ROAD WEATHER INFORMATION SYSTEM

CONCEPT OF OPERATIONS

Superior Region
CS 84911 – JN 87648

Prepared For:

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Executive Summary

The Michigan Department of Transportation (MDOT) commissioned a study for road weather information system (RWIS) deployment in the Superior Region. An RWIS is one element of Intelligent Transportation Systems (ITS), consisting of remote sensing locations that together form an information system which gathers and transmits road-related weather information. The information may include atmospheric (temperature, wind, precipitation, etc.), roadway (temperature, pavement conditions), and sub-surface (frost depth) characteristics. Other ITS elements can be co-located with an RWIS site, leveraging the power and communications required to support an RWIS site.

The impact of lake-effect snow and ice events is one of the most influential factors of transportation operations and maintenance in the Superior Region, and has significant cost and safety implications.

Implementing RWIS throughout the Superior Region will provide for safer highways, improved road maintenance decision making, improved traveler information, and provide data for review of historical weather events to enhance transportation planning. It will also provide a greater density of weather data, allowing the National Weather Service (NWS) to improve the accuracy of weather forecasting. More accurate forecasting by the National Weather Service will also benefit the roadway maintenance agencies. These objectives are consistent with the MDOT Strategic Plan and the ITS Strategic Plan.

The stakeholder process included an RWIS information session, identification of Environmental Sensor Station (ESS) components, nomination of potential ESS locations, and a vendor open house. As a result of stakeholder input, thirty-two (32) ESS sites were identified throughout the Upper Peninsula. The sites include weather conditions for particularly weather-prone local areas and sites that are representative of long stretches of roadway. Based on the functional requirements, an RWIS specification was developed that could be used in conjunction with other ITS devices, such as CCTV and traffic detectors.

A Concept of Operations (COO) was developed to identify how the weather data can be used by operations, maintenance, and planning personnel, including MDOT's partner agencies.

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SECTION 1 INTRODUCTION AND OVERVIEW

1.1 OVERVIEW

The Concept of Operations (COO) is a document to identify the need for the Roadway Weather Information System (RWIS), which is one tool in the Intelligent Transportation Systems' (ITS) toolbox. The COO describes the requirements, the users, the alternatives to be considered, the constraints, and the anticipated benefits of the RWIS. The Superior Region RWIS will establish an MDOT-operated information system, focused on gathering current information to support roadway operations and maintenance decisions, particularly during the winter season, although it is anticipated to have applications throughout the year. The system is anticipated to be able to facilitate sharing of weather data and communications infrastructure with other agencies, avoiding unnecessary redundancies in collection and transmission of weather data. In addition, the system will have the capability to send information via the Internet to various agencies and the public.

1.2 WHAT IS A ROAD WEATHER INFORMATION SYSTEM (RWIS)?

An RWIS is a system of remote sensing locations called environmental sensor sites (ESS or RWIS ESS), connected to a central processing unit (CPU). Together they make up an information system which gathers and transmits road-related weather information. There are many different possible combinations of instruments which can make up an RWIS ESS. Collectively, the weather sensors measure atmospheric, roadway, and sub-surface characteristics.

In addition to the weather sensors, an ESS may also include various ITS sensors which gather ancillary data related to a weather event. As an example, a traffic sensor which identifies a diminished traffic speed at an ESS site during potentially freezing conditions could help identify that freezing conditions are impacting the flow of traffic. This same sensor could subsequently help identify when traffic speeds have returned to normal, signifying the resolution of the event.

Other sensors and devices provide data which is useful to MDOT or its partner agencies. These sensors and devices can be connected to an ESS opportunistically, since the ESS has the necessary power and communications connections. Examples include weigh-in-motion (WIM) scales and permanent traffic recorders (PTR).

Traveler information devices such as warning flashers, dynamic signs, and radio transmitters can also be included at ESS locations. Some of these devices can be controlled directly by the ESS, but more typically they are controlled by an Automated Traffic Management System (ATMS) or Automated Traveler Information System (ATIS). A more detailed discussion of RWIS ESS sensors is included in Section 6.

1.3 DESIRED OUTCOMES AND NEEDS

Currently, MDOT has limited ability to remotely collect road weather data to use as an operations and maintenance decision support tool in the Superior Region. The weather data currently available comes from the Department of Natural Resources' (DNR) 13 automated weather station (AWS) sites and the National Weather Service's (NWS) 12 AWS sites. The NWS sites are operated by NWS, MDOT, and Federal Aviation Administration (FAA). These sites are primarily at airport locations and are not designed or intended to serve highway needs. MDOT and its road maintaining agencies have access to this data and the forecasts generated by NWS; however, this information is geared more to aviation and atmospheric information, rather than developing information regarding the weather condition of the highway system and its environment. The International Bridge Authority (IBA) also utilizes information from the Montreal River Weather Station, Ontario, Canada, which is north of the International Bridge, providing information for weather approaching from Lake Superior.

Collecting weather information at sites specifically chosen because they are representative of a region or because they are situated in a microclimates that create localized hazardous road conditions would improve MDOT's ability to respond appropriately to weather events. Identifying these potential ESS locations was a primary goal of the stakeholder meetings and is documented in Section 5, RWIS ESS Location Siting.

1.4 ABBREVIATIONS

Abbreviation	Definition
ADA	American's with Disabilities Act
API	Application Programming Interface
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Transportation Management System
AVL	Automated Vehicle Location
ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
AWS	Automated Weather Station
bps	Bits per second
BUFR	Binary Universal Form for the Representation of meteorological data
CCTV	Closed Circuit Television
COO	Concept of Operations
CORS	Continuously Operating Reference Station
COTS	Commercial off-the shelf
CPU	Central Processing Unit
DMS	Dynamic Message Sign
DNR	Department of Natural Resources
DOT	Department of Transportation
DSL	Digital Subscriber Line
ESS	Environmental Sensor Site
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
get	SNMP operation that queries a MIB for object data
GIS	Geographic Information System
HAR	Highway Advisory Radio
IBA	International Bridge Authority
ITS	Intelligent Transportation Systems
Kbps	1,000 bits per second
LAN	Local Area Network
MBA	Mackinaw Bridge Authority
Mbps	1,000,000 bits per second
MDIT	Michigan Department of Information Technology

Abbreviation	Definition
MDOT	Michigan Department of Transportation
MIB	Management Information Base
MDSS	Management Decision Support System
MOE	Measures of Effectiveness
MPSCS	Michigan Public Safety Communications System
MSP	Michigan State Police
MTU	Maximum Transmission Unit
NTCIP	National Transportation Communications Information Protocol
NWS	National Weather Service
object	SNMP MIB entry
P/T/Z	Pan/tilt/zoom
PDA	Personal Digital Assistant (e.g., Palm)
PDU	Packet Data Unit
POTS	Plain old telephone service
PPP	Point to Point Protocol
RPU	Remote Processing Unit
RWIS	Roadway Weather Information System
SNMP	Simple Network Management Protocol
T1	Data circuit with a capacity of 1.544 Mbps
TMC	Transportation Management Center or Traffic Management Center
TSC	Transportation Service Centers
VII	Vehicle Infrastructure Integration
WI	Wisconsin
WIM	Weigh-in-Motion

1.5 REFERENCED DOCUMENTS

- Alberta Transportation, “Development of a Road Weather Information System (RWIS) Network for Alberta’s National Highway System,” Mark F. Pinet & Associates Limited.
- Environment Canada, Meteorological Services of Canada, “Road Weather Information Network Update”, 2004.
- Federal Highway Administration (FHWA), Road Weather Management Program, “An Introduction to Standards for Road Weather Information Systems (RWIS),” 2002.
- Federal Highway Administration (FHWA) “Road Weather Information System Environmental Sensor Station Siting Guidelines,” 2005.
- Michigan Department of Transportation (MDOT) “MDOT ITS Strategic Plan,” 2004.
- National Cooperative Highway Research Program, Transportation Research Board, “Benefit/Cost Study of RWIS and Anti-icing Technologies,” 2001.
- National Transportation Communications Information Protocol (NTCIP) NTCIP 1204, TS3.7-1998.

- Stakeholder User Requirements from MDOT Superior Region ITS Architecture and Deployment Plan Process, Prepared by Kimley-Horn, 2007.
- Washington State Transportation Commission, "Road Weather Information Systems: Enabling Proactive Maintenance Practices in Washington State," prepared by Washington State Transportation Center and Battelle Transportation Division, 2002.

1.6 STUDY PROCESS

The current study consisted of seven major elements:

- **Review of literature** from other state and provincial DOTs, other RWIS studies, and reports located on FHWA website.
- **Stakeholder meetings.** The first stakeholder meeting reviewed RWIS concepts, identified stakeholder user needs, selected ESS sensors, and nominated ESS locations. The second stakeholder meeting included a vendor open house, reviewed the nominated ESS locations, and featured Ohio DOT's RWIS case study, presented by Abner Johnson. The final stakeholder meeting included a review of the study deliverables.
- **Survey of RWIS use by other DOTs.** Telephone surveys were conducted with eleven state DOT representatives with responsibility for their respective RWIS programs. See **Appendix A** for a summary of the survey. The survey included:
    - **Indiana**
    - **Iowa**
    - **Kansas**
    - **Minnesota**
    - **Nebraska**
    - **North Dakota**
    - **Ohio**
    - **South Dakota**
    - **Utah**
    - **Washington**
    - **Wisconsin**
- **Interviews and discussions** were conducted throughout the project with MDOT and NWS experts in weather data collection, MDOT experts in winter roadway maintenance, and technical resources in the RWIS industry.
- An **RWIS concept of operations** was developed to address who are the users, why it is needed, intended capabilities, how it will be developed, operated, and maintained, benefits, and costs.
- The proposed **RWIS ESS locations** were identified and prioritized.
- An **RWIS ESS special provision** was developed for future construction projects.

SECTION 2 SYSTEM USERS AND STAKEHOLDERS

2.1 USERS / STAKEHOLDERS

The anticipated primary user groups of the RWIS will be:

2.1.1 MDOT Highways

The RWIS will provide MDOT Highways with information for immediate decisions on roadway operations and maintenance, and it will also provide archival data for planning decision support.

2.1.2 MDOT Aeronautics

The RWIS information will provide MDOT Aeronautics with additional weather collection data points, densifying the information, and allowing for enhanced decision-making for general aviation.

2.1.3 International Bridge Authority (IBA) and Mackinaw Bridge Authority (MBA)

These agencies operate the two major bridges in the Superior Region. The International Bridge is a two-mile long bridge between Canada and Sault Ste. Marie, Michigan. The Mackinac Bridge is a five-mile long bridge between Michigan's Lower Peninsula and the Upper Peninsula. Both bridges are important decision points for travelers and allow excellent opportunities for communication to the traveling public. Because of their long spans and the very harsh weather they experience in the upper Great Lakes area, advanced knowledge of weather events is critical for safe operation. RWIS will also assist in providing additional weather station collection sites at critical locations.

2.1.4 National Weather Service (NWS)

NWS provides forecasting services and additional data collection sites. RWIS ESS site locations can fill in the current NWS data collection voids. This will allow NWS to improve forecasting for the region and enhance decision-making for MDOT, its maintenance partners, and the traveling public. NWS does not currently process pavement-related weather data, but would benefit from the atmospheric data provided through ESS sites.

2.1.5 Maintenance Partner Agencies

In some areas of the Superior Region, MDOT provides winter maintenance with its own crews. In other areas, the county road commissions provide those services. These crews occasionally are sent to conduct reconnaissance to determine whether a maintenance crew is required for snow removal or road pre-treatment. RWIS could potentially provide much of this information quicker and without requiring the reconnaissance trip which allows the maintaining agency to focus on higher priority tasks.

2.1.6 Other Users

The trucking industry, the traveling public, visitor bureaus, and similar interest groups could all benefit from road weather information, particularly if it is readily available via the Internet and/or through information service providers (e.g., cell phones or PDAs).

2.1.7 Emergency Response Agencies

Fire, police, ambulance and towing services all rely heavily on accurate weather information to schedule their resources and to determine the best routes to take in response to an incident.

SECTION 3 PROJECT VISION, GOALS AND OBJECTIVES

3.1 MDOT MISSION STATEMENT

"Providing the highest quality integrated transportation services for economic benefit and improved quality of life."

3.2 MDOT ITS MISSION STATEMENT

"Develop and sustain a program at MDOT to improve transportation system safety and operational performance using existing and innovative Intelligent Transportation Systems technologies for economic benefit and improved quality of life."

3.3 MDOT VISION

The following are quotes from the MDOT Vision which have particular application to the Superior Region RWIS Project.

"Michigan's 2030 transportation system will be the foundation of the state's economic vitality and will sustain quality of life for its residents. Transportation providers throughout the state will work together to address the system's needs. The entire system will be maintained, preserved and protected as one of the state's most important physical assets."

Another facet of MDOT's Vision statement is, "MDOT solves customers' mobility and access needs through innovative, technologically sound, environmentally sensitive and safe solutions that are also sensitive to benefits and costs."

Additionally, "MDOT is business process oriented and focused on teamwork, with a well trained, diversified work force that is committed to customer satisfaction, continuous improvement and measurable results."

3.4 MDOT ITS PROGRAM VISION

MDOT has identified its ITS Program Vision in two area of focus: internal and external. As the MDOT Vision applies to the RWIS project, the external focus includes:

- focused on customers, adding measurable value to their daily lives with an emphasis on commerce and economic growth.
- engaged in effective partnerships for the promotion and integration of ITS.
- statewide, coordinated, integrated and seamless.

Internal Strategic Focus

- integrated fully into MDOT's business processes.
- supported by dedicated long-term funding and managed in a sustainable manner.

The RWIS Project for the Superior Region focuses on both external and internal targets. It develops a system which improves the traveler experience through improved response to a weather event, as well as improved communication about weather events. For success, it requires the cooperative, coordinated effort of a wide group of stakeholders to operate this RWIS, as a scalable program throughout the state. Through a planned capital and operations plan, it is expected to be centrally integrated with the ATMS and ATIS programs of MDOT.

3.5 MDOT STRATEGIC PLAN

Several components of the current MDOT Strategic Plan are pertinent to the Superior Region RWIS project. The primary facet is the expansion and enhancement of the state's Intelligent Transportation System (ITS). RWIS is a critical aspect of ITS and the RWIS project will extend the ITS system in the Superior Region as described in the following section, "MDOT ITS Strategic Plan".

RWIS features will also aid in the goals of repairing, rebuilding, and maintaining the state's road and bridge infrastructure by collecting road weather data (e.g., freeze/thaw cycles) and traffic data (e.g., average daily trips) which can be used as planning tools to support repair and maintenance decisions. Where air quality sensors are installed, their data can be used to support decisions for congestion mitigation and air quality planning.

3.6 MDOT ITS STRATEGIC PLAN

Two major focus points of MDOT's ITS strategy are to make the state's "ITS program statewide, coordinated, and seamless" and to "engage in effective partnerships for the promotion and integration of ITS." Establishing an RWIS program in the Superior Region will help reach both goals. RWIS will significantly increase ITS in the Superior Region by providing the crucial road weather data which is important to road safety during the unpredictable winter months. Successfully implementing an RWIS will also require partnerships throughout the region and the state with all stakeholders who will provide and use the system's road weather data.

3.7 PROJECT VISION

The vision of MDOT's Superior Region is to improve the safety and quality of life for people traveling through Michigan's Upper Peninsula by assisting the individual Transportation Service Centers (TSCs) and their maintenance partner agencies in maintaining and improving the travelers' safety, mobility, and productivity.

The objectives of MDOT's Superior Region RWIS implementation are:

- Provide safer highways
- Improve road maintenance decision making
- Improve traveler information
- Provide data for review of historical weather events to enhance transportation planning

The specific goals of the RWIS program are to reduce the impact which weather events have on the traveling public by:

- Reducing the duration of hazardous conditions, returning to normal seasonal conditions as rapidly as possible
- Improve maintenance efficiency of all resources utilized in response to a weather event
- Improve quality and accuracy of near-real time traveler information, allowing travelers to approach adverse weather events with knowledge of the severity of the conditions they may encounter

3.8 PROJECT OBJECTIVES

The following are specific road maintenance and road condition information practices which have shown benefit through implementation of RWIS in other states' RWIS programs:

- Improved roadway anti-icing maintenance
- Reduced use of routine patrols
- Cost-effective allocation of maintenance resources (labor and material)
- Better traveler information provided to the public
- Improved information available for incident management situations
- Cost-effective summer maintenance scheduling
- Increased collection and sharing of weather data

SECTION 4 STAKEHOLDER INPUT

In Section 2, stakeholders to the RWIS program were identified. This stakeholder group included MDOT; county road commissions; state, county and local law enforcement; college and university officials; tourism bureaus; transit officials; trucking industry representatives; Federal Aviation Administration (FAA); National Weather Service (NWS) staff; and Federal Highway Administration (FHWA) representatives. Over 200 invitations were extended to the stakeholders, asking them to provide their input. In all, more than 50 individuals provided input, which included two topics:

- Selection of ESS instruments (components) and system requirements
- Identifying proposed ESS locations

Stakeholder input on recommended system requirements of the RWIS is documented below. The stakeholder input on proposed ESS site locations is included in Section 5.

Utilizing stakeholder input from the Automated Transportation Management System (ATMS) Stakeholder process (which was compiled by Kimley-Horn for MDOT), and incorporating input from the RWIS Stakeholder process, the system requirements were identified (see **Table 4-1** through **Table 4-5)**. The items listing the source as "ATMS, RWIS" are extracted from the verbiage of Kimley-Horn's documentation and filtered by the findings of the RWIS Stakeholder process.

The items listing the source as "Stakeholder meetings" are directly from the RWIS Stakeholder process (see **Table 4-6** through **Table 4-8**). These requirements were evaluated against what is currently available from the manufacturers of RWIS systems. Based on the outcome of that process, the RWIS ESS special provision was developed.

Table 4- 1 RWIS User Requirements: Operators

User Need	Name	Description	Source
OP-01	Integrated Functions	Operators need an interface where all functions are integrated in a common user interface.	ATMS, RWIS
OP-02	Interface that Complements Workflow	Operators need an interface that complements their workflow, i.e., is event-oriented rather than device-oriented.	ATMS, RWIS
OP-03	Easy to Use	Operators need an interface that is intuitive and easy to use.	ATMS, RWIS
OP-04	Data Validation	Operators need a system that validates data entry to minimize typographical errors.	ATMS, RWIS
OP-06	System Map	Operators need to view all spatial information on a single system map	ATMS, RWIS
OP-09	View Field Devices on Map	Operators need to view field devices as annotated icons on the system map.	ATMS, RWIS
OP-12	View AVL-equipped Vehicles on Map	Operators need to view AVL-equipped vehicles as annotated icons on the system map.	ATMS, RWIS
OP-17	ADA Compliance	Operators need a system that is ADA compliant per MDIT standards.	ATMS, RWIS
OP-18	One Database	Operators need a single repository for all incident information (including special events, construction lane closures, accidents) to streamline data entry and distribution, and to improve response coordination across different events or incidents.	ATMS, RWIS

User Need	Name	Description	Source
OP-21	Remote Operation	Operators need to access the system from outside the TMC.	ATMS, RWIS
OP-22	Camera Control	Operators need to view live video, and control (pan, tilt and zoom) cameras.	ATMS, RWIS
OP-23	Role-based Camera Control	Operators need to assert control over a camera despite attempts or requests for control from users with lower priority.	ATMS, RWIS
OP-24	Take Over Camera Control	Operators need to assume camera control over users with lower priority.	ATMS, RWIS
OP-25	See Who Has Camera Control	Operators need to see who has control of a particular camera at any given time.	ATMS, RWIS
OP-26	Request Camera Control	Operators need to request control of a camera controlled by a user with higher priority.	ATMS, RWIS
OP-30	Video Frame Capture	Operators need to share video frames with responders or other operators, and include these images with incident and event reports.	ATMS, URS
OP-32	Camera Tours	Operators need to set up camera tours enabling them to scan multiple video images in preset sequences.	ATMS, RWIS
OP-34a	Track Incidents	Operators need to track an incident, with all traveler information, incident updates and camera information fully integrated.	ATMS, RWIS
OP-34b	Forward Incident Records	Operators need to forward all information about a past or active incident, including a digital image to an email address or distribution list.	ATMS, RWIS
OP-37	Incident Notification	Operators need to send incident alerts to multiple individuals—to include the traveling public—via instant message, email address or distribution list, phone, pager, or subscription service	ATMS, RWIS
OP-42	Nearby Incident Alerts	Operators need to be alerted of a prior incident nearby that could affect response plans to a subsequent incident.	ATMS, RWIS
OP-58	Anti-Icing	Operators need to be alerted when anti-icing systems are automatically activated.	ATMS, RWIS
OP-59	Logging	Operators need the system to automatically log system activity in a single database (e.g., phone calls, incident detection, verification, clearance, DMS updates, etc.) for later review and performance measurement reporting. The log needs to be readable and understandable by an operator.	ATMS, RWIS
OP-60	Web Site	Operators need to post information (Pre-planned events, construction, maintenance, congestion, incidents, and travel times) to a public traveler information web site without additional data entry.	ATMS, RWIS

User Need	Name	Description	Source
OP-61	511	Operators need to post information (Pre-planned events, construction, maintenance, congestion, incidents, and travel times) to a 511 system without additional data entry.	ATMS, RWIS
OP-62	511	Operators need to view the menu tree of current 511 messages.	ATMS, RWIS
OP-66	Dispatch Contractor	Operators need to dispatch contractors for maintenance.	ATMS, RWIS
OP-67	Malfunction Notification	Operators need to be notified of system or device malfunctions.	ATMS, RWIS
OP-68	Report Device Malfunctions	Operators need to alert maintenance personnel of device malfunctions.	ATMS, RWIS
OP-69	Equipment Repair Notification	Operators need to be notified when malfunctioning devices have been repaired.	ATMS, RWIS
OP-74	Email Subscriptions	Operators need to subscribe to email alerts for incidents, filtered by geography, freeway, time of day, severity, type, and other criteria.	ATMS, RWIS
OP-75	Documentation	Operators need thorough and accessible user manuals.	ATMS, RWIS

Table 4- 2 RWIS User Requirements: System Administrators

User Need	Name	Description	Source
SA-01	ITS Standards	System administrators need to add devices from different manufacturers without writing new drivers, to the extent possible. Therefore, the system must conform to ITS standards.	ATMS, RWIS
SA-02	MDIT Standards	System administrators need to maintain and troubleshoot the system without specialized training. Therefore, the system must conform to MDIT technology standards.	ATMS, RWIS
SA-03	MDIT Procurement Cycle	MDIT needs to upgrade the system hardware as part of its normal hardware upgrade cycle.	ATMS, RWIS
SA-04	COTS Components	System administrators need a system made up of components that are widely deployed and tested, which implies commercial off-the-shelf (COTS) components to the extent possible.	ATMS, RWIS
SA-05	MDIT Hosted and Maintained	MDIT needs to host and maintain the system hardware.	ATMS, RWIS
SA-06	Compatible with State of Michigan LAN	Operators need a system that is on the State of Michigan LAN, but is protected from bandwidth spikes and security breaches.	ATMS, RWIS

User Need	Name	Description	Source
SA-07	Open Architecture	System administrators need a system with a well-defined and documented application programming interface (API) or protocol interface to facilitate integration with external systems.	ATMS, RWIS
SA-08	GIS	System administrators need all spatial data (i.e., the system map and all information on it) to conform to statewide GIS standards to enable seamless information exchange with other statewide spatial databases.	ATMS, RWIS
SA-09	Crash Notification	System administrators need to be automatically notified if the system crashes.	ATMS, RWIS
SA-10	Role-Based Security	System administrators need to provide different levels of access to different users based on user roles	ATMS, RWIS
SA-11	Database Audit	System administrators need to easily audit the database to identify what changes were made, when and by whom.	ATMS, RWIS
SA-12	Documentation	System administrators need good documentation for upgrades, configuration, troubleshooting and general maintenance.	ATMS, RWIS
SA-13	Maintainable	System administrators need to easily maintain, upgrade, configure and add software and devices to the new system.	ATMS, RWIS
SA-14	Data Integrity	System administrators need a system that will not lose database records or transactions in case of a system crash.	ATMS, RWIS
SA-15	Remote Administration	System administrators need to administer the system remotely.	ATMS, RWIS
SA-16	New Device Types	System administrators need to integrate device types not already deployed, such as weigh-in-motion (WIM) and VII.	ATMS, RWIS
SA-17	View Device Information	System administrators need to easily query for device information, including model, manufacturer, firmware version, driver version, etc.	ATMS, RWIS
SA-18	Backup and Restore	System administrators need to perform point-in-time backup and restore operations.	ATMS, RWIS
SA-19	Add and Remove Devices	System administrators need to add, remove and configure devices in the system.	ATMS, RWIS
SA-20	Add Links	System administrators need to add links to the system.	ATMS, RWIS
SA-21	Source Code	Source code needs to be provided, with data models.	ATMS, RWIS
SA-22	Development Instance	System administrators need to test and develop system upgrades on a development instance of the software.	ATMS, RWIS

User Need	Name	Description	Source
SA-23	Data Archival and Restoration	System administrators need to easily access archived data.	ATMS, RWIS
SA-26	Reliability	System administrators need a system that is stable and reliable (i.e., it does not crash), especially under peak load,	ATMS, RWIS
SA-27	Virus Protection	System administrators need a system with good virus protection.	ATMS, RWIS
SA-28	Email	System administrators need a system that can communicate messages or alerts to individuals or distribution lists using the State's existing email system.	ATMS, RWIS
SA-29	Segregate Data	System administrators need to integrate and segregate data from external partners.	ATMS, RWIS
SA-30	Manage User Accounts	System administrators need to create, remove and make changes to user accounts.	ATMS, RWIS
SA-31	Manage User Permissions	System administrators need to grant or restrict permission to different system functions by user or user group.	ATMS, RWIS
SA-32	Manage and Monitor User Activity	System administrators need to track user activity, including when users log onto and off of the system, and what actions they performed while logged in.	ATMS, RWIS
SA-33	Network Monitoring and Management	System administrators need to monitor bandwidth utilization and control bandwidth allocation to lower priority functions to protect the performance of core functions.	ATMS, RWIS

Table 4- 3 RWIS User Requirements: Maintenance Technicians

User Need	Name	Description	Source
MT-01	Device Malfunction Alerts	Maintenance Technicians need to be notified of equipment malfunctions in a timely manner.	ATMS, RWIS
MT-02	Work Orders	Maintenance Technicians need to enter, close and update work orders electronically.	ATMS, RWIS
MT-03	Device Status Check	Maintenance Technicians need to run tests to identify and troubleshoot malfunctioning devices.	ATMS, RWIS
MT-04	Track Inventory	Maintenance Technicians need to manage assets and track spare parts inventory.	ATMS, RWIS
MT-05	Remote Access	Maintenance Technicians need to test and diagnose problems remotely.	ATMS, RWIS
MT-06	Inventory Updates	Maintenance Technicians need to access the device inventory through a database which can be updated as equipment is updated	RWIS

Table 4- 4 RWIS User Requirements: Guest/Student/Trainee

User Need	Name	Description	Source
GU-01	Training Instance	Operators need to train on a non-production instance of the system.	ATMS, RWIS
GU-02	Training Exercises	Trainees need to run scenarios on a non-production instance of the system for mock drills or simulation exercises.	ATMS, RWIS
GU-03	Reports	Students need to create and save reports from the non-production system.	ATMS, RWIS

Table 4 - 5 RWIS User Requirements: Management/VIP

User Need	Name	Description	Source
VP-01	Reporting	Managers need to see standard performance measure reports at regular intervals (e.g., weekly).	ATMS, RWIS
VP-02	Customized Database Queries	Managers need to create customized reports using standard query tools.	ATMS, RWIS
VP-03	Incident Notification	Managers need to be notified of high priority incidents.	ATMS, RWIS
VP-04	Malfunction Notification	Mangers need to be notified of high priority system or device malfunctions.	ATMS, RWIS
VP-05	Camera Control	Managers need to access and control cameras.	ATMS, RWIS
VP-06	After-Event Reporting	Managers need to easily view summaries of an event for after-event reviews, including a timeline of all system activity, messages, call logs, operator notes, MOE data, traveler information disseminated, etc.	ATMS, RWIS
VP-07	Budgeting for Device Maintenance and Replacement	Managers need to track maintenance activity by asset for budgeting purposes.	ATMS, RWIS

4- 6 RWIS User Requirements: Media

User Need	Name	Description	Source
MD-01	Media Notification	The media needs to receive incident notification to allow enhanced notification of the public	Stakeholder meetings
MD-02	Live Traffic Map	The public served by the media would benefit by availability of graphic maps depicting incident locations.	Stakeholder meetings

Table 4- 7 RWIS User Needs: Public/Private Partners

User Need	Name	Description	Source
PP-05	Transit Agencies	Transit agencies need to be able to receive incident information from the system.	Stakeholder meetings
PP-06	Other Agencies	Other agencies need to be able to receive incident information from the system.	Stakeholder meetings
PP-07	Other Weather Data Sources	System needs to be able to utilize weather data from other sources (NWS, DNR, WI)	Stakeholder meetings

Table 4- 8 RWIS User Needs: Road Maintenance Services

User Need	Name	Description	Source
RM-01	Transit Agencies	Transit agencies need to be able to receive incident information from the system.	Stakeholder meetings
RM-02	Other Agencies	Other agencies need to be able to receive incident information from the system.	Stakeholder meetings
RM-03	On-board Maintenance Vehicle Weather Data	If possible, system needs to be able to receive on-board weather and road condition data from maintenance vehicles	Stakeholder meetings
RM-04	On-board Maintenance Vehicle AVL Data	If possible, system needs to be able to receive on-board vehicle location data (AVL) from maintenance vehicles	Stakeholder meetings

SECTION 5 RWIS ESS LOCATION SITING

5.1 RWIS ESS SITING GUIDELINES

There are two primary sensor station types identified in the FHWA *"Road Weather Information System Environmental Sensor Station Siting Guidelines."*

> **Local -** This type of sensor station location and the sensors selected are to address specific weather-related issues in a particular location. The measurements from these locations may not be applicable to the road conditions nearby this specific location. For example, the ESS may be to measure bridge deck freezing which may not give similar information to the roadway condition 500 yards from the bridge.
>
> **Regional -** This ESS type is selected to be generally representative of the roadway condition in a significant stretch of road, perhaps up to ten to fifteen miles in each direction. The sensors selected usually provide a full spectrum of road weather information.

The approach selected during the stakeholder process is a combination of these two approaches. Because the Superior Region RWIS implementation will be spread over many years, it will be appropriate to select "local" sites to allow gathering data in specific trouble spots. These sites will be equipped with the full complement of ESS sensors to allow "regional" use of the data. In making the final selection of these sites, care will need to be taken to assure that the specific site can meet both local and regional criteria for the data collection. In extreme cases, this may require additional sensors be distributed in the area of the selected site to assure satisfying both regional and local requirements.

The FHWA Road Weather Information System Environmental Sensor Station Siting Guidelines are well developed and accepted within the ITS community. They should be the basis for final siting decisions and should be reviewed for each new RWIS project, to assure that the siting decisions are current with the purpose of the guidelines document. In some cases these standards may suggest relocating a site, removing vegetation, or developing a buffer zone around a site to diminish the effects of local vegetation and terrain characteristics. As a part of the final design process, an analysis must be conducted to refine the site selection and identify any limiting factors at a proposed site with respect to the Siting Guidelines. The ESS sites will need to be selected for their ease of future maintenance, including access, and encroachment from vegetation.

After installation, the sites will need to be monitored for encroachment from vegetation. This will be a service provided either by MDOT or as a task to the maintaining organization.

5.2 RWIS ESS CO-LOCATION

As a part of the initial site selection process, ESS sites were placed close to areas of development where utility connections should be less costly. During final site selection evaluation, sites should be reviewed to consider opportunities to co-locate with other state or federal agencies which have existing communications and/or power connections which could be shared or upgraded to accommodate the ESS site. These include:

- MDOT office locations
- MDOT PTR locations
- MSP office locations
- DNR locations
- DNR, NWS, or FAA weather station locations

Impact to these organizations where co-location is feasible, should be minimal, requiring a small amount of space for electronics and a communications and power pathway to the location of the respective utility demarcation. Occasional access to the co-location facility would be necessary. The sharing of utility costs will also require a memorandum of understanding between the agency and MDOT.

5.3 RWIS ESS PROPOSED LOCATIONS

As a part of the stakeholder process, a list of potential RWIS ESS sites was developed. This list was the product of group interaction to propose and evaluate sites. The initial site nominations are included in **Appendix B**. The final nominated ESS sites are listed in **Table 5-1.** The sites have been prioritized according to the following categories:

- Priority A, based on regional importance (average daily traffic volumes) and part of the current road closure system.
- Priority B, based on importance to regional traffic and at least twice the average crash rate per mile in adverse weather conditions.
- Priority C, based on the maintenance benefit of location at a county line, where maintenance vehicles typically turn around and are at the furthest point from the maintenance garage.
- Priority D, based on above average crash rate per mile in adverse weather conditions.
- Priority E, Based on unique weather information needs and filling the gaps in the weather data collection network.

Figure 5-1 displays the proposed RWIS ESS locations. Priorities of the respective sites will be finalized by MDOT as the project progresses and reviewed during the design and implementation phases of the project.

5.3.1 Regional Routes

From a regional perspective, the roadways with the highest traffic volumes between cities (including commercial traffic) are as follows:

- US-2 between St. Ignace and Iron Mountain
- M-28 between I-75 and Marquette
- M-35 and M-553 between Menominee and Marquette
- US-41 between Menominee and Houghton
- I-75 between St. Ignace and Sault Ste. Marie
- M-95 between Iron Mountain and US-41
- M-117 between US-2 and M-28

5.3.2 Alternate Route Opportunities

RWIS, coupled with traveler information, will be most effective for facilitating traveler rerouting in situations where a parallel route can be used for an alternate route. To describe the practical alternate route options, the Superior Region was divided into three sub-areas: west, central, and east. The alternate state route opportunities for each area are as follows:

West area (Iron and Baraga counties and west):

- US-2 and M-28, with connectivity via US-141, US-45, and M-64.
- M-64 and US-45/M-26, with connectivity via US-2, M-28, and M-38.

Central area (Menominee, Marquette, Delta, and Alger counties):

- US-2 and M-28, with connectivity via US-41, M-35/M-553, and M-95.
- M-35/M-553 and US-41, with connectivity via M-28, M-94, and US-2.
- M-35 and US-41 south of US-2, with connectivity via US-2/US-41.
- M-28 and M-94 between Marquette and Munising, with connectivity via US-41.

East area (Schoolcraft and Luce counties and east):

- US-2 and M-28, with connectivity via I-75, M-123, M-117, M-77, and M-94.
- I-75 and M-129, with connectivity via M-134, M-80, and M-28.
- M-94, M-77, M-117, and M-123, with connectivity via M-28 and US-2.

The crash information is provided in **Table 5-2**. The crash rate per mile of highway was developed using data between 2003 and 2006 on the state highways with snow or blowing snow conditions in which the road surface condition was icy, snowy, or slushy. It is important to note that the crash rates are per mile of roadway, and are not based on the traffic volumes. A total of 141 crashes met this criteria and are represented in the crash analysis. **Figure 5-2** displays the state highway segments that experienced an above-average crash rate. The average adverse weather crash rate was 0.08 crashes per mile. The average adverse weather crash rates are generally similar for the west, central, and east areas.

5.3.3 Recommendations

The phased implementation of RWIS can be considered a function of several variables: regional importance (average daily traffic volumes between cities), crashes during adverse weather events, maintenance benefits, unique weather information needs, and gaps in the weather data network. The ESS sites in each priority category are listed for each sub-area.

Priority A – based on regional importance (average daily traffic volumes) and part of the current road closure system.

East area (3 sites):

- I-75 (1), at the Mackinac Bridge
- US-2 in Mackinac County (2)

Central area (2 sites):

- M-28 in Alger and Marquette Counties (2)

West area (0 sites)

Priority B - based on importance to regional traffic and at least twice the average crash rate per mile in adverse weather conditions.

East area (3 sites):

- I-75 (1)
- M-28 (2)

Central area (4 sites):

- US-41 (2)
- US-2 (1)
- M-35 (1)

West area (1 site):

- US-41 (1)

Priority C – based on the maintenance benefit of location at a county line, where maintenance vehicles typically turn around and are at the furthest point from the maintenance garage.

East area (1 site):

- M-134 (1)

Central area (2 sites):

- US-2 (1)
- M-95 (1)

West area (3 sites):

- M-28 (1)
- US-2 (1)
- US-141 (1)

Priority D - based on above average crash rate per mile in adverse weather conditions.

East area (1 site)

- M-134 (1)

Central area (1 site):

- US-2 (1)

West area (5 sites):

- US-2 (2)
- M-26 (1)
- US-41 (2), including the Houghton/Hancock Bridge

Priority E - based on unique weather information needs and filling the gaps in the weather data collection network.

East area (3 sites):

- US-2 (1), at the Cut River Bridge
- M-28 (1)
- M-123 (1)

Central area (1 site):

- M-35 (1)

West area (3 sites):

- M-28 (1)
- US-45 (1)
- M-64 (1), at the Ontonagon Bridge

5.3.4 Project Phasing

When project phasing is considered, it may be advantageous to build out some or all of a sub-area, if this would improve weather monitoring on alternate routes. To prioritize the sub-areas for RWIS deployment, the following aspects should be considered:

- In addition to connections with the central area, the east area benefits from two distinct points of entry (the Mackinac Bridge and International Bridge), allowing for efficient communication to motorists entering the Superior Region. Information dissemination at these points would provide motorists with information about weather conditions on I-75, US-2 and/or M-28.
- The central area includes the most miles of roadway with regional importance, based on average daily traffic volumes between cities.
- In the west area, the regional traffic patterns are diffused among several routes as compared to the other areas. However, US-41, M-26, and US-2 experience above average adverse weather crash rates on a per mile basis.

Table 5-1: Proposed RWIS ESS Sites

TSC	Priority	Route	Description	Nearest City / Village	County	Features	Justification
Crystal Falls	C	M-95	Near Floodwood Rd.	South of Witch Lake	Dickinson / Marquette	Forested	1, 4
Crystal Falls	C	US-2	Near Foster City Rd.	Waucedah	Dickinson / Menominee	Forested	1, 4
Crystal Falls	E	US-45	Near M-26	Rockland	Ontonagon	Forested	5 (snow, steep grade), 6
Crystal Falls	E	M-64	Near River Rd.	Ontonagon	Ontonagon	Open	5 (bridge)
Crystal Falls	C	US-2	Near Gogebic / Iron County Line	East of Watersmeet	Gogebic / Iron	Forested	2B, 4
Crystal Falls	D	US-2	Near N Cedar Avenue	Bessemer	Gogebic	Open/Residential	2B
Crystal Falls	D	US-2	Near M-189 (4th Avenue)	Iron River	Iron	Open/Residential	2B
Crystal Falls	E	M-28	Near Ash Street	Bergland	Ontonagon	Open/Residential	5 (snow), 6
Escanaba	A	M-28	Near E. Munising Ave	Munising	Alger	Open	1, 2A, 3, 5 (wind, snow)
Escanaba	B	US-41	Near Eben Trenary Rd. & M-67	Trenary	Alger / Delta	Farmland/Forested	1, 2B, 4
Escanaba	B	M-28	Near M-77	Seney	Schoolcraft	Forested	1, 2A, 5 (snow)
Escanaba	B	US-2	Near CR-442	Cooks	Schoolcraft / Delta	Forested	1, 2B, 4, 5 (snow, fog)
Escanaba	D	US-2	Near US-41	Rapid River	Delta	Open/ Wetlands	1, 2B, 5 (snow, fog)
Escanaba	E	US-2	Near Escanaba River Bridge	Escanaba	Menominee	Open / Near River	5 (bridge, ice)
Escanaba	E	M-35	Near Old Mill Lane Number 20 75	Cedar River	Menominee	Open/Forested	1
Ishpeming	C	US-141	Near Net River Dam Road X2	South of Watton	Baraga / Iron	Forested/Wetland	4, 6
Ishpeming	B	US-41/M-28	Near W. Railroad St.	Michigamme	Baraga / Marquette	Forested	1, 2A, 4, 5 (snow)
Ishpeming	D	US-41/M-26	Near Houghton/Hancock Bridge	Houghton	Houghton	Open/Commercial	1, 2B, 5 (bridge, snow)
Ishpeming	A	M-28	Near Kawbawgam Rd.	Harvey	Marquette	Open	1, 2A, 3, 5 (wind, snow)
Ishpeming	D	US-41	Near Old US-41, North Intersection	Arnheim	Baraga	Open/Forested	1, 2B, 5 (snow)
Ishpeming	C	M-28	Near N. County Line Rd.	Trout Creek	Houghton / Ontonagon	Forested	4, 5 (snow), 6
Ishpeming	D	M-26	Near Donken Rd	Donken	Houghton	Forested	2B, 5 (snow)
Ishpeming	B	M-35	Near M-553	Gwinn	Marquette	Open	1, 2A
Ishpeming	B	US-41/M-28	Near Juniper St.	Ishpeming	Marquette	Open/Residential	1, 2A
Newberry	B	I-75	Near M-48	Rudyard	Chippewa / Mackinac	Farmland	1, 2A, 4
Newberry	B	M-28	Near I-75	Dafter	Chippewa	Farmland/Forested	1, 2A, 5 (wind)
Newberry	A	I-75	Mackinac Bridge Admin. Bldg.	St. Ignace	Mackinac	Open, on slope	1, 2A, 3, 5 (bridge, ice)
Newberry	A	US-2	Near Ozark Rd.	Brevort	Mackinac	Forested near water	1, 2B, 3, 5 (wind, snow, sand, fog)
Newberry	A	US-2	Near Naubinway Rd.	Naubinway	Mackinac	Open/Forested	1, 2B, 3, 5 (snow, fog)
Newberry	C	M-134	Near North Cedar Campus Rd.	Port Dolomite	Mackinac / Chippewa	Open near water	4, 6
Newberry	E	US-2	Near Cut River Rd.	Epoufette	Mackinac	Open near water	5 (bridge, fog)
Newberry	E	M-28	Near M-123	South of Eckerman	Chippewa	Forested	1
Newberry	E	M-123	Near M-123 at Paradise	Paradise	Chippewa	Open/Residential	6 (Int'l Bridge info)

Justification Key:
1 – Regional importance (traffic volumes)
2A – Adverse weather crashes per mile are 0.16 or greater (2x average)
2B - Adverse weather crashes per mile are between 0.08 and 0.16 (greater than average)
3 – Within current road closure section
4 – Maintenance benefit – near county line
5 – Unique weather information needs
6 – Gap in weather data network

Table 5-2: Adverse Weather Crash Summary

West Area

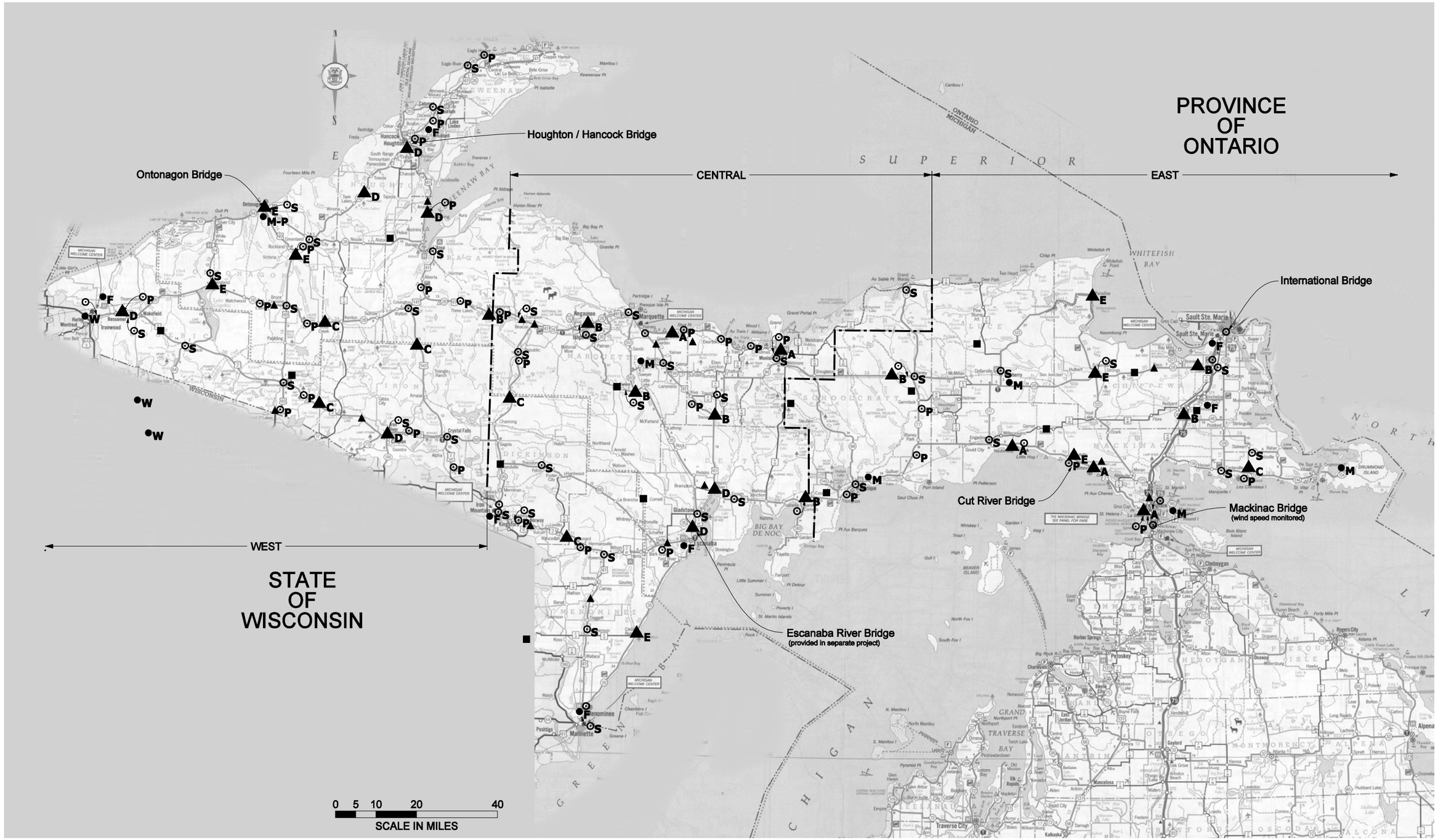
Route	County	Route Length	No. of Crashes	Crash Rate Per Mile
US-2	Gogebic	65	6	0.092
US-2	Iron	44	5	0.114
M-26	Ontonagon	16	0	0.000
M-26	Houghton (N)	20	9	0.450
M-26	Houghton (S)	25	3	0.120
M-26	Keweenaw	21	0	0.000
M-28	Gogebic	12	0	0.000
M-28	Ontonagon	39	2	0.051
M-28	Houghton	15	1	0.067
M-28	Baraga	7	0	0.000
M-38	Ontonagon	20	1	0.050
M-38	Houghton	9	0	0.000
M-38	Baraga	10	1	0.100
US-41	Baraga	44	5	0.114
US-41	Houghton	34	7	0.206
US-41	Keweenaw	32	1	0.031
US-45	Gogebic	11	0	0.000
US-45	Ontonagon	40	3	0.075
M-64	Ontonagon	33	1	0.030
M-69	Iron	10	0	0.000
M-73	Iron	9	1	0.111
US-141	Iron	24	0	0.000
US-141	Baraga	14	0	0.000
M-189	Iron	8	1	0.125
M-203	Houghton	16	0	0.000
Totals/Average		578	47	0.081

Central Area

Route	County	Route Length	No. of Crashes	Crash Rate Per Mile
US-2	Dickinson	22	1	0.045
US-2	Menominee	19	1	0.053
US-2	Delta	51	4	0.078
US-8	Dickinson	2	0	0.000
M-28	Marquette	11	1	0.091
M-28	Alger	41	8	0.195
M-35	Menominee	36	1	0.028
M-35	Delta	41	2	0.049
M-35	Marquette	42	4	0.095
US-41	Menominee	42	1	0.024
US-41	Delta	16	0	0.000
US-41	Alger	11	1	0.091
US-41	Marquette (W)	36	13	0.361
US-41	Marquette (S)	25	3	0.120
M-67	Alger	11	0	0.000
M-69	Menominee	17	0	0.000
M-69	Dickinson	25	0	0.000
M-69	Delta	5	0	0.000
M-77	Alger	13	0	0.000
M-94	Marquette	14	0	0.000
M-94	Alger	23	2	0.087
M-95	Dickinson	27	1	0.037
M-95	Marquette	19	0	0.000
M-183	Delta	16	1	0.063
M-553	Marquette	19	5	0.263
Totals/Average		584	49	0.084

East Area

Route	County	Route Length	No. of Crashes	Crash Rate Per Mile
US-2	Schoolcraft	37	5	0.135
US-2	Mackinac	59	8	0.136
M-28	Schoolcraft	24	2	0.083
M-28	Luce	32	6	0.188
M-28	Chippewa	43	2	0.047
M-48	Chippewa	37	2	0.054
I-75	Mackinac	25	5	0.200
I-75	Chippewa	28	10	0.357
M-77	Schoolcraft	27	0	0.000
M-80	Chippewa	9	0	0.000
M-94	Schoolcraft	32	0	0.000
M-117	Mackinac	9	0	0.000
M-117	Luce	5	0	0.000
M-123	Luce	28	1	0.036
M-123	Chippewa	40	1	0.025
M-123	Mackinac	19	0	0.000
M-129	Mackinac	5	0	0.000
M-129	Chippewa	29	2	0.069
M-134	Mackinac	22	1	0.045
M-134	Chippewa	26	0	0.000
M-149	Schoolcraft	10	0	0.000
M-221	Chippewa	2	0	0.000
Totals/Average		548	45	0.082



LEGEND

- ▲A Priority A (5 Total)
- ▲B Priority B (8 Total)
- ▲C Priority C (6 Total)
- ▲D Priority D (6 Total)
- ▲E Priority E (7 Total)
- ●M MDOT Airport Weather Station
- ●M-P MDOT Airport Weather Station - Proposed
- ●F FAA Airport Weather Station
- ●W Wisconsin DOT Weather Station
- ▲ Permanent Traffic Recorder
- ■ Existing DNR Weather Station
- ⊙N DNR Office
- ⊙ MSP Post
- ⊙T MDOT Office
- ⊙R MDOT Rest Areas
- ⊙P MDOT Roadside Parks
- ⊙S MDOT Salt Sheds

MDOT Michigan Department of Transportation

PREPARED BY: URS

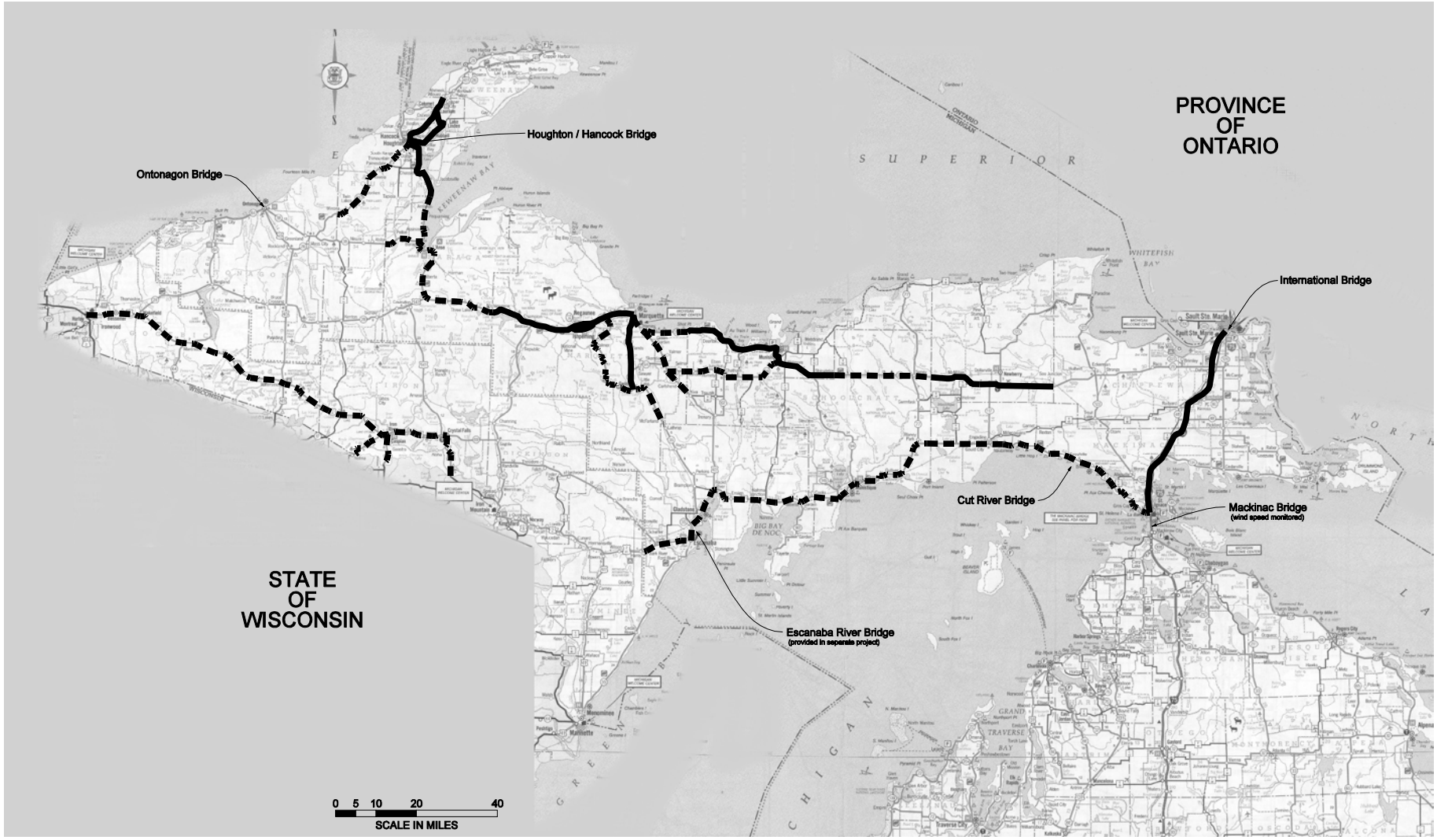
ROAD WEATHER INFORMATION SYSTEM (RWIS)

PROPOSED ESS SITE LOCATIONS

FIGURE 5-1

P:/ 12940344 /CADD

06-26-07



LEGEND

CRASH RATES

- 0.08 - 0.15 adverse weather crashes / mile
- 0.16+ adverse weather crashes / mile

MDOT Michigan Department of Transportation

PREPARED BY: URS

ROAD WEATHER INFORMATION SYSTEM (RWIS)

UPPER PENINSULA CORRIDOR
ADVERSE WEATHER CRASH RATES

FIGURE 5-2

SECTION 6 RWIS ESS SENSORS AND DEVICES

6.1 RWIS ESS DEVICE USE IN OTHER RWIS DEPLOYMENTS

From review of the RWIS literature and interviews with representatives from eleven state DOTs, there is generally a commonly used set of RWIS ESS sensors. The set includes the typical AWS configuration of:

- Air temperature
- Dew point and humidity
- Wind speed, direction, and gust speed
- Precipitation occurrence (yes or no)

Pavement surface and sub-surface sensors are added to the above to create an ESS configuration:

- Pavement temperature
- Road surface condition, including a passive sensor to identify wet, dry, snow covered, or icy pavement
- Sub-surface condition, including a frost sensor that measures at two depths

A visibility sensor is also frequently added. A barometric pressure sensor is sometimes included.

In the more recent RWIS deployments or planned deployments, the following sensors and ITS devices have been included in the RWIS ESS configuration:

- Snow depth
- CCTV camera
- Vehicle detection

6.2 SPECIFIC APPLICATIONS OF RWIS

6.2.1 Roadway Surface Monitoring

A primary purpose of RWIS is monitoring of roadway surface conditions. Road condition sensors are not part of typical atmospheric weather monitoring systems. One class of roadway sensors, called passive sensors, monitor road surface condition (dry, wet, drizzle, freezing, and snow), and can indicate the freezing point of applied chemicals of known type and concentration. The latest generation sensors, called active sensors, are capable of providing the actual road surface freezing temperature regardless of the current chemical mix that has been applied. This monitoring can facilitate identification of the freezing point in those instances when one or more chemicals have been applied to a roadway.

Roadway sub-surface sensors provide measurements of frost depth and soil moisture content. Both measurements are critical in identifying spring roadway load conditions.

A sensor which is not currently available is a sand presence sensor. There are frequent conditions in specific areas of the Superior Region, such as the segment of US-2 between Naubinway and Brevort, which are subject to periodic accumulation of blowing and drifting sand. Sand can accumulate up to six inches in depth, creating a hazardous driving condition. Sensors to identify these conditions would be beneficial to maintenance operations by providing notification that a significant quantity of sand is present in a travel lane, allowing dispatch of maintenance vehicles.

A related non-winter maintenance need which can be addressed through an ESS enhanced with a CCTV camera is the identification of blowing and drifting sand on the roadway. Although no sensor currently exists to identify the accumulation of sand on the roadway, placement of ESS in locations prone to this condition will allow review of the recent weather

(very low recent precipitation), and identification of the historical atmospheric conditions (low humidity and high wind from a specific direction). Through use of a CCTV camera, the existing condition could be visually verified.

6.2.2 Bridge Condition Monitoring

Bridges create a particularly hazardous potential, since their driving surface experiences differing conditions from the roadway, prone to freezing prior to the paved roadway. There are two major bridges identified in the RWIS stakeholder process which should be considered for RWIS monitoring. These major bridges are operated separately from the MDOT Superior Region, but require coordination with Superior Region where it is important for operation of the bridge and road facilities. These bridges are:

- Mackinac Bridge, operated by the Mackinac Bridge Authority (MBA)
- International Bridge, operated by the International Bridge Authority (IBA)

The Mackinac Bridge already has several locations where wind speed and direction measurements are taken. Additional opportunities for roadway icing detection and video would improve motorist safety and incident management.

In addition, there are five minor bridges which were suggested during the stakeholder process for consideration as RWIS ESS sites:

- Ontonagon Bridge
- Houghton/Hancock Bridge
- Cut River Bridge
- Menominee Bridge
- Escanaba River Bridge

These bridges are subjected to icing, snow, fog, and wind conditions, presenting adverse travel conditions. RWIS can quickly identify adverse conditions to provide early notification to travelers and to maintaining agencies. DMS and HAR devices, where available, can provide information about adverse weather events in other areas, expanding their current use, which is primarily focused on bridge–related weather conditions. MDOT will evaluate options for a 2009 construction project.

RWIS can support an anti-icing program, which includes distribution of anti-icing materials by a maintenance vehicle or through a fixed anti-icing system. A fixed system is most often installed on a bridge structure to pre-treat the bridge deck when conditions for icing are imminent. The system consists of tank storage of material distributed through nozzles, triggered by either an automatic or manual decision process. An RWIS ESS is an integral part of a fixed anti-icing system.

6.2.3 Roadway Maintenance

The greatest value of RWIS to a roadway agency is to provide decision support for roadway maintenance activities. Currently, NWS data and anecdotal input from crews, MDOT staff, or law enforcement agencies provide primary decision support. This information, although helpful, provides an incomplete picture of the roadway weather conditions and is limited in its availability. RWIS can provide a more complete and consistent data profile of the roadways at a higher frequency, and allow for customizing the data output to the needs of MDOT and its partner maintaining agencies. As a result, more detailed decision support for snow plowing will be available, as well as roadway pre-treatment and treatment applications. RWIS can also provide opportunities for other decision support for road maintenance (e.g., pavement temperature or rain occurrence – both important for patching crews) without the need to dispatch a maintenance crew for reconnaissance purposes.

6.2.4 Traveler Information & Safety

Roadway operations can be enhanced via the output from an RWIS which would provide information to agencies and travelers via the Internet and the commercial media (TV, radio, and cellular phone) for trip planning and en route decision support. Additional information could be available along the roadside via DMS and/or warning flashers at locations that pose specific hazards or at critical decision points. Local information of interest can be provided through highway advisory radio (HAR) broadcasts. Kiosks at rest areas can provide graphic information to travelers who would not otherwise have in-vehicle access to graphical information for trip planning. HAR, DMS, and/or warning flashers can be portable to allow relocation to support varying weather conditions or seasonal conditions.

6.2.5 Incident Management

Incident prevention can be facilitated with RWIS through pre-notification of weather events (e.g., bridge icing), and assist in decision support for roadway closures. RWIS can also provide data to review historical conditions and locations which experience weather-related hazardous conditions. This analysis can be useful in maintenance planning and event decision making.

6.3 RWIS ESS DEVICE SELECTION

The sensors and devices which are available for inclusion in an ESS are in three general classes: atmospheric, pavement surface, and sub-surface. ITS sensors and devices can also be added to augment the weather-related data. Through the stakeholder process the sensors and devices included in a Basic RWIS ESS were identified. **Table 6-1** provides the weather and environmental sensors, pavement sensors, and sub-surface sensors that were identified as a part of the Basic RWIS ESS configuration.

Table 6-1: Basic RWIS ESS Sensors and Devices

Class	Sensor	Parameter
Clock	GPS	Time
Atmospheric	Thermistor (thermometer)	Air Temperature
		Dew point temperature
	Wind	Wind Speed
		Gusts
		Wind Direction
	Barometer	Pressure
	Present Weather Detector	Precipitation Occurrence, Type, Intensity, Accumulation
	Visibility	Visibility
Pavement Surface	Thermistor (thermometer)	Temperature
	Road Surface Condition (passive sensor)	Presence of moisture and classification
		Chemical Factor
Sub-Surface	Frost depth (4 sensors total, 2 at each depth)	Temperature (frost depth, deep and shallow)

Table 6-2 provides the weather and environmental sensors, pavement sensors, and sub-surface sensors that were identified as a part of the Reduced Power RWIS ESS configuration.

Table 6-2: Reduced Power RWIS ESS Sensors and Devices

Class	Sensor	Parameter
Clock	GPS	Time
Atmospheric	Thermistor (thermometer)	Air Temperature
		Dew point temperature
	Anemometer, unheated	Wind Speed
		Gusts
		Wind Direction
	Barometer	Pressure
	Occurrence Meter, unheated	Precipitation
	Visibility, unheated	Visibility
Pavement Surface	Thermistor (thermometer)	Temperature
	Road Surface Condition (passive sensor)	Presence of moisture and classification
		Chemical Factor
Sub-Surface	Frost Depth (2 sensors total, 1 at each depth)	Temperature (deep and shallow)

Table 6-3 identifies the optional ESS sensors which can be added to the Basic RWIS ESS described above:

Table 6-3: Optional RWIS ESS Sensors – Additions to Basic RWIS ESS

Class	Sensor	Parameter
Atmospheric	Pyranometer (sun radiation)	Total Radiation (solar & IR)
	Acoustic Range	Snow Depth
	Air Quality	Ozone
	Lightning	Lightning Strikes to Earth
	Smoke	Optical
Pavement Surface	Active Sensor	Freeze Point Chemical Factor
	Passive Sensor	Presence of moisture and classification
	High Water	Water Level
Sub-Surface	Soil Moisture	Soil Moisture Content

Table 6.4 provides a listing of optional ITS sensors and devices which can be added to a Basic RWIS ESS, providing additional functionality and information gathering capability.

Table 6-4: Optional ITS Sensors and Devices

Class	Sensor	Parameter/ Function
Optional Sensors and Devices	CCTV Motion Video Camera[1, 3]	Motion Video Images
	CCTV Still Video Camera[2]	Still Video Images
	Weigh-in-motion (WIM)[3]	Vehicle Axle Weight, Gross Weight, Bridge Formula and EASL Calculations
	Vehicle Detector, Non-Invasive[3]	Traffic Speed, Volume, and Class
	Permanent Traffic Recorder (PTR)	Traffic Speed, Volume, and Class
	Warning Flasher[3] (Sign Optical)	Visual Notification of Hazardous Condition
	Highway Advisory Radio (HAR)	Radio Notification of Event Condition
	Dynamic Message Sign, Small	Visual Notification of Event Condition

1. The CCTV Motion Video Camera may be specified for ESS sites where bandwidth is ample to support full motion video streaming or where bandwidth is limited to 56 Kbps and camera resolution and/or video frame rate is reduced.

2. The CCTV Still Video Camera may be specified for ESS sites where bandwidth is limited to 9.6 Kbps and / or where reduced power is required.

3. See special provisions for these ITS sensors and devices for accuracy and specification details.

6.4 STATION CONFIGURATION FLEXIBILITY

Flexible sensor configurations allow ESSs to be customized to meet the desired monitoring requirements. The flexibility of ESS configurations and their remote processing unit (RPU), often allows additional weather or environmental parameters to be measured by adding sensors to the system.

There may also be a need to provide special ESS configurations at locations of specific environmental conditions (e.g., flooding, icing bridge deck). These locations may allow a reduced set of sensors to be deployed to provide information about the specific hazard along with communications output component(s) (e.g., warning flasher, small DMS, and communications connection).

As an example, a **Seasonal Flooding RWIS ESS** could include:

- Water level sensor
- Warning flasher at a static sign
- 800 MHz radio

A **Portable RWIS ESS** can be specified which would include the following:

- **Reduced Power RWIS ESS** sensors
- Trailer
- Solar/battery array
- 800 MHz radio
- High water sensor, flasher beacon, and generator

The portable RWIS ESS allows testing of proposed ESS sites to confirm a potential permanent site location or for locations which need monitoring of seasonal or temporary conditions.

SECTION 7 COMMUNICATIONS, POWER, AND PROCESSING

7.1 STATION COMPONENTS

Each RWIS ESS site will have the following components:

- Various atmospheric, road surface, sub-surface sensors, and possible ITS devices (see Section 6).
- Communications to the long haul communications network, which provides the connection to the RWIS server
- Power system, lightning protection, grounding and bonding as applicable to the ESS site
- Remote Processing Unit (RPU), for sensor data pre-processing

7.1.1 Communications

The communications of the ESS data to the long haul communications network represents the data transmissions from the ESS to the CPU. The communications alternatives which can be used at the ESS are based on the selection of the long haul communications network (see **Table 7-1**).

Based on NTCIP 1204 ESS MIB (Version 2.23), a complete ESS data set can be sent over a 9.6 Kbps connection in approximately five minutes, including a ten second interval allowing for establishing the connection and terminating the connection after the transfer. Verification of these calculations will need to be conducted as a part of the acceptance testing process during construction. As a safety factor a ten minute interval could be used. A ten minute interval is common in many weather station transmissions, although NWS would prefer five minute or shorter intervals.

The transmission of video data is not included in the ESS data set, and would require longer transmission times over a 9.6 Kbps connection, particularly motion video. Video data transmission requirements are discussed in Section 7.2.

Technical Discussion:

Using the NTCIP 1204 ESS MIB (Version 2.23) as a reference for ESS data throughput calculations, the total accessible parameters are:

- 125 integers at 4 bytes each (long integers are assumed)
- 27 strings at 256 bytes each

A full ESS MIB get would correspond to 7,412 bytes. The total SNMP PDU size is estimated at 8,988 bytes. With a maximum SNMP PDU length in a PPP frame is 1,472 bytes, the total number of SNMP PDUs is estimated to be 54. Including 8-12 seconds overhead for establishing the connection of a 9.6 Kbps link (the minimum bandwidth requirement), a five-minute polling interval should allow the transmission of the entire ESS metadata, not including Motion Video.

Table 7-1 RWIS ESS Communications Alternatives[1]

ESS Communications Alternative	Network Type	Bandwidth	Advantages	Disadvantages
Dial-up (POTS-based asynchronous communications)	Public Switching Telephone Network	14.4 Kbps to 56Kbps[2]	Inexpensive, Ability to transmit up to 15 frames per second of motion video[2]	Limited availability in remote areas Low bandwidth Recurring monthly cost ($40)
High-speed leased line (T1, DSL)	National / Rural Network Carriers	128 Kbps to 1.544 Mbps	High bandwidth Ability to transmit up to 20 frames per second of motion video[2]	Relatively expensive to install Recurring monthly cost (T1 - $500) Not widely available in remote areas
Fiber	Private Network or National / Rural Network Carriers	Up to 40 Gbps	Ability to transmit full motion video[2]	Not widely available Most expensive installation cost
Wireless (microwave)	Private Network or National / Rural Network Carriers	Up to 600 Mbps	Ability to transmit full motion video[2]	Expensive to install Range limited to line of sight
Cellular	Wireless Service Provider	50 Kbps to 1+ Mbps[3]	Widely available, Ability to transmit up to 15 frames per second of motion video[2]	Recurring monthly cost ($80)
Satellite	National Network Carriers	9.6 Kbps to 700 Kbps[4]	Available everywhere, Ability to transmit limited resolution still video[5]	Moderately expensive to install Recurring monthly cost ($90 to $200) Outages in bad weather
MPSCS (800 Mhz) APCO25	State of Michigan owned, MDIT managed	Up to 9.6 Kbps	Widely available Infrastructure, State owned Ability to transmit limited resolution still video[3]	Very low bandwidth, may be interrupted in emergency public safety operations) "best effort" quality of service Possible membership fee ($200 to $300 per site per year)

1 Monthly fees are estimated, lower fees may be negotiated with provider.

2 Motion video resolution is defined at 704 x 480 pixels color

3 Available cellular bandwidth varies according to location, 50 Kbps is frequently available

4 Various satellite bandwidth available at additional cost

5 Still video resolution is defined at 110 x 110 pixels black and white

7.1.2 Power

The power alternatives are generally in three categories:

- **Existing –** power is available at the site.
- **Available –** power is available near the site and it is economically feasible to connect to the power grid.
- **Remote –** power is too distant for it to be economically feasible to connect to the power grid. Alternative sources of power (solar and/or wind) with a battery storage capability is required.

Commercial power is expected to be available at most of the areas identified in the stakeholder meetings. Most areas appear to be either near areas of commercial or residential development or, with some relocation of the site, may be able to utilize either existing or available connections. MDOT, MSP, DNR, rest areas, and roadside parks may have power available, if co-location with these facilities is selected.

7.1.3 Communications and Power Assumptions

The Basic RWIS ESS assumes that there is commercial power available (120 volt AC) and communications connections capable of a minimum 56 kbps data transfer. These minimums will allow sites to include even the heaviest power consuming sensors and devices (e.g., CCTV pan/tilt/zoom camera with heater). If the available bandwidth is at least 1 Mbps, then the most bandwidth-intensive devices (e.g., CCTV camera providing full motion video) may be specified.

7.1.4 Limited Power

If the cost of running a conventional power service to a site is many times the cost of the RWIS ESS, the only feasible alternative may be a stand-alone power alternative, such as solar and/or wind power generation system. If power is provided by solar and/or wind, the generating capacity will be limited, particularly during winter months. As a result, the Reduced Power RWIS ESS will be limited to 100 watts, allowing for sufficient battery system recharging.

In this situation, the ESS components, which can be supported by the power source, may be limited to the unheated passive sensors available in that sensor type. Some sensor types may not be feasible in conjunction with stand-alone power alternatives (e.g., active pavement sensors, due to their heating and cooling functions). Other devices may be limited in their functionality (e.g., camera lenses may fog without the use of a heater or cameras may be able use their pan/tilt/zoom functions only rarely). Certain sensors may not provide data when the performance of moving parts (e.g., anemometers) or optical sensors are hampered due to icing.

7.1.5 Limited Communications Bandwidth

Motion video components require a significant amount of communications bandwidth for effective transmission (e.g., streaming video). In conditions where bandwidth is limited, the ESS or ITS sensor type which is affected is motion video. These requirements may eliminate motion video from the options list when the only feasible communications alternative is POTS (plain old telephone service).

7.2 VIDEO OPTIONS

Video, whether still or motion, can provide additional information about a weather event to allow visual verification of weather status. The amount of information is increased as the frame frequency increases, but the bandwidth required also increases. In site locations where bandwidth is limited,

lower frame frequencies will be necessary. Based on stakeholder input, video imagery at five or more frames per second is desired.

An image frequency of one frame per five seconds is considered the minimum speed for “motion” video. Frame frequencies less than one frame per five seconds is considered “still“ video. The progression of a weather event may be adequately depicted in a frame frequency as low a frame per five to ten minutes.

- **Motion Video** imagery offers the opportunity to see the weather conditions in remote locations without the need to send a reconnaissance vehicle to review the weather at a specific location. The primary disadvantage of motion video is that it requires a significant amount of bandwidth for transmission and may interfere with weather data transmission if bandwidth is not sufficient. Conventional power is required to maintain a fog and ice-free lens during all weather conditions.

  By adding pan/tilt/zoom (P/T/Z) functions to the video camera, greater flexibility in weather monitoring can be achieved. P/T/Z can also allow monitoring of roadway incidents up to one mile away, in the absence of obstructions.
- **Still Video** imagery provides an alternative to video with the obvious loss of information. Its transmission requires significantly less bandwidth, if resolution is reduced. A further reduction in the bandwidth requirements can be achieved if the image is transmitted as a grayscale image. This approach can retain much of the weather-related information using a lower bandwidth communications connection, such as a POTS line.
- A range of **Video Frame Frequency** can be considered at ESS sites which have reduced communications bandwidth, as shown in **Table 7-2**.

Table 7-2 RWIS ESS Video Options

Video Type	Frames per unit time	Resolution	Required Bandwidth	Communications Options
Motion Video	30 frames/sec	704 x 480 pixels (4 CIF)	3.0 Mbps	F
	5 frames/sec	704 x 480 pixels (4 CIF)	0.5 Mbps	T, F, C
	1 frame/5 sec	704 x 480 pixels (4 CIF)	20.5 Kbps	P, T, C, F, S
Still Video	1 frame/min	110x110 pixels	630 bps	P, T, C, F, S, M
	1 frame/5 min	110x110 pixels	126 bps	P, T, C, F, S, M
	1 frame/10 min	110x110 pixels	63 bps	P, T, C, F, S, M
	1 frame on demand	110x110 pixels	63 bps minimum	P, T, C, F, S, M
Communications options: P – POTS; T – T1, C – cellular phone; F – fiber optic; S – satellite; M – MPSCS				

7.3 RWIS ESS POWER AND COMMUNICATIONS

The ESS power requirements include conventional power for each option, with the exception of the Reduced Power RWIS ESS. The communications requirements step up incrementally, offering several alternatives at most ESS configurations. **Table 7-3** indicates several options and their power and communications alternatives. The Enhanced RWIS ESS option is included, consisting of a Basic RWIS ESS with all Optional RWIS ESS Sensors added to the configuration. Cost estimates for the RWIS ESS configurations and for individual sensors and devices are based on vendor budgetary estimates for the specific configuration.

Table 7-3 RWIS ESS Power and Communications Requirements and Options

RWIS ESS Package	Estimated Power Requirements	Power Options	Required Bandwidth	Communications Options
Reduced Power RWIS ESS	85 watts	S/W, E	9.6 Kbps	P, T, C, F, S, M
Basic RWIS ESS	210 watts	E	56 Kbps	P, T, C, F, S
Enhanced RWIS ESS (Basic RWIS ESS with all Optional ESS Sensors)	255 watts	E	56 Kbps	P, T, C, F, S
Basic RWIS ESS with Still Video	245 watts	E	56 Kbps	P, T, C, F, S
Enhanced RWIS ESS with Motion Video	290 watts	E	1 Mbps	T, F, S.
Enhanced RWIS ESS with Motion Video and HAR	300 watts	E	1 Mbps	T, F, S
Power options: S/W – solar/wind; E – electric service Communications options: P – POTS; T – T1, C – cellular phone; F – fiber optic; S – satellite; M – MPSCS				

Table 7.4 identifies the power and bandwidth requirements of the Basic RWIS ESS components. Because of the large overhead requirement of the NTCIP standard, the minimum bandwidth required to send an "empty" message (all the structure of the message, but without data), is effectively the same as the size of a fully populated message. Power requirements and estimated replacement frequency are listed individually for each device. The Basic RWIS ESS cost is estimated to be $69,000.

The average failure rates listed are approximations based on vendor data for specific sensors and may include incidents of sensor failure due to a replaceable part or sub-assembly, rather than a failure which would require the replacement of the sensor.

Table 7-4: Basic RWIS ESS Sensors and Devices

Class	Sensor	Power Required (Watts)	Average Failure Frequency (years)	Estimated Replacement Frequency (years)
RPU	Processor	75	10	10
Clock	Global Positioning System (GPS)	1	10+	10+
Atmospheric	Thermistor (temperature)	0.25	8	10+
	Hygristor (humidity)	1	10	10+
	Wind, heated	50	2	5
	Barometer	0.15	10+	10+
	Present Weather Detector (precipitation)	40	2	5
	Visibility, heated	36	2	5
Pavement Surface	Thermistor (temperature)	1	10+	10+
	Road Surface Condition, passive sensor	1	4	10+
Sub-Surface	Frost Depth (temperature)	4	4	10+
Totals		210 Watts		

Table 7-5 identifies the power and bandwidth requirements of the Reduced RWIS ESS components. The reduction in power is achieved by eliminating the sensor and device heaters. Power requirements and estimated replacement frequency are listed individually for each device. The Reduced Power RWIS ESS cost is estimated to be $59,000. The Portable RWIS ESS cost is estimated to be $64,000.

The average failure rates listed are approximations based on vendor data for specific sensors and may include incidents of sensor failure due to a replaceable part or sub-assembly, rather than a failure which would require the replacement of the sensor.

Table 7-5: Reduced Power RWIS ESS Sensors and Devices

Class	Sensor	Power Required (Watts)	Average Failure Frequency (years)	Estimated Replacement Frequency (years)
RPU	Processor	75	10	10+
Clock	Global Positioning System (GPS)	1	10	10
Atmospheric	Thermistor (temperature)	0.25	8	10+
	Hygristor (humidity)	1	10	10+
	Anemometer, unheated (wind)	.25	10+	10+
	Barometer	0.15	10+	10+
	Occurrence Meter, unheated (precipitation)	0.80	7	10+
	Visibility, unheated	1	2	5
Pavement Surface	Thermistor (temperature)	1	10+	10+
	Road Surface Condition, passive sensor	1	4	10+
Sub-Surface	Frost Depth (temperature)	2	4	10+
Totals		85 Watts		

Table 7-6 identifies the power and bandwidth requirements of the optional RWIS ESS sensors which can be added to the Basic RWIS ESS. The optional atmospheric devices would be added to a ground-mounted H-frame where possible, and only sensors requiring pole mounting would be added to the tower. The power requirements and estimated replacement frequency are listed individually for each device.

The average failure rates listed are approximations based on vendor data for specific sensors and may include incidents of sensor failure due to a replaceable part or sub-assembly, rather than a failure which would require the replacement of the sensor.

Table 7-6: Optional RWIS ESS Sensors – Additions to Basic RWIS ESS

Class	Sensor	Power Required (Watts)	Average Failure Frequency (years)	Estimated Replacement Frequency (years)	Installed Cost
Atmospheric	Pyranometer (solar radiation)	1	3	10	$1,500
	Acoustic Range (snow accumulation)	0.6	2	5	2,500
	Air Quality (particulate)	10			3,500
	Lightning	10			5,000
	Smoke	10			5,000
Pavement Surface	Road Surface Condition, passive sensor	Battery powered	3	10	5,000
	Road Surface Condition, active sensor	10	3	10	8,500
	High Water Level	0.24			4,000
Sub-Surface	Soil Moisture	1	10+	10+	3,500
Totals		45			$38,500

Table 7-7 identifies the power and bandwidth requirements of the optional ITS sensors and devices which can be added to a Basic RWIS ESS described above. The addition of video transmission does add significantly to the required bandwidth of the ESS.

Table 7-7: Optional ITS Sensors and Devices

Class	Sensor	Power Required (Watts)	Bandwidth Required	Installed Cost
Optional ITS Sensors and Devices	Weigh-in-motion (WIM)	10		$15,000
	Vehicle Detector, Microwave	7.5		6,500
	Vehicle Detector, In-Pavement (4 lanes)	Battery based		8,000
	Permanent Traffic Recorder (4 lanes)	10		8,000
	Flashing Beacon, with sign	200		7,500
	Highway Advisory Radio (HAR)	10		36,000
	Dynamic Message Sign, Small	2000		50,000
	CCTV Video, Still Camera with Heater	35	63 – 630 bps	3,500
	CCTV Video, Still Camera, no Heater	1	63 – 630 bps	3,300
	CCTV Video, Motion Camera	35	20.5 Kbps – 3.0 Mbps	$8,200

7.4 RWIS ESS REMOTE PROCESSING UNIT (RPU)

The RPU collects, pre-processes, and archives RWIS ESS sensor and device data. The RPU has the capability to record and archive automated weather reports for a period of 7 days. The interval between archived reports can typically vary between 1 and 20 minutes. It should be noted that under low bandwidth conditions, the time required to download 7 days of measurements may make it impractical.

The communications system should support IP network communications to the CPU over one or Ethernet or PPP data link interfaces to wired or wireless mediums. Transmission of all of the required data must occur within 25% of the total polling period (e.g., if the site is polled every 20 minutes the data pipe must be sufficiently large to transmit all real time data within five minutes).

If near 100% uptime is desired (continuous, uninterrupted ESS availability) using a conventional power service, battery backup may be needed to account for power outages. If solar or wind generation is used as a power source, as it is in some states, the power system should be sized with battery storage capable of providing power through the periods of the year when solar and/or wind may not be adequate to sustain the system's power requirements.

ESSs may also require the ability to communicate directly to the motoring public using a static sign with warning flasher. Additional communications to the traveling public will be through the statewide ATMS system, via the ITS devices which may be co-located with the ESS. These devices are connected by either a hardwired or short distance wireless communications link.

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SECTION 8 SYSTEM ARCHITECTURE AND STANDARDS

The RWIS provides a platform to collect, process, and disseminate road weather data in an open, robust, and scalable architecture. The standards which guide the RWIS design and deployment are developed to ensure its seamless integration into existing traffic, weather, and public safety and travel information systems.

8.1 RWIS ARCHITECTURE

The RWIS architecture includes the hardware, software and communications systems necessary to provide reliable road weather data to support operation and maintenance of MDOT roadways.

Figure 8.1 illustrates the building blocks of a preliminary RWIS architecture. The final RWIS architecture will be solidified with the design phase of the first RWIS project and development of the state-wide Traffic Management Center (TMC) Concept of Operations.

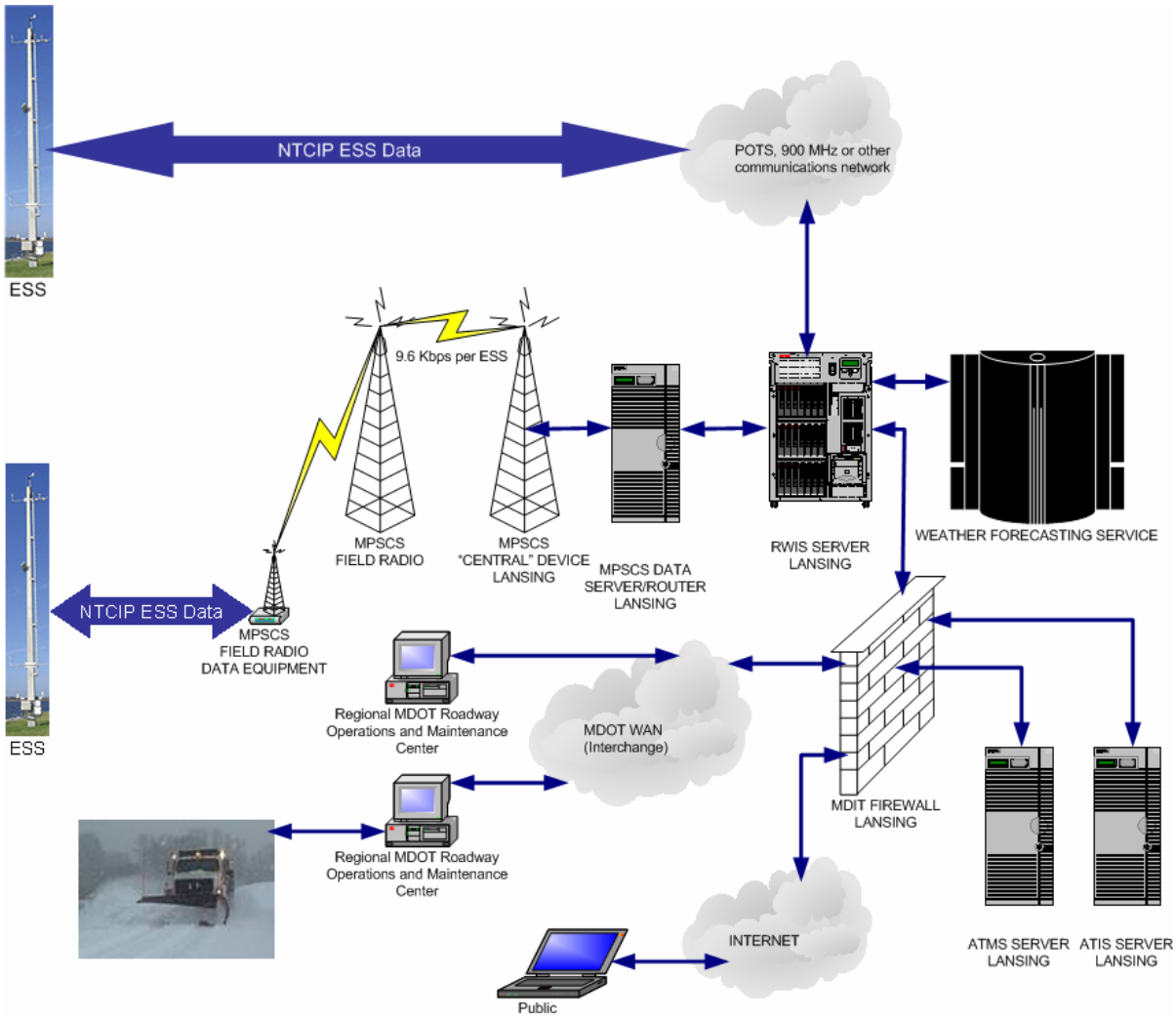

Figure 8-1 RWIS Architecture Components

The RWIS could be a fully stand-alone system utilizing only MDOT-owned environmental sensor systems (ESS) in the field, MDOT-owned communications links, and MDOT-owned

interface and processing capability. The more "stand-alone" it is, however, the more costly the overall system will be per RWIS ESS location. An early goal of the system was to integrate with other data sources and to take advantage of existing communications infrastructure opportunities wherever possible, and thereby minimize the cost per RWIS ESS location. Wherever it is feasible, the architecture will utilize existing communications connections and will also co-locate with existing State of Michigan infrastructure to reduce construction and maintenance costs.

8.1.1 Environmental Sensor Station

The RWIS ESS is comprised of sensors and devices to measure and report road weather conditions packaged in fixed or mobile stations. The configuration of sensors and devices is based on the required field parameters (e.g., road and air temperatures, relative humidity, and wind characteristics), and the available power source (commercial or solar/battery) at the ESS site.

The data structure between the sensors and RPU is proprietary and is not likely to be standardized in the near future. However, the industry has developed de facto hardware standards to allow sensors from various manufacturers to be integrated into a coherent ESS structure, allowing some interchangeability. The application of the de facto standards is not anticipated to preclude any of the requirements of the Superior Region RWIS. Since many of these sensors were developed for use for atmospheric weather forecasting, these sensors are standardized in conformance with the World Meteorological Organization (WMO) code form FM 94 **BUFR** (Binary Universal Form for the Representation of meteorological data). NTCIP for ESS follows this standard quite closely. The data is communicated from the RPU to CPU in the NTCIP standard format.

The RPU performs all the pre-processing on the RWIS ESS to the current version of NTCIP (NTCIP 1204, TS3.7-1998) for communication between ESS and the central processing unit (CPU) at the central facility (the Center). The current NTCIP standard is being updated and the new draft should be voted on within the next six months. It is anticipated that the RWIS deployments will be based on the new standard, after it has been accepted. This allows the polling of the RWIS data in a standards compliant operation using the vendor-developed ESS polling and processing software, third party or in-house developed applications.

8.1.2 Central Processing Unit

The CPU is comprised of software systems which provide for polling, processing, and archiving of RWIS data from the ESS(s). The data collection occurs when the CPU, based on pre-defined polling cycles or manually, issues a query to the ESS NTCIP MIB within the ESS RPU. The query type and returned data is based on preset scripts which will interrogate the ESS for either RWIS data or health status of the ESS sensors and devices.

Some MDOT locations use weather data from the Michigan Department of Natural Resources (DNR), other states (e.g., Wisconsin) and provinces (e.g., Ontario). Some of these data sources are not NTCIP standard and will need to be translated into an NTCIP-compliant format to be used as source data for evaluation by MDOT's road forecasting partner. Because of the standards in place for weather data formatting, the data translation will likely require a memorandum of understanding between MDOT and the respective agencies. If the translation or timely transfer of this data to the forecasting partner proves unwieldy, the data can continue to be used on an ad hoc basis, requiring manual processing.

8.1.3 Use of RWIS Data for Forecasting and Maintenance

Once the data is collected, processed and stored, it is ready for dissemination to other departments and partner agencies which may use it for operations decisions and information management. An aspect of the system architecture is determined by how the RWIS data is distributed and used. The distribution can be in the form of a web page or a client application interface. The RWIS data available for maintenance or forecasting purposes is provided by

the CPU and represents the most current report from any ESS location. It is time-stamped to allow identifying the report in its context. In review of some state RWIS web sites it was noted that some reports were as old as 90 minutes, possibly indicating a communications interruption.

The data types are divided into two classifications:

- atmospheric data
- road surface and subsurface data

The atmospheric data will be collected by the RWIS and transferred to the NWS for processing into the atmospheric forecasting system to generate local and regional forecasts. NWS currently does not process pavement and subsurface data, although it can be transferred to NWS as text fields for manual processing. The atmospheric, road surface, and subsurface data will be transferred to MDOT's partner organization for processing into location-specific Superior Region pavement forecasts.

8.1.4 System Control and Management

The RWIS is a networked system to be managed centrally, with proposed network management functions and hardware (i.e., server and other electronics) to be located in Lansing. All ESS data would be transferred by the communications back-haul carrier to the Lansing center and transferred to the forecasting partners for processing. The processed data is then available to MDOT and its partner agencies for a variety of uses.

The proposed system architecture will place system management and control in the Lansing TMC. The proposed Superior Region TMC will have access to all data for the region and will have operational control over the ITS devices (e.g., ability to change messages and control cameras) and will see data from all RWIS and ITS devices, but will not provide system level control.

The TSCs and the road maintenance partner agencies will receive data from the RWIS system and output from ITS devices (e.g., CCTV cameras) which will facilitate their road maintenance decision process. The RWIS ESS devices provide data to the centers according to the pre-programmed parameters input to them at the time of configuration.

8.1.5 RWIS Users

Once processed, the data would be available in several forms to users. These would include the following options:

- Application-based access over the State Intranet from MDIT
- Web-based application over the public Internet from MDOT/MDIT
- Secure (password protected) web-based access over public Internet from MDIT
- Secure (password protected) web-based access over public Internet from Vendor
- Web-based application over the public Internet from Vendor

Each access location would have access to the RWIS data, which could be customized for the needs of each user.

Those RWIS ESS sites which have ITS devices (e.g., CCTV cameras, DMS, or HAR) would allow control of those devices for verifying weather conditions and providing the appropriate public notification through the ATMS/ATIS operators at the TMC(s).

RWIS data is also distributed to the public via the ATIS to provide travelers with pre-trip planning information. An example of this service in Washington State is: http://www.wsdot.wa.gov/traffic/weather/default.aspx?station=1883&id=sa), where most recent and historical roadway weather data is displayed for the selected station.

SECTION 9 ANTICIPATED IMPACTS

The implementation of an RWIS will create new responsibilities for management, operations, and coordination. The major areas of this impact and the impacted organizations are described in this section.

9.1 RWIS SYSTEM MANAGEMENT AND IT RESOURCES

Impacted Organization: **Michigan Department of Information Technology (MDIT)**

The RWIS will require a server or a segment of a server in the Center location (proposed to be in Lansing). The available bandwidth necessary for the connection to the Lansing location will need to be evaluated, however, preliminary discussions indicate that the current bandwidth is adequate to support the RWIS requirements. A nominal amount of hardware and software management will be required, based on discussions with RWIS vendors. Anecdotal information from other states during the interviews indicated that the workload associated with server and system maintenance was not significant. Server software upgrades typically occur about every two to three years.

9.2 ROAD MAINTENANCE OPERATIONS

Impacted Organizations: **MDOT and Partner Road Maintenance Agencies**

The groups which provide winter maintenance services for MDOT highways will have new tools at their disposal through RWIS. Particularly affected are those who make the strategic decisions of what, when, and where to distribute materials and to conduct plowing. Based on interviews with other state DOTs, proper training and acclimation to the system should provide the maintenance decision makers with tools which increase their effectiveness without increasing their workload. Most states with well-maintained RWIS ESS sites also reported that they experienced increased efficiency of overall winter maintenance operations.

9.3 INTER-AGENCY DATA COLLECTION COORDINATION

Impacted Organizations: **MDOT, NWS, DNR, WI, Ontario**

Weather data from the above agencies is currently used by MDOT or its partner winter maintenance agencies. Weather data to from other agencies that is intended to be an input to the atmospheric and roadway weather forecasting systems will require that the data be transmitted to MDOT's RWIS server. Once transmitted, the data will need to be translated from standard BUFR format into NTCIP format, so it can be made available to the proposed Superior TMC, the TSCs, and to the road weather forecasting service. The untranslated data will also need to be transmitted to the NWS for processing into weather forecasts, unless those data sets are being transferred to the NWS by the originating agency.

If it is to be included in the RWIS, data originating from Ontario will be in WMO standard (BUFR) and will need to be translated to NTCIP format or input in its native form.

Although the data originates from several different meteorological agencies, the data is in a common standard (BUFR). Retrieving some information, like text fields, may require customized filtering of the data from each agency. The data filtering process represents a minor one-time cost, since the data is in a delimited ASCII format. As an example, temperature data is coded as degrees Celsius, and the tenths of degree are often stored as a text field.

9.4 INTER-AGENCY UTILITY SHARING

Impacted Organizations: **MDOT, MDIT, MPSCS, DNR, MSP, FAA**

Depending on final RWIS ESS site selection, some locations may be able to share existing communications or power infrastructure. This may include various state and federal agencies from the list above. The facilities impact to the agencies involved in the co-location should be minimal, requiring a small amount of space for electronics and pathways to and from the utility demarcation point. Occasional access to the facilities would be required. A memorandum of understanding between the respective agencies would be required to address issues of costs, access, and future improvements to the communications infrastructure.

9.5 RWIS / SUPERIOR REGION ITS ARCHITECTURE COORDINATION

Impacted Organizations: **MDOT, MDIT (including MPSCS)**

A primary goal of the RWIS program development is to coordinate with the Regional ITS architecture and deployment plan, as well as the ATMS software development. Both of these efforts are ongoing and have been consulted while developing the RWIS plan. This coordination will need to be completed as an initial task of the Phase 1 deployment of the RWIS implementation.

The impact to the named organizations will be clarified through the development of the COOs for the statewide TMC and the regional TMCs, and establishment of statewide standards for the statewide ITS communications architecture.

9.6 RWIS ESS MAINTENANCE

Impacted Organizations: **MDOT and partner RWIS/ITS maintainance organizations**

The RWIS system, including its ITS components will be under warranty for four years from delivery of the systems. During this warranty period MDOT will not be responsible to provide preventive maintenance or service; it will be the responsibility of the vendor providing the system. If desired, MDOT could use this time to train its staff and learn how to perform maintenance and service to prepare for the time the system's maintenance and service is turned over to MDOT. When they have a significant number of sites, many states choose to do their own do maintenance with their own forces. Examples of states with less than ten RWIS ESS sites are not available, but it would appear that conducting annual maintenance on fewer than ten to fifteen sites would not be cost effective, considering the training and field experience necessary. (Refer to **Section 13 Ongoing Expenses** for a discussion of operating costs.)

9.7 STAFFING

As new ITS projects are deployed, there is always a concern of the additional work required for operating and maintaining each component. The current RWIS project is no exception. Approximately thirty-three RWIS ESS locations have been identified for potential deployment throughout the Superior Region and one or two control locations will be developed as well. The RWIS will make new tools available for operations and maintenance staff in existing roles to perform their day-to-day duties. Additional staff requirements are not anticipated, unless MDOT would determine to maintain the systems on their own. The majority of the maintenance work is conducted in the late fall in preparation for the winter season and may be accomplished by temporary staff reassignment. Based on initial discussions with MDOT personnel, no additional expenses are anticipated for staffing needs to operate the RWIS.

9.8 TRAINING

As part of the initial phases of RWIS project deployment, a detailed training plan will be necessary to define initial and future training requirements of each component. The current staff within the Region will be trained on each component as appropriate (operating, maintaining, etc.). Staff at MDOT's partner agencies can benefit from the training as well. Training is expected to be provided by the field installation vendor and/or equipment suppliers, and may possibly be provided at low or no cost from the vendor.

The specific areas of training include:

9.8.1 Wireless Communications

The wireless system portions of the RWIS will include the 800 MHz MPSCS, which MDIT currently manages and maintains. The RWIS ESSs will be connected as field units transmitting data which is different than the current use of the MPSCS, but the radios and connectivity will be similar to the existing system. MDIT MPSCS staff will need training on the RWIS-specific components, but the majority of the pathway used by the RWIS is the same as the current configuration.

9.8.2 Cabinet Wiring and Routine Maintenance and ESS

Basic ESS wiring and preventive maintenance has been successfully accomplished by several DOTs in our survey. This vendor-provided training does not require electronic knowledge, and provides the basic troubleshooting skills to accomplish system diagnostics and maintenance.

9.8.3 ESS Troubleshooting

ESS troubleshooting does require some level of knowledge in electronics. However, the basic skills can be taught quickly, according to vendors. This troubleshooting task benefits from training a few persons who will focus on troubleshooting.

9.8.4 ITS Troubleshooting

Troubleshooting ITS systems, especially CCTV and DMS, does require a level of knowledge and experience with the systems. Training is available from the vendors or could be accomplished through existing ITS maintenance expertise in Detroit or Grand Rapids.

9.8.5 Solar Power

Solar power systems require simple preventive maintenance and battery system checks. These skills can be taught by system vendors with good results.

9.8.6 Communications and Network Troubleshooting

These skills are highly specialized and will likely be provided by the respective groups within MDIT who currently maintain and troubleshoot these systems.

SECTION 10 ROLES AND RESPONSIBILITIES

Initially, the responsibility for the operations and maintenance of the RWIS will be shared between state agencies (MDOT and MDIT) and the system vendor. From the onset, MDIT will be the lead agency for the system network management and operations. MDOT and its partner agencies will be the lead agency for receiving and utilizing RWIS data.

During the warranty period, maintenance will be provided by the system vendor including preventive maintenance, failure repair, and sensor replacement. After the warranty period, MDOT will have the option of training its own forces to perform the preventive maintenance and service or to contract these services. Of the eleven state DOTS interviewed for this project, four do their own preventive maintenance and service, five contract for the service, and two split the responsibilities between DOT forces and contract services. Two state DOTs stated that they recommended performance-based contracting for RWIS services.

Based on RWIS responsibilities after the warranty period has expired, **Table 10-1** provides a quick reference of the owner, operations lead, maintenance lead, and potential partner(s) for each RWIS ESS component deployed as part of this project in the Superior Region. It is also important to note that there are additional agreements which are needed between stakeholders for deploying these devices/systems.

Table 10-1 RWIS ESS Roles and Responsibilities

Device/System	Owner	Operations Lead	Maintenance Lead	Partner(s)
RWIS ESS sensors	MDOT Superior Region	MDOT Superior Region	MDOT Superior Region or vendor contract	County Road Commissions
ITS Sensors and Devices	MDOT Superior Region	MDOT Superior Region	MDOT Superior Region or vendor contract	County Road Commissions
RWIS Control Center - Lansing	MDOT - Lansing	MDOT - Lansing	MDOT – Lansing with MDIT	24/365 partner agency
RWIS Access at TMCs	MDOT Superior Region	MDOT Superior Region	MDOT Superior Region with MDIT	24/365 partner agency

SECTION 11 PROJECT OUTCOMES AND BENEFITS

11.1 PROJECT BENEFITS

Cost savings directly related to RWIS have typically been described in an anecdotal manner, most likely due to the inherent difficulties associated with measuring the RWIS-related performance measures. The cost evaluations have focused on material and staffing savings, and have not typically included travel time and/or safety-related savings to the traveling public. According to a study published in 2001 by National Cooperative Highway Research Program, methods utilized by agencies to evaluate RWIS cost/benefit (listed in order of frequency) have included:

- Employee feedback
- Visual observation
- Event logs
- Customer survey
- Complaint data

Based on RWIS implementations by other state and provincial DOTs and reinforced through interviews of representatives from state DOTs, the following benefits are anticipated for the Superior Region:

11.1.1 Improved Roadway Anti-icing Maintenance

An anti-icing program is intended to anticipate a weather event which could result in icing road conditions and allow pre-treatment of the road surface. The pre-treatment prevents bonding of ice or snow to the road, which facilitates plowing and a more rapid return to a bare and wet road condition. The pre-treatment can result in reduced material, equipment, and labor costs, compared to a post-event application of chemicals and abrasives. To maximize the benefit, an anti-icing program requires accurate atmospheric and road weather monitoring and road surface forecasting in advance of the weather event, and is dependent on the quality of the weather data.

Kansas and Missouri DOTs reported improved safety and faster snow removal from an anti-icing program. In addition to improved safety, Oregon DOT also reported it expected to save $7 million over 25 years through reduced chemical application from their anti-icing program.

An RWIS supported anti-icing program provides benefit from two types of icing conditions:

- Location-specific icing conditions (e.g., bridges and low-lying areas)
- Regional icing conditions

Location specific benefit. There is one major bridge and four minor bridges identified in the RWIS stakeholder process that may benefit from RWIS monitoring for anti-icing. These bridges are:

- Mackinac Bridge, operated by the Mackinac Bridge Authority (MBA)
- Ontonagon Bridge
- Houghton/Hancock Bridge
- Cut River Bridge
- Escanaba River Bridge

ESSs located at these bridges should provide improved weather maintenance response to these locations prone to icing conditions. When combined with DMS and HAR devices, information about adverse weather events on and near the bridge or in other areas can be

provided to motorists, thereby expanding their usefulness, which is primarily focused on bridge–related weather conditions.

Regional benefit. The primary benefit of RWIS to a roadway agency is to provide decision support for roadway maintenance activities. This can be in the form of support to an anti-cing program delivered by maintenance vehicles or a fixed anti-icing system on a bridge.

RWIS-supported anti-icing program should benefit all areas of the Superior Region. Those benefits are expected to seen in remote areas (e.g., M-28 near Seney) and areas exposed to blowing and drifting along the lakeshore (e.g., M-28 east of Marquette and US-2 near Brevort).

The benefits reported by other DOTs through use of RWIS which can be anticipated from RWIS assisted anti-icing program are:

- Higher level of service through improved road conditions, travel time reduction, and improved mobility
- Improved safety through fewer crashes and associated injuries
- Reduced property damage through fewer crashes
- Reduced environmental impact through reduced use of chemicals and abrasives
- Kansas, Oregon, and Colorado DOTs have reported significant savings of reduced equipment use hours, lower material costs through more efficient application, and lower labor costs through reduced hours of winter maintenance operation. However, others (Ohio DOT) have indicated that cost savings were not experienced, but improved efficiency and more rapid return to “normal” winter driving conditions after a weather event were a benefit of their anti-icing RWIS deployment.

Drifting Sand. The conditions leading to the accumulation of drifting sand on the roadway can be identified through RWIS. It is expected that placement of ESS with a CCTV camera in locations prone to this condition will facilitate more rapid maintenance response to this condition.

11.1.2 Improved Traveler Information

Improved quality of pre-trip or en route weather and roadway condition information allows travelers to anticipate adverse conditions and adjust their travel plans accordingly.

Weather Solutions Group, in their 2001 multi-state study reviewing RWIS benefits/costs, reported that improvements in road safety attributed to RWIS were at least in part due to improved traveler information from RWIS. Specific states were not singled out in this part of the report. Illinois DOT reported finding improved driving condition information contributed to improved road safety.

The benefits which can be experienced through RWIS-assisted traveler information include:

- Better prepared travelers; higher level of “customer” satisfaction
- Safer travel behavior and reduced number of crashes
- Reduction in travel during most unsafe times, providing opportunity for more efficient maintenance activities and more rapid return to “normal” driving conditions

11.1.3 Incident Management Information

Improved information for incident management situations, such as:

- Support for road closure decisions due to weather conditions.
- Selection of routes used by emergency vehicles during storm events.

These benefits are particularly helpful to determine when US-2, M-28 or other routes should be closed due to weather conditions, which occurs quite frequently.

11.1.4 More Efficient Resource Allocation

RWIS-assisted maintenance system can provide more efficient use of the labor and material resources utilized in winter roadway maintenance activities.

Similar to the benefits described in the anti-icing benefit, some DOTs (e.g., Texas and West Virginia) have reported significant cost reductions due to more efficient allocation of resources (labor, equipment, and material). Minnesota DOT reported a return on investment of between 200% and 1300%. Ohio DOT has reported that cost savings to the Department were not appreciable (although fewer applications of inappropriate material or poorly timed applications have been reported), but the effectiveness of the winter maintenance program was improved as measured by a more rapid return to "wet and clear" roadways, after a weather event. In the Weather Solutions Group report, all 19 states which are cited reported savings of labor, material, and/or improved scheduling efficiency as a result of an RWIS-supported anti-icing program.

The anticipated benefits experienced through other RWIS implementations include:

- More appropriately timed winter maintenance activities
- Less material waste, due to more accurate weather and roadway forecasts
- Reduced reliance on patrols or reconnaissance vehicles to determine road conditions
- Summer roadway maintenance improvements benefit from RWIS in cases where a specific road temperature range or weather condition is required which can be identified through the RWIS.

11.1.5 Density of Weather Data

Improvements in the quantity of weather data can also have a significant effect on MDOT's ability to effectively respond to a weather event. This is particularly true if there are voids in the current NWS data collection network, as is the case in some areas of the Superior Region (e.g., northwest of Escanaba and near Paradise). Filling these voids can improve weather forecasting for roadways as well as for the public in general. There are several locations proposed for RWIS ESS sites which will serve to significantly enhance the NWS data collection system, as well as the collection of the MDOT roadway weather information.

The benefits of improved weather data collection through RWIS include:

- Improved atmospheric weather forecasts
- Improved roadway weather forecasts

11.1.6 Historical Weather Event Information

Planning benefits include improved historical weather information for planning purposes, particularly at adverse weather and incident-prone locations. This data is also valuable for crash investigations. For example, this information, combined with crash data, can assist cooperative efforts between MDOT and NWS in analyzing effectiveness and accuracy of weather warnings and advisories.

11.2 PERFORMANCE MEASURES

When fully implemented, the RWIS network is anticipated to have significant positive impact on traveler safety and maintenance operations, through enhanced decision making, improved traveler information, improved efficiency in resource utilization, and availability of historical weather event information. These benefits should be measured and tracked over time, as with any ITS system implementation.

After the RWIS ESS devices/systems are deployed, the performance of the system could be measured using the performance measures listed in **Table 11-1**.

The performance measure evaluation may include a before and after comparison with respect to when the RWIS ESS was implemented, or it may include tracking the performance measures on an ongoing basis as MDOT and its partner agencies continue to develop ways to improve maintenance performance through the use of RWIS information.

Table 11-1 RWIS System Possible Performance Measures

Device/System	Possible Performance Measures
RWIS System	1. Time required to clear roadway (achieve normal travel speeds) after the onset of the event 2. Crash rates in proximity to the RWIS ESS before and after RWIS deployment 3. Maintenance response times 4. Maintenance vehicle miles traveled 5. Emergency response times based on 911 calls 6. Quantity of road treatment material used (per event, annual) 7. Traffic volumes during weather events 8. Number of visits (“hits”) on website containing RWIS info 9. Percentage of “uptime” on all system components
Communications for RWIS	10. Number of communications failures to RWIS ESSs 11. Number of power failures to RWIS ESSs 12. Timeliness to perform repair to RWIS ESSs 13. Failure monitoring and signal diagnostic 14. Ongoing operational costs for communication system
CCTV Surveillance Cameras	15. Report the use of cameras (incident management, seasonal events)
Permanent Dynamic Message Signs (DMS)	16. Report/categorize the use of each sign (construction, weather) 17. Keep a log of the message signs posted to each DMS
Highway Advisory Radio (HAR)	18. Report/categorize the use of each HAR (construction, weather, etc.) 19. Keep a log of the message posted to each HAR

Refer to numbered Performance Measures in **Table 11-1** for reference to associated benefits identified in **Table 11-2**.

Table 11-2 RWIS Anticipated Benefits

Beneficiary	Benefits	Performance Measure
Roadway Maintenance Staff	Improve maintenance vehicle response time, resulting in faster clearing of event	1, 2, 3, 5
	Schedule crews more accurately, resulting in less wasted resources	1, 3, 4
	Plan and prepare for weather events more efficiently	1, 3, 4, 6
	Schedule road treatments more effectively, resulting in material savings	1, 3, 4, 6
	Review traffic speeds during past events to evaluate application techniques	1, 6
	More accurate forecasts	1, 3, 4, 5, 6
Crash Investigators	Improved understanding of weather and roadway condition at time of incident	
Travelers	Improved quality of weather and travel information to the traveling public	2, 7, 8, 9
	Improve the ability of the traveling public and other users to make route choice decisions using real-time information, reducing travel delay	2, 7, 8, 9
Major Bridges	Improved maintenance	1, 2, 3, 5, 7
	Improved monitoring of bridge condition allowing improved traffic hazard notification, avoiding incidents	2, 7
	Improved forecasts	1, 2, 3, 5, 6
	Notification of travelers approaching the bridge of adverse roadway and weather conditions	1, 2, 7, 8, 9
Minor Bridges	Improved maintenance	1, 2, 3, 5, 7
	Improved monitoring of bridge condition allowing improved traffic hazard notification, avoiding incidents	2, 7
Incident Management	Incident prevention through pre-notification	2, 7, 8, 9
	Improve historical information of previous incident-prone areas and conditions for planning and incident decision-making	1, 2, 3, 4, 6

SECTION 12 FUTURE ACTIVITIES

The following activities are suggested for future consideration, which may benefit MDOT's goals and objectives related to RWIS deployment and utilization.

12.1 PROPOSED RWIS ESS SITE EVALUATION

This project has provided a high level identification of proposed RWIS ESS sites. As the project moves to final design, the sites will need to be evaluated at the site-specific level to identify specific utility connections and make final site and need-based decisions on site locations and site sensor packages. A detailed ESS site survey will need to be undertaken at each site, using the "FHWA Road Weather Information System Environmental Sensor Station Siting Guidelines".

12.2 COORDINATION WITH ONGOING ITS PROJECTS

Coordination with the ongoing Superior Region ITS Architecture and Deployment Plan and the ATMS Software development should be reviewed after those projects are completed. The RWIS project has provided input to both of those efforts and has considered the likely impacts to the RWIS project.

12.3 ROAD CONDITION DATA FROM MAINTENANCE VEHICLES

Some of the maintenance vehicles used by county road commissions and MDOT gather road surface condition and atmospheric weather data as they travel on maintenance routes. This data could be useful input to the RWIS, and vice versa.

The applications which store this data on-board vary from agency to agency. Retrieving this data while the vehicle is in service will require use of a wireless data interface between the vehicle and the proposed Lansing TMC. The data will need to be translated to NTCIP standard either on-board the vehicle or at the Lansing Center, and transmitted to the TMC and TSCs for decision support. The road surface data, coupled with vehicle GPS location to allow dynamic location of the data from the moving source, would be processed and used to develop road weather forecasts, if desired. The overall task is analysis of the various data gathering applications, identifying translation and communications alternatives for each application, and evaluating the benefit and cost of the overall program.

12.4 RWIS ESS MAINTENANCE RFP

After the warranty period is completed, MDOT will need to determine if they will maintain and service the RWIS ESS with their own forces or through contracted service. There are many states using each model with reported success. If MDOT would prefer to contract for some or all of the associated services, an RFP would need to be developed.

12.5 BENEFIT / COST EVALUATION

Since there are a limited number of rigorous benefit / cost studies by other DOTs available, Michigan has an opportunity to provide some much needed evaluation in this arena. It would also assist MDOT in evaluating its next steps in deployment of RWIS. The ability to collect pre-installation data on costs will assist the evaluation process. Data collection could be planned for the 2007-08 (before) and 2008-09 (after) winter seasons needed to support benefit / cost analysis conducted after the initial RWIS implementation. Examples of the data collection requirements include:

- Miles of maintenance vehicle travel
- Maintenance vehicle patrols when little or no material is distributed

- Hours of maintenance staff time, including overtime
- Quantities of materials distributed
- High, low, and average daily temperatures
- Total snow fall for each weather event

12.6 ORGANIZATION PARTICIPATION

MDOT is currently a participant in Clear Roads, sponsored by FHWA, which promotes research for winter highway maintenance. Two other organizations are prominent in RWIS standards and research and should be evaluated for participation in support of the RWIS program.

- **Clarus**. The Nationwide Surface Transportation Weather Observing System (project name Clarus), sponsored by FHWA, has been established with the goal "to provide timely and accurate weather observation data seamlessly across State and jurisdictional boundaries for the management and operation of the surface transportation infrastructure". Clarus is a large group of states and provinces which have joined together to develop standards for communicating RWIS data, management decision support tools, and training methods.
- **Aurora.** Aurora is "an international partnership of public agencies who work together to perform joint research activities in the area of road weather information systems." This consortium collaborates to facilitate and fund research into RWIS technologies and methods.

12.7 THERMAL MAPPING OF ROADWAY

Thermal mapping is a process of mapping roadways using sensors attached to probe vehicles to identify areas which are subject to temperatures which vary from average and under which conditions those variances occur. This can be useful in evaluating RWIS ESS locations, both for "local" sites which have unique weather patterns and for identification of sites which can be used as representative of "regional" weather patterns. These studies typically survey each roadway during three different winter weather conditions. This method is used by some states for evaluating RWIS ESS locations.

12.8 PAVEMENT FORECASTING RFP

Pavement forecasting utilizes atmospheric, roadway surface, and sub-surface data and processes it along with the NWS atmospheric weather data. Through analysis, this data is used to develop specific forecasts for individual roadway segments. Along with the pavement forecasts, the service can include specific anti-icing recommendations to support roadway maintenance decisions. This ability can be developed within a DOT, but many states are utilizing a private contracted service, often as a secondary stage to RWIS implementation.

12.9 CORS SITE CO-LOCATION

CORS (continuously operating reference station), utilizes a global positioning stations (GPS) which are used to communicate with field survey equipment to “truth” the survey measurements. The Superior Region has five sites owned by MDOT and five sites operated by others. These locations require power and communications connections which are similar to those needed by RWIS ESS locations. The opportunity to co-locate ESS and CORS locations should be a part of the final location decisions of the RWIS deployment. This may allow some sharing of the communications costs associated with each. Additional requirements in construction and approval for a CORS site may make co-location with CORS challenging, but possible for some locations.