 dBmW

>= -97.8 to -88.7 dBmW

< -97.8 dBmW

DAQ 3.4 or Better

DAQ 2.0 to DAQ 3.4

Less than 2.0

Display threshold level: -250.0 dBmW

MILES

-1 0 4

M

MissionCriticalPartners

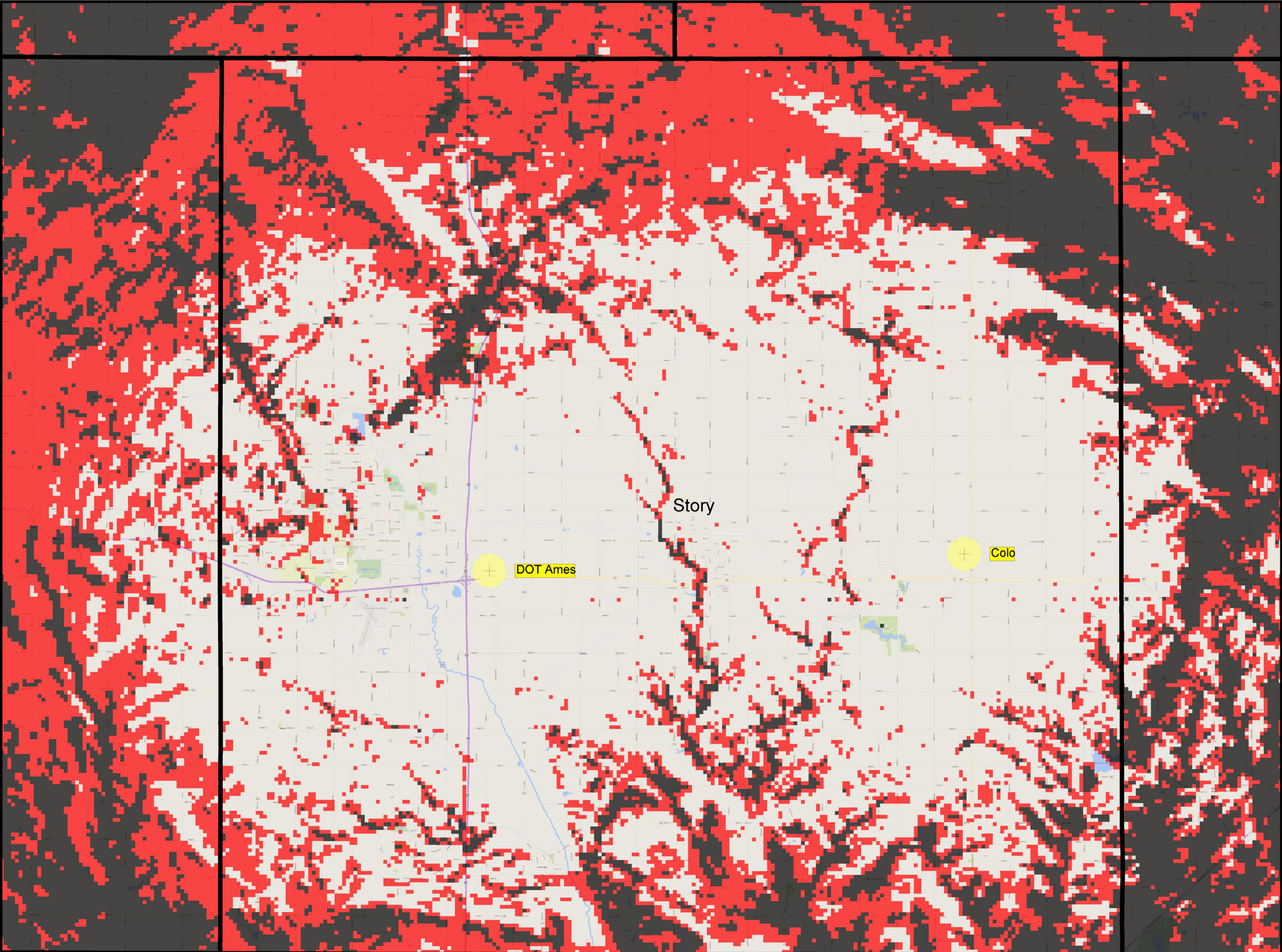
Story County, IA

Story County Owned System-Ames and Colo

12 dB in building

Fri Dec 01 09:31:58 2017

© 2017 Microsoft Corporation
© 2017 HERE



EDX® SignalPro®: Story Country Zoom In

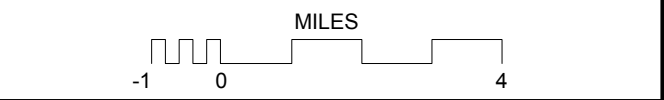
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

Story County Owned

>=	-80.7 dBmW	DAQ 3.4 or Better
	-89.8 to -80.7 dBmW	DAQ 2.0 to DAQ 3.4
<	-89.8 dBmW	Less than 2.0

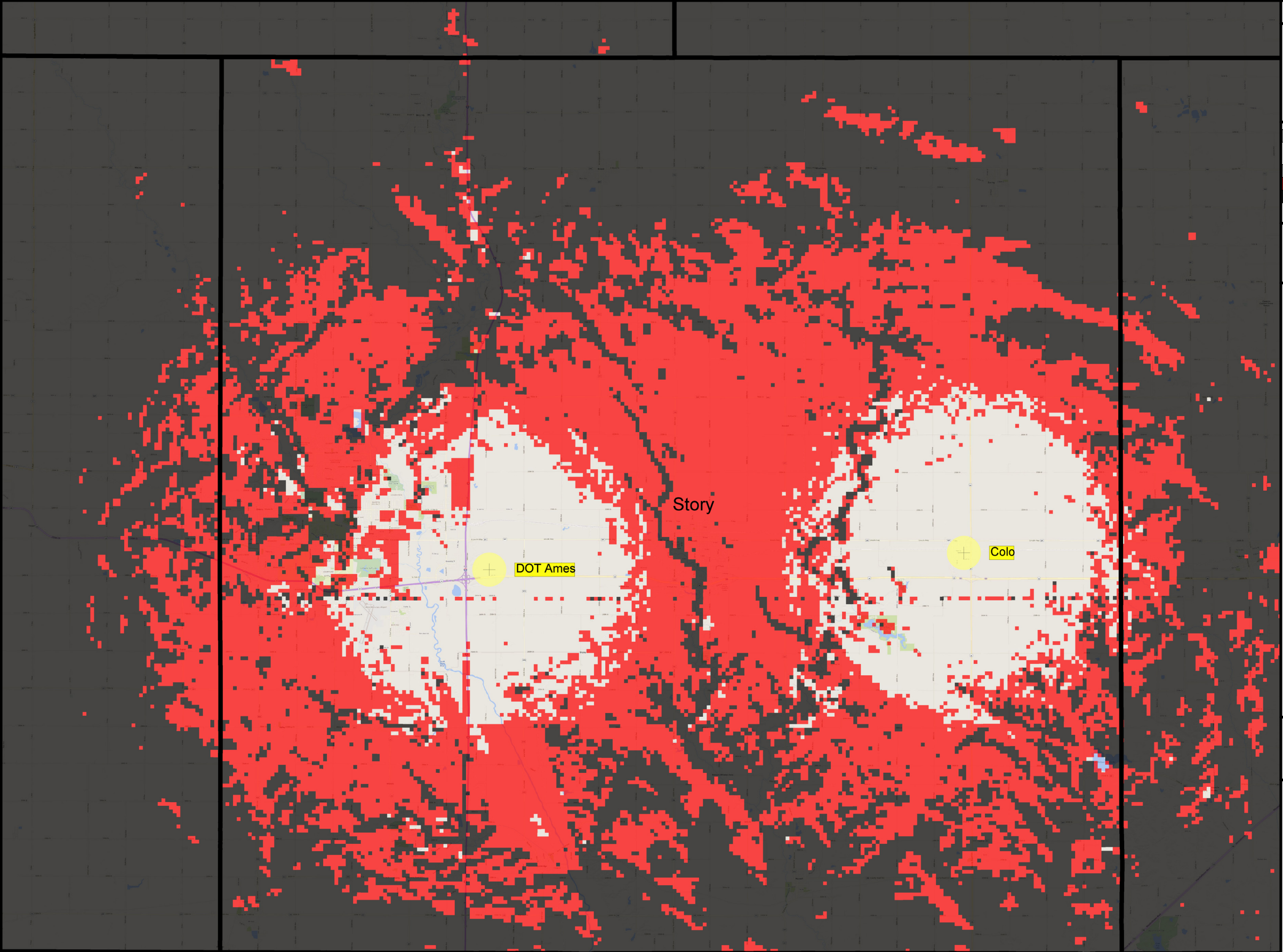
Display threshold level: -250.0 dBmW



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Story County Owned System-Ames and Colo
20 dB in building
Fri Dec 01 09:34:33 2017



EDX® SignalPro®: Story County Zoom In

Prop. model 1: Anderson-2D v1.00

Time: 50.0% Loc.: 50.0%

Prediction Confidence Margin: 10.2dB

Climate: Continental Temperate

Land use (clutter): USGS-EDX format (.151 files)

Atmospheric Abs.: none

K Factor: 1.333

County Boundaries

Story County Owned

>=

-70.7 dBmW

DAQ 3.4 or Better

-79.8 to -70.7 dBmW

DAQ 2.0 to DAQ 3.4

< -79.8 dBmW

Less than 2.0

Display threshold level: -250.0 dBmW

MILES

-1

0

4



Story
County

IOWA • 1853

M

MissionCriticalPartners

Story County, IA

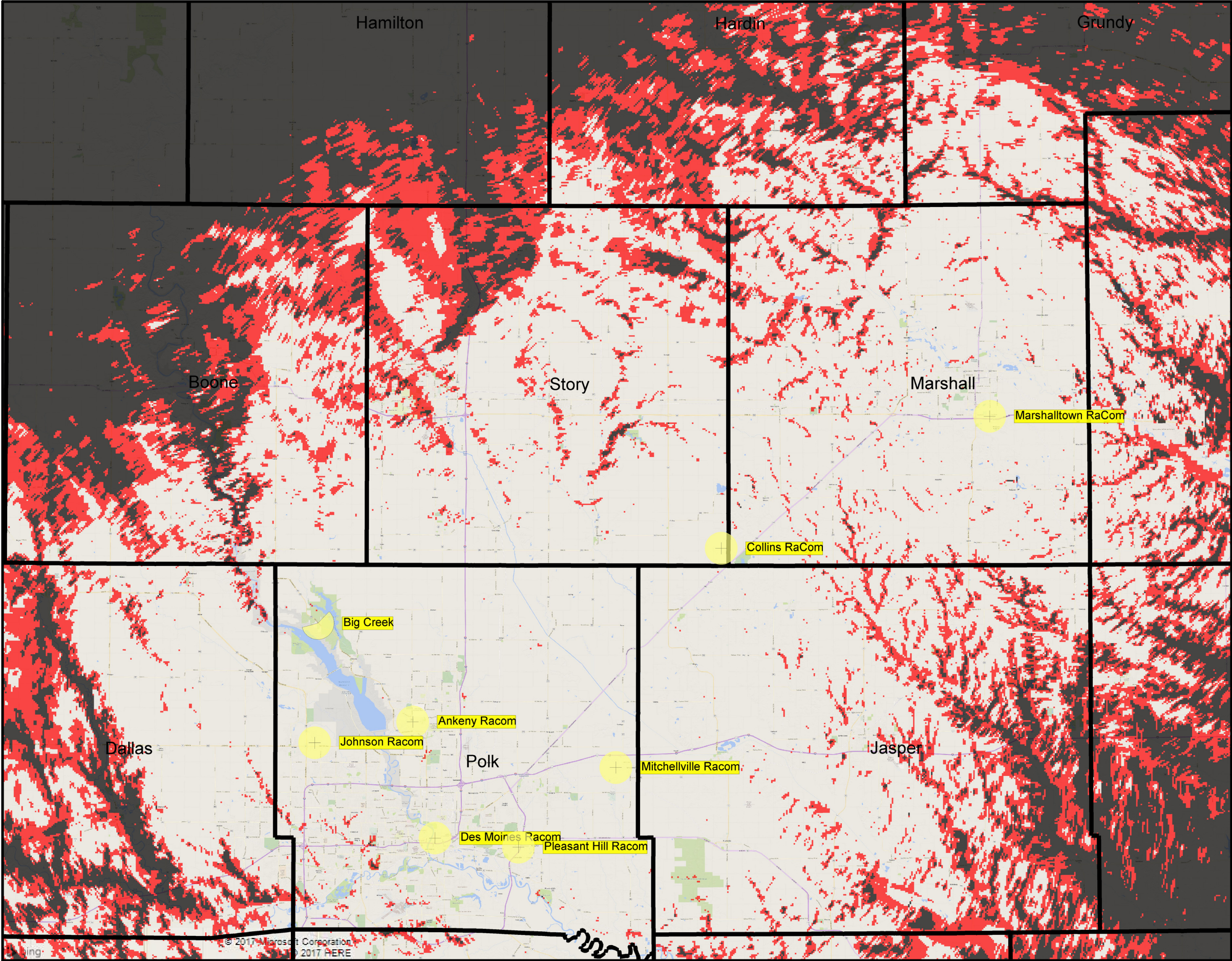
Story County Owned System-Ames and Colo

30 dB in building

Fri Dec 01 09:36:38 2017

Appendix D – RACOM Maps

1. Existing on street
2. Existing in 12 dB building
3. Existing in 20 dB building
4. 2 Sites on street
5. 2 Sites in 12 dB County level
6. 2 Sites in 12 dB with surrounding Counties
7. 2 Sites in 20 dB County level
8. 2 Sites in 20 dB with surrounding Counties
9. 2 30 dB in Ames



EDX® SignalPro®: Story Country Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>= -100.7 dBmW	DAQ 3.4 or Better
-109.8 to -100.7 dBmW	DAQ 2.0 - DAQ 3.4
< -109.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES
-5 0 5



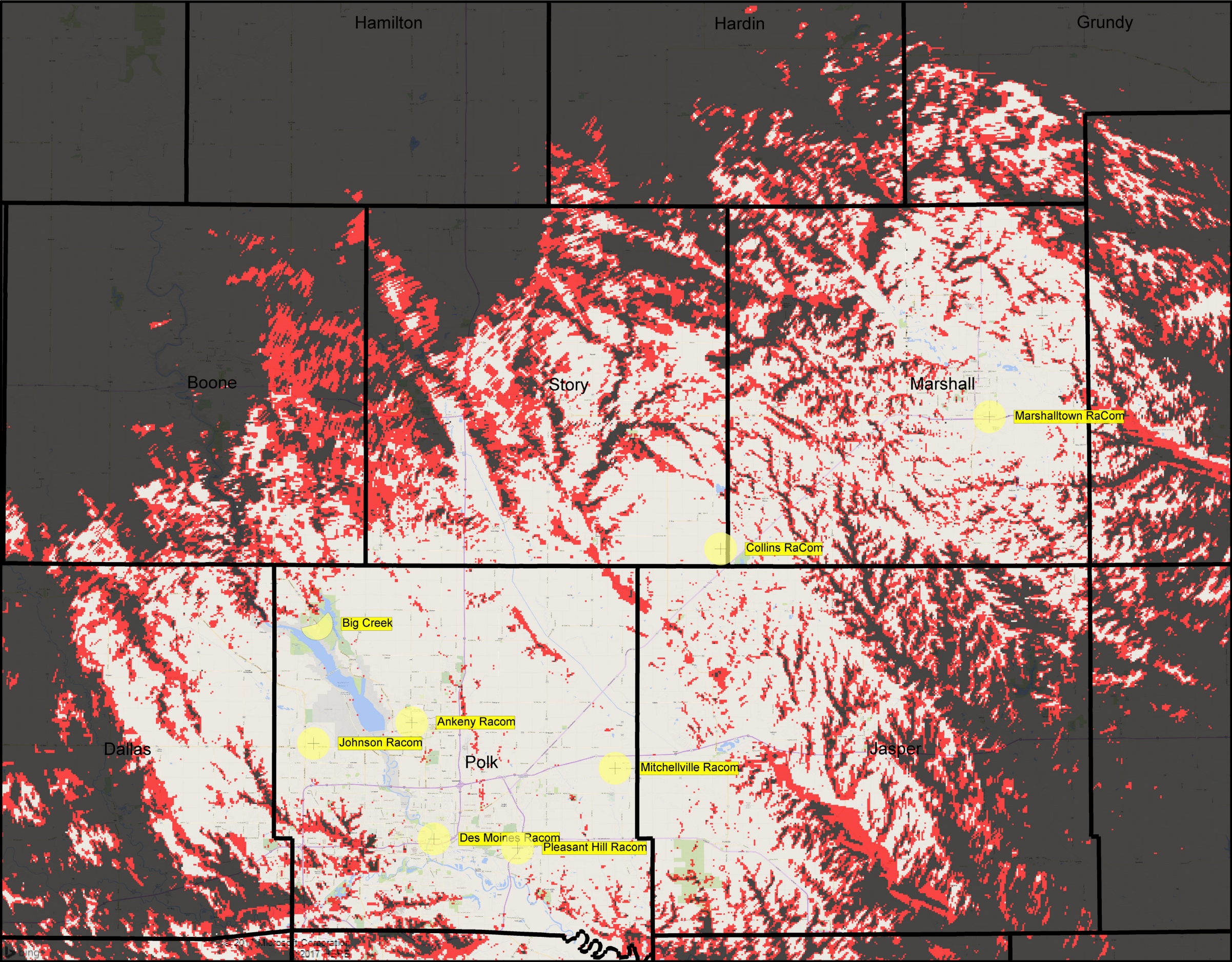
Story
County
IOWA • 1853



MissionCriticalPartners

Story County, IA
Existing SARA System

On Street Mon Dec 18 14:25:10 2017



EDX® SignalPro®: Story Country Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>=	-88.7 dBmW	DAQ 3.4 or Better
	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES

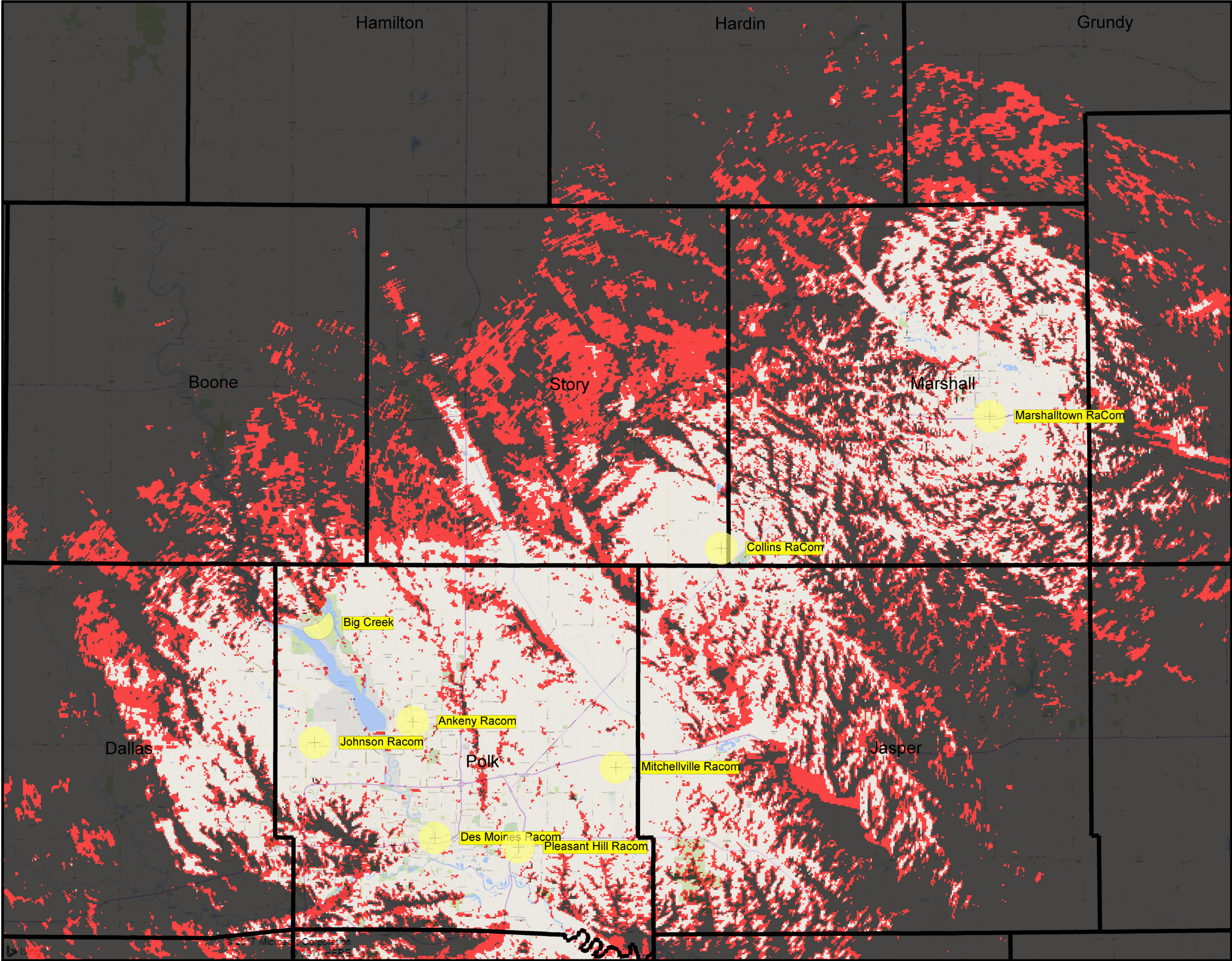
-505

Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing SARA System

12 dB buildingMon Dec 18 14:33:00 2017



EDX® SignalPro®: Story Country Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

	>=	-80.7 dBmW	DAQ 3.4 or Better
		-89.8 to -80.7 dBmW	DAQ 2.0 - DAQ 3.4
	<	-89.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES

-5

0

5

Story
County
IOWA • 1853

M

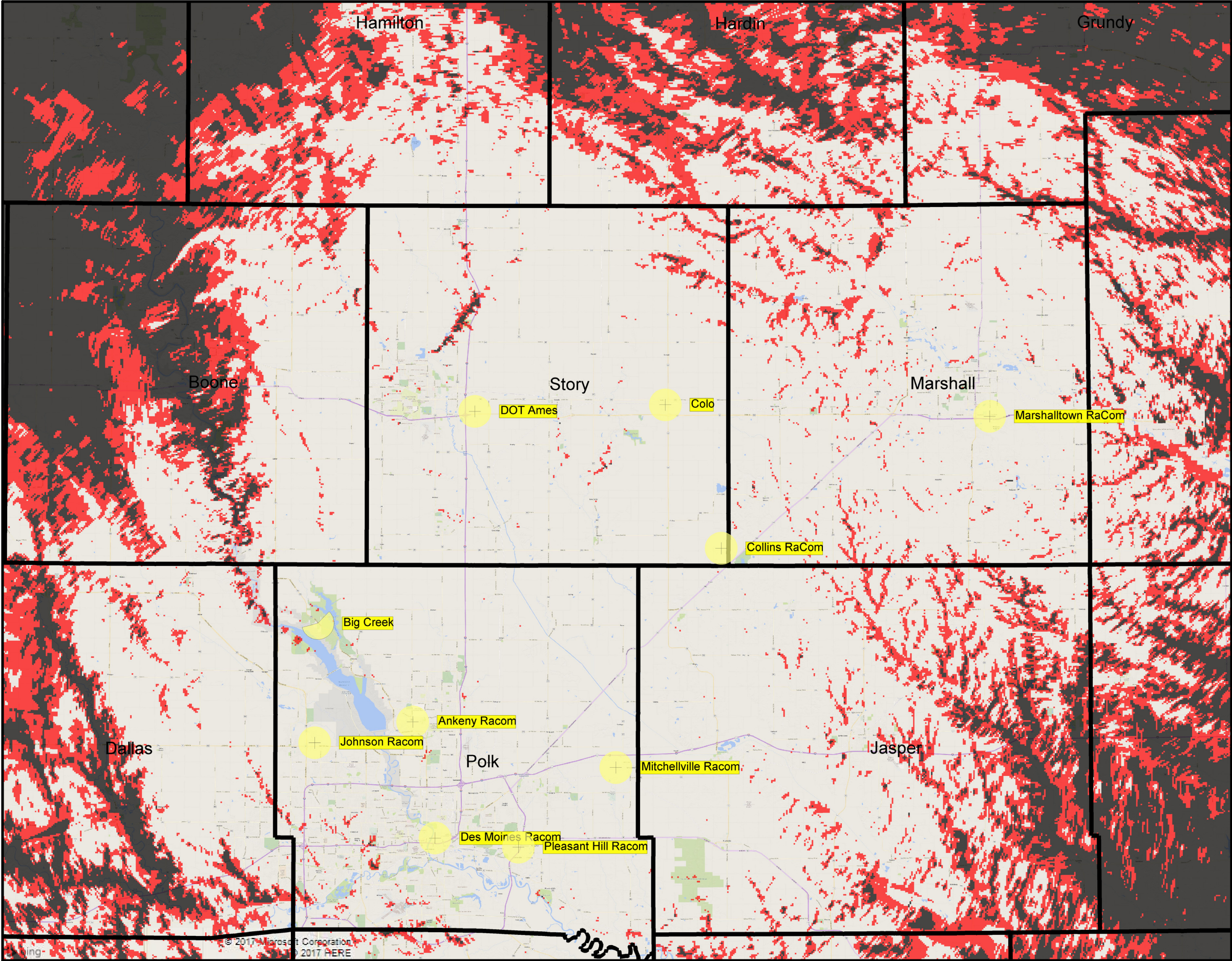
MissionCriticalPartners

Story County, IA

Existing SARA System

20 dB building

Mon Dec 18 14:37:11 2017



EDX® SignalPro®: Story County Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>= -100.7 dBmW	DAQ 3.4 or Better
-109.8 to -100.7 dBmW	DAQ 2.0 - DAQ 3.4
< -109.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES
-5 0 5

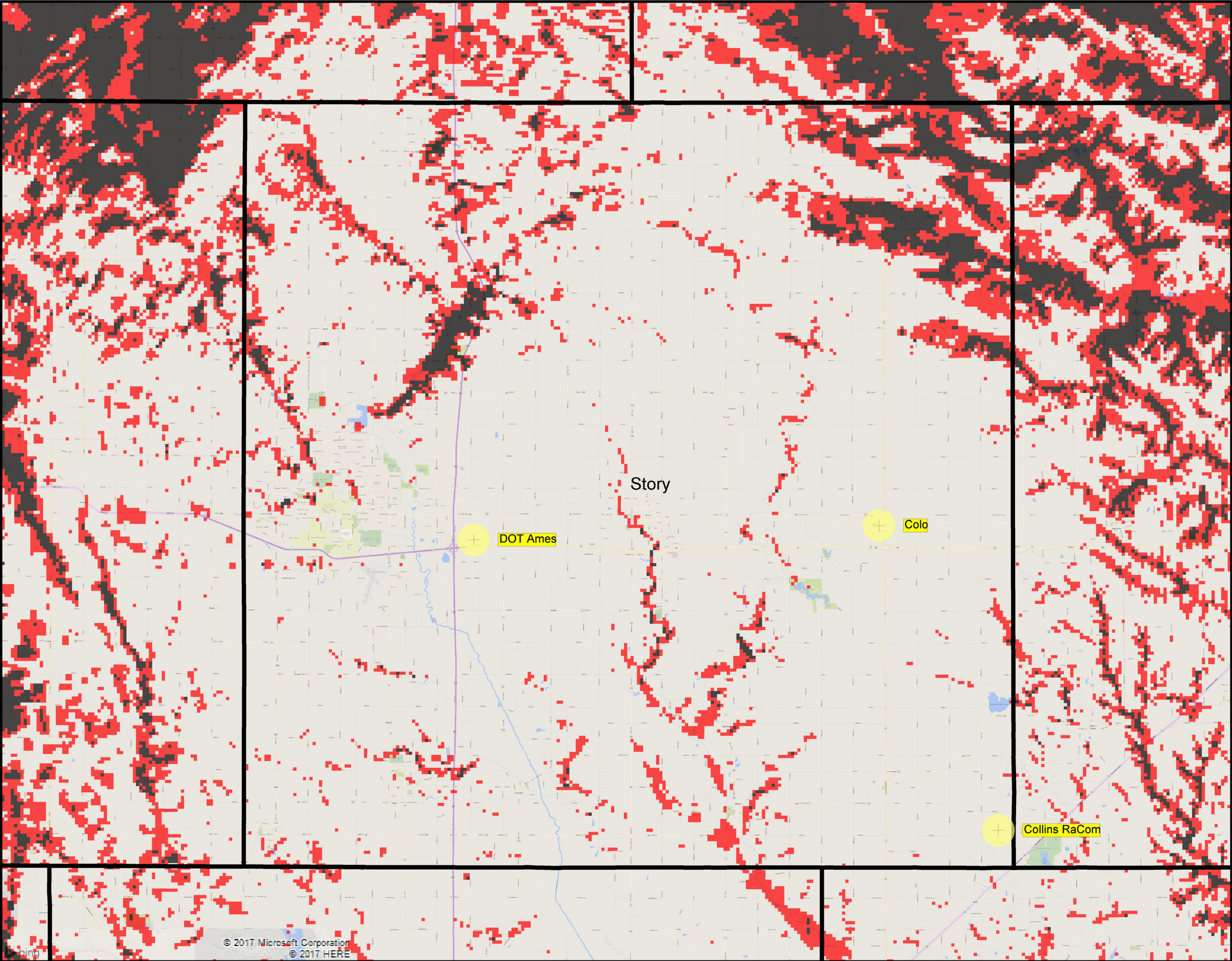


Story County
IOWA • 1853



MissionCriticalPartners

Story County, IA
Existing SARA System with Ames and Colo
On Street Mon Dec 18 14:55:32 2017



EDX® SignalPro®: Story Country Zoom Out

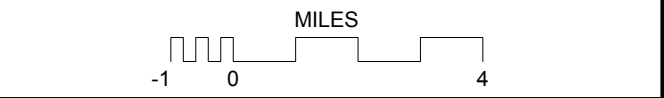
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>=	-88.7 dBmW	DAQ 3.4 or Better
	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

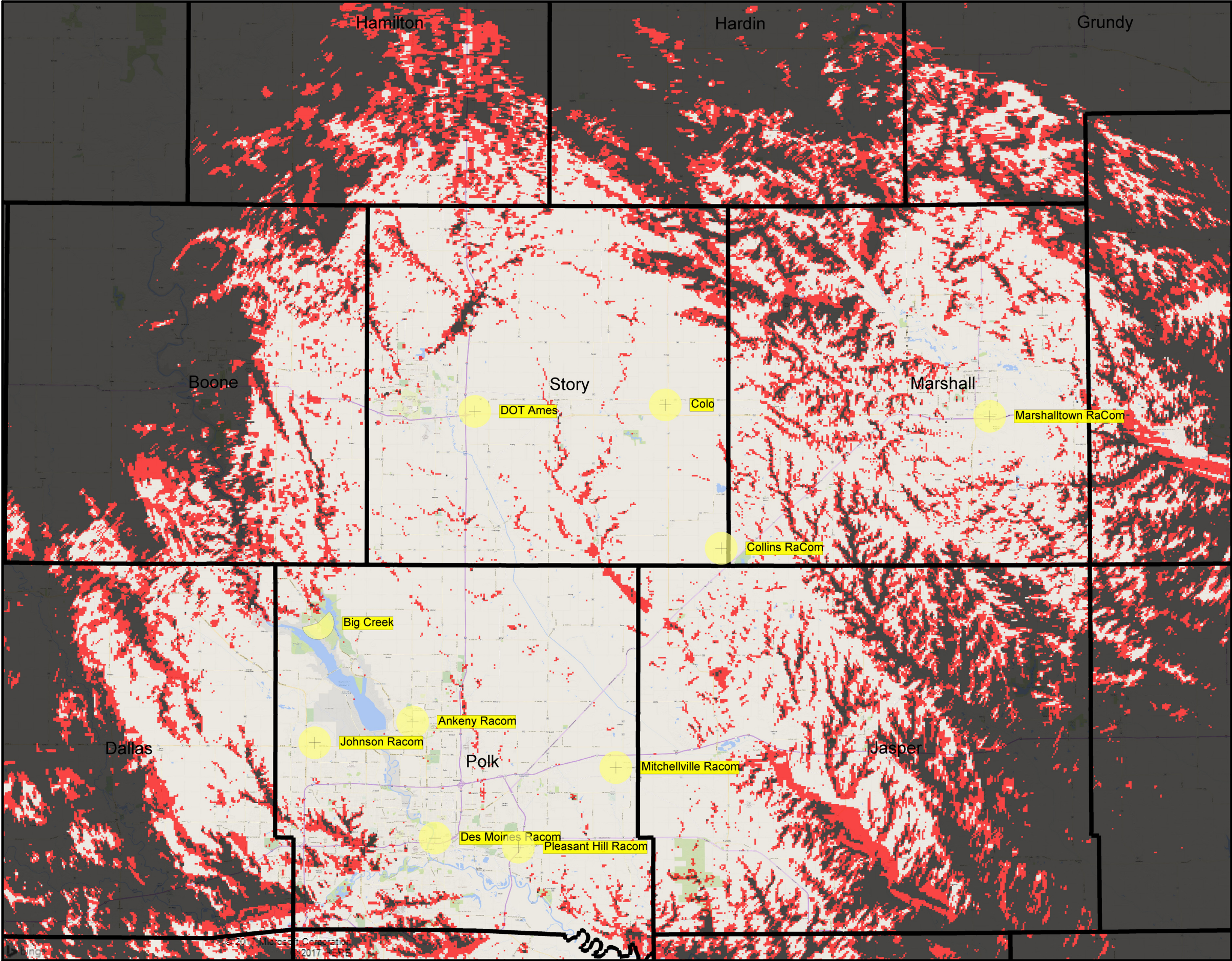
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing SARA System with Ames and Colo
12 dB in building county view Mon Dec 18 15:45:54 2017



EDX® SignalPro®: Story Country Zoom Out

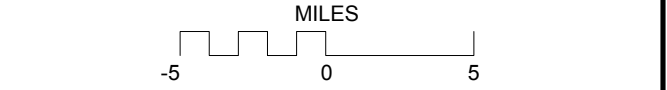
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>=	-88.7 dBmW	DAQ 3.4 or Better
>	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

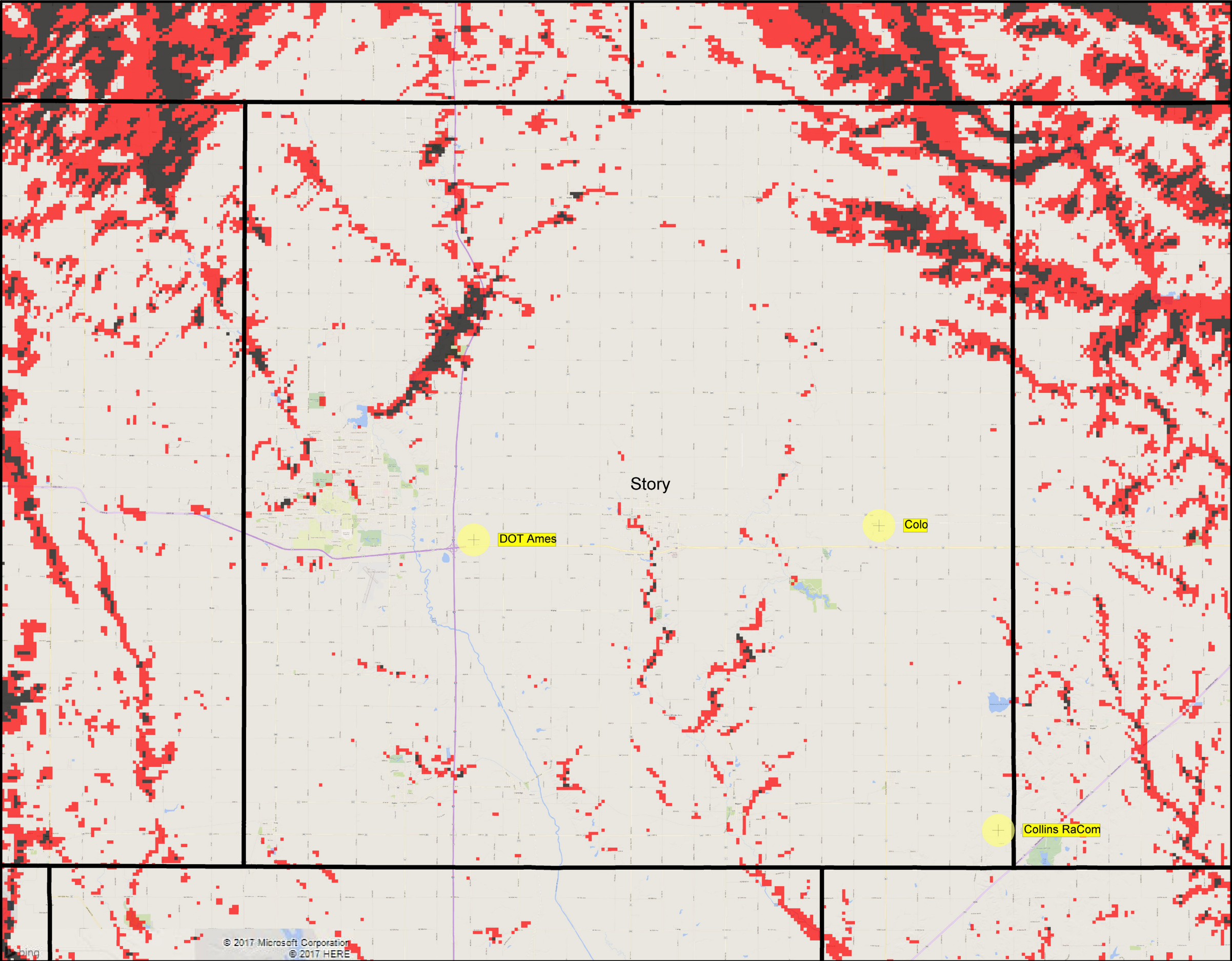
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing SARA System with Ames and Colo
12 dB building Mon Dec 18 14:46:47 2017



EDX® SignalPro®: Story Country Zoom Out

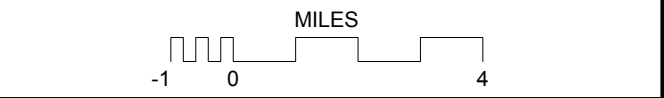
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>=	-88.7 dBmW	DAQ 3.4 or Better
	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

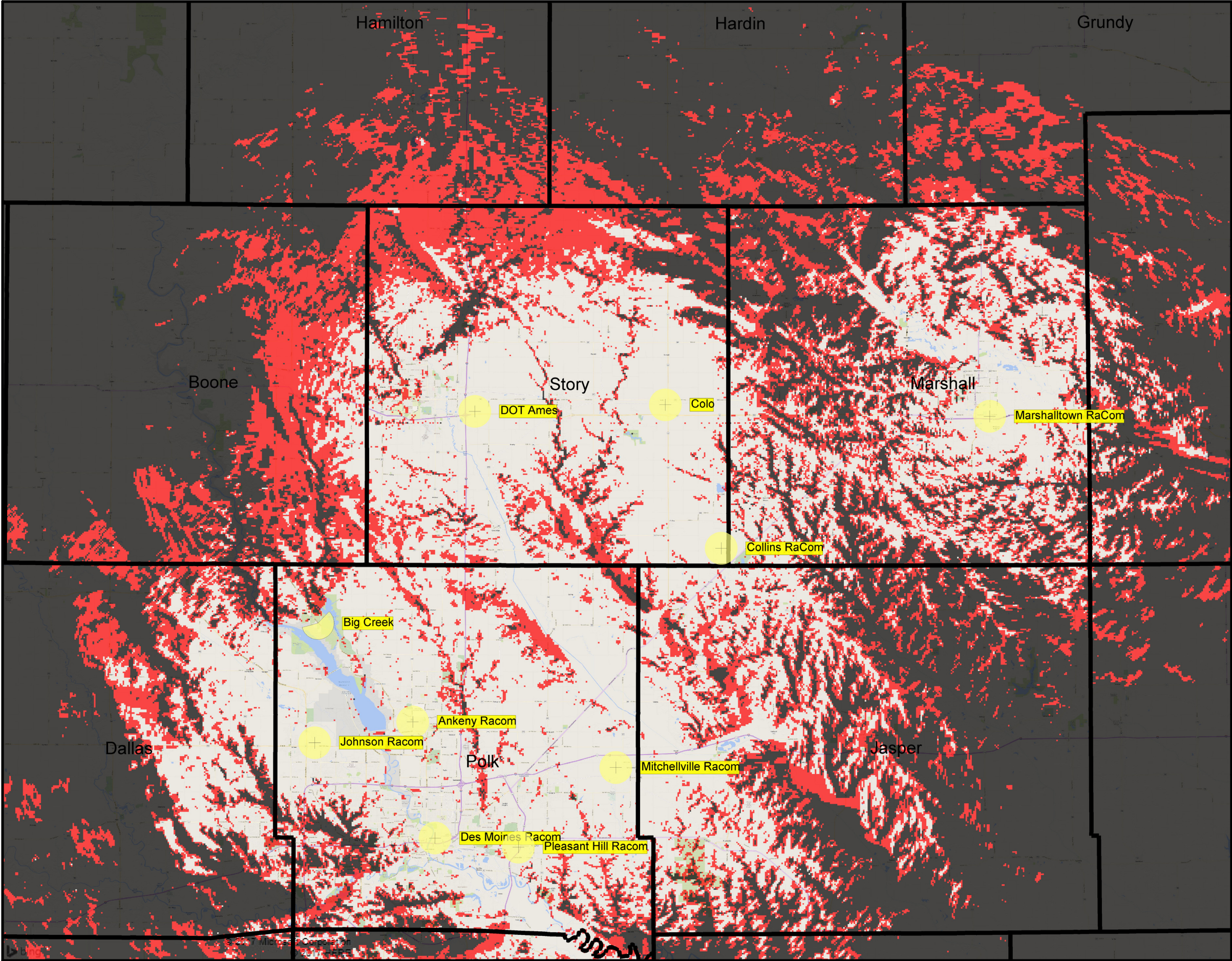
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing SARA System with Ames and Colo
20 dB in building county view Mon Dec 18 15:49:48 2017



EDX® SignalPro®: Story Country Zoom Out

Prop. model 1: Anderson-2D v1.00

Time: 50.0% Loc.: 50.0%

Prediction Confidence Margin: 10.2dB

Climate: Continental Temperate

Land use (clutter): USGS-EDX format (.151 files)

Atmospheric Abs.: none

K Factor: 1.333

County Boundaries

RaComP25

>=	-80.7 dBmW	DAQ 3.4 or Better
	-89.8 to -80.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-89.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW

RX Antenna - Type: ISOTROPIC

Height: 3.0 ft AGL Gain: 0.00 dBd

MILES

-5

0

5

Story
County
IOWA • 1853

M

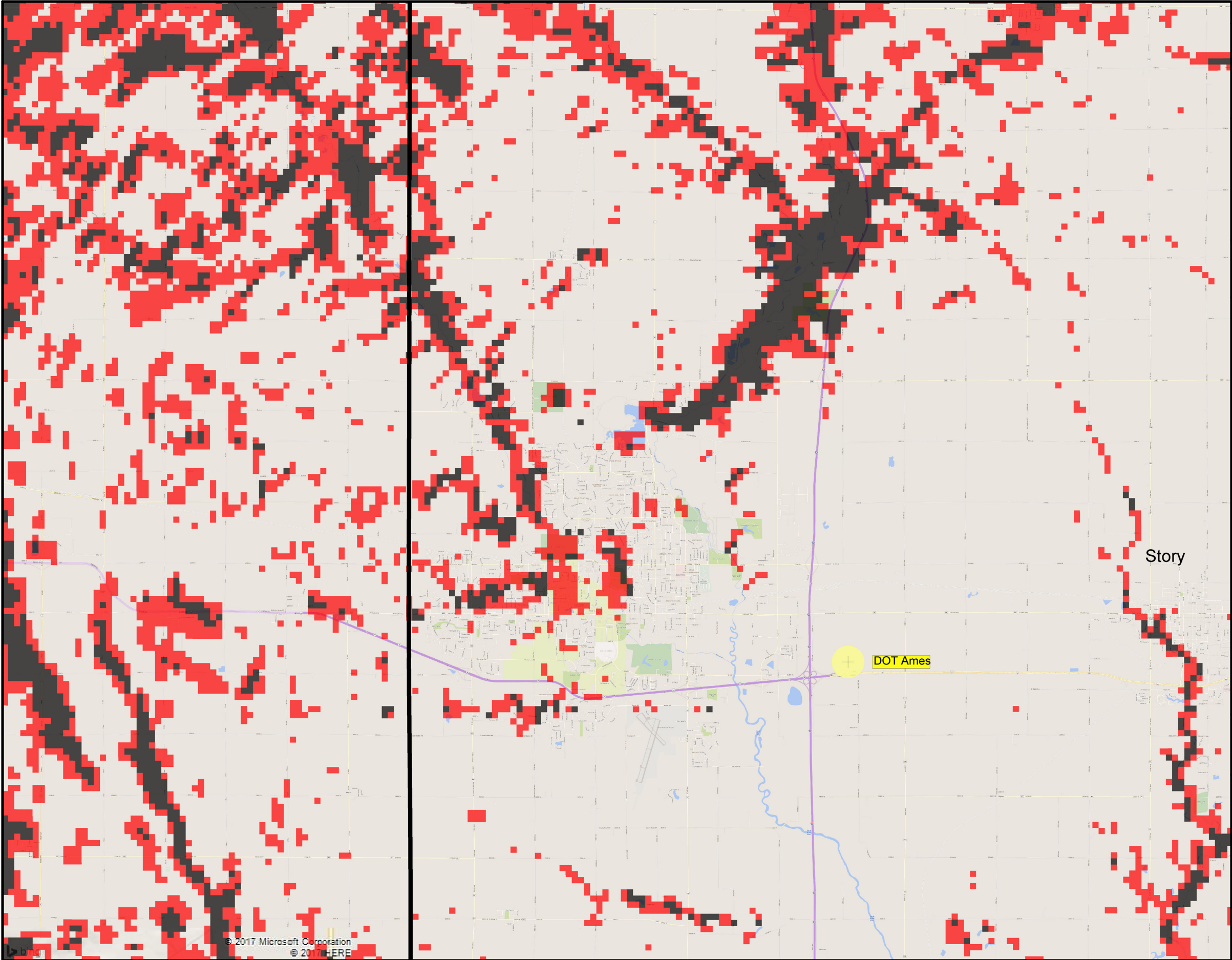
MissionCriticalPartners

Story County, IA

Existing SARA System with Ames and Colo

20 dB building

Mon Dec 18 14:39:44 2017



EDX® SignalPro®: Story Country Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

RaComP25

>=	-80.7 dBmW	DAQ 3.4 or Better
	-89.8 to -80.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-89.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES

-1 0 2

Story
County
IOWA • 1853

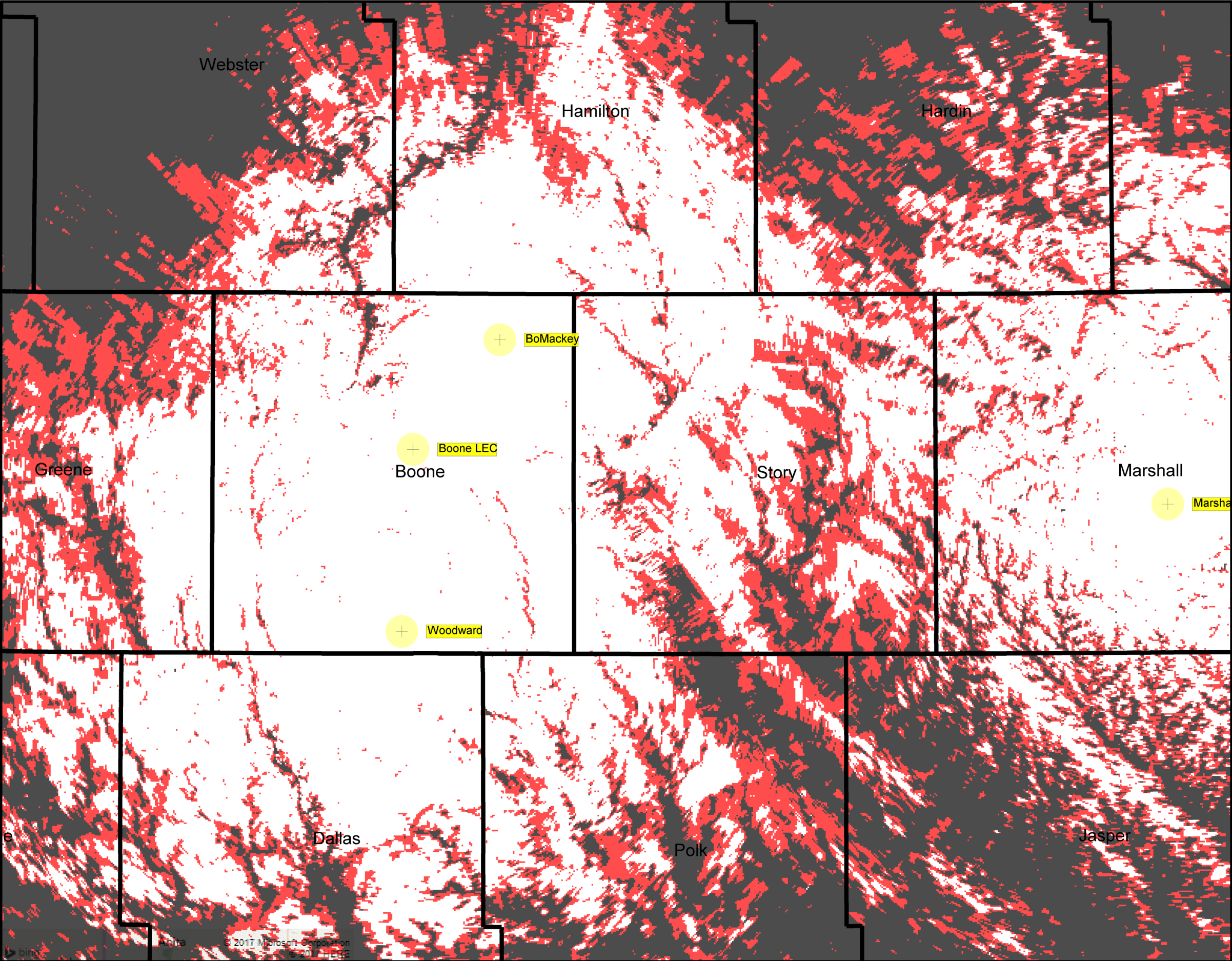
MissionCriticalPartners

Story County, IA

Existing SARA System with Ames and Colo
30 dB in building county view Mon Dec 18 15:53:48 2017

Appendix E – ISICS Maps

1. Existing on street
2. Existing in 12 dB building
3. Existing in 20 dB building
4. 2 Sites on street
5. 2 Sites in 12 dB County level
6. 2 Sites in 12 dB with surrounding Counties
7. 2 Sites in 20 dB County level
8. 2 Sites in 20 dB with surrounding Counties
9. 2 30 dB in Ames



EDX® SignalPro®: Story Country Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>= -100.7 dBmW

-109.8 to -100.7 dBmW

< -109.8 dBmW

DAQ 3.0 or Better

DAQ 2.0 - DAQ 3.4

Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES

-505



Story
County
IOWA • 1853

M

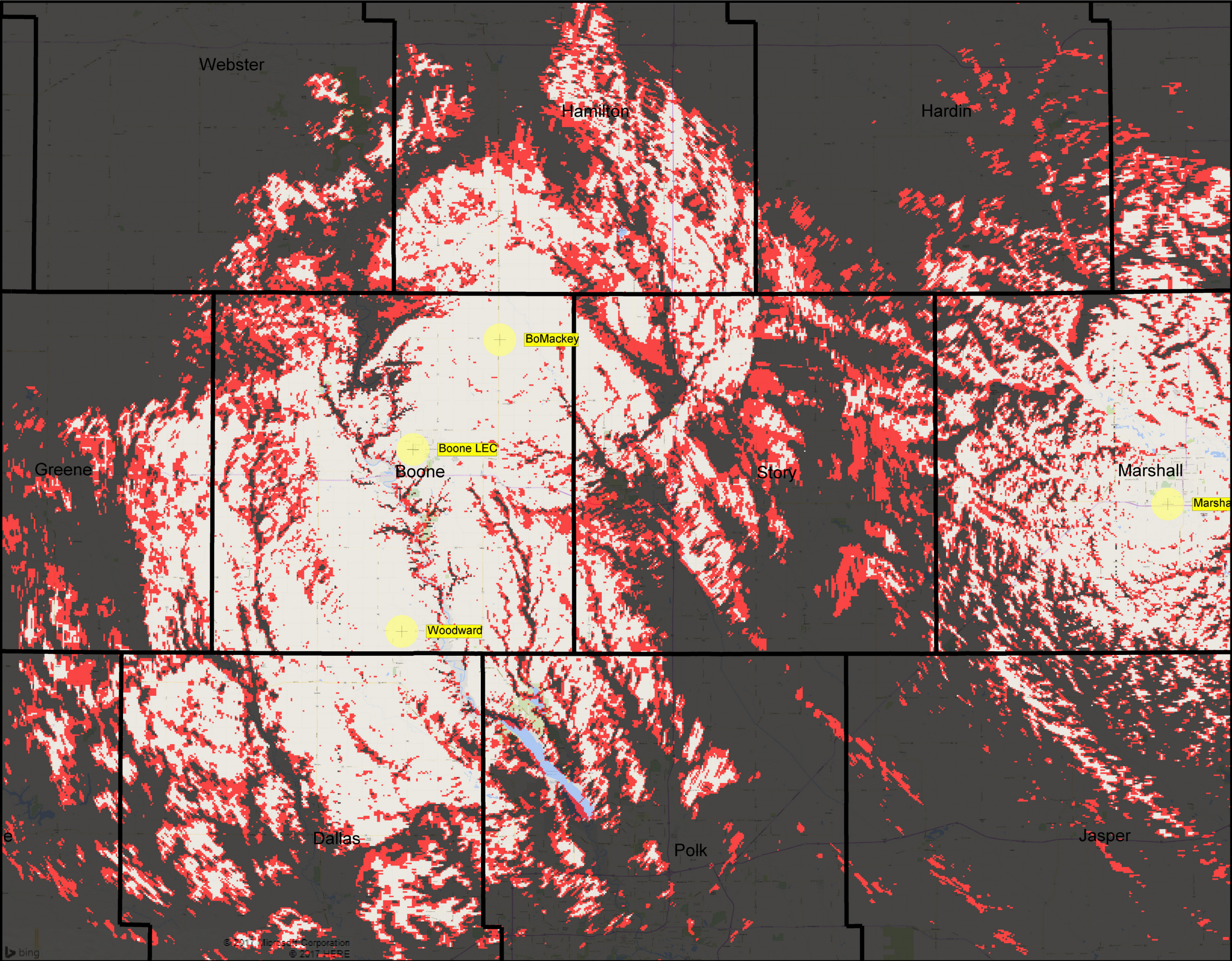
MissionCriticalPartners

Story County, IA

Existing ISICS System

On Street

Fri Dec 01 08:19:30 2017



EDX® SignalPro®: Story County V.3

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>=	-88.7 dBmW	DAQ 3.0 or Better
	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

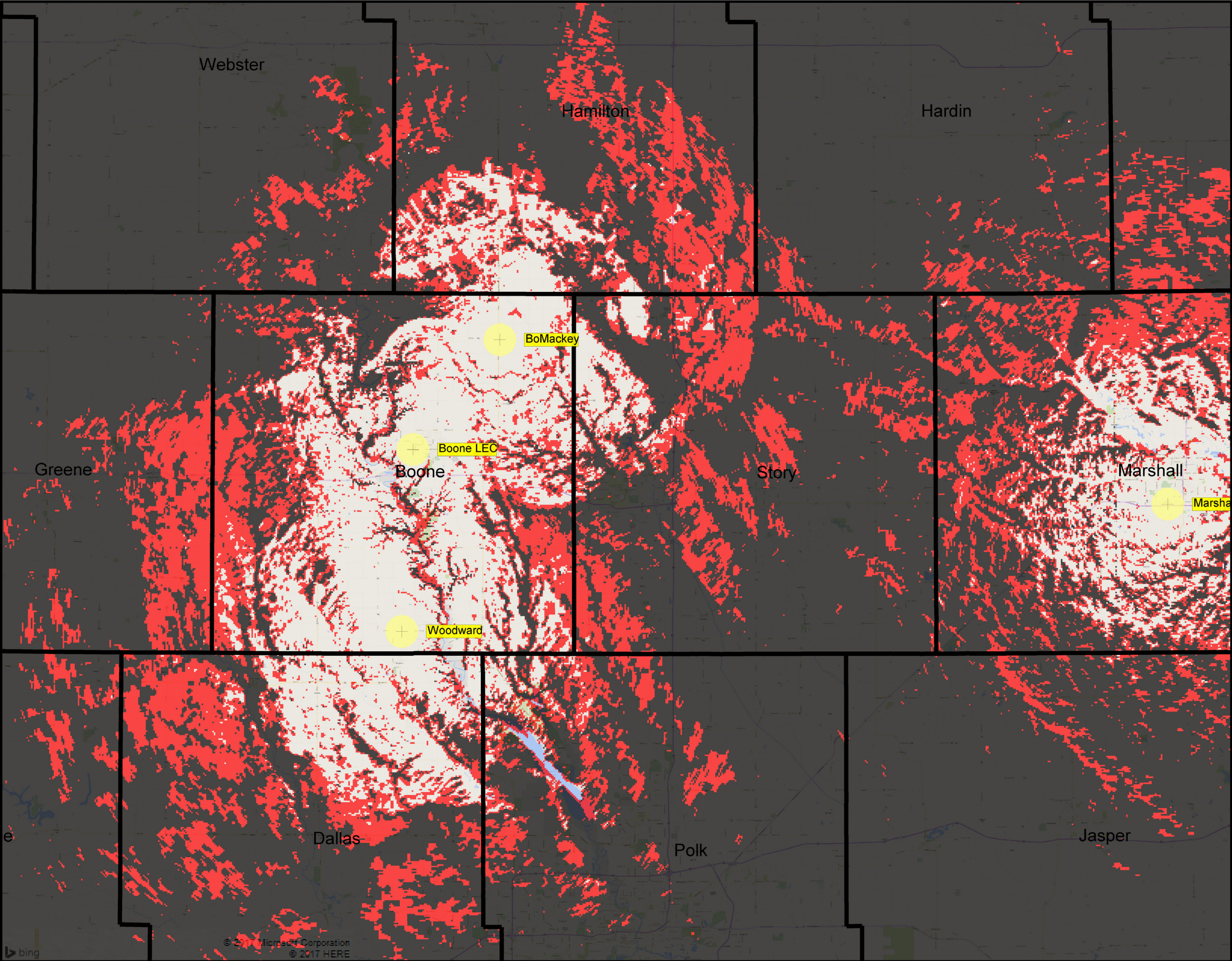
MILES
-5 0 5

Story County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing ISICS System

12 dB in building Mon Nov 27 15:18:46 2017



EDX® SignalPro®: Story County V.3

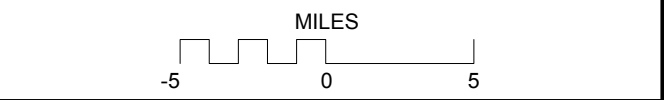
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>=	-80.7 dBmW	DAQ 3.0 or Better
	-89.8 to -80.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-89.8 dBmW	Below DAQ 2.0

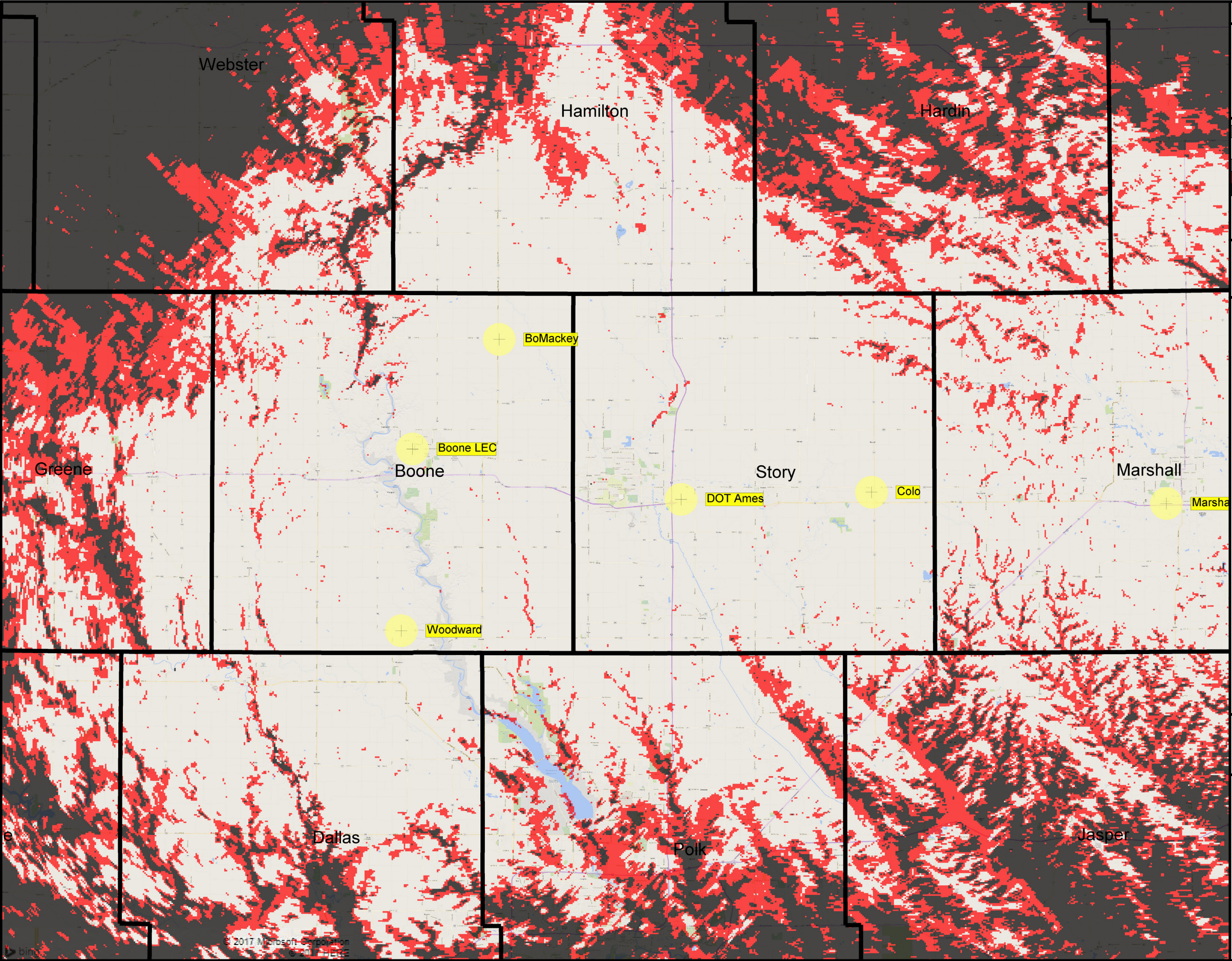
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing ISICS System
20 dB in building Mon Nov 27 15:39:04 2017



EDX® SignalPro®: Story County Zoom Out

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>= -100.7 dBmW	DAQ 3.0 or Better
-109.8 to -100.7 dBmW	DAQ 2.0 - DAQ 3.4
< -109.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES
-5 0 5

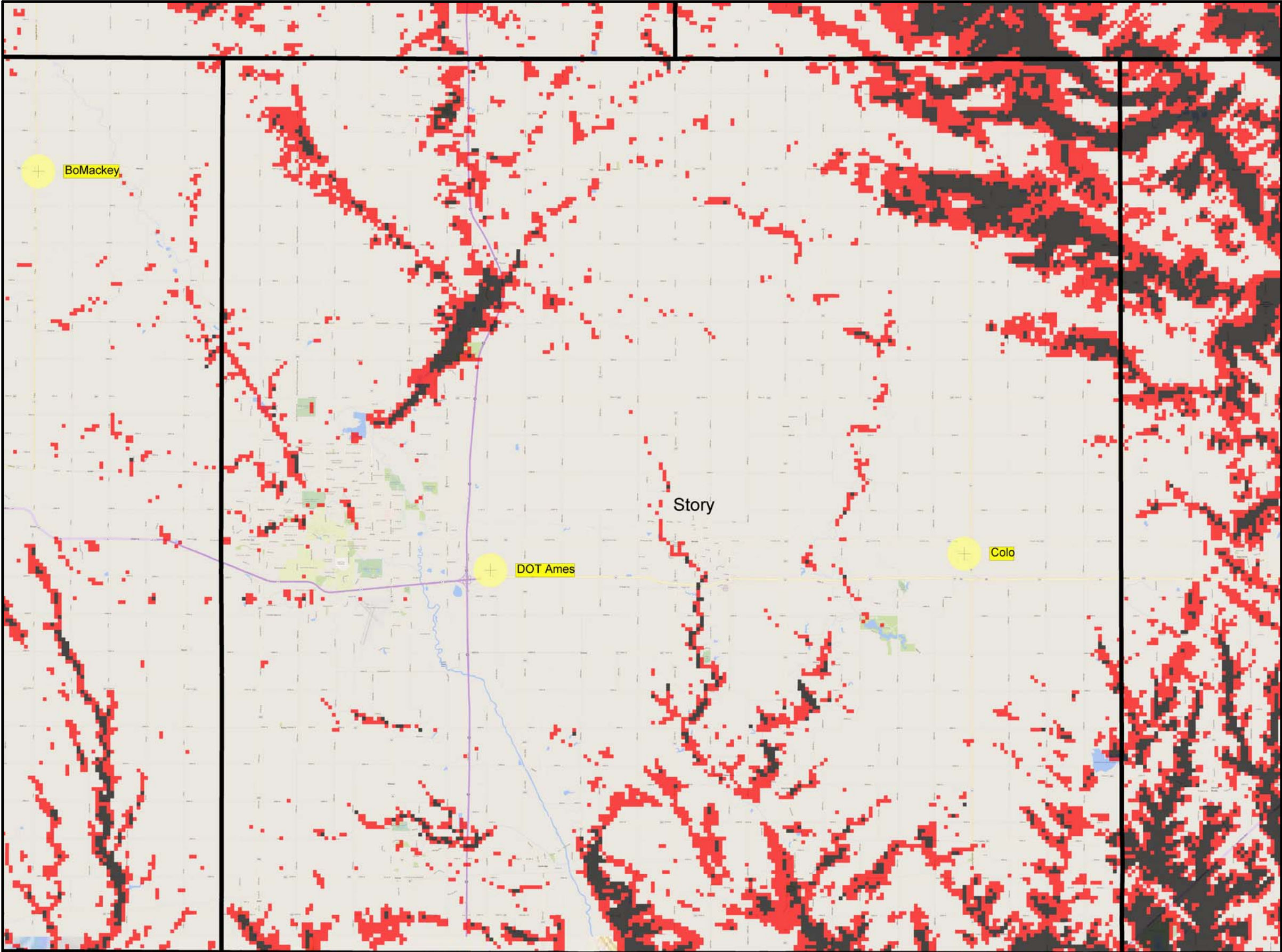


Story County
IOWA • 1853



MissionCriticalPartners

Story County, IA
Existing ISICS System with Ames and Colo
On Street Fri Dec 01 08:23:20 2017



EDX® SignalPro®: Story Country Zoom Out

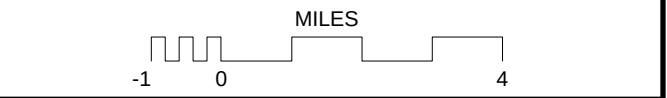
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>=	-88.7 dBmW	DAQ 3.0 or Better
	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

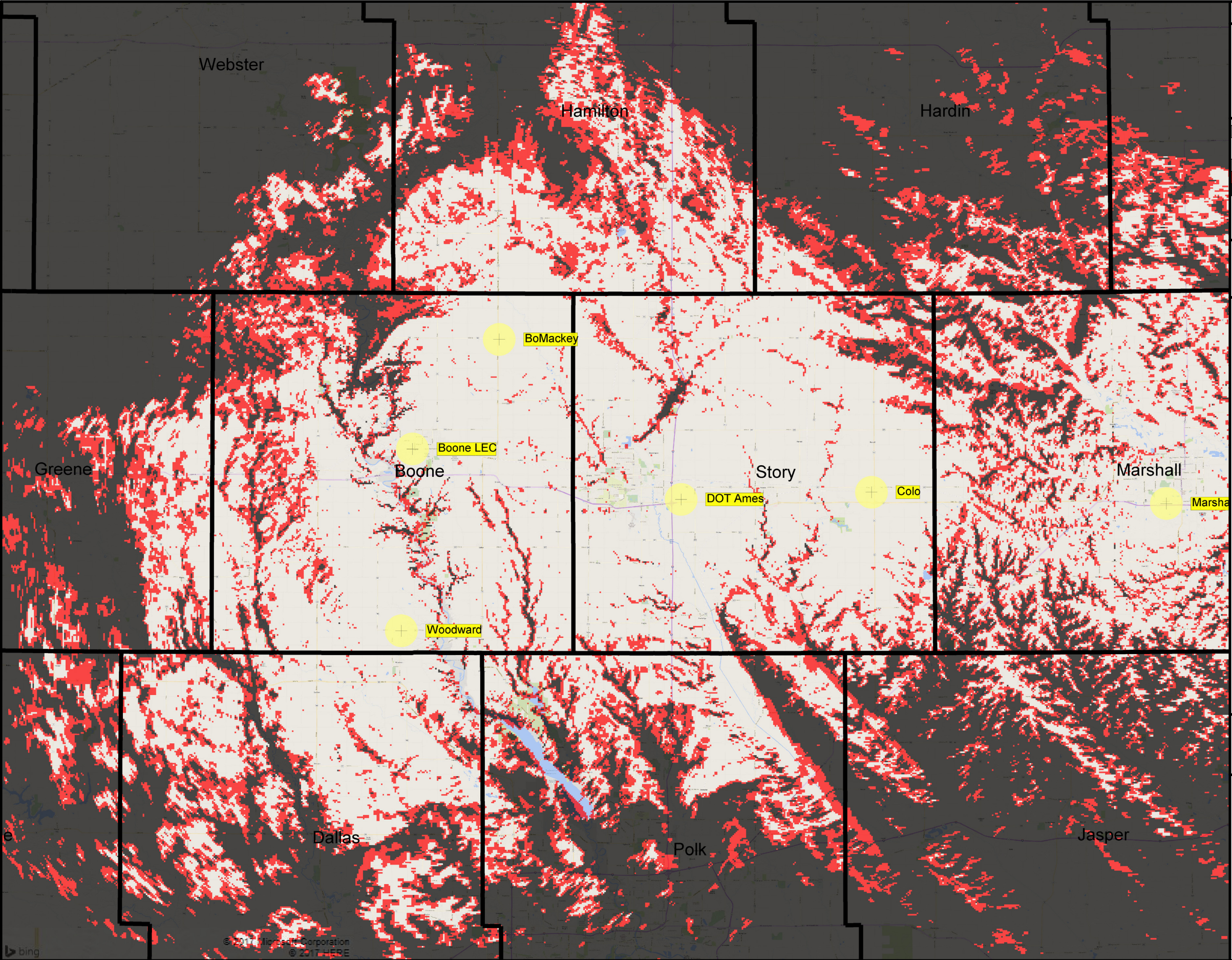
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Current ISICS System with Ames and Colo
12 dB in building Mon Nov 27 17:09:09 2017



EDX® SignalPro®: Story County V.3

Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>=	-88.7 dBmW	DAQ 3.0 or Better
>	-97.8 to -88.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-97.8 dBmW	Below DAQ 2.0

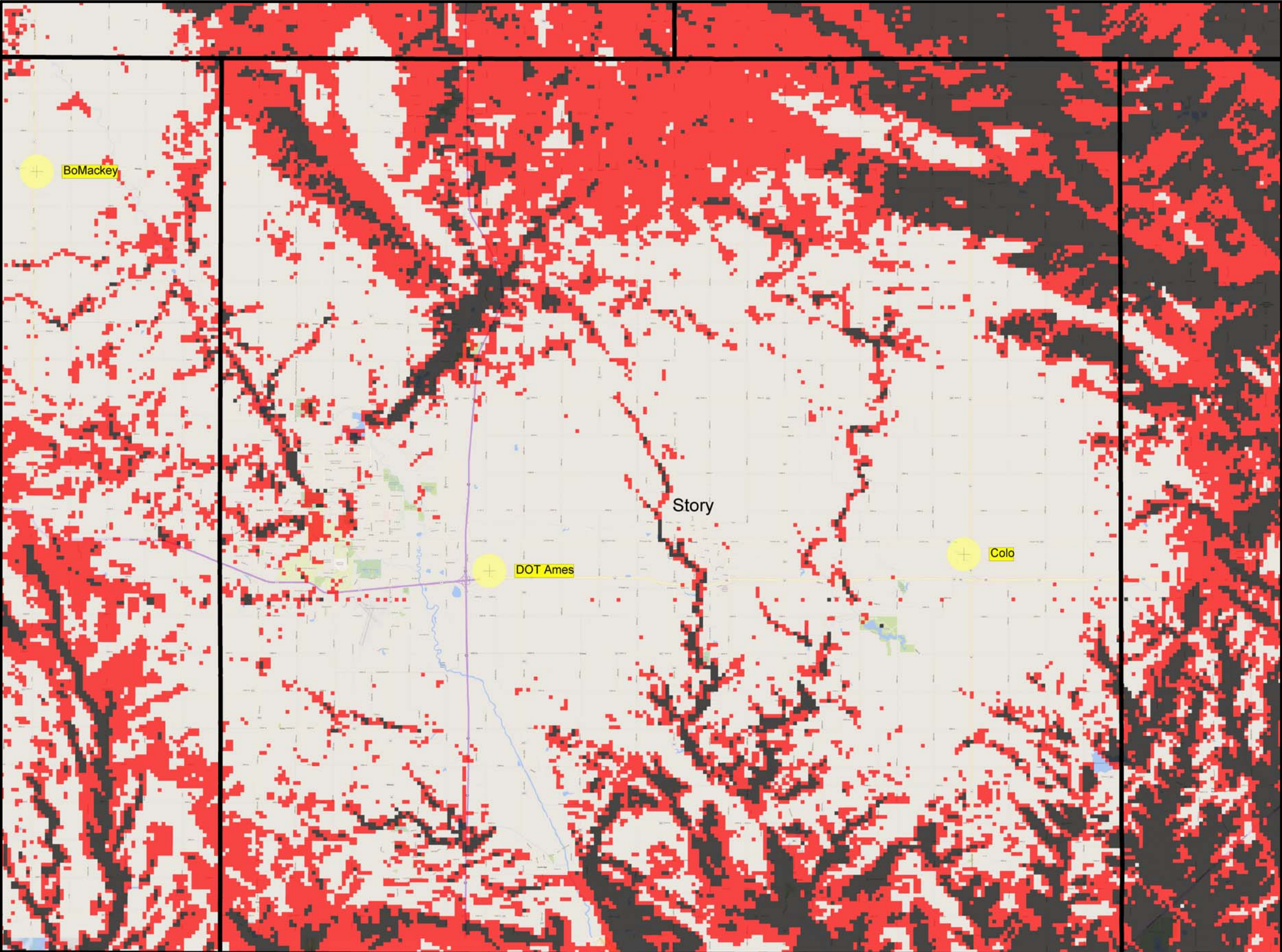
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd

MILES
-5 0 5

Story County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Existing ISICS System with Ames and Colo
12 dB in building Mon Nov 27 15:20:48 2017



EDX® SignalPro®: Story Country Zoom Out

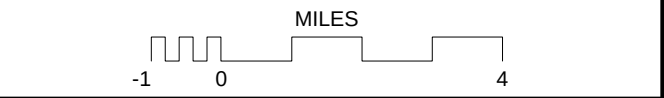
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

State System

>=	-80.7 dBmW	DAQ 3.0 or Better
	-89.8 to -80.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-89.8 dBmW	Below DAQ 2.0

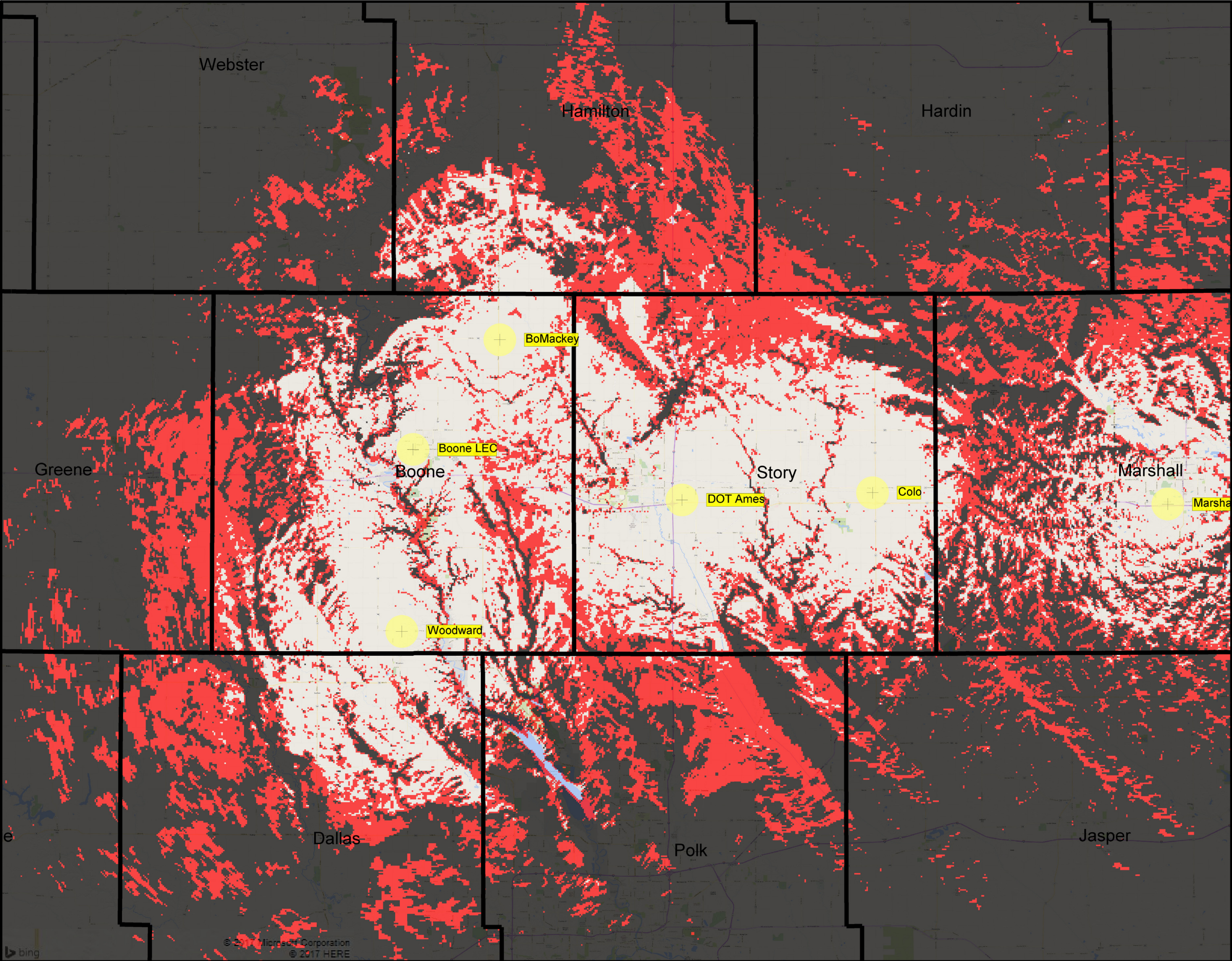
Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story
County
IOWA • 1853

MissionCriticalPartners

Story County, IA
Current ISICS System with Ames and Colo
20 dB in building Mon Nov 27 17:05:06 2017



EDX® SignalPro®: Story County V.3

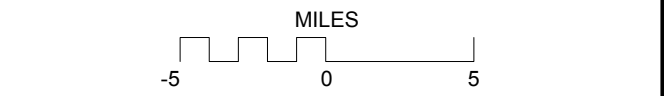
Prop. model 1: Anderson-2D v1.00
Time: 50.0% Loc.: 50.0%
Prediction Confidence Margin: 10.2dB
Climate: Continental Temperate
Land use (clutter): USGS-EDX format (.151 files)
Atmospheric Abs.: none
K Factor: 1.333

County Boundaries

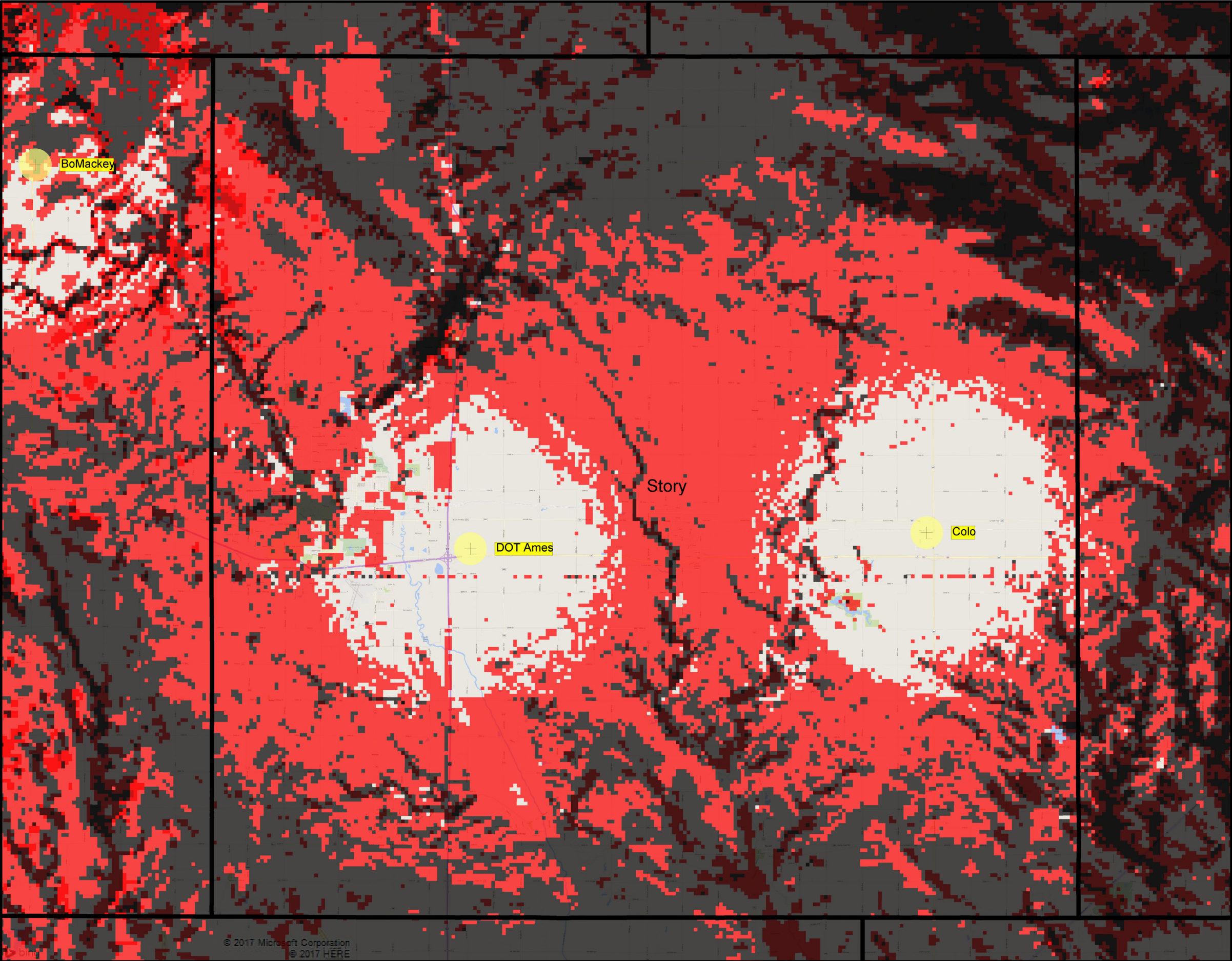
State System

>=	-80.7 dBmW	DAQ 3.0 or Better
	-89.8 to -80.7 dBmW	DAQ 2.0 - DAQ 3.4
<	-89.8 dBmW	Below DAQ 2.0

Display threshold level: -250.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 3.0 ft AGL Gain: 0.00 dBd



Story County, IA
Existing ISICS System with Ames and Colo
20 dB in building Mon Nov 27 15:36:48 2017



EDX® SignalPro®: Story Country Zoom In

Prop. model 1: Anderson-2D v1.00

Time: 50.0% Loc.: 50.0%

Prediction Confidence Margin: 10.2dB

Climate: Continental Temperate

Land use (clutter): USGS-EDX format (.151 files)

Atmospheric Abs.: none

K Factor: 1.333

County Boundaries

State System

>=

-70.7 dBmW

DAQ 3.0 or Better

-79.8 to -70.7 dBmW

DAQ 2.0 - DAQ 3.4

< -79.8 dBmW

Below DAQ 2.0

Display threshold level: -250.0 dBmW

RX Antenna - Type: ISOTROPIC

Height: 3.0 ft AGL Gain: 0.00 dBd

MILES

-1

0

4

Story County

IOWA • 1853

M

MissionCriticalPartners

Story County, IA

Current ISICS System with Ames and Colo

30 dB in building Tue Nov 28 23:07:08 2017

© 2017 Microsoft Corporation

© 2017 HERE