



Final Report

Pennsylvania Department of Transportation,
Bureau of Planning and Research



Future Direction of the Roadway Weather Information System (RWIS) at PennDOT
Project Number 06-02 (C01)



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16. Abstract Weather events have a significant impact on our transportation network. Motorist safety can be jeopardized if roadways are not maintained in the most efficient method possible or if motorists are uninformed about roadway conditions. Mobility can be impacted by weather-related incidents, and weather conditions may slow traffic resulting in lower operational levels of service. Additionally, weather can impact the productivity of public agencies and private business resulting in additional economic burdens. One way to address these weather impacts is through roadway weather management practices as well as other operational strategies to advise agencies and motorists, control/regulate roadway conditions, and treat roadways efficiently. All of these strategies rely on gathering accurate information, processing data quickly and efficiently, and disseminating that information to stakeholders in a format that supports their needs. Roadway Weather Information Systems (RWIS) may provide situational awareness of roadway weather conditions that when combined with other information and decision making tools would allow decision makers to implement the appropriate advisory, control and/or treatment strategy. The future direction of the RWIS program must consider what is needed in order to manage roadway weather maintenance and transportation operations including emergency management activities. Decision makers need to have access to the same information and resources so that they can introduce the right combination of strategies. Communication, coordination tools and management practices need to be adopted that allow advisory, control and treatment strategies to be implemented in a coordinated manner. This guided the suggested direction presented below.					
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1. Executive Summary

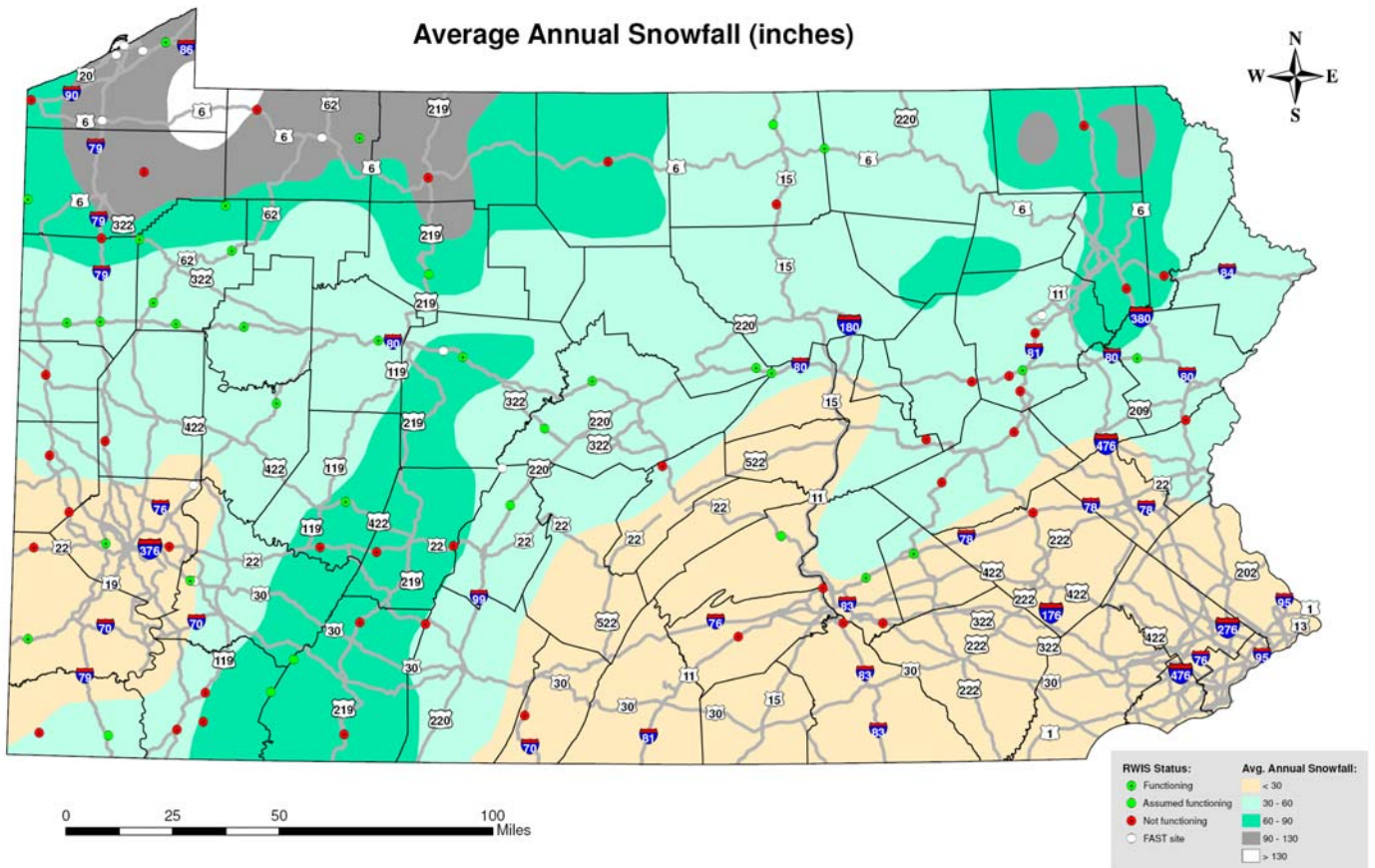
Weather events have a significant impact on our transportation network. Motorist safety can be jeopardized if roadways are not maintained in the most efficient method possible or if motorists are uninformed about roadway conditions. Mobility can be impacted by weather-related incidents, and weather conditions may slow traffic resulting in lower operational levels of service. Additionally, weather can impact the productivity of public agencies and private business resulting in additional economic burdens.

One way to address these weather impacts is through roadway weather management practices as well as other operational strategies to advise agencies and motorists, control/regulate roadway conditions, and treat roadways efficiently. All of these strategies rely on gathering accurate information, processing data quickly and efficiently, and disseminating that information to stakeholders in a format that supports their needs.

Roadway Weather Information Systems (RWIS) may provide situational awareness of roadway weather conditions that when combined with other information and decision making tools would allow decision makers to implement the appropriate advisory, control and/or treatment strategy.

1.1 Existing Conditions

Historically, RWIS deployments occurred at perceived weather trouble spots. Initial deployments occurred in 1982; however, the majority (54 out of 75) of deployments occurred from 1997 to 2000. As of March 2007, approximately two-thirds of RWIS were not functioning properly which may be attributed to communication degradation and proprietary maintenance practices, but it may also be attributable to the fact that many sites had reached the normal life expectancy of computer equipment and should have been replaced as part of normal maintenance.



Most of the sites were deployed prior to the development of any open communications protocol such as NTCIP (National Transportation Communications for ITS Protocol). As a result, most of the current systems utilize proprietary field controllers and are managed by proprietary software which limits their ability to be integrated with other systems.

The *Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania (Independent Report)* which was released on March 27, 2007 made the following observations and recommendations related to the RWIS program and other roadway weather management practices:

Observations

- Information Systems and Resources:
 - **Roadway Weather Information System (RWIS) currently has 55 sensor sites inoperable out of a total of 75 sites statewide...This technology (RWIS) would have allowed managers to verify not only the weather but also the condition of traffic flow.**
 - Not all districts contract transportation- specific weather forecasting services
- Maintenance Practices
 - Staffing guidance not followed, particularly in PennDOT's Berks County, and lack of guidance at the district level.
 - PennDOT allows districts and counties to modify individual approaches for snow and ice control.
 - Quantity of chemical additives in PennDOT's stockpiles is not governed by policy or procedure.
 - Turnpike has a "Bare Pavement" philosophy to snow and ice control; PennDOT does not.
- Transportation Operations
 - PennDOT's representative at the State Emergency Operations Center did not have access to all information available to PennDOT's Traffic Control Center staff.
 - Emergency operations do not appear to be treated as a core mission of PennDOT
 - PennDOT provided flawed information to the public in press releases, on highway electronic message boards and over its telephone information system.

In summary, the *Independent Report* provided four key themes that should be considered when developing a plan for the RWIS program and other roadway management activities:

- **RWIS itself was not functioning and program guidance is needed** – Maintenance practices and oversight is needed to ensure that the system is functional and reliable. Deployment guidance is needed so that RWIS can be a future asset.
- **Other weather forecasting and maintenance tools were not available** – RWIS alone will not provide situational awareness and does not provide a tool for winter decision making. RWIS may be part of a more comprehensive solution that includes weather forecasting data, maintenance and operational decision making tools.
- **There was a failure in Department and inter-agency communication /coordination** – In order to manage roadway weather operations including emergency operations, decision makers within the Department as well as within the agency need to have access to the same information and resources so that they can introduce the right combination of strategies. In some case, Districts may have varying information or maintenance decision makers may not have access to the same information as operational decision makers. Communication, coordination tools and management practices need to be adopted that allow advisory, control and treatment strategies to be implemented in a coordinated manner.
- **There was a failure in public notification** – Often information provided to the public was not updated or the tools to notify the public themselves were not operational.

These issues were echoed by Department staff through outreach activities (interviews, surveys and workshops) and based on the RWIS assessment team's review. Of the Department staff surveyed, 62 percent of



respondents stated they do not utilize RWIS; however, 77 percent said they would use RWIS if data was more accessible (and reliable).

1.2 National Trends

Nationally, there are several initiatives that will impact roadway weather management and RWIS programs.

- The Clarus Initiative attempts to create a more complete and reliable weather picture (across state boundaries) by assimilating from a variety of sources, cleansing and checking weather data and disseminating more complete weather data. While this initiative has much merit, it may be more prudent in the short-term to focus resources on reestablishing a reliable RWIS system. It is worth noting that FHWA anticipates the announcement of a “Collection Incentive Program” to be announced in June 2007 that will be available to all U.S. transportation agencies that operate a network with one or more RWIS/ESS who want to contribute data to Clarus. Funds will be provided as a Federal Aid Grant, and funding is based on a sliding scale dependent on the number of RWIS/ESS in the network. **This grant opportunity should be explored as it may provide an opportunity to implement future enhancements to the RWIS program as it relates to metadata required for connection to the Clarus Initiative.**
- Maintenance Decision Support System (MDSS) is a tool that merges weather forecasting with roadway maintenance rules of practice and generates treatment recommendations on a route by route basis. MDSS offers an opportunity to enhance winter conditions awareness and maintenance decisions, both of which were identified by the Independent Report. Like Clarus, it may be more prudent in the short-term to focus resources on reestablishing a reliable RWIS system as well as additional maintenance training. A reliable RWIS network is fundamental to the success of MDSS.
- The Aurora Program provides an opportunity to engage other stakeholders on issues relating to roadway weather management. PennDOT’s continued involvement in the Aurora Program provides access to resources and participation in various initiatives.
- FHWA strongly encourages state and local agencies to use NTCIP RWIS/ESS standards. ESS standards are mature and offer immediate benefits for agencies by:
 - Providing interoperability between ESS and other NTCIP-compatible field devices running on common communications channels
 - Enabling simplified administration of ESS subsystems.

Migrating to a standards-based RWIS/ESS program will provide both immediate and long-term benefits. **“Open” communication and systems in Pennsylvania would lessen dependence on proprietary products and services (allowing for flexibility in procurement and maintenance) as well as allow for easier integration into other operational initiatives.**

Pennsylvania’s RWIS program has faced issues that many other states have noted when surveyed. Several states noted concerns over the proprietary nature of many RWIS programs already deployed, and several states have begun to migrate to an NTCIP (“open”) program to lessen proprietary dependencies and to provide a greater opportunity for integration with other systems (road condition systems, 511, etc). Most states utilize both RWIS and contract weather forecasting to provide a complete weather picture and have begun to recognize that maintenance and transportation operations need weather data and need to coordinate roadway weather management strategies.

1.3 Operational Vision and Needs

Based on a review of best practice, a review of PennDOT's current RWIS program and input of Department staff, the following operational vision was established.

1-Reestablish baseline operational conditions

- Need existing system to be functional and reliable
- Need to continue proactive/ preventive maintenance practices
- Need to restore confidence of existing system

2-Establish deployment and program guidelines

- Need coordinated planning with TSOP
- Need to develop an "open" system
- Need deployment guidelines
- Need an overall game plan for RWIS program management (maintenance, contracting and funding)

3-Strategically introduce new data elements

- Consider pros/cons of in-roadway data collection elements (intrusive vs. non-intrusive; active vs. passive)
- Pilot new RWIS elements
- Overcome proprietary issues
- Provide improved video imaging (Color, PTZ, real-time)
- Provide speed and volume data
- Provide precipitation intensity and accumulation
- Active (existing) alert notification options

4- Integrate with other data and decision making tools

- Integrate with forecast weather service
- Consider role of pilot snow plow AVL system
- Integrate into TMC's operational environments (ATMS)
- Consider testing/ implementing / integrating MDSS
- Consider integrating with RCRS in short-term
- Consider integrating with PEIRS and GATIR

5-Restore confidence in RWIS program

- Test RWIS sites (periodically) to verify site accuracy
- Engage internal stakeholders to gage successes
- Develop user-friendly portals for stakeholders, public and media
- Consider partnership opportunities with the media

1.4 Core Suggestions

The future direction of the RWIS program must consider what is needed in order to manage roadway weather maintenance and transportation operations including emergency management activities. Decision makers need to have access to the same information and resources so that they can introduce the right combination of strategies. Communication, coordination tools and management practices need to be adopted that allow advisory, control and treatment strategies to be implemented in a coordinated manner. This guided the suggested direction presented below.

The operational vision is not achievable overnight. The program direction must be phased in such a way to produce success within available resources while establishing an opportunity for future enhancements. The suggested direction is based on seven key concepts:

- 1) Repair existing RWIS sites to baseline conditions – Need to fix what we have before we can make it better
- 2) Establish baseline for program enhancements – The current system, even if operational, may not be capable of supporting future enhancements
- 3) Begin to establish complete weather picture – RWIS data is one piece of the weather picture. It needs to be combined with other sources of information such as contract weather data and provided to all users
- 4) Begin to transition to an “open” RWIS system – The proprietary nature of the existing system has resulted in maintenance issues and a lack of flexibility in use of RWIS data. By transitioning to an “open” system, maintenance can be enhanced (and costs reduced) and there would be more flexibility in how data is managed.
- 5) Expand/ upgrade data elements being collected – Other information would be helpful in winter maintenance and transportation operations. Precipitation intensity and accumulation sensors could aid in maintenance decision making. In-roadway sensors assist in maintenance decision making, but could provide valuable traffic data to transportation operations decision makers. Enhanced and updated CCTV systems can improve situational awareness for all parties.
- 6) Fill RWIS gap areas – To complete the picture, gaps in coverage must be filled. These gaps should be coordinated with other initiatives in order to maximize resources.
- 7) Develop integrated/ enterprise solutions – Ultimately, weather information must be shared with other parties and combined with other information tools.

The phased approach outlined below provides a plan to reestablish the existing system, strategically upgrade and expand, and introduce an open architecture system that can be integrated with other activities.

Phase Concept	Phase Task	Considerations	Suggested Timeframe	Resource Requirements
1. Repair existing RWIS sites to baseline conditions	1. Reestablish baseline operations	<ul style="list-style-type: none"> ▪ Reestablish existing dial-up communication ▪ Make repairs to RWIS elements ▪ BOMO actively working ▪ Development of uptime metrics 	Directed to be complete by September 2007	\$450,000
2. Establish baseline for program enhancements	2.A Revise data management system and conduct requirements study	<ul style="list-style-type: none"> ▪ Current system has dial-up from CO to District to County to device ▪ Proposed interim system would be on WAN and dial-up from District to device ▪ All data would first be pulled to CO for integration/ processing before distribution ▪ Provide basic data viewing functions like current vendor systems ▪ Conduct requirements study to determine system requirements for software and hardware 	0-2 years	\$90,000



Phase Concept	Phase Task	Considerations	Suggested Timeframe	Resource Requirements
	2.B Introduce RWIS/ESS Database and Server at Central Office	<ul style="list-style-type: none"> Pull data sets from SSI, NU, Boschung, other, open protocols and integrate into one data set Metadata – device configuration information Data dictionary based on NTCIP Data security and integrity administration Post data to central database Post images to central database 	0-2 years	\$65,000
	2.C Introduce new communications to promote system reliability, diagnostic and to support RWIS sensors and upgraded CCTV	<ul style="list-style-type: none"> Hardwire, CDMA, DSL or practical alternative Existing dial-up could be used as a back-up Address BIS security concerns and coordinate with SOCP 	1-3 years	\$228,000
	2.D Develop an asset management and maintenance tool	<ul style="list-style-type: none"> Collect Metadata Maintenance and operations 	1-3 years	\$162,000
	2.E Establish future funding for maintenance and operations	<ul style="list-style-type: none"> Existing costs per site were \$3K to \$4.2K per year, but were limited by contract Other states spend \$3.5K Continue current funding level 	NA	Estimated at \$4M over next 10 years
3. Begin to establish complete weather picture	3.A Integrate RWIS data with contract weather data	<ul style="list-style-type: none"> BOMO awarded a statewide weather forecast for the next winter season Is an amendment to the contract an option 	1-2 years	\$15,000
	3.B Develop weather portal - a new PennDOT and public website with both RWIS and contract weather data	<ul style="list-style-type: none"> Develop web portal functional requirements 	1-3 years	\$74,000
	3.C Explore usage of existing notification systems	<ul style="list-style-type: none"> Include as part of 3.B planning 	1-3 years	NA
4. Begin to transition to an "open" RWIS system	4. Introduce NTCIP open protocol RPU's at existing sites	<ul style="list-style-type: none"> Open, NTCIP communication Rugged hardware Less RWIS vendor dependency and shared maintenance contracting with other ITS devices Establish standard specifications for "open" RWIS system 	1-4 years	\$2,828,000
5. Expand/ upgrade data elements being collected	5.A Utilize existing traffic data not being transmitted	<ul style="list-style-type: none"> Traffic volume, class and speed data could be collected at NU sites 	0-2 years	NA
	5.B Install "missing" in-roadway sensors to collect surface conditions as well as traffic volume, speed and class	<ul style="list-style-type: none"> Maintenance staff desire surface conditions data Other staff requested traffic data Sensor maintenance issues exist with in-roadway devices 	1-4 years	\$766,000
	5.C Reassess fixed CCTV systems settings	<ul style="list-style-type: none"> Reduce refresh times to <5 minutes Adjust fixed camera view angles to consider surface, roadway perspective and sun 	1-4 years	\$114,000
	5.D Install PTZ CCTV at strategic locations	<ul style="list-style-type: none"> Install PTZ CCTV at locations consistent with ITS deployment plans and based on District input Integrate into District TMC 	1-7 years	\$164,000
	5.E Strategically install precipitation accumulation, type and intensity sensors	<ul style="list-style-type: none"> Rain Gauge, Optical Present Weather Detector, Hot-Plate Type Precipitation Sensor 	3-7 years	\$662,000
	5.F Pilot/ explore and introduce non-intrusive methods to measure surface and traffic data.	<ul style="list-style-type: none"> Road Surface Spectroscopic Sensor (for surface conditions) Traffic data collection are more well proven (video, radar, etc) Alternative to traditional RWIS sensor technology utilizing remote sensor technology Eliminates need for in-road sensors and most atmospheric sensors 	3-7 years	\$4,454,000
6. Fill RWIS gap areas	6.A Strategically introduce new RWIS sites	<ul style="list-style-type: none"> Recurring intervals based on deployment guidelines Consider trouble spots, needed recurring coverage, etc Piggyback with ITS and traditional construction projects Consider using (FHWA) ITS checklist for highway projects 	1-10 years	\$2,815,000
7. Develop integrated/ enterprise	7.A Coordinate with information exchange initiatives	<ul style="list-style-type: none"> Weather data may be needed by PEMA, PSP, etc 	TBD	



Phase Concept	Phase Task	Considerations	Suggested Timeframe	Resource Requirements
solutions	7.B Integrate RWIS data with contract weather data into 511 phone and web services	<ul style="list-style-type: none"> Web 511 Targeted Turn-On – June 2008 Voice 511 Targeted Turn-On – June 2009 	1-3 years	Incorporate in 511 RFP
	7.C Integrate RWIS data with contract weather data into RCRS as a geospatial layer	<ul style="list-style-type: none"> RCRS requested the ability to see weather information 	1-3 years	\$10,000
	7.D Integrate Snowplow AVL into complete weather picture	<ul style="list-style-type: none"> Pilot ongoing using 800 MHZ system 	TBD	\$25,000
	7.E Monitor Clarus opportunities	<ul style="list-style-type: none"> Monitor for Grant opportunity in summer 07 Integrate into weather solution 	TBD	TBD
	7.F Monitor MDSS opportunities	<ul style="list-style-type: none"> Test free version Integrate into weather portal? 	TBD	TBD

In addition to direct capital and operations and maintenance costs, recurring communication costs for existing and future conditions should be considered for planning and programming purposes. Below is an estimate of yearly communication costs which is subject to the outcome of the Statewide Operations Connectivity Plan which is under development.

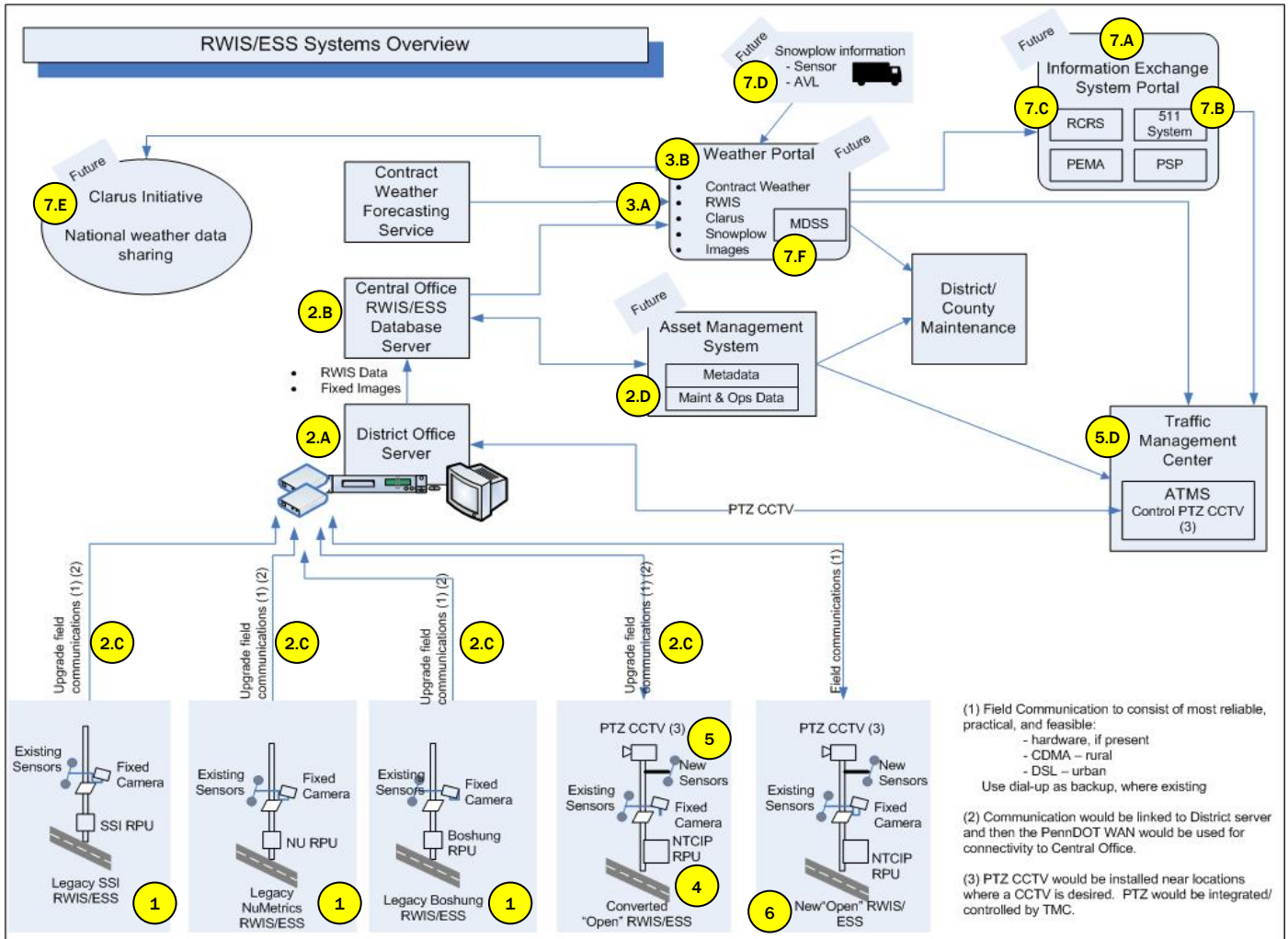
	Existing	Future
RWIS Sites	75	130+
Communication Type	POTS	Combination (CDMA, DSL, etc.)
Estimated Monthly Cost (per site)	\$40	\$120 - \$210 *
Estimated Annual Cost	\$3,000	\$15,600 - \$27,300 *

* Subject to outcome of SOCP

In addition to the action plan presented above, the following actions should be considered in order to better manage, operate and maintain:

- Review program management and funding responsibilities per section 7.5.1
- Eliminate proprietary contracts and coordinate with District/ Central Office ITS maintenance activities
- Identify potential partnership opportunities
- Provide outreach internally and to the public when proven enhancements are made
- Integrate RWIS program into winter maintenance and transportation operations training programs
- The findings of this report should be included in planned development of standard specifications for ITS systems and consider the statewide operations connectivity plan. The specifications should include guidance on device design and deployment and should include an “open” architecture interface enabling the integration of emerging technologies.

It is estimated that the total program investment would be \$10.3M over the next 10 years; however, the plan is estimated at \$7.5M if additional deployments are excluded from the total.



1.5 Program Management

Nationally, most of the best practices with respect to winter maintenance and operations highlight the need for shared responsibility between winter maintenance and transportation operations. Over 80 percent of states responding noted that RWIS data is used by both maintenance and transportation operations. Additionally, program management activities are divided with nearly one-third of states reporting having maintenance manage their RWIS program, one-third having operations manage their RWIS program, and one-third of having multiple departments manage their RWIS program.

Senior management must provide direction to the Department's roadway weather management program as it cuts across traditional "Bureau" boundaries. Specifically, senior management should consider the RWIS program in the context of other maintenance and transportation operations initiatives as well as each group's mission and provide guidance regarding program funding and "ownership" as well as deployment, data management and maintenance.

Funding, planning and deployment should be a shared responsibility between BOMO and BHSTE with input from the district and county level. Data management practices should be initiated by BOMO and BHSTE with guidance and support from BIS. Maintenance may be best served if it is made less proprietary in nature, then



coordinated and combined with District/ Central Office ITS maintenance with oversight and specialty expertise provided by BOMO. This shift in maintenance practices may not be possible until “proprietary” sites have been converted to an “open” system. To maintain and enhance the RWIS program, responsible groups must be allocated additional resources.

Ultimately, an enhanced RWIS program would be utilized by multiple stakeholders addressing roadway weather management and could be used for other non-roadway weather purposes as well.

Stakeholder Group	RWIS Program Management					Roadway Weather Management Activities			Non-winter Traffic Conditions Usage
	Funding Responsibility	Program Strategic Planning	Site Upgrades and Future Deployments	Data Management and Enterprise Solutions	Preventative System Maintenance	Advisory (notify and advise public)	Control (control of access to roadways)	Treatment (winter maintenance activities)	
BOMO and county maintenance	TBD (note 1)	Lead (note 2)	Lead (note 3)	Lead (note 4)	Lead (note 5)	Input	Input	Primary	
BHSTE and district traffic operations/ TMC		Input (note 2)	Input (note 3)		Support (note 5)	Primary	Input/Support	Aware	Primary
BIS				Support (note 4)	Support (note 5)				
BPR (traffic data collection program)			Input	Input					Second
Public Relations and CRCs with output to: ■ Municipalities ■ Public				Input		Support	Aware	Aware	
Emergency Management (including PSP and PEMA)			Input	Input		Aware	Primary	Aware	

- 1) Program funding needs to be identified and directed by senior management recognizing that while BOMO may be the primary lead, there may be opportunities to piggyback deployments and upgrades with BHSTE operational initiatives.
- 2) The primary use of the RWIS program is winter maintenance; however, transportation operations will be a significant user and should have significant input as it relates to operational initiatives. The relationship should be similar to the relationship established as part of this project.
- 3) It is appropriate for BOMO to provide program leadership with respect to site upgrades and future deployments, but these efforts should be coordinated with ongoing ITS deployment activities such that deployment and O&M resources are maximized.
- 4) Data management and enterprise solutions should be developed in such a way as to support multiple user needs and to allow for common situational awareness. BIS should provide guidance as it relates to identifying business requirements and developing solutions.
- 5) As the RWIS system transitions to an “open” system, proprietary maintenance practices may be less necessary. This would allow for preventive maintenance to be coordinated with District ITS maintenance. Specialty maintenance may still need to be led by BOMO with BIS provided support for data management and enterprise solutions.

- TBD – to be determined by management
- Lead – should provide leadership with input and support from other groups
- Input – should provide input to lead party
- Support – provide support/ assistance to primary party
- Primary – primary usage
- Second – secondary usage
- Aware – should be aware of conditions

1.6 Future Program Expansion

Many of the upgrade activities associated with repairing baseline conditions and establishing a baseline for program enhancements may be best served by completely updating the existing system in order to maximize contract resources. As phase concept 5) *Expand/ upgrade data elements being collected* and phase concept 6) *Fill RWIS gap areas* begin to be introduced, upgrades and future deployments should be prioritized based on several issues.

1. Local need such as weather related crashes
2. Regional needs
 - a. Consider daily vehicle miles
 - b. Consider roadway class
 - c. Consider average snowfall
3. Ability to coordinate with other projects/ need
4. Deploy RWIS in needed area if other ITS elements are being deployed

FHWA recommends that spacing RWIS at 2.5 miles may be desirable to contribute to more accurate weather forecasts, but doing so may be cost prohibitive; therefore, a spacing of approximately 20-30 miles is recommended as a guide. Other state practices were examined to verify the 20-30 mile deployment guideline. While regular intervals are suggested for forecasting purpose, the need for RWIS is not as strong in areas with lower snow and ice accumulations. Additionally, while coverage of all state roadways would be desirable, it may not be practical to deploy RWIS at the same densities on lower classification roadways. Using national guidance and an understanding of the extensive transportation network under the jurisdiction of the Department, the following deployment criteria were developed.

Roadway Classification	Winter Snowfall Totals		
	<30 inches	30-60 inches	>60 inches
Interstates	30 mile/ site	25 mile/ site	20 mile/ site
Freeway/ Expressways (US Routes)	30 mile/ site	25 mile/ site	20 mile/ site
Other Principal Arterials	As warranted based on local conditions, assumed 400 mile/ site		
Minor Arterials	As warranted based on local conditions, assumed 800 mile/ site		
Major Collectors	As warranted based on local conditions, assumed 1,200 mile/ site		
Minor Collectors/ Local Roads	As warranted based on local conditions and funded by others		

Based on the gap analysis presented in this report, it is estimated that an additional 45 to 50 RWIS sites may be warranted to provide adequate system coverage.

1.7 Benefits and Performance Metrics

While little research exists quantifying the benefits of the RWIS program, early test results from several state highway agencies showed that **snow and ice control costs could be reduced by as much as 10 percent** using RWIS technologies¹. Other research using computer models found that when using only RWIS sensor systems, the B/C ratios are small and range from -1.5 to almost 1.0. However, when **RWIS systems are combined with**

¹ NCHRP Benefit/Cost Study of RWIS and Anti-Icing Technologies and Transportation Research Board, Transportation Research Record 1352, Washington DC. Benefit-Cost Assessment of the Utility of Road Weather Information Systems for Snow and Ice Control

other data such as forecast weather data, the model produced a B/C ratio of approximately 5.0 and average computed level of service improvements were on the order of 20 percent.²

To document a program's success, performance metrics should be implemented and measured in order to document the program benefits versus program costs. By measuring performance, the RWIS program can address the following issues:

- Document successes – Has the program provided a realized benefit?
- Rationalize investments versus the benefits – Do the financial benefits of the program outweigh the costs?
- Identify potential improvements – Can the program be modified to maximize benefits and minimize costs?

Performance metrics should be kept simple and easily measurable, when possible. Performance metrics may be best developed if they are linked to roadway weather management strategies; however, safety and mobility are overarching principles that supersede strategy areas. These metrics can be historically referenced for the life of the RWIS program and through implementation of the proposed program enhancements.

Roadway Weather Management Strategy Areas	Suggested Performance Metrics
Safety and Mobility	<ul style="list-style-type: none"> ▪ Statewide weather-related fatalities ▪ Statewide weather-related crashes ▪ Winter road closures
Advisory - Provide information to transportation officials and transportation managers as well as the public	<ul style="list-style-type: none"> ▪ Customer usage (satisfaction) ▪ Transportation operations staff usage (satisfaction)
Control - Provide transportation officials with weather data such that they can coordinate or implement control strategies	<ul style="list-style-type: none"> ▪ TBD
Treatment - Treatment strategies include road maintenance activities	<ul style="list-style-type: none"> ▪ Maintenance staff usage (satisfaction) ▪ Maintenance costs

In addition to the performance measures listed above, up-time metrics (% of system that is functional) should be monitored as part of maintenance and asset management activities in order to justify and monitor the benefit of operations and maintenance expenditures.

² Transportation Research Board, Transportation Research Record 1352, Washington DC. Benefit-Cost Assessment of the Utility of Road Weather Information Systems for Snow and Ice Control

2. Introduction

2.1 Background

Weather events have a significant impact on our transportation network. Motorist safety can be jeopardized if roadways are not maintained in the most efficient method possible or if motorists are uninformed about roadway conditions. Mobility can be impacted by weather-related incidents, and weather conditions themselves may slow traffic, resulting in lower operational levels of service. Additionally, weather can impact the productivity of public agencies and private business resulting in additional economic burdens.

One way to address these weather impacts is through roadway weather management practices as well as other operational strategies to advise agencies and motorists, control/regulate roadway conditions, and treat roadways efficiently. All of these strategies rely on gathering accurate information, processing data quickly and efficiently, and disseminating that information to stakeholders in a format that supports their needs.

Roadway Weather Information Systems (RWIS) may provide situational awareness of roadway weather conditions that when combined with other information and decision making tools would allow decision makers to implement the appropriate advisory, control and/or treatment strategy.

2.2 Study Goals and Objectives

The goal of this study was to determine the future direction of the Roadway Weather Information System (RWIS) in Pennsylvania.

Objectives:

- An evaluation of the current RWIS technologies being used in Pennsylvania as well as any other currently available technologies to determine a future program direction to meet the needs of the PennDOT Maintenance community and the traveling public.
- Analyze the Federal Highway Administration's Maintenance Decision Support System (MDSS) initiative to ensure compatibility with that particular project.

Key work tasks include:

- Assess Current RWIS Systems and Locations
- Determine Operational Needs/ Formats in Roadway Weather Management and RWIS Systems
- Review Existing and Potential Locations
- Review State of Technology & National Initiatives Review



National Weather Impacts (source: FHWA)

- **Safety** - Approx 1.5 million weather-related crashes/year resulting in 690,000 injuries and 7,400 fatalities
- **Mobility** -15 percent of congestion is attributed to weather and an additional 6 percent of congestion is attributed to weather-related crashes resulting in 1 billion hours in delay
- **Productivity** - Weather affects about 1/3 of the national gross domestic product resulting in \$2.2 - \$3.5 million in delays to truck companies
- **DOT Resources** - Chemical anti-icing and deicing account for roughly 1/3 of expenditures for snow and ice control and winter maintenance accounts for 1/4 of maintenance budgets

- **Assess Operations, Maintenance, and Personnel Issues**

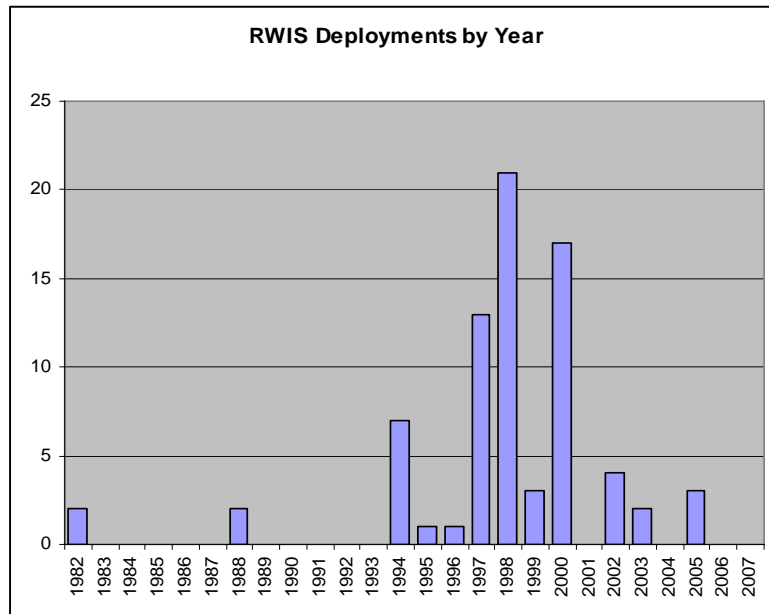
2.2.1 Common Acronyms and Terms

The following terms and acronyms are used throughout this document

AVL	Automated Vehicle Location	FHWA	Federal Highway Administration	PTZ	Pan-Tilt-Zoom
ATMS	Advanced Traffic Management Software	GATIR	Geospatial Analysis of Threats and Incident Reports	PVC	Permanent Virtual Circuit
BHSTE	Bureau of Highway Safety and Traffic Engineering	IES	Information Exchange System	RCRS	Road Closure Reporting System
BIS	Bureau of Information Systems	ITS	Intelligent Transportation Systems	RPU	Remote Processing Unit
BOMO	Bureau of Maintenance and Operations	LATA	Local Access and Transport Area	RWIS	Roadway Weather Information System
BOS	Boschung	MDSS	Maintenance Decision Support System	SEOC	State Emergency Operations Centers
BPR	Bureau of Planning and Research	NTCIP	National Transportation Communications for ITS Protocol	SOCP	Statewide Operations Connectivity Plan
C2C	Center-to-center	NU	Nu-metrics	SSI	Surface Systems Incorporated
CCTV	Closed Circuit Television	NWS	National Weather Service	SWOT	Strengths, Weaknesses, Opportunities and Threats
CDMA	Code-Division Multiple Access	OA	Office of Administration	SVC	Switched Virtual Circuit
COTS	Current off the Shelf	PEIRS	Pennsylvania Emergency Incident Response System	TCP/IP	Transmission Control Protocol / Internet Protocol
CRC	Community Relations Coordinator	PEMA	Pennsylvania Emergency Management Agency	TDMA	Time Division Multiple Access
DMS	Dynamic Message Signs	PennDOT	Pennsylvania Department of Transportation	TMC	Traffic Management Center
DSL	Digital Subscriber Line	POTS	Plain Old Telephone Service	TSOP	Transportation Systems Operations Plan
ESS	Environmental Sensor Station	PSP	Pennsylvania State Police		
FAST	Fixed Automated Spray Technology				

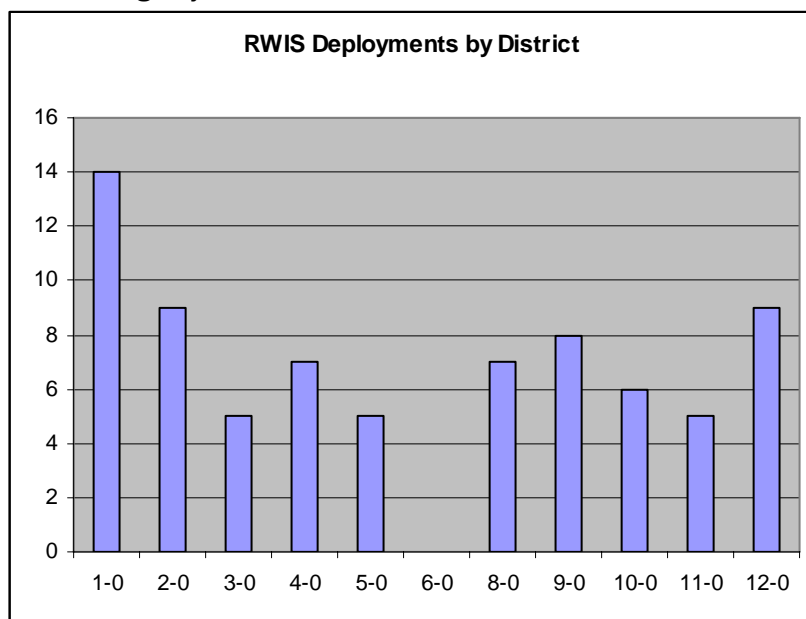
2.3 RWIS History at PennDOT

No historic record of RWIS deployment rationale occurs. Based on interviews with key staff, it was noted that RWIS deployments occurred at perceived weather trouble spots. Initial deployments occurred in 1982 in District 1-0, but only four deployments occurred before 1994. While seven deployments occurred in 1994, the majority (54 out of 75) of deployments occurred from 1997 to 2000.



3

Deployments were driven at the District level with no unified guidance from Central Office. Most Districts have between four and ten deployments; however, District 1-0 has 14 sites while District 6-0 has no sites. While these deployment profiles are logical based on climatic conditions it also illustrates the variation of deployment levels and RWIS usage by District.



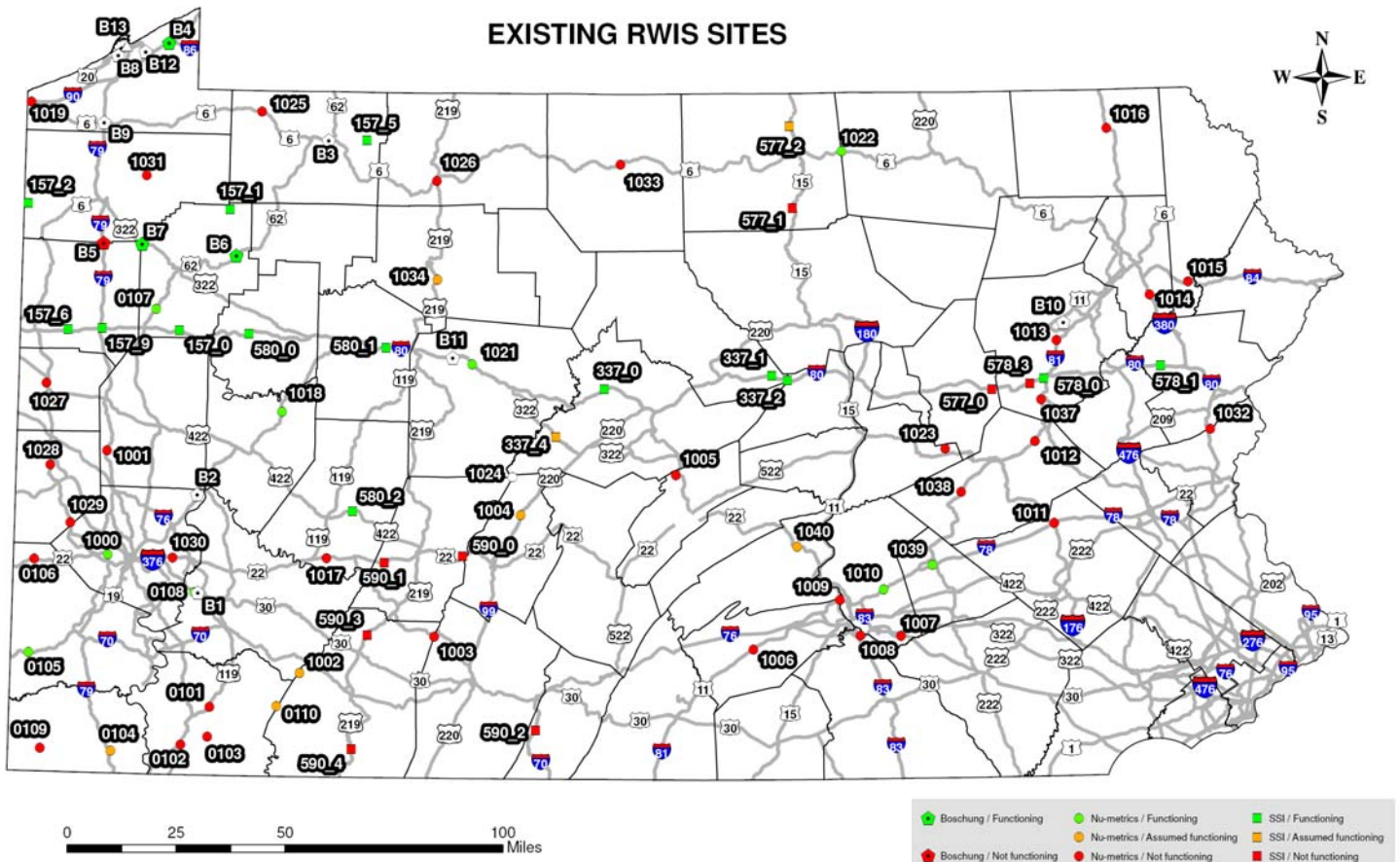
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³ Source Dave Hughes, BOMO

BOMO has provided oversight to the RWIS program since its inception as RWIS deployments were largely viewed as a winter maintenance tool. Providing RWIS data on PennDOT's RWIS website was a secondary benefit.

Three suppliers of RWIS have been utilized to date: Surface Systems Incorporated (SSI), Nu-metrics (NU) and Boschung. All deployments in the 1980's were SSI deployments. SSI was the predominate provider until the late 1990's when NU sites were widely deployed. Since that time SSI and NU have merged and utilize the SSI name under its parent company of Quixote. In the 2000's the Department began to deploy Boschung RWIS sites. In addition to RWIS sites, Boschung has provided FAST (Fixed Automated Spray Technology) at nine locations throughout the state.

Time Period	Surface Systems (SSI)	Nu-metrics (NU)	Boschung	Subtotal
1980's	4	0	0	4
1990's	15	11	0	26
2000's	5	17	3	25
Total	24	48	3	75⁵



⁴ Source Dave Hughes, BOMO

⁵ Source Dave Hughes, BOMO

Exact siting of deployments was adjusted to accommodate power and communications. In some cases, this resulted in deployments that were not located in the area of true concern. In other cases, sites were equipped with solar power (with battery back-up) which in some cases has proved problematic during winter months. Many sites were deployed utilizing a service that allowed the dial-up phone line to be split for RWIS data transmission and CCTV image updates. While this technology appeared to provide a financial savings when deployed, it resulted in communication failures, which could partially contribute to the recent lack of reliability.

The existing sites do not take advantage of any open communications protocols such as NTCIP or TCP/IP. Also, the current systems utilize proprietary field controllers and proprietary software interfaces. The proprietary nature of the components and communications systems prevents the simple integration of the various systems into a single overall system.

It is worth noting that there has been no systematic numbering of RWIS deployments. As a result, records of site characteristics may vary. A summary of available site characteristics is presented in **Appendix A**.



2.4 Pennsylvania Weather Trends

To understand the need for RWIS and other roadway weather management programs, an overview of climatic conditions provides historical insight and understanding of regional variations. This overview is succinctly covered in a book entitled *The Pennsylvania Weather Book* by Ben Gelber. Section 2.4 includes several excerpted sections from that book with the permission of the author.

2.4.1 Physiographic Regions and Climatic Patterns⁶

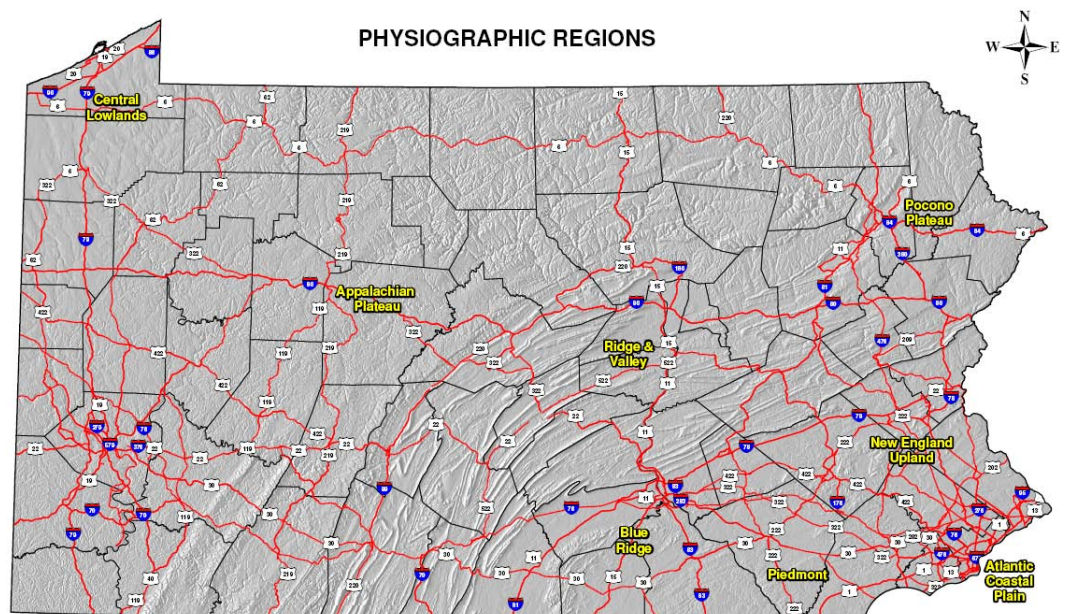
The State of Pennsylvania encompasses 46,059 square miles, including a small part of Lake Erie. The widest portion of the Keystone State extends 306 miles from west to east and 175 miles from north to south. The geographical midpoint of Pennsylvania is located 2.5 miles southwest of Bellefonte in Centre County, which places the heart of the state near latitude 40.5 degrees North and longitude 77.5 degrees West.. The highest point in Pennsylvania is Mount Davis in Somerset County, which rises to 3,213 feet near the Maryland border. The lowlands along the Delaware River in the southeast corner of the state are near sea level.

The climate of Pennsylvania is influenced a great deal by topography. The Appalachian Mountains that bisect the state are high enough to affect Pennsylvania weather on a daily basis. Air is frequently forced to rise over the high plateaus and taller ridges in northern and western Pennsylvania. Rising air cools by expansion and may reach the condensation point if the air is relatively moist, resulting in greater cloud cover and more frequent showers over the higher elevations. The air warms by compression as it sinks crossing the eastern slopes of the mountains, which is why southeastern Pennsylvania experiences more hours of sunshine and fewer rainy and snowy days compared with other parts of the state.

The landscape of Pennsylvania is distinguished by a seemingly endless pattern of parallel ridges and verdant valleys trending northeast to southwest through the middle of the state. Northwestern Pennsylvania is comprised of high, rugged plateaus that are separated by deep river valleys. The southwestern portion of the state blends into a low plateau with rolling hills. Southeastern Pennsylvania features gently rolling farmland bounded in the east by the heavily urbanized Delaware River valley.

There are seven distinct physiographic regions of Pennsylvania:

1. Atlantic Coastal Plain
2. Piedmont
3. New England Upland;
4. Ridge and Valley
5. Blue Ridge
6. Appalachian Plateaus
7. Central Lowland



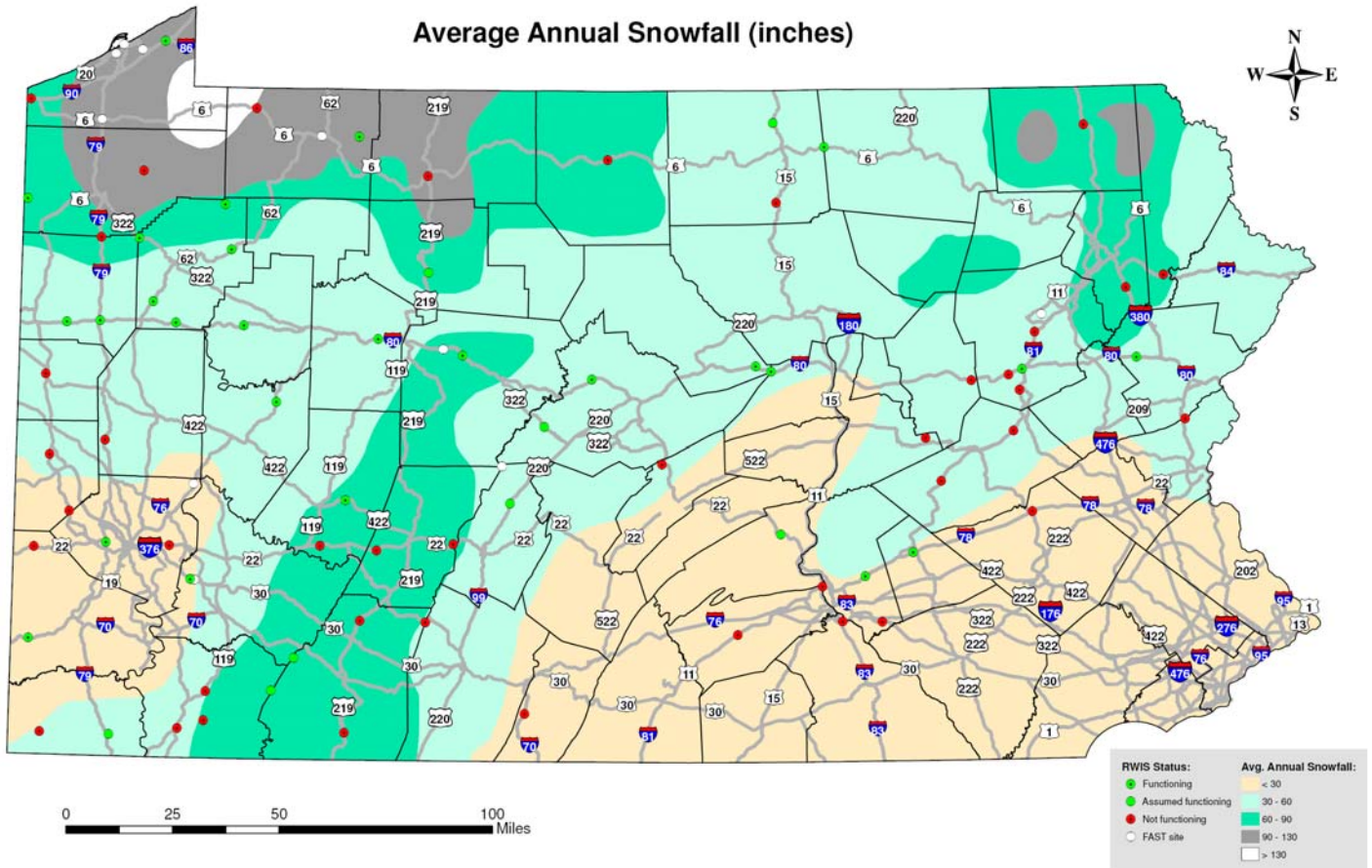
⁶ *The Pennsylvania Weather Book* by Ben Gelber, 2002



Physiographic Regions	Description	Winter Conditions
Atlantic Coastal Plain	The Atlantic Coastal Plain is narrow strip of mostly urban land about ten miles wide and fifty miles long that lies adjacent to the Delaware River, which includes all but the northwestern part of Philadelphia.	Winters in the Atlantic Coastal Plain are much less severe compared with those in northwestern Pennsylvania. The average January maximum/minimum temperatures at Philadelphia are 38/23 degrees, and the mean annual snowfall is about 20 inches. Most winter storms are accompanied by a mixture of snow, sleet, and rain in the Philadelphia area, due to the modifying effects of mild Atlantic air.
Piedmont	The Piedmont province of southeastern Pennsylvania stretches from the edge of the Atlantic Coastal Plain to the Blue Ridge Mountains in the south-central portion of the state. The topography comprises rolling hills and extensive farmland, with elevations ranging from 100 to 600 feet above mean sea level. The Piedmont begins in the northwestern part of Philadelphia and continues westward just beyond Gettysburg to the foothills of the Appalachians	Winters are usually moderate, with infrequent subzero temperatures. The average January maximum temperature in southeastern Pennsylvania ranges from 36 to 39 degrees, and minimum readings vary from 18 to 22 degrees. Winter snowfall in southeastern Pennsylvania is relatively light-25 to 35 inches- compared to northern and western parts of the state, because the majority of winter storms are accompanied by a mixture of snow and rain.
New England Upland;	The New England Upland province is a discontinuous rectangular section of east-central Pennsylvania composed of resistant rock worn down by erosion into rounded hills. The region known as the Reading Prong begins at Mount Penn in Reading and includes a portion of southern Northampton and Lehigh Counties, and parts of northern Berks and Bucks Counties.	The climate of the New England Upland province of Pennsylvania is quite similar to that of the northern Piedmont.
Ridge and Valley	The distinctive feature of the Appalachian Ridge and Valley province is a series of parallel ridges that arc from southwest to northeast. The Pennsylvania Appalachian Mountains extend all the way from southeastern Canada to northern Alabama. The Great Valley marks the southern margin of the Ridge and Valley province in east-central Pennsylvania. Prominent ridges in the northeast (Poconos), east-central (Blue Mountain) and south-central (Tuscarora and Jacks Mountains) sections rise to elevations of 1,500 to 2,000 feet, with visually striking local relief of about 400 to 800 feet through heavily wooded areas.	Winters in the Ridge and Valley province are sometimes severe, but generally alternate between periods of cold weather and milder days. Maximum readings in January average 32 to 36 degrees, with the lower readings in the northeastern highlands. Mean minimum temperatures in January fall between 14 and 18 degrees, and even lower values are recorded in the high elevations. Most sections of the Ridge and Valley province receive about 40 to 50 inches of snow annually, though higher totals are often observed in the northeast.
Blue Ridge	A small portion of south-central Pennsylvania, known locally as South Mountain, is part of the Blue Ridge province. The Blue Ridge province extends from Cumberland County in Pennsylvania southwestward to Virginia.	The climate of the Blue Ridge is typical of the higher elevations of the Appalachian Ridge and Valley province.
Appalachian Plateaus	The northern fringe of the Appalachian Plateaus province includes more than half of Pennsylvania. The Allegheny Plateaus section comprises a large portion of western and northern Pennsylvania west of the Allegheny Front. The high plateau region experienced considerably less folding and compression compared with areas farther east. The ridges rise above 2,000 feet, while lower plateaus in the northeastern and southwestern counties lie about 1,000 feet above mean sea level. The high elevation of the Appalachian Plateaus affords pleasantly cool weather at times during the summer, but winters may be harsh, with little sunshine and lengthy periods of snow cover.	Typical January maximum/minimum readings in this broad region of Pennsylvania range from the upper twenties in the northern mountains to the upper thirties in the southwestern corner of the state. High elevation stations report average January maximum readings of 27 to 32 degrees, while the temperatures in the southwestern hills are milder, ranging from 33 to 37 degrees. Mean minimum readings in January average from 10 to 15 degrees in the northern mountains and 15 to 20 degrees in the southwestern counties. Seasonal snowfall averages a little less than 40 inches in southwestern Pennsylvania, but more than 90 inches in western Venango County and nearly 130 inches in eastern Erie County, in the northwest corner of the state. On the opposite end of the state, the seasonal snowfall averages between 60 and 80 inches over the higher ridges of western Monroe and Pike Counties and the Endless Mountains. The greatest average snowfall is recorded in Susquehanna and Bradford Counties near the New York border. The weather site at Montrose in Susquehanna County receives an average of nearly 90 inches of snow annually.
Central Lowland	Adjacent to Lake Erie lies a forty-mile-wide strip of fertile land marked by gently sloping terrain and low hills called the Central Lowland province, or locally the Lake Erie Lowland.	Moisture picked up by cold air masses crossing the relatively mild water promotes considerable cloudiness during the cooler months. Rain and snow squalls are common when cold, dry air crosses the warmer waters. Moistened air is forced to rise over higher terrain east of Lake Erie, resulting in condensation and squally precipitation. Snowfall rates of 3 inches per hour are not unusual in a lake-effect snow event. The average annual snowfall in the city of Erie is 86 inches.

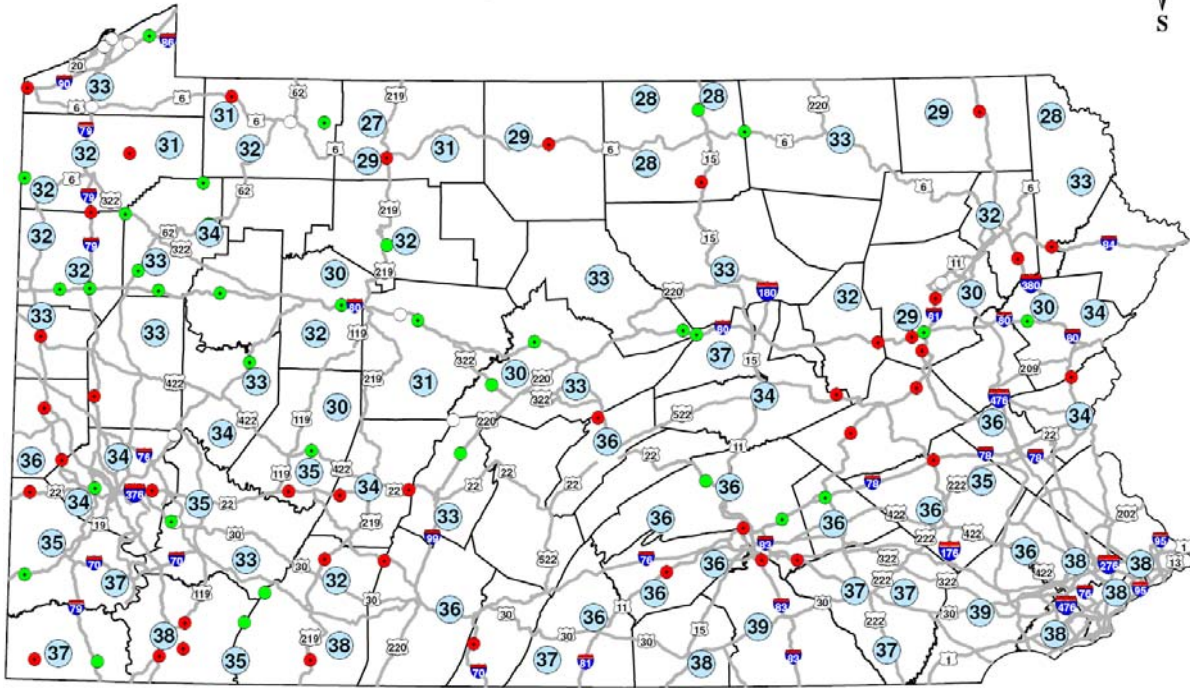
2.4.2 Winter Temperatures and Average Snowfall

The seven physiographic regions create distinct climatic conditions throughout the state. Average snowfall accumulations range from fewer than 20 inches to 130 inches yearly. Average winter high temperatures range from 27 to 38 degrees and average winter low temperatures range from 4 to 26 degrees.

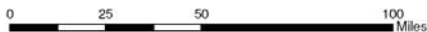
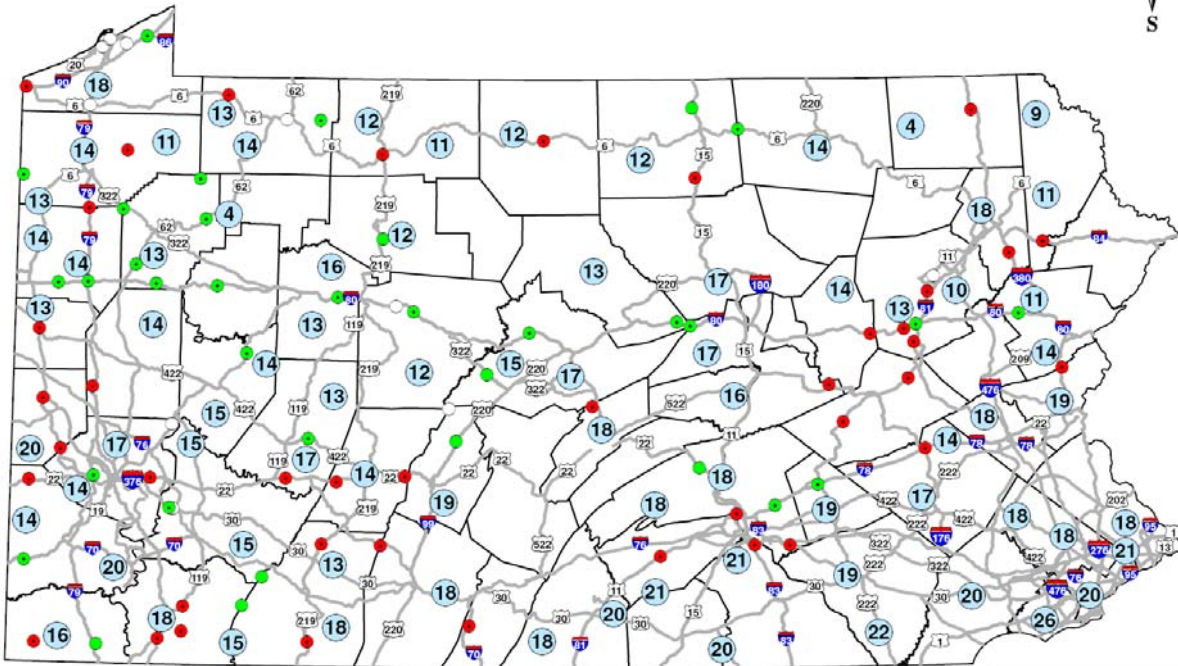




Average January Maximum Temperatures (F)



Average January Minimum Temperatures (F)



RWIS Status:

- Functioning
- Assumed functioning
- Not functioning
- FAST site

These wide variations create challenges in roadway weather forecasting since one roadway may have varying conditions depending on the topography of that area. RWIS can provide a tool to monitor conditions of specific sections of roads such that the appropriate treatment can be administered.

2.4.3 Ice Storms

When snow falls through a shallow layer of above-freezing temperatures aloft and begins to melt, the result at the surface is often a mixture of ice pellets (sleet) and rain. Ice pellets are usually quite small (0.16 inch in diameter), occasionally accumulating to the depth of a few inches in a heavy fall. A mixture of sleet and rain at near-freezing temperatures creates very slippery conditions as smaller drops freeze on contact with the cold ground. The most treacherous form of winter precipitation is freezing rain, which glazes roadways, sidewalks, and exposed surfaces. Freezing rain occurs when a layer of mild air overrides a wedge of subfreezing air near the surface. The air a few thousand feet overhead may be warm enough to melt snowflakes into rain, but a pocket of cold, dense air trapped in the deeper valleys of the Appalachians sets the stage for a prolonged interior ice storm, referred to by meteorologists as cold air damming.⁷

While maintenance activities associated with snow falls are the most common winter maintenance activities, weather events including accumulation of ice create unique challenges. While ice events at just below freezing temperatures can be treated with chemical agents, ice events at lower temperatures and with significant ice accumulation while rare are problematic.

At least one or two glaze storms can be expected in a Pennsylvania winter. Ice storms rarely occur before the middle of December, because the ground is still relatively warm. Ice storms are also unlikely after the middle of February, because the increasing sun angle allows more diffuse solar radiation to filter through leaden skies.

Severe ice storms have affected large portions of Pennsylvania on January 5, 1873, February 21-22, 1902, December 29-30, 1942, January 1, 1948, January 8-11, 1953, and December 16-17, 1973. One of the earliest widespread ice storms occurred on the morning of November 14, 1997. Nearly an inch of mixed precipitation fell over east-central and northeastern Pennsylvania in subfreezing nighttime conditions, resulting in an unprecedented mid-November ice storm as far south as the Lehigh Valley. Ice storms rarely occur after the middle of March, when the sun is higher in the sky and increasing solar energy warms the ground. Yet, a damaging spring ice storm struck the northern mountains of Pennsylvania on April 15-16, 1929, while a chilly rain fell in the valleys. On April 7, 1972, a thin layer of ice glazed roads in the Delaware Valley, southern New Jersey, and the nation's capital.⁸

It should be noted that this study was commissioned prior to the winter storm which hit Pennsylvania on February 13 and 14 of 2007. However, more focus has been given to this study as a result of the storm and the impending after action report entitled *the Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania* which documents the failures and inadequacies in responses to the storm by several stated agencies.

While there were many failures in response to the February 13 and 14, 2007 storm, it should be noted that the storm was a unique event historically. Pennsylvania was caught in the middle of the storm between a northerly snow front and southerly ice and freezing rain. Much of the state experienced a combination snowfall (4" to >14") and freezing precipitation (2" to >4").⁹ The results were disastrous. Snow and ice built up on primary and secondary roads in Pennsylvania. Tractor-trailers jackknifed and blocked the interstates. Drivers and passengers in cars and trucks, including some public safety personnel, were stuck in the resulting backups. In

⁷ *The Pennsylvania Weather Book* by Ben Gelber, 2002

⁸ *The Pennsylvania Weather Book* by Ben Gelber, 2002

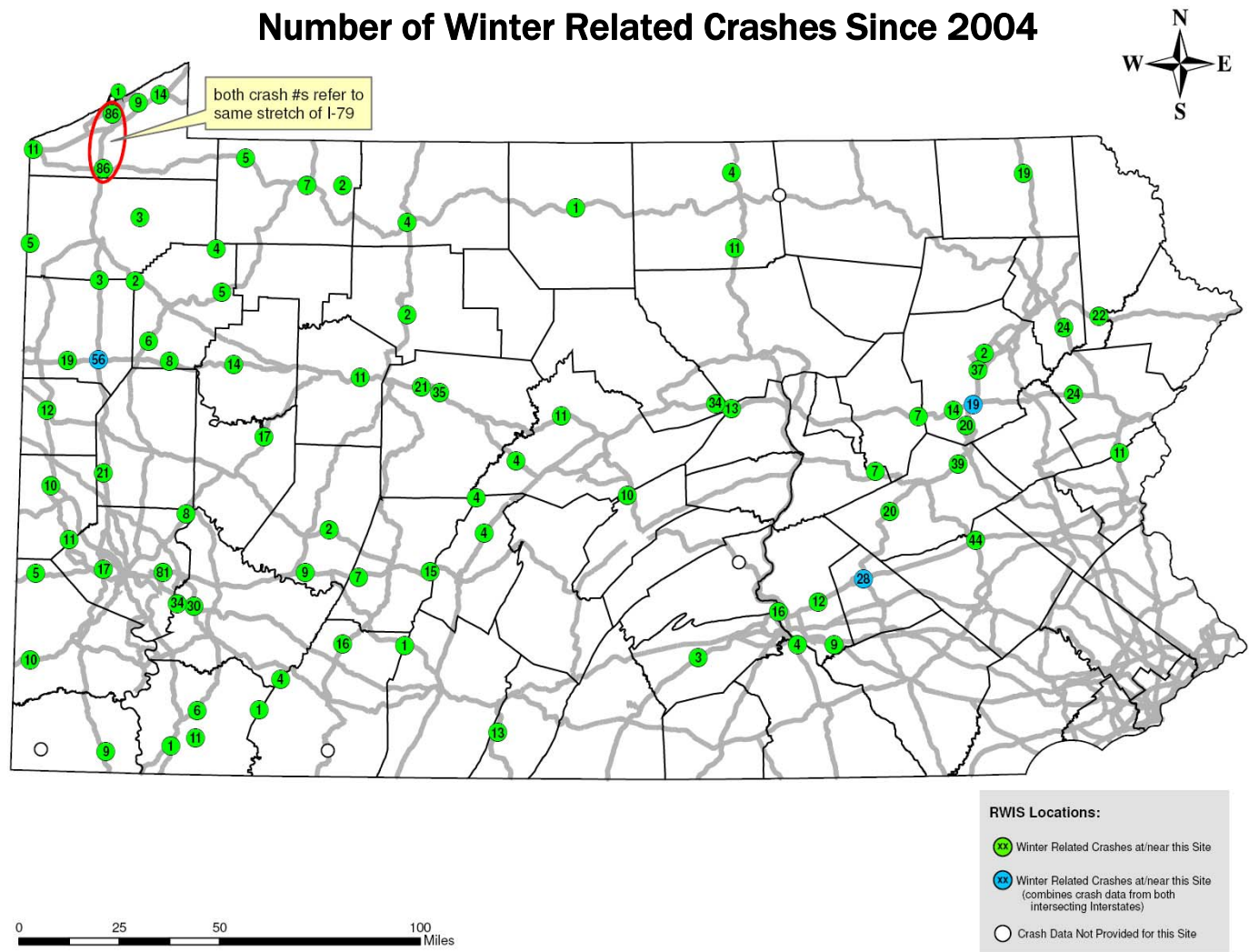
⁹ *Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania*

some cases, traffic crawled as little as one mile an hour. For others stranded on the road, traffic stood still all night. All told, approximately 150 miles of interstate highways were blocked. Although the exact vehicle and passenger counts are not available, at least hundreds of motorists were stranded on the interstates for extensive periods of time, some for more than 20 hours. The situation and road conditions were so bad that PennDOT officially closed parts of Interstates 78, 80 and 81 on February 15, impairing travel and commerce. Once the ice and abandoned vehicles were removed, the roads were reopened on February 17.¹⁰

2.4.4 Weather Related Crashes

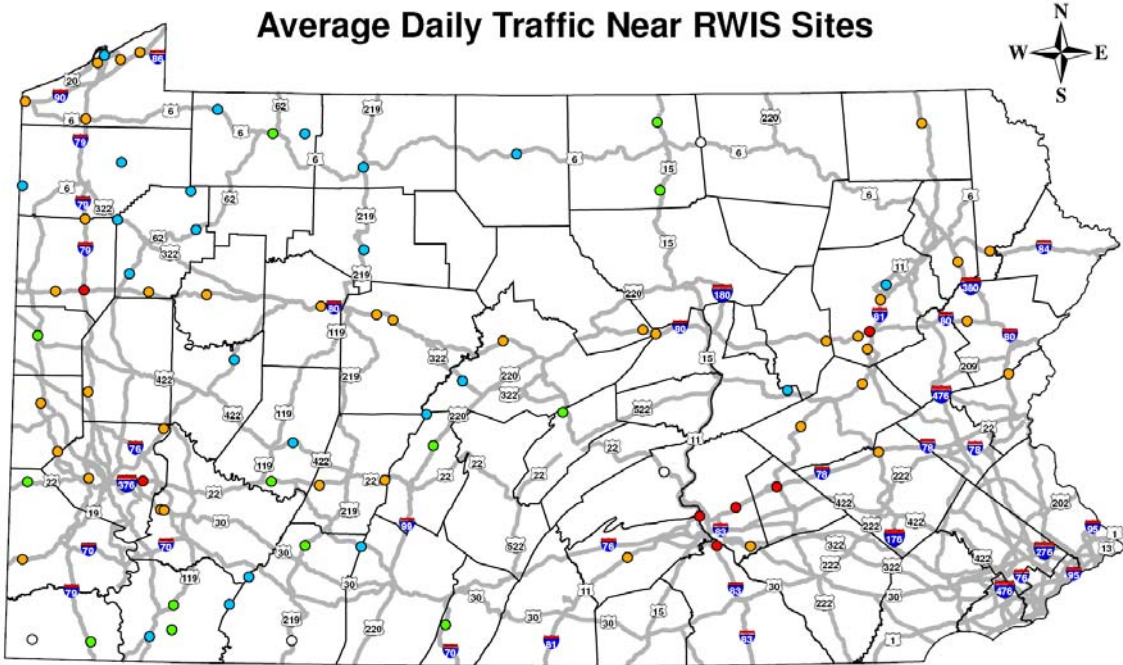
When the RWIS program was initialized, site locations were primarily chosen because of unique weather conditions or high weather related crashes. This methodology still applies today in site deployments; RWIS site spacing guidelines and high weather related crash areas should be examined concurrently to determine the most effective site location and for prioritizing site upgrades. Below are several maps that display winter related crashes, average daily traffic, and categorized (top third as high, middle third as average, bottom third as low) crash rates for current RWIS/FAST site deployments.

Number of Winter Related Crashes Since 2004



¹⁰ Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania

Average Daily Traffic Near RWIS Sites

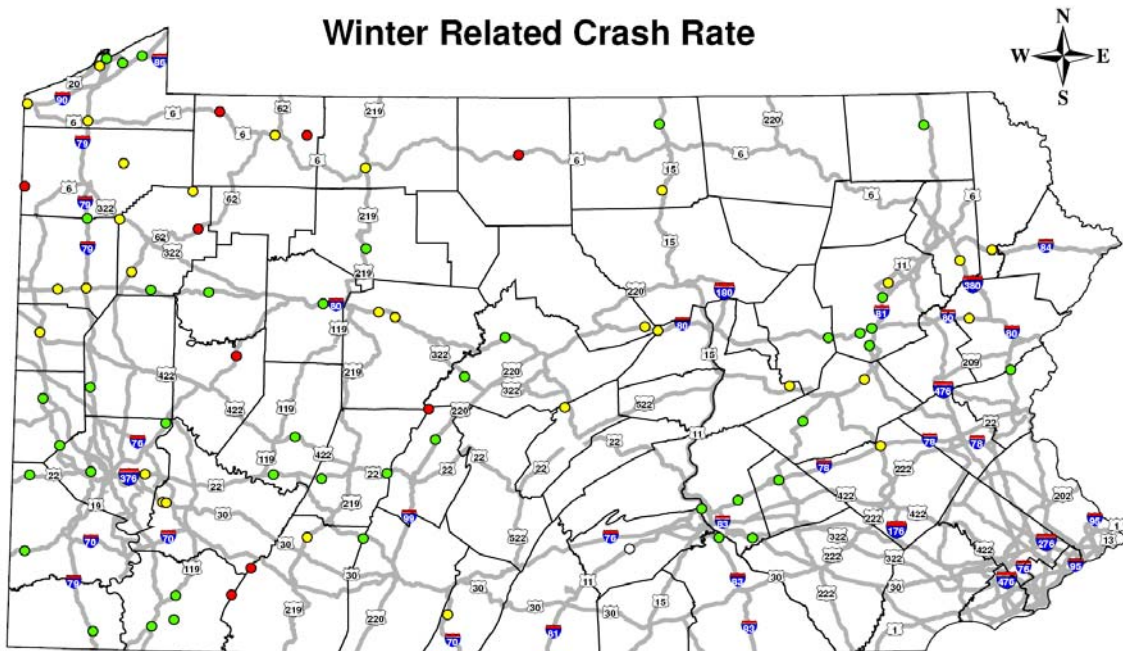


RWIS Site ADT:

- No Data
- < 10,000
- 10,000 - 19,999
- 20,000 - 50,000
- > 50,000



Winter Related Crash Rate



RWIS Locations:

- No Winter Related Crash Data
- Low Winter Related Crash Rate
- Average Winter Related Crash Rate
- High Winter Related Crash Rate





2.4.5 Winter Maintenance Expenditures

PennDOT expends a significant portion of the yearly budget on winter maintenance activities. These expenditures include: personnel, materials, equipment and rentals as well as service contracts.

The following illustrates the winter maintenance expenditures for the last five winter seasons¹¹. The reasons for the higher cost in 2002-2003 were not readily available; however, the expenditures were higher across most county maintenance offices.

Winter	State Total
2006-2007	\$144,751,971
2005-2006	\$140,166,862
2004-2005	\$177,635,633
2003-2004	\$176,678,300
2002-2003	\$253,023,259

The chart illustrates the opportunity that exists if system or management practice could be modified to provide a minor decrease in resource expenditures.

¹¹ Source Dave Hughes, BOMO

3. Existing Conditions

3.1 Summary of Site Visits

3.1.1 Locations Visited

The scope of this assignment included site visits at ten example locations. Sites were selected as a representative sample of manufacturer sites as well as functioning and non-functioning sites.

The following sites were visited:

RWIS Sites	Manufacturer	Functionality
I-83 Exit 38 Reeser Summit York County	nu	Down
I-81 Exit 77 South Dauphin County	nu	Running
I-81 @ I-78 Split Lebanon County	nu	Running
I-81 Exit 112 Hegin's Schuylkill County	nu	Down
I-81 Exit 134 South Schuylkill County	nu	Down
I-80 Exit 242 Roadside Rest Columbia County	ssi	Down
I-80 Exit 192 MP 194 Clinton County	ssi	Running
I-80 Exit 192 MP 190 Clinton County	ssi	Running
I-80 Exit 147 Roadside Rest Centre County	ssi	Running
I-80 Exit 101 MP 106 Anderson Creek Clearfield County	bos	Running

An initial site visit was made on April 25th, 2007, but most site visits were delayed to May 11th due to the availability of site keys. Site visits were completed on May 17th. While the controller and hardware components were assessed at most of the ten example sites, the lack of a complete inventory of site keys prohibited evaluation of some components.

RWIS SURVEY RESULTS:

Index	Site Name	County	Longitude	Latitude	Equipment Manufacturer	Equipment Drawings	Enclosure Keys	Protection	Approximate Roadway Offset	Power	Communication	Estimated Sensors
1	I-83 Reesers Summit	York	40° 11.873'	76° 51.833'	Nu-metrics	YES	YES	Concrete Barrier	15 ft	Solar	(2) dialup modems	Camera, Wind, Precipitation, Visibility, Humidity, Road sensor
2	I-81 Exit 77	Dauphin	40° 20.963'	76° 44.081'	Nu-metrics	YES	YES	On bank	25 ft	Solar	(2) dialup modems	Camera, Wind, Precipitation, Visibility, Humidity, Road sensor
3	I-81 & I-78 Split	Lebanon	40° 25.506'	76° 31.346'	Nu-metrics	YES	YES	Guard Rail	20 ft	Solar / Utility	(2) dialup modems	(3) Camera, Wind, Precipitation, Visibility, Humidity, Road sensor
4	I-81 Exit 112 Hegin's	Schuylkill	40° 39.981'	76° 23.323'	Nu-metrics	YES	YES	Guard Rail	10 ft	Solar / Utility	(2) dialup modems	Camera, Wind, Precipitation, Visibility, Humidity, Road sensor
5	I-81 Exit 134	Schuylkill	40° 50.171'	76° 03.767'	Nu-metrics	YES	YES	Guard Rail	10 ft	Solar / Utility	(2) dialup modems	Camera, Wind, Precipitation, Visibility, Humidity, Road sensor
6	I-80 Exit 242 Roadside Rest	Columbia	41° 00.505'	76° 14.964'	SSI	NO	NO	Chain link fence	50 ft	Utility	(1) dial up modem	Camera, Wind, Precipitation, Humidity, Temperature, Road sensor
7	I-80 Exit 192 MP 194	Clinton	41° 02.764'	77° 08.743'	SSI	NO	NO	On bank with chain link fence	80 ft	Utility	(1) dial up modem	Camera, Wind, Precipitation, Humidity, Temperature, Road sensor
8	I-80 Exit 192 MP 190	Clinton	41° 03.731'	77° 12.862'	SSI	NO	NO	On bank with chain link fence	70 ft	Utility	(1) dial up modem	Camera, Wind, Precipitation, Humidity, Temperature, Road sensor
9	I-80 Exit 147 Roadside Rest	Centre	41° 01.210'	77° 56.972'	SSI	NO	NO	On bank with chain link fence	50 ft	Utility	(1) dial up modem	Camera, Wind, Precipitation, Humidity, Temperature, Road sensor
10	I-80 Exit 101 MP 106 Anderson Creek	Clearfield	41° 07.297'	78° 37.055'	Boschung	NO	NO	Guard Rail	15 ft	Utility	Unconfirmed	Camera, Wind, Precipitation, Visibility, Humidity

Notes:
1) Because there was no documentation on the SSI and Boschung sites the function of all the sensors was uncertain.
2) Two dialup modems indicate two phone lines. One modem indicates one phone line.

General site findings are grouped by the original equipment manufacturer below. It appeared that most of the site's hardware had reached the anticipated life expectancy of computer equipment of around 10 years and should have been replaced as part of normal maintenance, even if the system hadn't been subject to neglect. In general, sites of each manufacturer were found to utilize similar equipment and installation techniques except as noted.

3.2 Numetrics sites:

3.2.1 Strengths:

Hardware:

The Numetrics sites appear to be in generally good physical condition with no obvious structural defects. The exposed components appear to be constructed of aluminum or stainless steel which has held up against the weather.

Software:

No strengths evaluated

Data Management:

The Numetrics control panels appear to separate the video data from the other sensor data. Most of the sites observed had one dialup telephone line connected to the video codec and a separate dialup telephone line connected to the analog signal controller. This configuration may enable faster downloads of the analog data since it does not have to wait on the video data.

3.2.2 Weaknesses:

Hardware:

The Numetrics control panels are poorly organized and integrated. The panels make little use of commonly available control system appurtenances to organize and fasten wire, cable, and components. Instead the panels utilize a series of shelves fastened to a back panel. The components loosely rest on the shelves. Wires are run half hazardly with little consideration to organization, separation, or labeling. It is difficult to access components from both sides. The control panels are undersized and overly deep for the components contained within. The battery compartments of the control panels are undersized for the batteries provided. The batteries impinge upon the vents on either side of the battery compartment, in some cases obstructing the vents. The vents are covered with a foam material which appears to be damaged in most of the panels because of battery installation interference. The panel interiors should be insulated to provide a thermal barrier to mitigate ambient temperature extremes. Many of the components used in the control panels are not rated for use in outdoor environmental conditions, however, the panels are not fitted with heating or cooling equipment. The panels should be fitted with an external sun shield. Several panels were found to have unconnected cables. The control system does not appear to feature any type of remote diagnostics which could facilitate preventative maintenance. Many of the system components appear to be proprietary in their construction and programming.

Software:

No component programming or configuration software or programming cables were available to assess the RWIS field site software. It is assumed that this software is proprietary.

Data Management:

The separation of the video data from the analog data requires two dialup telephone lines to be run to each site. This configuration, however, does not provide any communications redundancy. If either modem or associated component fails, that connected equipment is unavailable to the system.

3.2.3 Opportunities:

Hardware:

The control panels are generally in good shape and could be used to house upgraded equipment. There are control devices available today which are very suitable for installation in extreme environments which could be used to upgrade the systems. Such control devices are available that are based upon "open standards" to help guard against planned obsolescence and single sourcing issues that have plagued control manufacturers in the past. The existing systems can and should be made to work through improved maintenance efforts, most specifically, preventative maintenance. The buildup of communities in many areas has made electric service more readily available for many of the sites. It is possible to upgrade communications to the sites for redundancy and to enable advanced sensing features such as streaming video. Third generation cellular communications technologies such as CDMA may be available in most locations to provide reliable, inexpensive communications. Telephone lines may be upgraded to provide DSL service where available. The existing telephone communications lines may be used with more sophisticated devices and software to provide a measure of communications redundancy. Finally, all system components may be reconfigured to provide additional redundancy and reduce single points of failure.

Software:

Open source software would allow use of COTS technology that is easily accessible from within the state to be added and integrated into the systems as the needs may change in the future.

Data Management:

Data could be logged at each site and backed up at the district or central office. This would allow the system to be flexible enough to meet all the needs of the RWIS system and provide redundancy of storage to avoid lost data.

3.2.4 Threats:

Hardware:

Poor preventative and corrective maintenance appear to be the greatest threats to the system. A few sites have been lost to crashes as well. One of the greatest maintenance challenges is likely the lack of diagnostic tools. The system should be designed for automatic diagnostics and reporting to the central site. The sites are relatively soft vandalism targets and should be hardened to avoid opportunistic damage. The unprotected telephone and ground circuits on the outside of the site poles are critical elements with almost no protection against casual tampering.

Software:

Proprietary software can quickly become obsolete and vendors become unwilling to provide support for their outdated software. Upgrading to open standards would eliminate this dependency.

Data Management:

Not providing redundant backup of the data can cause vital information to be lost in the event of a storm condition. This data could be stored at the RWIS site during storm outages until communication is brought back up.

3.3 SSI sites:

3.3.1 Strengths:

Hardware:

Overview system architecture documentation was available for the SSI sites, but there were no system configuration drawings or panel layout drawings. The keys for these sites were not available to gain access to evaluate the SSI controller hardware or enclosure conditions. The analysis for the SSI sites is based on one site

that had a broken lock on the SSI enclosure. Other than the broken lock, the sites did not appear to have any other observable physical damage.

Software:

Controller programming software was not available and thus could not be analyzed for this study.

Data Management:

The data management was slightly different than the Numeric sites. The video and analog data appeared to be accessed via the same dialup telephone line. This configuration has a lower monthly cost in comparison to the two telephone lines.

3.3.2 Weaknesses:

Hardware:

The SSI system configurations were not organized in any neat or orderly fashion. Cable labels were rudimentary or not labeled at all and many of the connections were not securely fastened and loose. The entire system consisted of exposed circuit boards such as would be found inside of a PC and were not suited for rugged outdoor use with no environmental control. The circuit boards were easily subject to electrostatic discharge which could destroy the electronics on the circuit boards. The enclosures consisted of a sealed stainless steel enclosure with no ventilation. Without ventilation condensation could accumulate inside of the enclosures and would eventually destroy circuitry by shorting components and also corroding connections. The panels should be equipped with ventilation slots and sun shields to better maintain a consistent environmental temperature inside of the enclosures. Heaters would also prevent moisture from accumulating inside the enclosures keeping the connectors and circuits dry. The components of this system are all proprietary and making changes and additions to the system would be very difficult. There did not appear to be any UPS back up at any of the SSI sites. Without electrical backup loss of AC power would cause the RWIS site to no longer be functional (for example during a snow storm when most needed). Communications lacked redundancy if the modem being used failed. This single point failure would cause a functional RWIS site to be lost. Although each site was equipped with a CCTV camera it was not connected on the one SSI site that could be accessed. There also did not appear to be provisions for this cable to be connected any where inside of the panel. This may have been an isolated incident at this site since only one location was accessible, but it does show a lack of quality control.

Software:

Vender specific software relies on the proprietor to implement changes and upgrades to the system. This dependency can become very costly to PennDOT since there are no competitors to compete for the contracts. Future support for the software can be terminated by the vendors or costly upgrades may be demanded for increased functionality in the system.

Data Management:

The data access appeared to be consolidated to one phone line. This also appeared to be consistent with the overview system architecture. Consolidating all of the data to one line to one modem caused a single point of failure in the event that the modem or telephone line failed. At a minimum there should have been redundant modems to provide an alternate backup for the system to communicate back to a district office.

3.3.3 Opportunities:

Hardware:

The stainless steel enclosures all appeared to be in good condition and could be retrofitted with ventilation slots and sunshields to better control the interior environmental conditions. The proprietary system architecture could easily be replaced with an "open standard" architecture that could provide flexibility both with communication and integration to other software based systems. The system configuration should include

redundancy both within the system, power supply, and communication. This would eliminate the single point failures that are plaguing the systems already. There is a need for better maintenance and determining the causes of failure at each of the RWIS sites. A self diagnostic based software program could be configured to report back the status of the systems and in the event of a component failure it would report back an alarm to the responsible district informing of the failure and the action needed to correct the problem. All of the SSI sites had utility supplied AC power running to it so little improvement would be needed there. Another improvement would be in the communication. A more reliable means of communication could be with a cellular CDMA modem. All of the sites visited had very good cellular coverage which would provide a more reliable means of communication since it would not be affected by downed telephone lines, which can become the case in a severe ice storm. Alternately the telephone lines could be upgraded to DSL service for streaming video and providing real time feed back in the event of storm conditions.

Software:

All proprietary software should be upgraded to open standards based system that is NTCIP compliant and utilizes ESS formatting.

Data Management:

Data logging could be provided at the RWIS site and at the regional or central district office for redundant backup of the data.

3.3.4 Threats:

Hardware:

The greatest threat to the SSI sites is poor maintenance and the inability to diagnose failures at the sites. Providing consistent maintenance procedures and self diagnostic tools would greatly improve the reliability of the RWIS sites. Exposed cables in the towers should be placed in conduit to protect against vandalism and rodents. The SSI sites did have a chain link fence surrounding them which is a good idea that could be implemented at other sites. There should be better coordination within the districts for accessing the keys for the sites to avoid unnecessary trips to each site.

Software:

Proprietary software can quickly become obsolete and vendors become unwilling to provide support for their outdated software. Upgrading to open standards would eliminate this dependency.

Data Management:

Not providing redundant backup of the data can cause vital information loss in the event of a storm condition. This data could be used by the RWIS site as a stand alone system until communication is brought back up.

3.4 Boschung sites:

3.4.1 Strengths:

Hardware:

Little information could be gathered on the Boschung sites since only one site was visited and the keys to the enclosure were not available. The site did appear to be in good condition and was supplied with utility AC power. A nearby telephone maintenance building was providing immediate access for telephone service and possibly DSL.

Software:

Software is from a proprietary vendor and could not be accessed for analysis.

Data Management:

Since access to the Boschung enclosure was not available, it could not be determined how the data was being accessed.

3.4.2 Weaknesses:

Hardware:

Many of the remarks regarding previous sites with respect to proprietary systems would be applicable here as well. The other weaknesses would be lack of redundant communication, UPS back up, exposed cabling, outdated components that no longer are supported, poor grounding, and no surge protection. The panel for the Boschung site was very small and would not be sufficient to use for an upgraded architecture.

Software:

Software is proprietary and possibly no longer supported in the future, or could require costly upgrades.

Data Management:

Because access was not available to the enclosure the data management could not be confirmed, but there probably is little difference between the SSI sites and the Boschung.

3.4.3 Opportunities:

Hardware:

The Boschung enclosure was very small and would not be adequate for an upgraded architecture. Telephone service could possibly be upgraded to DSL. Provide self diagnostic tools and provide "open standard" architecture.

Software:

Upgrading the software to an open standard system would eliminate outdated and unsupported technology and provide a readily integrated system configuration.

Data Management:

As with the other sites there could be a redundant backup of the data at the RWIS site and at the district office. Decision making would be determined at the district office unless the communication is lost and would then be capable of operating as a stand alone system and remotely make decisions regarding roadway conditions and providing remote feed back at that location to travelers via message signs or warning lights. Current bridge deicing techniques already being implemented could be maintained while communication between the site and the district server is down.

3.4.4 Threats:

Hardware:

The greatest threats here are basically the same for all the system configurations. The maintenance support is not sufficient to prevent failures at the sites and the lack of self diagnostic tools hinder the ability to determine what is happening at each site. Single points of failure render the site useless and should be provided with redundancy both with communication and with power supply UPS. Little protection was available to prevent casual vandalism and rodents from destroying the cabling.

Software:

Proprietary software that is not easily integrated and possibly no longer supported is another threat to the system.

Data Management:

Without redundant storage of the data at the site and at the district office renders the site useless in the event of communication failure.





3.4.5 Summary of Site Conditions

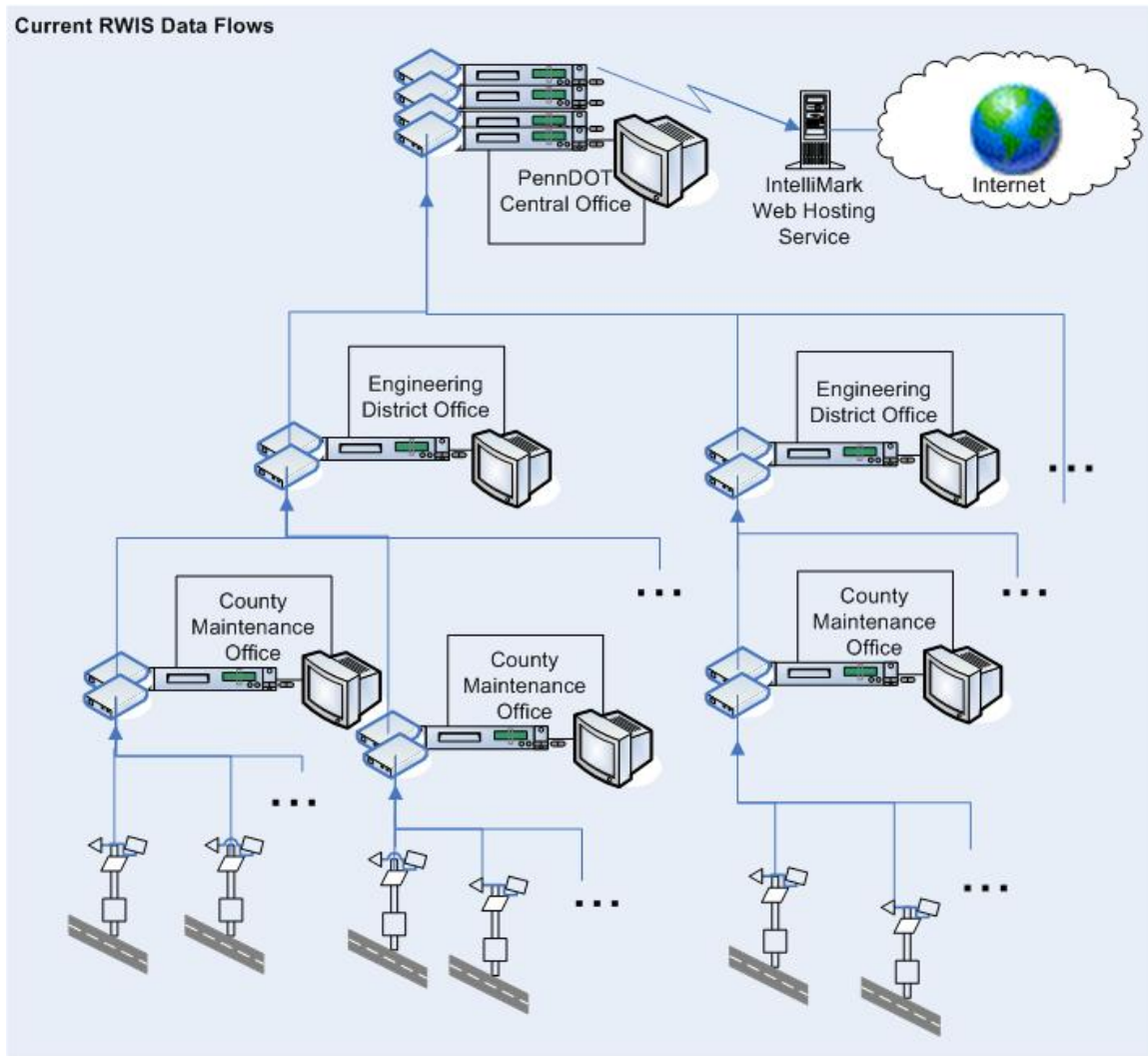
Index	Site Name	County	Site Damage	Problems	Recommendations	Opportunities
1	I-83 Reesers Summit	York	NO	Solar Panel was disconnected, Solar charge light did go on when plugged in, Wind meter at poor location, Solar panel at poor location, Data dialup line did not pickup, No panel insulation, No fan or heater to remove moisture, Poor Grounding, Could use higher pole to see over bridge, Vines growing up pole, Insects inside panel, No power TVSS, Telephone cables not in conduit, Batteries hard to remove and easily shorted on panel, Panel vents blocked by batteries and bug filter is easily torn when removing batteries	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Remove vegetation from equipment, Install Charge indicator/voltmeter, Provide self diagnostics, Install new grounding system	Could function as a future site for PTZ camera, but an existing ITS site is across the highway so there would be no added benefit to adding this functionality
2	I-81 Exit 77	South Dauphin	NO	Data dialup line went to the video modem and the video line went to the data modem, telephone utility had open splice box on pole, data modem did not appear functional, Poor grounding and rusty connections, wiring not labeled, Equipment not securely fastened, No ventilation fan or heater, No panel sunshield, No panel insulation, Telephone cables not in conduit, Batteries difficult to replace, Switches not labeled, Cables not labeled, TVSS not closely coupled to ground, RF connectors bent and loose, Batteries easily shorted in panel, Panel vents blocked by batteries and bug filter is easily torn when removing batteries, Grounds not bonded	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Install Charge indicator/voltmeter, Call telephone utility about open splice box, Provide self diagnostics, Install new grounding system	Could function as a future site for PTZ camera, A utility electrical service should be provide first before adding PTZ capabilities, Video processor would need to be upgraded
3	I-81 & I-78 Split	Lebanon	NO	Poor grounding and rusty connections, wiring loose and not labeled, Equipment not securely fastened, Solar panel obstructed by trees, No ventilation fan or heater, No panel sunshield, No panel insulation, Telephone cables not in conduit, Batteries difficult to replace, Switches not labeled, Cables not labeled, TVSS not closely coupled to ground, Batteries easily shorted in panel, Panel vents blocked by batteries and bug filter is easily torn when removing batteries, Grounds not bonded, New pole installations appears to be taking place beside the RWIS site and could potentially block the RWIS camera view, There are 3 cameras at the site but only appears to have one connected, GFI protection not needed in panels	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Install Charge indicator/voltmeter, Provide self diagnostics, Remove or trim back the trees blocking the solar panel and wind vane, Remove GFI receptacles to avoid nuisance tripping, Install new grounding system	Could function as a future site for PTZ camera, Utility service is already installed, Video processor would need to be upgraded
4	I-81 Exit 112 Hegin	Schuylkill	NO	Poor grounding and rusty connections, Heavy corrosion on connections, Wiring loose and not labeled, Equipment not securely fastened, No ventilation fan or heater, No panel sunshield, No panel insulation, Batteries difficult to replace, Cables not labeled, TVSS not closely coupled to ground, Improper grounding conductor size, Batteries easily shorted in panel, Panel vents blocked by batteries and bug filter is easily torn when removing batteries, Grounds not bonded, GFI no working. GFI protection is not needed in panels	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Install Charge indicator/voltmeter, Provide self diagnostics, Remove GFI receptacles to avoid nuisance tripping, Install new grounding system	Could function as a future site for PTZ camera, Utility service is already installed, Video processor would need to be upgraded
5	I-81 Exit 134	South Schuylkill	NO	Poor grounding and rusty connections, Wiring loose and not labeled, Equipment not securely fastened, No ventilation fan or heater, No panel sunshield, No panel insulation, Batteries difficult to replace, Cables not labeled and not connected, TVSS not closely coupled to ground, Batteries easily shorted in panel, Panel vents blocked by batteries and bug filter is easily torn when removing batteries, Grounds not bonded, GFI not working, GFI protection is not needed in panels, Power fuse broken, Flexible conduit is run above ground and not protected	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Install Charge indicator/voltmeter, Provide self diagnostics, Remove GFI receptacles to avoid nuisance tripping, Install new grounding system, Replace flexible conduit with rigid in exposed locations and PVC where underground	Could function as a future site for PTZ camera, Utility service is already installed, Video processor would need to be upgraded
6	I-80 Exit 242 Roadside Rest	Columbia	NO	No panel or fence gate key, Enclosures have no ventilation, No ventilation fans or heaters, No panel sun shields, Open electronic circuit boards in SCTI enclosure are not protected from being shorted, Cables not labeled, Exposed cables in tower, Loose cables not strapped, No status indicator lights for equipment, No visible UPS backup, Roadway is being paved with 6 inches of black top which covers the road sensor and may reduce its effectiveness	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Provide self diagnostics, Inspect ground connections for continuity, Provide panel ventilation	Could function as a future site for PTZ camera but only the east lane is visible from this site, Utility service is already installed, Video processor would need to be upgraded
7	I-80 Exit 192 MP 194	Clinton	NO	No panel key or fence key but gate was open, Enclosures have no ventilation, No ventilation fans or heaters, No panel sun shields, Cables not labeled, Exposed cables in tower, Loose cables not strapped, No status indicator lights for equipment, No visible UPS backup	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Provide self diagnostics, Inspect ground connections for continuity, Provide panel ventilation	Could function as a future site for PTZ camera but only the east lane is visible from this site, Utility service is already installed, Video processor would need to be upgraded
8	I-80 Exit 192 MP 190	Clinton	NO	No panel key or fence key but gate was open, Enclosures have no ventilation, No ventilation fans or heaters, No panel sun shields, Cables not labeled, Exposed cables in tower, Loose cables not strapped, No status indicator lights for equipment, No visible UPS backup	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Provide self diagnostics, Inspect ground connections for continuity, Provide panel ventilation	Could function as a future site for PTZ camera but only the east lane is visible from this site, Utility service is already installed, Video processor would need to be upgraded
9	I-80 Exit 147 Roadside Rest	Centre	NO	No panel key or fence key but able to gain access since lock was broken on SSI panel, Enclosures have no ventilation, No ventilation fans or heaters, No panel sun shields, Cables not labeled, Exposed cables in tower, Loose cables not strapped, No status indicator lights for equipment, No visible UPS backup, Connectors not secure, Open circuit boards not protected, Camera coax cable not connected, No phone line TVSS, Modem did not seem to be functioning	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Provide self diagnostics, Inspect ground connections for continuity, Provide panel ventilation, Provide phone line TVSS protection	Could function as a future site for PTZ camera but only the east lane is visible from this site, Utility service is already installed, Video processor would need to be upgraded
10	I-80 Exit 101 MP 106 Anderson Creek	Clearfield	NO	No panel key therefore little information could be gathered for this site, No panel sun shields, Cables not labeled, Exposed cables in tower, Loose cables not strapped, No status indicator lights for equipment, No visible UPS backup, Poor grounding system	Upgrade communications to a standard open platform not a proprietary system, Provide electrical maintenance and electrical troubleshooting, Provide self diagnostics, Upgraded the grounding system, Provide panel ventilation	Could function as a future site for PTZ camera for all lanes, Utility service is already installed, Video processor would need to be upgraded

Overall recommendation for all the RWIS sites:

- 1) Consider upgrading communications from a dialup line to CDMA modem.
- 2) Replace existing system architecture to a ruggedized open source programmable controller for increased flexibility and easily integrated to ATMS or other systems
- 3) Grounding and surge protection system should be upgrade and test on all sites

3.5 Summary of Data Management System

Field equipment from three different manufacturers are deployed – NU, SSI, and Boschung. Each manufacturer provides computer hardware and software for data collection. The data collection systems are deployed in a multi-tiered architecture, depicted in the figure below, to compile the data from individual field elements at the county, district, and statewide levels.



3.5.1 System Communications

A server in the county maintenance office dials each site within the county every 15-60 minutes. Camera images and data are on separate telephone lines. All phone services use land lines. PennDOT is considering switching over to cellular because it offers unlimited calls.

County data are collected at the districts. A district server polls each county within the district via dial-up connection. In some instances, the district office server polls an RWIS site directly. These are cases where the proximity of the site to the district office makes it a local phone call, whereas a call from the county would be long-distance.

3.5.2 Data Elements

Calculations of chemical agent percentages are done onsite, so transmitted data is complete. Some sites are solar powered, and transmit their battery power status as a percent of capacity. NU equipment also has the capability to collect traffic data – speed, volume, occupancy, and truck percent. However, neither the battery status data nor the traffic data are transmitted up the line to the district or central office.

3.5.3 Server and Software Configurations

Central office has a stack of 3 servers, one for each vendor, and a stack of 10 modems to pull data from the districts. A fourth server accumulates data from the other three. These servers are several years old and have only 4Gb storage each. They can store only a few days worth of data. They reclaim space automatically, which prevents a system failure from occurring because of lack of disk space. However, the data is lost when the space is reclaimed.

During winter months, PennDOT strives to collect data from each site every 15 minutes. In summer months, a 1-hour refresh rate is acceptable.

Each server has vendor software with monitoring capability. The same software is on county, district, and central office data collection servers. The SSI system includes a map-based graphical user interface (GUI) to show the locations of RWIS devices. The GUI has static map interface with tool tips and clickable symbols representing each RWIS site. The user can display linked site listings. On all systems (Numetrics, SSI, and Boschung), the user can display the most recent weather data and the most recent camera image for any individual site. The SSI system will also graph the temperature data for the last several readings. Depending on the amount of data available, the graph may be able to show the trend over the past 12 to 18 hours.

The software has the ability to perform notification action based on a preset data threshold. For instance, if the sub-grade temperature drops to a given preset value, the system will generate a notification to a designated user by a variety of methods, such as email or text message. However, these notification features are not used.


Statewide data is transmitted to Intellimark in Mechanicsburg where the RWIS Web site is hosted. The web site and the data transmission process between PennDOT central office and IntelliMark operate under Lotus Notes software. Dial-up processes are slow. Data and camera image at a given site are transmitted over separate phone lines, so the collection of these items is not necessarily coordinated.

RWIS Data currently available at PennDOT Central Office for all sites:

- ID
- Name
- Location
- Weather Data
 - Air Temperature
 - Dew Point
 - Humidity
 - Precipitation (type)
 - Visibility (feet)
 - Wind Direction
 - Wind Speed (mph)
 - Date/Time Reported
 - Road Surface Data – for each lane
 - Date/Time Last Reported
 - Surface Temperature
 - Surface Condition
 - ADI Agent Index (%)
 - Freeze Point
 - Subgrade Temperature
- Video image
 - Still image
 - Date/Time reported

Road Surface Data	L70 EB Driving 03/13/06 02:15 PM	L70 EB Passing 03/13/06 02:15 PM	L70 WB Passing 03/13/06 02:15 PM	L70 WB Driving 03/13/06 02:15 PM
Last Reported	52.2F	Dry	Dry	No Report
Surface Temperature				
Surface Condition				
ADI Agent				
Freeze Point	51F*	51F*	51F*	51F*
Sub Grade Temperature				

Image generated 03/13/2006 02:53:37 PM



Weather Data	
Air Temperature	76.8F°
Dew Point	46F°
Humidity	34
Precipitation	None
Visibility	1.1 mi.
Wind Direction	SW
Wind Speed	7 mph

Site Meteorological Data Reported at
03/13/2006 02:15 PM



3.5.4 Other Considerations

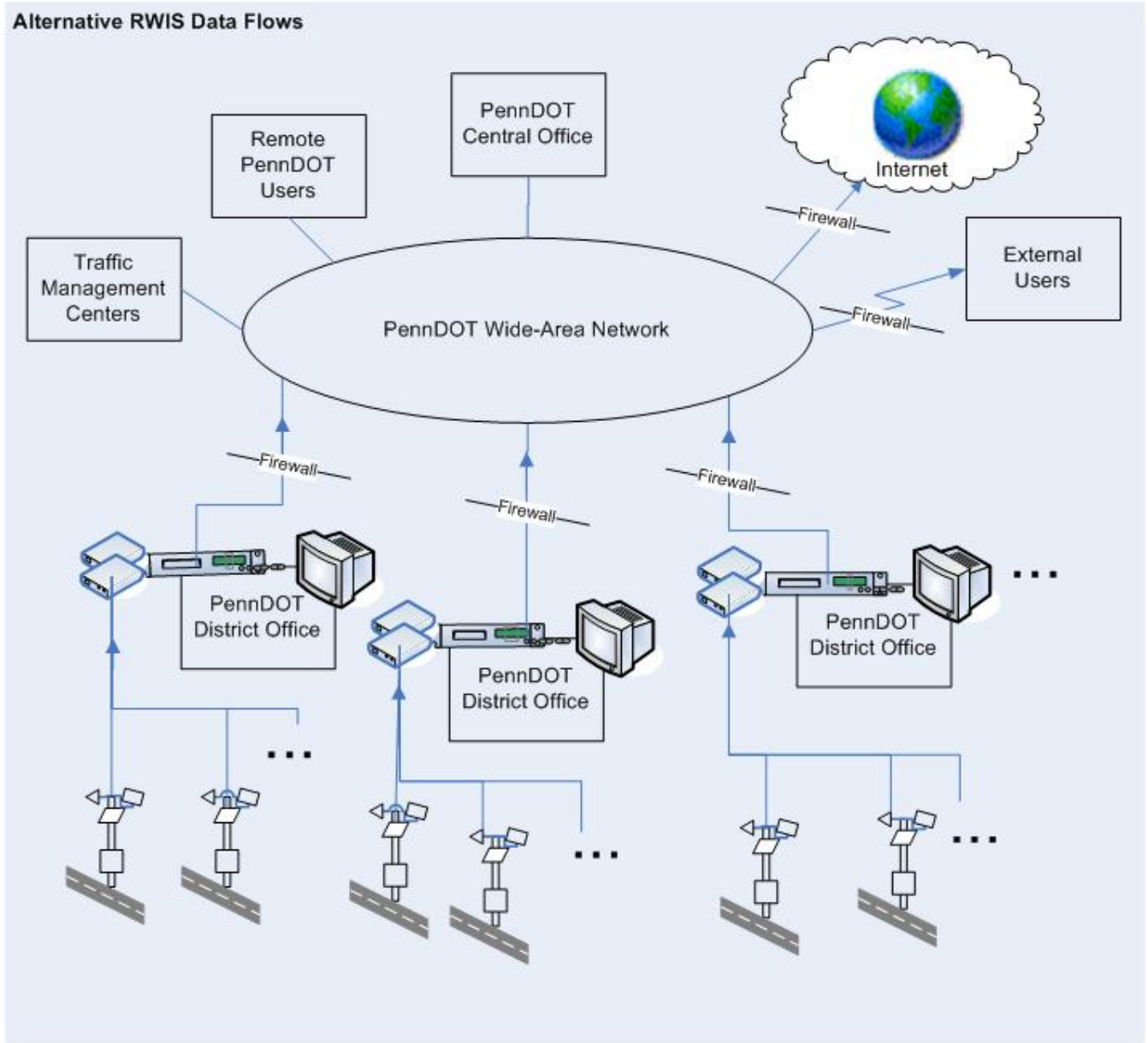
There are no standard procedures or conventions for internal use of the data at county, district, or state levels. The system could be utilized for county and/or district planning of weather-sensitive maintenance and paving operations, such as striping and patching. Another potential use would be in post-event performance review. This would only require recent data related to the event. If data could be archived, it could be managed as a materials usage history, which would be useful for such applications as budgeting winter chemicals stockpiles.

3.5.5 Data Management SWOT

The PA Office of Administration, Geospatial Technologies Office has expressed interest in integrating RWIS data into the PA emergency incident response system (PEIRS), which is used by the PA Emergency Management Administration (PEMA). They are interested in information on the weather condition related to an incident location. Potentially, the data could be used in vehicle/infrastructure integration (VII) applications by the CLARUS Initiative to develop a Nationwide Surface Transportation Weather Observing and Forecasting System.

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ Statewide coverage ▪ Data is ultimately available on an easy-to-use public web site ▪ Several years experience with technical infrastructure 	<ul style="list-style-type: none"> ▪ Access to the data – Raw data can only be accessed through vendor software running on a limited number of computers ▪ 3 different proprietary software applications ▪ Slow retrieval because of dial-up connections used for data transfers ▪ Use of dial-up connection to transfer data between PennDOT offices is expensive compared to file-sharing alternatives ▪ Stand-alone systems – No integration at either software level or data level ▪ Web site is outsourced and thus not directly under PennDOT control ▪ Under-utilized equipment – Not collecting traffic data ▪ Under-utilized data: No data archiving for long-term data analysis applications ▪ Under-utilized visual images – Camera images could be useful to Traffic Management Centers and other applications if shared ▪ Lack pan-tilt-zoom (PTZ) control over cameras ▪ Lotus Notes software is out of compliance with PennDOT software development norms
Opportunities	Threats
<ul style="list-style-type: none"> ▪ PennDOT database management systems and technical support are available in-house, offering opportunities to accumulate data over time, extend the usefulness of the data, and thus gain higher return on infrastructure investment. ▪ PennDOT wide-area network (WAN) is available for data sharing internally, offering a cost-saving alternative to dial-up ▪ Traffic volume data sharing – Investigate sharing traffic data collected from NuMetrics RWIS sites with the Bureau of Planning and Research ▪ Camera image – Investigate sharing camera images with district Traffic Management Centers ▪ Electronic notification capabilities are available in the RWIS monitoring software to automatically alert personnel managing winter storm operations or operating Traffic Management Centers ▪ Use of RWIS data in planning weather-sensitive maintenance and paving operations could be expanded by developing procedures and training for county highway maintenance personnel 	<ul style="list-style-type: none"> ▪ Telecommunication cost – Data transfers from RWIS sites currently depend on telephone dial-up connection, which can be costly and sometimes unreliable. ▪ Software integration cost – Extending the usefulness of the data will require potentially costly investment in software development. ▪ Lack of SOPs contributes to under-utilization – Software investment will need to be accompanied by organizational changes and training to improve data utilization.

The figure below offers an initial alternative data flow for RWIS. Once collected at the District Office level directly from RWIS field sites, the data could be moved to a shared file location on the PennDOT wide-area network (WAN), where it would be instantly available to all PennDOT users. This would reduce the need for many of the existing dial-up communications. The information would also be delivered to an Internet-based application for public consumption. In addition, data could be delivered to other external consumers, if necessary, through various outbound-only transfer methods.



3.6 Resources and Manpower

3.6.1 Resource Expenditures

There is limited available information on yearly expenditures for the RWIS program. Program expenditures would likely include:

- Site power
- Site communications
- System communications
- System management
- Web-site maintenance
- Maintenance activities

It has not been confirmed who within the Department is responsible for site power and communications. Since Central Office has no record of these expenditures, they are likely expenses that occur at the District or county level.¹²

Based on maintenance records, it was calculated that approximately \$235K could be expended per year on maintenance activities. This equates to approximately \$3,100 per site per year. Most maintenance activities included the maintenance and repair of RWIS systems when a malfunction occurred. The vendors were not responsible for repairs that were not a result of normal operational malfunctions. The contracts did not include repair of systems outside of normal operations such as the replacement of sensors as a result of PennDOT paving and maintenance operations or other unforeseen circumstances. Historic maintenance practices are further discussed in the next section.

The *Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania* released on March 27, 2007 noted that 55 sensor sites were inoperable out of a total of 75 sites statewide. The Bureau of Operations and Maintenance has been directed to have all out-of-service sites operational by September 2007. This will reestablish the existing operations baseline. The cost of this expenditure is still being determined.

3.6.2 Manpower and Organizational Structure

There are no full-time positions dedicated to the RWIS program. BOMO provides program oversight from Central Office. Within Districts, there is a RWIS coordinator who provides oversight of RWIS caretakers at the county level.

Central Office oversight is provided by Dave Hughes of BOMO. Many of the District coordinators reside in the District ITS unit which is part of traffic engineering. At the District level, traffic engineering resides in the District maintenance unit which also includes winter maintenance activities; however, at Central Office winter maintenance is a BOMO responsibility while traffic engineering and ITS is a BHSTE responsibility.

3.7 Maintenance Practices

RWIS maintenance has been hampered by maintenance contracts that limited the ability to repair sites with needs due to construction activities or other unforeseen circumstances. These contracts were developed to address normal system operations only. Recently, a preventive maintenance contract has been awarded to address SSI and NU RWIS and a preventative maintenance contract is being processed to address Boschung FAST and RWIS sites.

¹² Source Dave Hughes, BOMO



RWIS Maintenance Contracts*					
# Sites	Vendor	Start/End		Amount	Status
24	Surface Systems	8/23/01 - 4/30/06	Approx \$4.2K per site per year	\$464,741.22	Complete
47	Nu-Metrics	11/16/01 - 4/30/06	Approx \$3.0K per site per year	\$618,588.45	Complete
RWIS Preventive Maintenance and Repair Contract**					
	Vendor	Start/End		Amount	Status
71	Nu-Metrics	11/02/06 - 11/07		\$200,000.00	Open
* RWIS Maintenance Contracts included the maintenance and repair of RWIS systems when a malfunction occurred. The vendors were not responsible for repairs that were not a result of normal operational malfunctions. The contracts did not provide service to repair systems outside of normal operations. ie. Replace sensors as a result of PennDOT paving and maintenance operations.					
** Combined SSI and Nu-Metrics contracts, companies now owned by parent company Quixote Corp. RWIS Preventive Maintenance and Repair Contract provides for a Preventive Maintenance (PM) visit for each installed site. Repairs outside of normal operations are covered under the current contract.					
FAST/ RWIS Maintenance Contract***					
	Vendor	Start/End		Amount	Status
	Boschung America	1/9/03 - 1/9/06		\$374,532.00	Complete
	Boschung America	2/27/07 - 5/27/07	Contract Extension	\$24,000.00	Processing
*** FAST/RWIS Maintenance Contract included the maintenance and repair of FAST/RWIS systems when a malfunction occurred. The vendors were not responsible for parts or repairs that were not a result of normal operational malfunctions. The contracts did not provide service to repair systems outside of normal operations.					
FAST/RWIS Preventive Maintenance and Repair Contract****					
	Boschung America	Currently processing contract		\$200,000.00	Processing
****FAST/RWIS Preventive Maintenance and Repair Contract provides for two (2) Preventive Maintenance (PM) visits for each FAST site and one (1) visit for each RWIS site. Repairs outside of normal operations are covered under the current contract. Negotiations yielded a 15% reduction in published repair part costs and a 10% reduction in published labor rates.					

A cursory review of the NU preventative maintenance contract noted several items not previously included in maintenance contracts.

- 48-hour (business day) response time during winter months
- Repair of the RWIS system by the way of part replacement or repair of existing part as deemed beneficial to PennDOT as determined by the District Coordinator or County Caretaker
- Provide for the installation of new system components which will provide for a more efficient and/or more informative system.
- Contractor shall make a minimum of one (1) scheduled Preventive Maintenance visit per year at each location. The cost of each Preventive Maintenance visit will be \$1,600.00 per site
- Monthly RWIS System status reports are required

While maintenance practices have historically been hampered by contract language, new maintenance contracts provide more preventative elements.

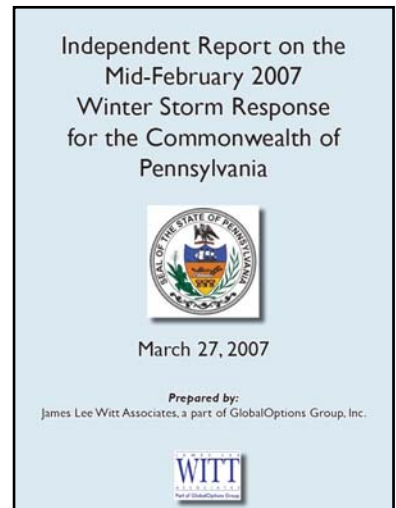
In the future, there may be opportunities to include RWIS maintenance with other ITS maintenance contracts as well as to utilize other states best practices for maintenance contracts some of which are available as part of the Aurora Program (to which PennDOT is a member). These opportunities will be discussed in later sections of this report.

3.8 Independent Report on the Mid-February 2007 Winter Storm Response

The *Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania (Independent Report)* which was released on March 27, 2007 has generated more interest in the RWIS program as well as the outcomes of this study.

Pursuant to the Governor's request for a RWIS recommendations report from the Bureau of Maintenance & Operations by July 1, 2007, the schedule of this study was expedited to have a draft final report by June 15, 2007. Additionally, BOMO has been directed to have all out-of-service sites operational by September 2007. This will reestablish the existing operations baseline for the RWIS program.

The Independent Report made the following observations and recommendations related to the RWIS program and other roadway weather management practices.



3.8.1 Report Observations¹³

- Information Systems and Resources:
 - Roadway Weather Information System (RWIS) currently has 55 sensor sites inoperable out of a total of 75 sites statewide...This technology (RWIS) would have allowed managers to verify not only the weather but also the condition of traffic flow.
 - Not all districts contract transportation- specific weather forecasting services
- Maintenance Practices
 - Staffing guidance not followed, particularly in PennDOT's Berks County, and lack of guidance at the district level.
 - PennDOT allows districts and counties to modify individual approaches for snow and ice control.
 - Quantity of chemical additives in PennDOT's stockpiles is not governed by policy or procedure.
 - Turnpike has a "Bare Pavement" philosophy to snow and ice control; PennDOT does not.
- Transportation Operations
 - PennDOT's representative at the State Emergency Operations Center did not have access to all information available to PennDOT's Traffic Control Center staff.
 - Emergency operations do not appear to be treated as a core mission of PennDOT
 - PennDOT provided flawed information to the public in press releases, on highway electronic message boards and over its telephone information system.

3.8.2 Report Summary and Recommendations¹⁴

While each of the report recommendations may have their own outcomes, the direction of the RWIS program as well as winter maintenance and operations needs to be considered in the context of one another in order to promote continuity and common situational awareness.

- PennDOT maintains technologies to help the State assess road conditions in an emergency. Yet, Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania existing weather-related technology has been allowed to degrade to the point where it has proven almost useless to PennDOT. The existing Roadway Weather Information System (RWIS) currently has 55 sensor sites inoperable out of a

¹³ *Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania*

¹⁴ *Independent Report on the Mid-February 2007 Winter Storm Response for the Commonwealth of Pennsylvania*

total of 75 sites statewide. This technology would have dramatically improved the situational awareness of managers up and down the PennDOT chain of command. The RWIS would have allowed managers to determine surface conditions and, in many cases, view a live picture of the roadway. This technology would have allowed managers to verify not only the weather but also the condition of traffic flow.

- **Recommendation:** Immediately repair existing RWIS. Develop an ongoing repair and oversight program. Identify areas where this technology could have helped and expand technology to those areas.
- PennDOT districts vary in their use of contracted weather forecasting services. It should be noted that PennDOT's Snow and Ice Control Manual offers several options for weather forecasting, mostly using freely available sources, such as commercial television or the National Weather Service website. PennDOT headquarters relies primarily on National Weather Service for its weather reports. The use of contracted weather forecasts is optional but is paid from a district's budget. As a result, Pennsylvania districts vary in their use of contracted weather forecasting services. District 4-0 and the Turnpike Commission use a contracted service; District 5-0 does not. The Turnpike's forecasting service provided them with 6 to 8 hours of advance notice of the anticipated mid-storm changeover from a snowstorm to an ice storm. This advance warning provided them adequate notice to reassess their snow-fighting plan, adjust the plan, and communicate the changes in approach to each equipment operator. District 4-0 also felt that the advance warning provided them adequate time to be prepared for the oncoming storm.
 - **Recommendation:** PennDOT should reassess the use of a common weather forecasting service as an option in counties and districts with the potential for problematic storms like heavy snowfall or ice.
 - **Initial Thought:** RWIS data needs to be integrated with common weather forecasting in order to provide a complete weather picture.
- During the Winter Storm there were problems with PennDOT reporting and communications technologies, like the Road Condition Hotline, PennDOT's toll free number to call about road conditions (1-888-783-6783). That system often reported incorrect conditions because staff did not provide timely updates. The lack of updates resulted in the Hotline playing an automatic "no adverse conditions reported" message. This added to the misinformation to the public about the storm. Additionally, the Highway Advisory Radio System (HAR) in District 5-0 was inoperable during the storm.
 - **Recommendation:** Public notification should have been a greater priority during PennDOT's response to the Winter Storm. PennDOT should review information protocols and adjust the communication process accordingly. PennDOT should repair existing HAR technology.
 - **Initial Thought:** RWIS data, contract weather and road conditions data can be used to feed the proposed 511 traveler information system.
- When the PennDOT liaison was called in to staff the State Emergency Operations Center, the agency's representative did not have access to all information available at the PennDOT Traffic Control Center. PennDOT's Liaison relied on Traffic Control Center staff to translate data and other information over the telephone. The lack of detailed information from PennDOT compounded the situational awareness gap in the State Emergency Operations Center.
 - **Recommendation:** PennDOT should consider relocating the Traffic Control Center to be physically within the State Emergency Operations Center and consider connecting all PennDOT weather systems and road condition systems into the State Emergency Operations Center. Additionally, PennDOT and State Police should establish a formal communications process to transmit detailed weather and road conditions data and analysis.
 - **Initial Thought:** RWIS data needs to be integrated with common weather forecasting in order to provide a complete weather picture.

3.8.3 Guidance on RWIS Program

In summary, the *Independent Report* identified several issues that relate to RWIS and roadway weather management activities.

- **RWIS itself was not functioning and program guidance is needed** – Maintenance practices and oversight is needed to ensure that the system is functional and reliable. Deployment guidance is needed so that RWIS can be a future asset.
- **Other weather forecasting and maintenance tools were not available** – RWIS alone will not provide situational awareness and does not provide a tool for winter decision making. RWIS may be part of a more comprehensive solution that includes weather forecasting data, maintenance and operational decision making tools.
- **There was a failure in Department and inter-agency communication /coordination** – In order to manage roadway weather operations including emergency operations, decision makers within the Department as well as within the agency need to have access to the same information and resources so that they can introduce the right combination of strategies. In some cases, Districts may have varying information or maintenance decision makers may not have access to the same information as operational decision makers. Communication, coordination tools and management practices need to be adopted that allow advisory, control and treatment strategies to be implemented in a coordinated manner. Example of each are presented below:
 - **Advisory** - Provide information to transportation officials and transportation managers as well as the public through various mechanisms such as the internet, hotline number, DMS, HAR and commercial media. Data may need to be packaged in various formats to accommodate the medium and target audience. Ultimately, a 511 (voice and internet) would be the ideal mechanism to disseminate information to the public.
 - **Control** – Provide transportation officials with weather data such that they can coordinate or implement control strategies. Control strategies themselves may be technology based (variable speed limits, ramp metering, signal timing modifications) or may require physical implementation (road closures, etc).
 - **Treatment** – Treatment strategies include road maintenance activities. Accurate and timely roadway weather information can assist snow and ice operations in the most efficient use of limited resources. If roadway weather data is integrated with other data elements and models as well as other roadway weather management best practices (maintenance decision support system (MDSS), GIS-based fleet management, etc) efficiency and productivity may be further enhanced while also improving safety and mobility.
- **There was a failure in public notification** – Often information provided to the public was not updated or the tools to notify the public themselves were not operational. RWIS data needs to be accessible and reliable for the traveling public along with other roadway information.

4. National Practice

4.1 Summary of Research Activities

The scope of this assignment included a review of national practices in RWIS program management as well as overall roadway weather management. The review included several efforts that are detailed below and summarized in this section and accompanying appendices.

- **Literature review** – More than 23 publications were reviewed as part of research activities. The review included publications from FHWA, the Aurora Program, and other states. The publications are listed in **Appendix B** and a summary is provided for 12 of the publications reviewed. *The electronic version of this report includes a hyperlink to each document.*
- **Seminars and roadshows** – Seminars and roadshows included two key activities.
 - Participated in the National Transportation Operations Coalition's, Roadway Weather Management Webinar on March 14, 2007- The webinar included an overview of FHWA's Roadway Management Program including a review of their weather observing program, the Clarus Initiative, their decision program, the Maintenance Decision Support System (MDSS) and their weather responsive traffic management program. The webinar included presentations from Utah on their roadway management program and the City of Denver on their usage of MDSS. Presentation materials are available at http://www.ntoctralks.com/web_casts_archive.php.
 - Hosted FHWA's Maintenance Decision Support System Roadshow on May 23, 2007 - The briefing was intended to show how MDSS technology is transforming the world of winter maintenance. The briefing was led by Ray Murphy, Senior ITS Specialist with the FHWA's Resource Center. The briefing focused on deploying MDSS technology and why it can be a smart investment for PennDOT's winter maintenance program. Key items discussed as they relate to Pennsylvania included:
 - The role of the Clarus Initiative
 - How MDSS can be integrated with RWIS and other weather data
 - Scenario/ treatment options and after action refinement of solution strategies
 - Integration with other systems
 - Future modifications and the possibility of an operational decision systemThe complete briefing is included as **Appendix C**. A detailed discussion and guidance for PennDOT on the Clarus Initiative and MDSS is in subsequent sections of this report.
- **Survey of other states** - A web-based state of the practice survey was distributed to other state DOT's including state traffic engineering and ITS contacts as well as state roadway weather management contacts. The survey resulted in 26 responses and was used as a basis for follow-on interviews. A summary is provided in this section of the report and a detailed summary is included as **Appendix D**.
- **Research of vendor products** - Capabilities and key products offered by RWIS vendors were reviewed. In particular, RWIS features and available sensors as well as other features/products such as communication, data management services and maintenance & operating solutions. Additionally, NTCIP compliance was reviewed. A summary is provided in this section of the report and a detailed summary is included as **Appendix E**.

4.1.1 Scanning Tour Opportunities

FHWA has a program that allows key PennDOT representatives to conduct a scanning tour of other states to review best practices. Previously, this program was utilized to conduct a scanning tour of other traffic management centers as PennDOT began to plan and assess their long-term needs. It proved to be a useful tool and helped PennDOT make key decisions that will maximize long term resources.

The program utilizes T2 Funding. Currently, there is \$4,300 available under fiscal year 2007 which must be obligated by June 30, 2007. Additional funding would need to be requested through FHWA in Washington D.C or provided by PennDOT. Based on a review of best practices including survey responses, the following is a suggested scanning tour team and suggested itinerary for future consideration.

Suggested Team:

Dave Hughes	Bureau of Maintenance & Operations
Bob Pento	Bureau of Highway Safety & Traffic Engineering
Rodney Young	PennDOT District 1-0
Jim Hunt or Kingsley Azubike	FHWA

Total – 4 team members - Other representatives including the Bureau of Information Systems (BIS), other district representation and consultant support would be beneficial if resources allowed.

Suggested Potential Itinerary:

State	# of RWIS	Program Owner	Other Considerations
Ohio	<ul style="list-style-type: none"> 169 Recently added approx 80 NTCIP compliant RWIS 	Maintenance	<ul style="list-style-type: none"> NTCIP and vendor RWIS RWIS data is ingested into forecast service Use of web-based MDSS by DTN
Iowa	<ul style="list-style-type: none"> 58 total Numerics and SSI 	Maintenance	<ul style="list-style-type: none"> No statewide third party weather data Use of web-based MDSS by DTN, but also in pooled fund study.
Washington	<ul style="list-style-type: none"> 91 total Plan build out to 120 Numerics, SSI and Vaisala 	Operations	<ul style="list-style-type: none"> Statewide third party weather data Integrated new ESS with legacy, proprietary ESS so that all devices could be controlled by a single server. Clarus initiative demonstration site
Utah	<ul style="list-style-type: none"> 58 total Numerics, Vaisala and Campbell Scientific 	Winter Operations	<ul style="list-style-type: none"> Statewide third party weather data On-site meteorologist
Others Considered			
Wisconsin	<ul style="list-style-type: none"> 57 total SSI 	Operations	<ul style="list-style-type: none"> Statewide third party weather data Limited use of web-based MDSS by DTN Through NTCIP allow RWIS to control DMS
Idaho	<ul style="list-style-type: none"> 33 total 49 additional under contract Vaisala and SSI 	Maintenance	<ul style="list-style-type: none"> Statewide third party weather data Use of web-based MDSS by DTN
Nevada	<ul style="list-style-type: none"> 70 total Vaisala 	Maintenance and Operations	<ul style="list-style-type: none"> Statewide third party weather data Use of web-based MDSS by DTN
Maine	<ul style="list-style-type: none"> 6 total Vaisala 	Maintenance	<ul style="list-style-type: none"> Statewide third party weather data Use of web-based MDSS by DTN

Estimated Air Travel: \$1,500 each
 Estimated Per Diem (Meals and Lodging) \$1,050 each (7 days at \$150)
 Estimated Car Rental \$ 500 (approx \$70/day for 7 days)
Estimated Total Travel Costs (4 people) \$10,700
 Please note, final air reservations (and possibly other purchases) must be made through FHWA

Suggested Agenda:

1. Review existing RWIS practices (site deployments, system management, NTCIP)
2. Review/ visit how RWIS is integrated in business practices (maintenance, operations)
3. Discuss integration with other weather data
4. Discuss/ review participation in MDSS and Clarus activities

4.2 National Initiatives

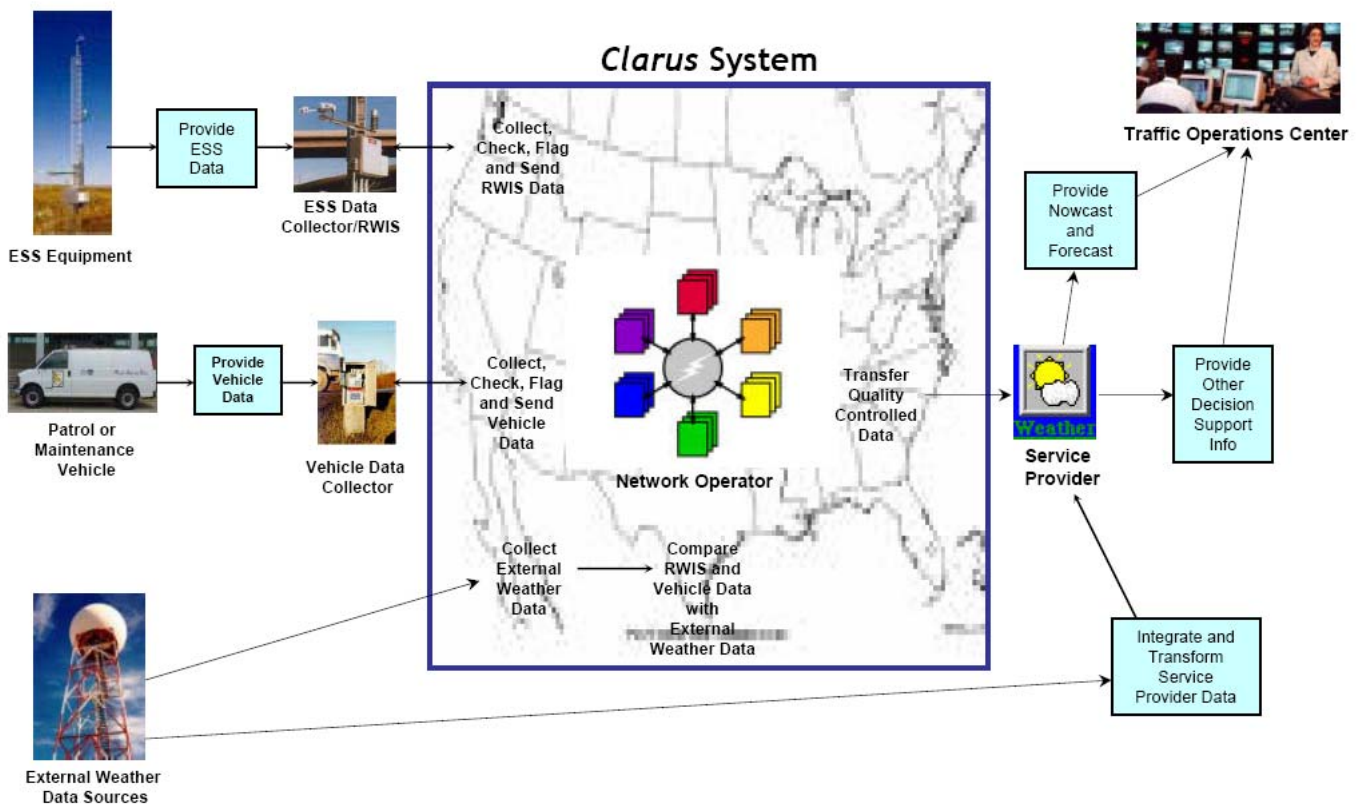
Key national initiatives were researched to determine their impacts on PennDOT's RWIS and roadway weather management practices.

4.2.1 Clarus Initiative¹⁵

Clarus is an initiative to develop and demonstrate an integrated surface transportation weather observing, forecasting and data management system, and to establish a partnership to create a Nationwide Surface Transportation Weather Observing and Forecasting System.

Clarus is an ITS initiative to demonstrate and evaluate the value of "Anytime, Anywhere Road Weather Information" that is provided by both the public and private weather enterprises to the breadth of transportation users and operators.

The objective of Clarus is to provide information to all transportation managers and users to alleviate the affects of adverse weather. The initiative is guided under the principle that in order to reduce the effects of adverse weather, the nation's network of weather and road condition observations must be modernized and integrated, and this data must be disseminated to the public and to surface transportation system operators.



The Clarus Initiative Concept

- Develop partnerships between the surface transportation and weather communities to leverage and share resources for both research and operations.
- Strengthen ties among federal agencies such as the Federal Highway Administration (FHWA) and the National Oceanic and Atmospheric Administration (NOAA) that have similar objectives.

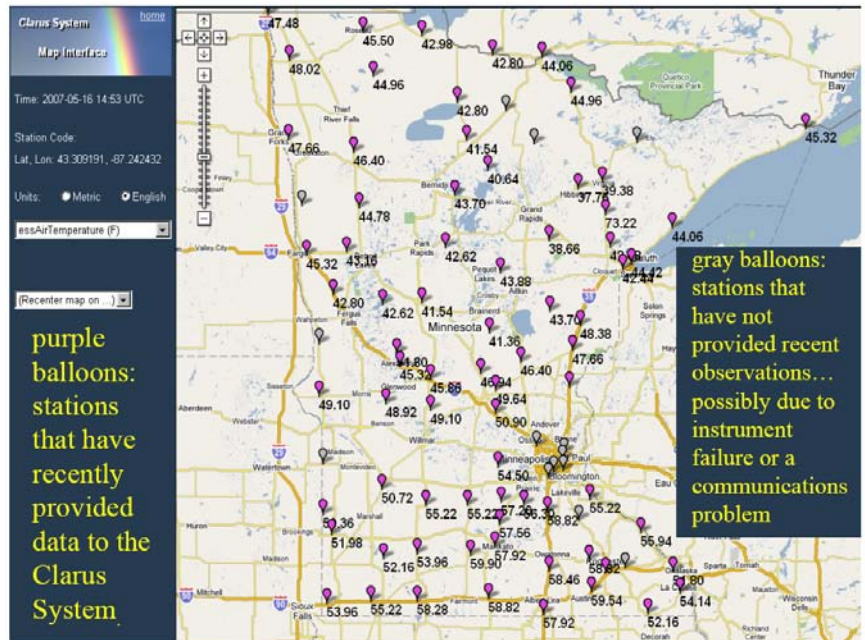
¹⁵ As modified from http://www.clarusinitiative.org/documents/Clarus_2_Pager.pdf

- Demonstrate a framework to collect the nation's current and future surface transportation weather and road condition observations, and provide quality data as input to advanced weather models to serve as the basis for value-added products.
- Establish an instrumented test bed to host new cutting edge technologies for fixed, mobile and remote sensing.
- Establish an Initiative Coordinating Committee to guide the development and deployment efforts.

Clarus is a U.S. DOT funded activity, drawing from the ITS program funds of the ITS Joint Program Office. So far there is no additional program funding from NOAA.

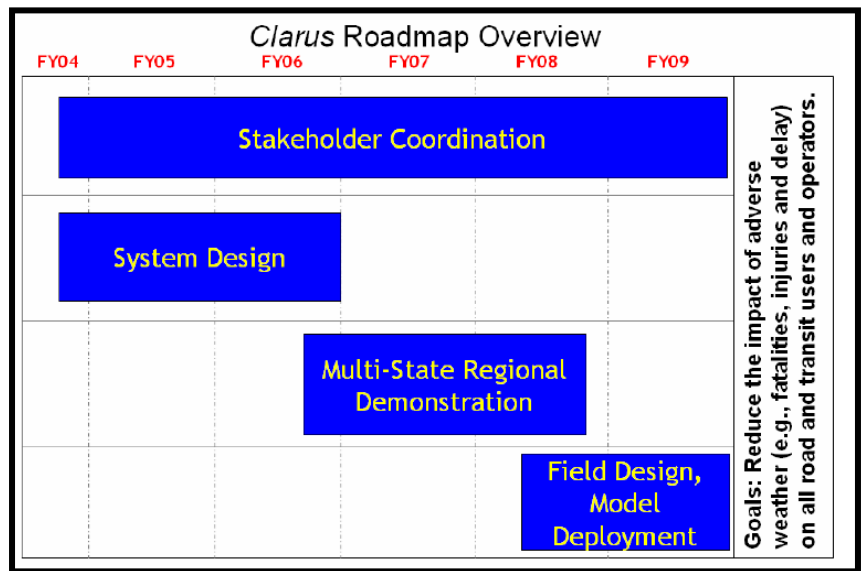
Potential Benefits

- Stable and reliable access to surface transportation weather related observations
- Continuous quality control of observations with direct feedback to transportation agencies
- Standards in data formats, communications and network architectures
- Real-time data for weather and traffic models and decision support systems
- Application of new technologies, such as:
 - Vehicle-based sensors
 - Video cameras for acquiring visibility and road condition information
 - Remote sensors such as low cost, low power, high-resolution weather radars



Milestones

- Establish stakeholder ownership and consensus in system design to support the concepts and objectives of the initiative.
- System Design: Work across the surface transportation and weather communities, build a consensus for a concept of operations, analyze the gaps in present day observation networks, and recommend solutions for an extensible, robust architecture to support 21st Century transportation operations.



- **Demonstrations:** Implement regional multi-state data collection systems with real-time quality control functionality, feedback to transportation agencies and an Internet data portal where both current and archived data can be retrieved.
- **Research:** Create instrumented corridors to promote and test cutting edge observational technologies including fixed, mobile, and remote sensors.
- **Evaluation:** Evaluate and revise the system designs until a blueprint for a deployable nationwide surface transportation weather observing system has been created.
- **Deployment:** Provide support implementation and continued development of the nationwide network. Promote use of the data for new products and services. Educate the users to the advantages of the new products. Monitor the impact on transportation safety and mobility.

Clarus Initiative and Pennsylvania

The Clarus Initiative attempts to create a more complete and reliable weather picture (across state boundaries) by assimilating from a variety of sources, cleansing and checking weather data and disseminating more complete weather data. While this initiative has much merit, the overall program is still in development.

While opportunities may still exist to participate in demonstration projects, it may be more prudent in the short-term to focus resources on reestablishing a reliable RWIS system. The Clarus Initiative should be monitored and participation should be initiated at the appropriate point when reliable data can be provided to RWIS and the Clarus Initiative can return a more complete and reliable weather picture.

Ultimately, Clarus may offer a slight reduction in the total number of RWIS sites needed by filling the voids between sensors by pulling data from other weather sources, vehicles and remotely (e.g., from satellites).

Other considerations:

- The Clarus Initiative is intended to provide a portal for viewing of data, but geospatial and XML subscriptions may provide a more flexible data that can be integrated into PennDOT's operational initiatives.
- Clarus meets a need for data made clearer by the MDSS project while also building on related road weather efforts.

It is worth noting that FHWA anticipates the announcement of a "Collection Incentive Program" to be announced in the summer/ early fall of 2007 that will be available to all U.S. transportation agencies that operate a network with one or more RWIS/ESS who want to contribute data to Clarus. Funds will be provided as a Federal Aid Grant, and funding is based on a sliding scale dependent on the number of RWIS/ESS in the network. This grant opportunity should be explored as it may provide an opportunity to implement future enhancements to the RWIS program as it relates to metadata required for connection

4.2.2 Maintenance Decision Support System¹⁶

The MDSS is a tool that merges weather forecasting with roadway maintenance rules of practice and generates treatment recommendations on a route by route basis.

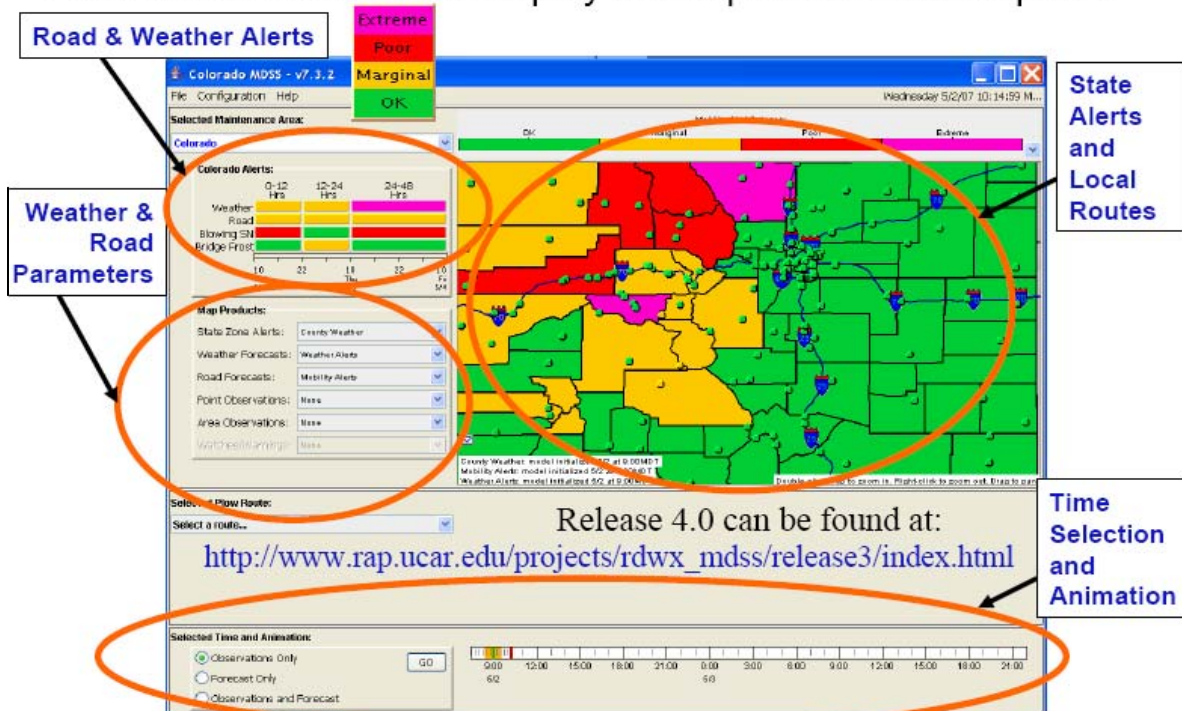
It is anticipated that components of the MDSS system developed by this project will ultimately be deployed by road operating agencies, including state departments of transportation (DOTs), and generally supplied by private vendors.

MDSS Concept

The intent of MDSS is to provide a decision making tool that can be used to assess conditions and validate alternative maintenance decisions.

- Report:
 - Actual road surface conditions
 - Actual maintenance treatments
- Assess:
 - Past & present weather conditions
 - Present state of the roadway
- Predict:
 - Storm-event weather
 - Road surface behavior
- Recognize resource constraints and identify feasible maintenance treatments
- Communicate recommendations to supervisors & workers

The MDSS Main Screen Display is composed of 4 main parts:



Release 4.0 can be found at:
http://www.rap.ucar.edu/projects/rdwx_mdss/release3/index.html

Modules are provided on a non-exclusive basis.

Release 5.0 will be available this Fall.

¹⁶ FHWA, MDSS one-pager and MDSS Road Show

Potential Benefits

Some potential benefits of MDSS include:

- Increased safety
- Decreased user costs
- Decreased work hours
- Decreased material use
- Decreased equipment use
- Decreased environmental impact

Iowa DOT estimates a 10% savings in operation costs equating to \$3 to \$4 million annual savings in labor, materials & equipment based on their demonstration experience.

Some potential costs of MDSS include:

- Costs for software
- Costs for instrumentation
- Increased data processing
- Costs for training

Status

Several states are participating in a MDSS pooled fund study or have purchased or tested privately developed MDSS modules.

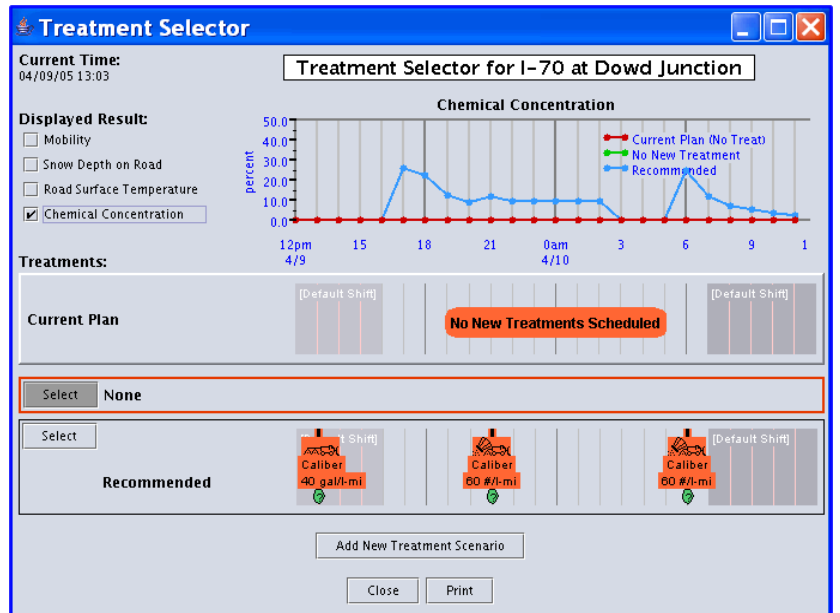
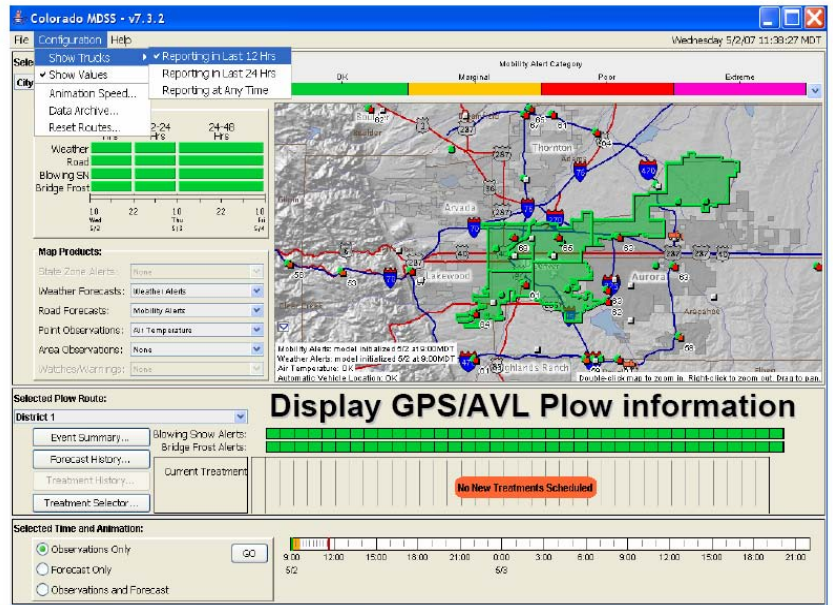
MDSS Pooled Fund participants have been investing in the development of the Meridian Environmental Technology-based MDSS System and membership includes: California, Wyoming, Colorado, Kansas, North Dakota, South Dakota, Minnesota, Iowa, Indiana, and New Hampshire. Pooled-Fund MDSS has not been officially deployed in an operational sense. It is still in a developmental period. However, member states are very close to being ready for reaching this stage. Once the developmental period is complete, PennDOT should consider joining the MDSS Pooled Fund.

State DOTs that purchased the DTN/Meteorlogix Web-based MDSS System (WeatherSentry) for the 2006-2007 winter season include Nevada, Idaho, Wyoming, Nebraska, Iowa, Missouri, Wisconsin, Michigan, Ohio, New York, and Maine.

While many are participating in some MDSS effort, some states responded that they are participating but are taking a “wait and see approach” before investing significant resources and fully deploying MDSS.

In addition to private suppliers, FHWA offers Version 4 of MDSS for free at:

http://www.rap.ucar.edu/projects/rdwx_mdss/release3/index.html. Version 5 is expected to be released in the fall of 2007.





Future plans include the development of operational decision support elements to add in non-winter maintenance, traffic operations and construction management. Timeframes of these enhancements are not readily available.

Maintenance & Operations Decision Support System (MODSS)				
Winter Maintenance Decision Support System (MDSS)	Non-Winter Maintenance Decision Support System (NWMDS)	Traffic Management Decision Support System (TMDSS)	Construction Management Decision Support System (CMDSS)	Other Surface Transportation Decision Support Systems

MDSS and Pennsylvania

MDSS offers an opportunity to enhance winter conditions awareness and to enhance maintenance decisions which were identified by the Independent Report.

Like Clarus, it may be more prudent in the short-term to focus resources on reestablishing a reliable RWIS system as well as additional maintenance training. A reliable RWIS network is fundamental to the success of MDSS.

In the interim, the feasibility of integrating the free version of MDSS should be explored with other web-based solutions being developed by the Department. The complexity of integration may vary depending on the object code for the free version. Once the existing RWIS program has been enhanced, the Department should explore the benefits of participating in the pooled fund study.

Ultimately, MDSS may be a decision making tool that can enhance decision making and supplement winter maintenance training, but integration into other solutions will make it more accessible and result in less dependence on roadway weather products and service providers.



4.2.3 Aurora Program¹⁷

PennDOT is an active member of the Aurora Program. Aurora is an international program of collaborative research, development and deployment in the field of road and weather information systems (RWIS), serving the interests and needs of public agencies. The program, launched in 1996, brings together a number of U.S., Canadian, and European agencies.

The Aurora vision is to deploy RWIS to integrate state-of-the-art road and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures. It is hoped this will facilitate advanced road condition and weather monitoring and forecasting capabilities for efficient highway maintenance, and the provision of real-time information to travelers. Aurora's initiatives are conducted and funded by member agencies for member agencies. PennDOT's membership is approximately \$25K per year.

Selected initiatives are led by "champion" member agencies, managed by committees of Aurora members, and funded out of the Aurora pooled fund. Some related projects (*hyperlink to Aurora Program in electronic version of report*) are listed below. PennDOT's membership in Aurora provides an opportunity to monitor the results of these studies and to participate in research where it is prudent.

Ongoing Aurora Program Projects

Project	Goal	Status
Benchmarking the Performance of RWIS Forecasts	Under this project, a report is being developed that will review the state-of-the-art within the meteorological community in regards to measuring the performance of weather forecasting information, review the current status of RWIS verification efforts by public agencies, establish procedures and parameters that can be used to measure forecast accuracy in any country, and benchmark the accuracy of forecasts provided to member agencies.	Anticipated start Fall 2007
Development of an RWIS Quality Assurance Monitoring System	This project will develop a quality assurance monitoring system that is modular to allow installation with different host organizations and platforms, expandable for incorporating additional quality assurance modules, accessible via the web, and holds historical database of quality assurance reports for future reference.	Not started
Evaluation of Vaisala Spectro Pavement Sensor	The objective of this project is to study the accuracy and usefulness of the new Vaisala Spectro sensor performed under real-world highway conditions.	Testing ongoing
Intelligent Image-Based Winter Road Condition Sensor - Phase III	This project involves a third phase of the intelligent image-based winter sensor project. The first two phases of this project have shown to be very promising and this third phase involves continuing research and movement of the test site to a new location to acquire more research data. In the field tests three neural nets will be used, one day network, one night network and one combined day/night network.	Testing
Low Cost Mobile RWIS	This project involves a third phase of the intelligent image-based winter sensor project. The first two phases of this project have shown to be very promising and this third phase involves continuing research and movement of the test site to a new location to acquire more research data. In the field tests three neural nets will be used, one day network, one night network and one combined day/night network.	Started in 2006
Multiple-Use ITS Data Collection Sites	This project involves a third phase of the intelligent image-based winter sensor project. The first two phases of this project have shown to be very promising and this third phase involves continuing research and movement of the test site to a new location to acquire more research data. In the field tests three neural nets will be used, one day network, one night network and one combined day/night network.	Scope of work under development
Off-the-Shelf Component RWIS	This project involves building an RWIS station with an open architecture to mix different sensors of different constructors. The open RWIS platform will be essential to test the performance of different sensors.	Construction of the site infrastructure has been completed. There is interest in installing a web camera and infrared sensor of traffic to complete the system.
Pilot Test of ESS Sensor Testing Guidelines	The research objectives of this project are to gain real world experience with the implementation of an ESS sensor testing program, to develop a standardized kit for testing ESS sensors, and to develop software/forms that can be used to record test data.	Results forthcoming

¹⁷ <http://www.aurora-program.org/index.cfm>



Project	Goal	Status
RWIS Equipment Monitoring System - Phase II	The objective of this project is to expand the RWIS Equipment Monitoring System by including in-commission rate reports with the percent of time the site was fully operational or degraded, implementing the specific changes to the RWIS data and reporting System proposed by the Aurora member states, evaluating how site performance by sensor can be added to the application, and completing a concept of operations, system architecture, implementation plan, and deployment for ingesting Clarus System quality checking output online.	Just started
RWIS Telecommunication Issues and Options	This project will investigate options to get the data from the RWIS sites to a central location in a significantly less expensive manner.	An evaluation and recommendation phase could be started soon.
Technology Transfer of Alternative Inexpensive RWIS	The purpose of this project is to research, through a proof of concept test, the ability to integrate pavement thermistors to existing atmospheric weather stations and document the application of this new RWIS concept for pavement management and to develop urban sighting guidelines for the addition of pavement sensors to existing infrastructure.	Estimated completion 2008

Projects completed by Aurora were reviewed to assess their impact on the direction of the RWIS program within PennDOT. These projects are below ([hyperlink to Aurora Program in electronic version of report](#)) and should be continued to be utilized as appropriate.

Completed Aurora Program Projects

Project	Goal	Status
Compilation of RWIS Specifications	The first objective of this project was to collect member specifications for the construction of, maintenance of, and/or forecasts at RWIS stations, then to develop a database of these specifications. The second objective was to survey the agencies that had provided specifications to better document and understand the issues associated with administering the various contracts.	Completed
Hot Plate Snow Gauge Demonstration	This project involved testing the utility of a new real-time snow gauge for use in winter road maintenance and possible addition to automated weather stations in the future. The project also tested the utility of the Weather Support for Deicing Decision Making (WSDDM) aircraft deicing/anti-icing nowcast system for winter road maintenance operations.	Completed
Institutional Issues	This project documented various institutional issues encountered by several agencies in the process of planning and deploying road weather information systems or programs, as well as measures taken to overcome these issues. All Aurora members were involved in this project, addressing issues such as public-private partnerships, barriers to implementation, and strategies for deployment. The project was considered an outreach activity, the product of which was a compendium of findings and lessons learned relating to the institutional issues involved in the development and implementation of RWIS.	Completed See Literature Review for Detailed Summary
Integration of Road Weather Information with Traffic Data	This project involved integrating road weather data with traffic flow data in order to quantify the impacts of weather on capacity and flow along urban freeways. The most important conclusion from this project and the findings of other transportation weather researchers is that weather conditions do have an important impact on traffic safety, traffic demand, and traffic flow. The final report also concluded that much more research is needed to measure, understand, and develop management strategies to mitigate the impacts of weather on traffic safety, traffic demand, and traffic flow. Another important conclusion of this work is that if RWIS environmental sensors are going to be of significant value to traffic managers, then they must reliably collect different data elements.	Completed Report available on web-site.
Intelligent Image-Based Winter Road Condition Sensor - Phase II	This project was undertaken to further previous research conducted under the Phase I project. Phase I showed that combining image and other RWIS data resulted in reliably determining road conditions. Since the first phase did not cover trials with illuminated roads at night, this second phase focused on classification of nighttime pictures. Results of this second phase have provided valuable insight into how to design a final version of the sensor system. The initial phase concluded that it was important to move the image-processing prototype to Dalarna University's RWIS test site. In both of the first two phases, analysis of the images was conducted at Dalarna University, rather than in the field. The third phase involves continuing research and movement of the test site to a new location to acquire more research data.	Completed Report available on web-site.
Interjurisdictional Traveler Information Exchange	This project focused on the ability to share weather data jurisdiction to jurisdiction (province or state) and to make weather information more available to travelers. The final report for the project provides a survey of road weather information systems in North American jurisdictions, a review of three systems (including the system architecture), and an evaluation of the financial and economic feasibility of those systems.	Completed Report available on web-site



Project	Goal	Status
RWIS Communications Standards	This effort provided support to the ongoing standards development process for RWIS communications and protocols. Aurora members played a supporting role, providing strategic input and technical expertise in many RWIS areas. As a part of these activities, Aurora prepared an RWIS protocol white paper submitted to the National Transportation Communications for ITS Protocol (NTCIP) Working Group. Aurora worked with numerous other groups; including the FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and NTCIP; as a part of this initiative.	Completed
RWIS Data Integration and Sharing Guidelines	This project was undertaken in order to provide agencies with a guide to fully utilize their own weather data and that of other agencies. This effort involved identifying the level of integration of data from different devices or from different jurisdictions, identifying best practices in integrating RWIS from multiple agencies and the barriers to that integration, and developing a conceptual design for information exchange among various states and different types of RWIS devices.	Completed Report available on web-site
RWIS Equipment Monitoring System	This project provided Aurora member agencies with an automated means of problem identification and reporting for RWIS equipment.	Completed

Aurora Program and Pennsylvania

The Aurora Program provides an opportunity to engage other stakeholders on issues relating to roadway weather management. PennDOT's continued involvement in the Aurora Program provides access to resources and participation in various initiatives.

4.2.4 NTCIP 1204 for RWIS¹⁸

Until recently, agencies deployed RWIS /ESS equipment and data collection procedures as independent and isolated systems. These legacy systems were designed with the vendor retrieving data from the field, reformatting it, and presenting it to the agency. Little or no communication took place between various vendor products. However, as agencies have sought to expand their RWIS networks and provide their road and weather data to all who may benefit from it, the need for RWIS integration and data sharing has grown.¹⁹

The increasing complexity of RWIS deployed by various state agencies has raised many data sharing and integration issues. An early key problem had been the lack of sufficient standards and protocols, resulting in the development of proprietary data formats for transmitting information between the RPU and CPU. Now that standards have been developed and slowly adapted to, the question remains of what to do with incompatible legacy systems from different vendors. Similar to the problem of transferring files from a Mac to a PC, incompatible data formats create difficulty in sharing and exchanging data that has been obtained from different sensor manufacturers. Neighboring agencies with incompatible equipment have historically been unable to share or integrate road and weather data. It is felt that successful RWIS data sharing/integration can offer a variety of benefits:²⁰

- Simplifies the step of gathering data from incompatible devices.
- Minimizes the amount of hardware that must be installed and upgraded.
- Minimizes the number of user interfaces that must be accessed and learned.
- Provides a “free market” approach to acquiring equipment due to the ability of agencies to procure devices from a variety of vendors.
- Better coordination of weather related maintenance activities.
- Better prediction of weather-related maintenance needs.

The NTCIP (National Transportation Communications for ITS Protocol) has developed communications standards for ITS devices including RWIS/ESS. These protocols are advocated for use by the FHWA National ITS Architecture Program.

NTCIP 1204:1998 NTCIP Object Definitions for Environmental Sensor Stations is V01.13 of the standard and includes Amendment 1 V02. NTCIP 1204 defines the data collected from sensors monitoring weather, pavement, and air quality conditions. Together with other related NTCIP standards, NTCIP 1204 allows the integration of devices and products from multiple vendors into a single system using standard communications and data.

NTCIP 1204 Version 2 is currently under development. A User Comment Draft was expected in October 2003; the Recommended Standard was expected in June 2004. Version 2 reflects industry-suggested edits to the data objects and allows the inclusion of new block objects for more efficient data exchange between an ESS and its central system. Other benefits include:

- An easier-to-use document that will facilitate the development of procurement specifications
- Additional data items requested by the community
- Reduced ambiguity.

The RWIS/ESS standards are available at the NTCIP web site:

<http://www.ntcip.org/library/groupstatus/default.asp?groupid=6>

¹⁸Excerpts from ITS Standards Advisory Environmental Sensor Stations (ESS) March 2003 Advisory No. 2

¹⁹ RWIS Data Integration Guidelines, Aurora Program

²⁰ RWIS Data Integration Guidelines, Aurora Program

NTCIP Testing

The purpose of testing the RWIS/ESS standard is to evaluate the completeness, suitability, and effectiveness of its features. The Minnesota Department of Transportation (MnDOT) independently tested NTCIP 1204 with the supporting global standard NTCIP 1201, and related base standards, in May 2001. The overall test results showed that the standard objects, associated message sets, and data definitions used to implement ESS in Minnesota achieved a successful ITS operational deployment.

NTCIP Deployment

With the increasing development of advanced traveler information systems, ESS deployment objectives have begun to encompass a higher level of standards-based integration than was needed for the support of roadway maintenance activities alone. Two states with such ESS deployments are Wisconsin and Washington. In Wisconsin, upgrades will be based on the NTCIP ESS standards to allow for interoperability among devices as well as the ability to control devices such as dynamic message signs. The Washington State DOT used the NTCIP standards to integrate new ESS with legacy, proprietary ESS so that all devices could be controlled by a single server. Query the Contacts Database on the Standards web site for additional deployments.

<http://www.standards.its.dot.gov/StdsSearch.asp>

NTCIP Tools

In addition to the ESS standard NTCIP 1204, there are several other ITS standards that are needed to implement ESS. For brevity we refer to these standards collectively as the ESS standards. Many tools and resources are available to assist those considering standards-based ESS deployments.

- The ESS Standards Application Package is a folder of documents providing an overview of ITS standards and specific information on ESS standards and ESS deployments. Send your request to flood@volpe.dot.gov.
- The NTCIP SpecWizard software helps vendors formulate NTCIP-compatible specifications for ESS procurements. This tool helps users remove many of the ambiguities that often slip into specifications. The SpecWizard is currently available from McTrans. Order by phone at 1-800-226-1013, by fax at 352-392-6629, or online at <http://mctrans.ce.ufl.edu/catalog/>.
- An ESS Specification Guide is currently under development that will address procurement of NTCIP-compliant environmental sensor stations. Guide available on Standards Web site ("What's New"): Mid-April 2003.
- The FHWA Road Weather Management Program has published a brochure, An Introduction to Standards for Road Weather Information Systems (RWIS): Siting Standards, Calibration Standards, Communications Standards. The brochure is available at http://ops.fhwa.dot.gov/weather/publications/rwis_brochure.pdf.
- Examples of state RWIS specifications that cite the NTCIP standards are available on the Aurora Program web site at <http://www.aurora-program.org/matrix.cfm>. Aurora is an international partnership of public agencies working on RWIS.

In addition to NTCIP, there are several other NTCIP standards related to RWIS/ESS noted below (*electronic version of this report includes hyperlinks*).

Standard	Document Title	Description	Type	SDO Status	Comment
NTCIP 1204	Object Definitions for Environmental Sensor Stations (ESS)	Defines data found in road-weather information stations and air quality sensors.	Data Dictionary	Version 1.13 Amendment 1 published Nov 01	Version 2 draft distributed for user comment
NTCIP 1206	Object Definitions for Data Collection and Monitoring (DCM) Devices	Defines the data stored in roadside count stations.	Data Dictionary	Current Status-User Comment Draft	Recommend standard expected in Dec 03
NTCIP 1301	Weather Report Message Set for ESS	Defines messages used to exchange weather and pavement data between centers. Data, such as time, to be used in	Data Dictionary	Current Status-Working Group Draft	Expected to go to User Comment Draft by Dec 03



Standard	Document Title	Description	Type	SDO Status	Comment
		multiple device types including ESS.			
NTCIP 1201	Global Object Definitions	Defines data, such as time, to be used in multiple device types including ESS	Data Dictionary	Published Apr 97	Version 2 in User Comment
NTCIP 1101	Simple Transportation Management Framework	Rules and protocols for organizing, describing and exchanging transportation management information between applications and equipment for interoperability.	NTCIP Base Standard	Published Apr 97 - Amended	To be replaced by NTCIP 1102, NTCIP 1103, and NTCIP 8004
NTCIP 1102	Base Standard: Octet Encoding Rules (OER)	Encoding/decoding rules to prepare data for transmission or to decode data before sending it to an application.	NTCIP Base Standard	Approved Aug 02	
NTCIP 1103	Simple Transportation Management Protocol (STMP)	Rules for exchanging data with little overhead for interoperability of transportation devices operating over limited bandwidth links.	NTCIP Base Standard	Preparing to submit to NTCIP Joint Committee as a recommended standard	Publication expected by Dec 03
NTCIP 8004	Structure and Identification of Management Information (SMI)	Defines how the NTCIP effort defines and registers its data, including how the SNMP MIB information is mapped into the ITS Data Registry.	NTCIP Base Standard	Current Status-Working Group Draft	Balloting expected by Dec 03
NTCIP 2301	Application Profile for Simple Transportation Management Framework (STMF)	Application, presentation, and session layer protocols to provide simple information management services.	Communications Protocol Profile - Application Layer	Published Mar 02	Working Group developing Version 2 draft
NTCIP 2201	Transportation Transport Profile	Defines a transport profile to transmit data when devices are directly connected to the central controller or computer and do not require network services.	Communications Protocol Profile - Transport Layer	Approved, awaiting publication	Publication in 03
NTCIP 2202	Internet (TCP/IP and UDP/IP) Transport Profile	Transport and network layer protocols to provide connectionless and connection-oriented transport services.	Communications Protocol Profile - Transport Layer	Published (Mar-02)	
NTCIP 2101	Subnet Profile for Point to Multipoint Protocol using RS 232	Data link and physical layer protocols applicable to roadside devices.	Communications Protocol Profile - Subnetwork Layer	Published Mar 02	
NTCIP 2102	Subnet Profile for PMPP over FSK Modems	Defines how to communicate over twisted wire using FSK modems.	Communications Protocol Profile - Subnetwork Layer	Approved, awaiting publication	Publication in 03
NTCIP 2103	Subnet Profile for Point to Point Protocol using RS 232	Rules for point-to-point protocol use over RS-232 related circuits for interoperability of devices linked by dial-up circuits.	Communications Protocol Profile - Subnetwork Layer	In ballot	Version 2 in Working Group Draft
NTCIP 2104	Subnetwork Profile for Ethernet	Provides interoperability for devices that communicate over local area network (LAN) interfaces.	Communications Protocol Profile - Subnetwork Layer	Approved, awaiting publication	

In addition to NTCIP, FHWA is presently working the proposed rule for SAFETEA-LU Section 1201, Real-time Monitoring Information Program which identify the data exchange formats for sharing real time information, including weather information, among agencies.

NTCIP for RWIS/ESS and Pennsylvania

FHWA strongly encourages state and local agencies to use RWIS/ESS standards. ESS standards are mature and offer immediate benefits for agencies by:

- Providing interoperability between ESS and other NTCIP-compatible field devices running on common communications channels
- Enabling simplified administration of ESS subsystems.

FHWA suggests that those with legacy RWIS/ ESS systems consider migrating to standards-based RWIS/ESS which will provide both immediate and long-term benefits. **“Open” communication and systems in Pennsylvania would lessen dependence on propriety products and services (allowing for flexibility in procurement and maintenance) as well as allow for easier integration into other operational**

4.2.5 Integration of Emergency and Weather Management into Transportation Management Centers²¹

In February 2006, FHWA completed an assessment of best and proposed practices for the integration of emergency and weather management into TMC's. The report looked at current best practices and provided guidance for future integration. The purpose of weather and emergency integration is to achieve optimal performance of a TMC in managing the transportation system during weather and emergency events in support of their customers' needs.

Weather Needs at TMCs

Weather information that could assist TMC operations comes in many different forms. Generic weather information, such as what you would find on various local and national public television and cable weather news sources, provides a broad view of weather conditions for a very general audience. Other forms of weather information including those available from commercial weather service providers are available that target the surface transportation decision maker with tailored weather information specifically designed to assist the traffic manager. Although the generic weather information can be of some help to TMCs, it is very limited. Moving from generic products to more tailored weather information providers will increase the effectiveness of integration activities discussed in this report where this information is appropriately incorporated within the decision making process.

The potential to reduce or avoid the impacts of weather on transportation system operations provides the rationale for improved weather integration within TMCs.

Often the most effective weather integration will result in the incorporation of weather data and information in a non-intrusive manner into existing TMC operations. These data and information can exist in a background state during periods when fair weather dictates that minor weather impacts on traffic will exist. As integrated weather information systems identify a growing risk of impact on transportation systems, the weather information moves to the forefront of the TMC decision-making process.

Integration

Two approaches are associated with the technical integration of weather information:

- One fundamental approach is visualization of information, e.g. constant display of weather radar or weather satellite images. This allows operators to see where adverse weather may be developing. Visual verification of traffic and traffic response to weather is relied upon to assess the consequences of the weather.
- The second fundamental approach is the combination of observations from a variety of subsystems, visual and non-visual, such as visually made road condition field reports and ESS data.

Decision Making

It is important to consider what traffic management decision options are available within a specific TMC when evaluating its level of weather information integration. A current concept of weather-responsive traffic operations incorporates three mitigation strategies: advisory, treatment, and control. While mitigation addresses one way TMCs use weather information in their operational strategy, this study suggests that in addition to mitigation there are two other operational strategies used by TMCs in support of weather information integration: sourcing and analysis. In operational terms, sourcing relates to how the TMC acquires the information needed, and analysis relates to how the information is applied to current and forecast traffic

²¹ Excerpted from FHWA-HOP-06-090 Final Report Integration of Emergency and Weather Elements into Transportation Management Centers

and road conditions. This section discusses these three operational elements of weather information integration.

- **Mitigation:** Of the three mitigation strategies, advisory is the most widely practiced and integrated. Here advisory not only addresses the users of the transportation system but the operators as well.
- **Sourcing:** Observed success at these TMC sites for weather information integration into traffic operations appears to depend significantly on the continuous and up-to-date source of weather information (tailored to the surface transportation decision makers) operating in the background of traffic operations. Specifically, this relates to the accuracy, content, appropriateness, and availability of the information. As the forecasted weather event materializes and conditions become more critical, there is a seamless and efficient escalation from background information to a primary information source consistent with the types of decisions or activities that need to be taken by the TMC as part of their “standard” operations.
- **Analysis:** At each of the sites visited, analysis strategies were illustrated by the way in which the TMCs integrated, in various ways and at various levels of sophistication, weather information (generic and tailored) into their operational procedures to better prepare for forecasted weather conditions and the likelihood of incidents relating to weather. Analysis strategies are where weather information integration has the most visible impact and potential for improving operational efficiencies. Many of the concepts and strategies described below in this report are directly related to analysis strategies aimed at effective use of weather information.

Weather Integration in the TMC Environment and Pennsylvania

As will be discussed in later sections, Districts in Pennsylvania have various states of TMC's. A plan has been developed for the future layout of District, Regional and State TMC's. Additionally, some Districts have begun to implement ATMS software at TMC's for combined command and control of ITS elements. In the near future, interim TMC's and C2C connectivity will be established where gaps exist. At a higher level, the need to share data between agencies has created the need for an Information Exchange System (IES).

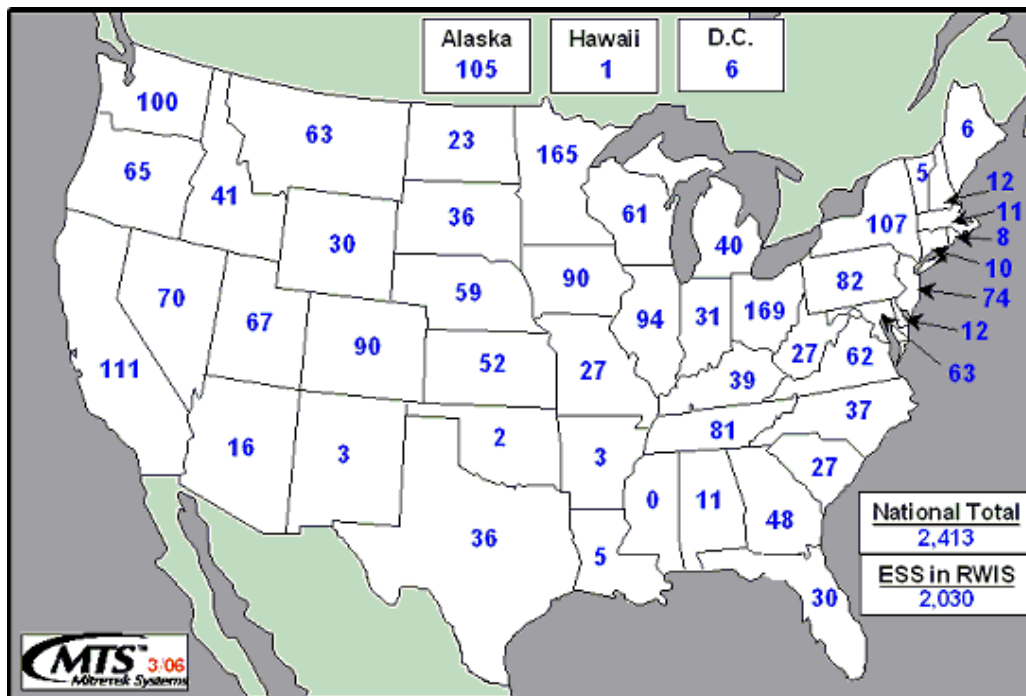
The proprietary nature of RWIS/ESS data may make it necessary to integrate data at a central location before distributing to TMC's. While the ATMS may be a logical location for this integration, ATMS is not fully developed and in place. Unlike other ITS devices, there is no control of RWIS/ESS sites. Also, the usage of RWIS data extends beyond the TMC environment to other users, especially maintenance; therefore, a web-based weather portal may be a more appropriate tool to disseminate weather data.

Enhancements to CCTV (at RWIS sites) may make it necessary to route control through the TMC environment; however, distribution to the public will then need to be addressed as well as security

Additional elements of the report are detailed in **Appendix B**.

4.3 State Practices

Many states have faced similar challenges to their RWIS program that Pennsylvania has faced. Other states that have widely deployed RWIS technologies have begun to deploy NTCIP compliant systems. Other states have integrated RWIS with other roadway weather management systems and solutions and are also gauging involvement in Clarus and MDSS.



Nine states have more RWIS/ESS sites deployed than Pennsylvania. Nationally, Ohio leads all states in RWIS/ESS deployments with 169 sites. This includes a recent expansion of their system including 80 NTCIP compliant sites and an integration with legacy systems. Washington has 100 deployments and has also begun to integrate NTCIP and legacy systems. Additionally, Wisconsin has used NTCIP compliance to integrate RWIS with DMS messaging.

Involvement in the Aurora Program as well as other research activities provides an opportunity for Pennsylvania to identify best practices and lessons learned.

4.3.1 Survey Summary

The development of this study included a review of practices by other states. In particular, reviews were conducted of several state-related RWIS assessments. Additionally, a web-based state of the practice survey was distributed to other state DOT's including state traffic engineering and ITS contacts as well as state roadway weather management contacts. The survey resulted in 26 responses and was used as a basis for follow-on interviews. A summary is provided in this section of the report and a detailed summary is included as Appendix D.



1. What Department of Transportation do you represent?	2. What is your title?	3. What is your name (optional)?	4. What is your phone number (optional)?	5. What is your email address (optional)?	6. Do you mind if PennDOT contacts you regarding your RWIS program?	7. How many RWIS sites do you have deployed?	8. How many staff positions are assigned to your RWIS program?	Sites Per Staff Position	9. What department manages your RWIS program?	10. What is your annual operations and maintenance budget?
Open-Ended Response	Open-Ended Response	Open-Ended Response	Open-Ended Response	Open-Ended Response	Yes/ No	Adjusted Data	Adjusted Data	Calculated Data	Adjusted Data	Adjusted Data
Arizona	State Traffic Engineer	Mike Manthey	602 712-8888	mmanthey@azdot.gov	No	20	NA	NA	Operations	NA
California	Senior Transportation Electrical Engineer	Steve Hancock	916-654-6007	steve.hancock@dot.ca.gov	No	106	1	106	Both	NA
Delaware	TMC Operations Manager	Gene Donaldson	302-659-2401	gene.donaldson@state.de.us	No	10	NA	NA	Operations	NA
Idaho	Winter Maintenance Coord.	Kent Wetzstein	(208) 334-8472	kent.wetzstein@itd.idaho.gov	No	33	1	33	Maintenance	\$50,000
Indiana	Snow and Ice Supervisor	Kirk Carpenter	317-234-5048	kcarpenter@indot.in.gov	No	28	2	14	Maintenance	NA
Iowa	RWIS Coordinator	Tina Greenfield	515-233-7746	tina.greenfield@dot.iowa.gov	No	58	1	58	Maintenance	\$150,000
Kansas	Staff Engineer	Peter Carttar	785-296-3576	carttar@ksdot.org	No	53	1.5	35	Both	NA
Kentucky	Transportation Engineer Branch Manager	Glenn Anderson	502-564-3020	glenn.anderson@ky.gov	No	39	0	NA	Both	NA
Maine	ITS Program Manager	Clifton Curtis	207 624-3600	clifton.curtis@maine.gov	No	6	0.5	12	Maintenance	\$20,000
Michigan	Traffic and Safety Engineer	Dawn Gustafson	906-786-1800	gustafson@michigan.gov	No	NA	NA	NA	NA	NA
Mississippi	State Traffic Engineer	Wes Dean	601-359-1454	wdean@mdot.state.ms.us	No	NA	NA	NA	Operations	NA
Montana	Traveler Information Coordinator	Brandi Hamilton	406-444-0468	brhamilton@mt.gov	No	66	NA	NA	Multiple	\$100,000
Nebraska	Maintenance Engineer	Dalyce Ronnau	402-479-4544	dronnau@dor.state.ne.us	No	60	NA	NA	Operations	\$125,000
New Hampshire	Special Projects Manager	Stephen Gray	603 271-4185	sgray@dot.state.nh.us	No	12	NA	NA	Both	NA

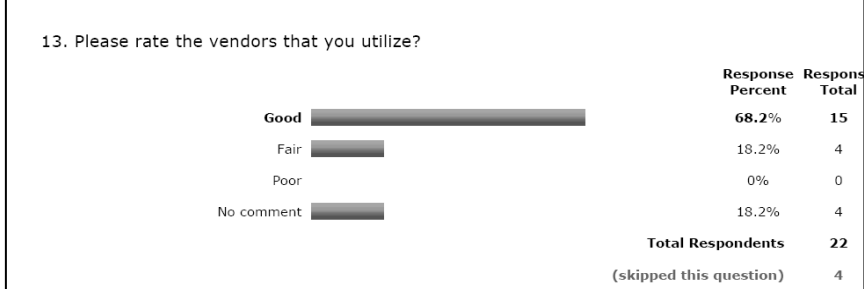
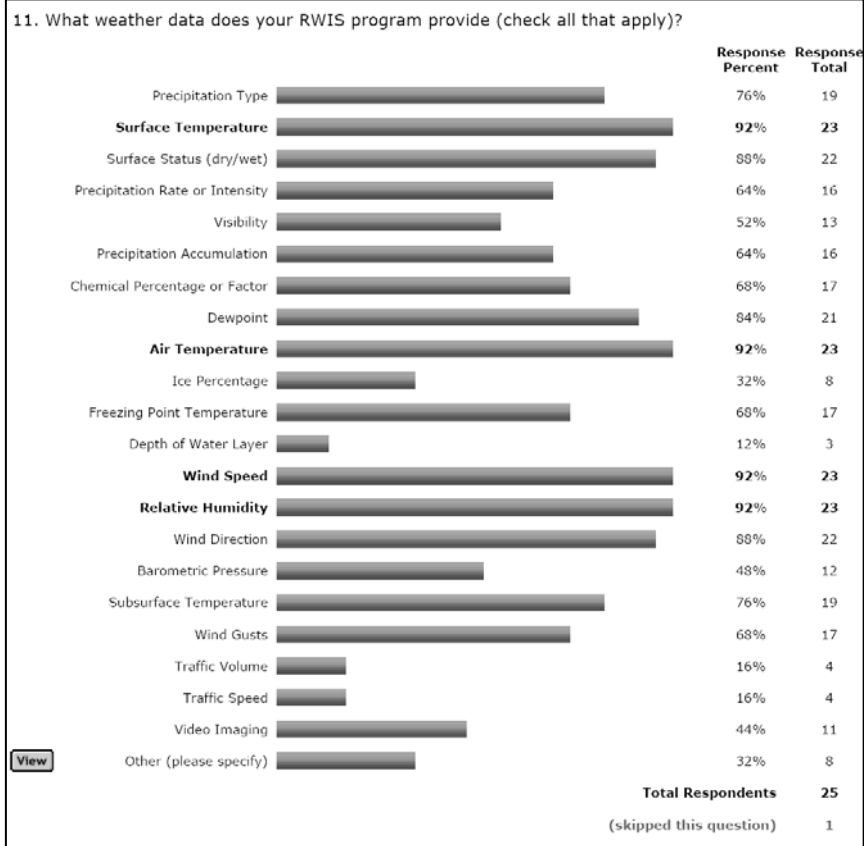


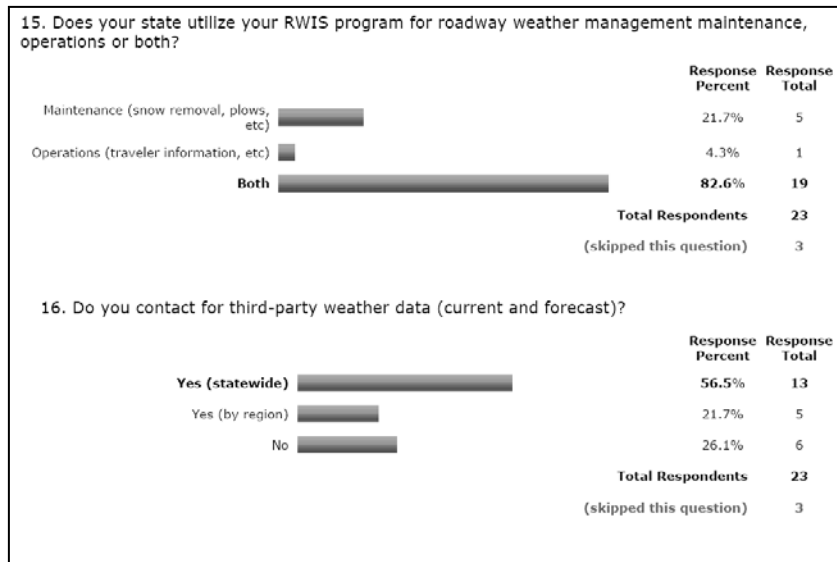
1. What Department of Transportation do you represent?	2. What is your title?	3. What is your name (optional)?	4. What is your phone number (optional)?	5. What is your email address (optional)?	6. Do you mind if PennDOT contacts you regarding your RWIS program?	7. How many RWIS sites do you have deployed?	8. How many staff positions are assigned to your RWIS program?	Sites Per Staff Position	9. What department manages your RWIS program?	10. What is your annual operations and maintenance budget?
North Dakota	ITS Engineer	Ed Ryen	701.328.4274	eryen@nd.gov	No	23	2	11.5	Maintenance	\$25,000
Ohio	RWIS Coordinator	Abner Johnson	614-466-4859	abner.johnson@dot.state.oh.us	No	169	13	13	Maintenance	\$80,000
Rhode Island	Chief Highway Maintenance Supervisor	Thomas Kesson	-222-2378 Ext. 4	tjkesson@dot.ri.gov	No	9	1	9	Maintenance	NA
Nevada	Asst. Chief Operations Engineer	Denise Inda	775-888-7867	dinda@dot.state.nv.us	No	70	NA	NA	Both	\$280,000
Utah	Weather Operations/RWIS Manager	Ralph Patterson	801 887-3735	ralphpatterson@utah.gov	No	58	5	11.6	Weather Operations	\$300,000
Virginia	Senior ITS Engineer	Gene Martin	804-786-4168	e.martin@vdot.virginia.gov	No	42	1	42	Operations	\$500,000
Washington	State ITS Operations Engineer	Bill Legg	360 705 7994	legg@wsdot.wa.gov	No	91	NA	NA	Operations	\$273,000
West Virginia	ITS Coordinator/System's Mgmt Engineer	Bruce Kenney	304 558 9449	Capitol Complex, Bldg 5, Rm 550, Charleston WV 25313	No	0	1	0	Operations	\$100,000
Wisconsin	RWIS Program Manager	Mike Adams	608-266-5004	michael.adams@dot.state.wi.us	No	57	1	57	Operations	\$300,000
Summary							31 Total	13 Avg		\$175,250 Avg

1. What Department of Transportation do you represent?	Yearly Expenditure Per Site	17. What third-party weather providers do you utilize?	18. Is RWIS data integrated with other third-party data?		MDSS Status of Respondants (from Ray Murphy of FHWA)	19. Has your agency considered any public-private partnerships for more effective roadway weather management?	
			Adjusted Data	Open-Ended Response		Adjusted Data	Open-Ended Response
Open-Ended Response	Calculated Data	Open-Ended Response	Adjusted Data	Open-Ended Response	Supplied	Adjusted Data	Open-Ended Response
Arizona	NA		No		Unknown		
California	NA	varies region by region	No		Meridian Environmental MDSS - pooled fund	No	
Delaware	NA				Unknown	No	
Idaho	\$1,500.00	We did not have good success with third party weather providers.	No		Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Indiana	NA		Yes		Meridian Environmental MDSS - pooled fund	No	
Iowa	\$2,600.00	DTN/Meteorlogix Meridian Environmental Technologies	Yes	They both use our RWIS to provide pavement temperature forecasts and they both have current RWIS obs on some of their weather maps on their websites.	Participating in pooled fund but utilizing DTN (Weather Sentry)		I don't know
Kansas	NA	DTN provides site-specific forecasts and statewide forecasts and Meridian provides statewide radar.	Yes	RWIS feeds our 511 system which integrates RWIS, road condition reporting and forecasts	Meridian Environmental MDSS - pooled fund		
Kentucky	NA	Accuweather provides images for kiosks but this is not part of the RWIS program	Yes	Data is ingested into NOAA MADIS	Unknown	No	
Maine	\$3,300.00	DTN Meteorlogix	Yes	We have incorporated the RWIS stations to compare to their pavement forecasting.	Utilizing web-based MDSS by DTN (Weather Sentry) -analysis lead for B/C	No	
Michigan	NA		No		Utilizing web-based MDSS by DTN (Weather Sentry)		
Mississippi	NA				Unknown		
Montana	\$1,500.00	Northwest Weather Net (contracted through Meridian I believe)	Yes	RWIS data integrated with Northwest Weather Net. Also integrated with 511 to provide roadway specific forecast information.	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Nebraska	\$2,100.00	Not certain, this is handled by the districts	Yes	It is used for our 511 and Road Condition Reportings system	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
New Hampshire	NA	Home Time Weather Forecasting Nashua, NH	No	Currently is not for weather forecast but is being shared with Plymouth Stae University meteorology department.	Meridian Environmental MDSS - pooled fund	No	No interest yet from third parties but department would consider any proposals that might be put forth.



1. What Department of Transportation do you represent?	Yearly Expenditure Per Site	17. What third-party weather providers do you utilize?	18. Is RWIS data integrated with other third-party data?		MDSS Status of Respondants (from Ray Murphy of FHWA)	19. Has your agency considered any public-private partnerships for more effective roadway weather management?	
North Dakota	\$1,100.00	Meridian Environmental Technology, Inc.	No		Meridian Environmental MDSS - pooled fund	Yes	We are currently involved with a multi-state MDSS pooled fund study that is a partnership with a private company.
Ohio	\$500.00	1. Meridian Environmental Technology, Grand Forks, N.D. 2. DTN/Meteorlogix, Minneapolis, Mn.	?	Question is unclear. Our RWIS data is ingested by the NWS and our weather service vendor and used in our forecasts.	Utilizing web-based MDSS by DTN (Weather Sentry)	Yes	See Question 17.
Rhode Island	NA	Private local weather forecast.	No	Our private weather service can access our web page.	Unknown	Yes	Rhode Island Turnpike & Bridge Authority has two RPU's on the Pell Bridge, and will share the data. The Providence Water Supply Board is looking into adding a RPU inside the Scituate Water Shed area.
Nevada	\$4,000.00	Northwest Weathemet provides a weather forecast that is road and crew specific. It is specifically tailored to our winter maintenance procedures.	Yes	NW Weathemet gets our RWIS data and utilizes it in their forecasting. We are working to improve the data sharing and pavement temperature forecasting for next winter.	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Utah	\$5,200.00	We use NorthWest Weathemet... We have their forecasters (hand picked) stationed inside our TOC facility.	Yes	Only to the affect that they use it in their operations to help them provide better service to me. We also have been known to use their Meteorologists in the field working on stations or assisting in RWIS deployment siting...	Unknown	Yes	As previously stated we have or Vendor supply the forecasters who work under my direction... We also let them forecast for adjacent states out of my office to help us offset costs of having an inhouse staff...
Virginia	\$11,900.00		No		Pursuing Meridian Environmental MDSS - pooled fund	No	
Washington	\$3,000.00	We use NW Weathemet to provide customized regional forecast as needed on an on-call basis.	Yes	The 3rd party mentioned above receives our RWIS data.	Unknown	Yes	We are a member on two of the recently announced CLARIS initiative project selection. We view this as a public-private partnership. Also, we will provide our RWIS data to anyone who needs it at now cost.
West Virginia	NA				Unknown		
Wisconsin	\$5,300.00	Meridian Environmental, Meteorlogix.	Yes	Limited MDSS from Meteorlogix.	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Summary	\$3,445 Avg \$5300 Max		40% Yes 9 total			17% Yes 4total	





4.3.2 Best Practices and Lessons Learned

Program Management

- Like many other initiatives, states are divided as to where RWIS program management should reside. 83% of survey respondents noted that RWIS is used for both maintenance and operations. Additionally, of the survey respondents eight have “Operations” manage their RWIS sites, seven have “Maintenance” manage their RWIS sites, six have multiple divisions manage their RWIS sites and Utah has a “Winter Operations” division.
- Staff assigned to the program ranged from one to 13, but the overall sites per staff member was approximately 13 RWIS sites/ staff.
- Average annual maintenance budgets averaged \$175K. This was for maintenance activities and did not include upgrades and major deployments. Maintenance per site ranged from \$500 to \$11,900 with the average being \$3,500 and more reliable (based on research and surveys) programs spending \$5,000.
 - Many noted issues and responsiveness associated with proprietary vendors as a concern. The Aurora Program provides sample maintenance contracts for member use.

Integration of RWIS Data with Other Systems

- Some states (Ohio, Washington, etc) have begun to deploy NTCIP compliant systems. These systems may include NTCIP compliant RPU (remote processing units) at RWIS sites as well as integration servers (or integration contracts) at the server and data management end. NTCIP compliance has resulted in operational flexibility with other systems.
- 77 percent of states contract for other weather forecasting services with more than half contracting for statewide coverage.
- 40 percent of states integrate RWIS data with other weather information and information systems.
 - Nebraska integrates RWIS into their Road Condition Reporting System as well as 511.
 - Kansas and Montana integrate RWIS into 511.
 - Idaho noted issues with RWIS data integration into third party systems.
- Many states are considering MDSS involvement, but statewide and wide scale deployment has not occurred. Most MDSS deployments have occurred on a local level.
 - Wisconsin noted concerns regarding their MDSS experience and concerns regarding integrating AVL.

Deployment Architecture and Configuration

- Most states surveyed have experienced similar proprietary issues associated with legacy RWIS systems and are migrating to an NTCIP compliant system when possible.
- Most states surveyed are utilizing FHWA's ESS Siting Guidelines for device configuration (layout, sensors, power and communication).

Deployment Considerations

- Limited guidance exists on deployment guidelines. The FHWA ESS Siting Guidelines notes a 2.5 mile (4 km) separation may be desirable to contribute to more accurate weather forecasts, but also notes that doing so may be cost prohibitive and therefore suggests a spacing of approximately 20-30 miles (30-50 km) as a guide.
- Nevada utilized Vaisala's thermal mapping service for RWIS siting.
- Wisconsin locates RWIS at trouble spots, but also attempts to co-locate with other ITS devices.
- Kansas deploys at regular intervals and trouble spots.
- Based on Ohio's RWIS Assessment, Iowa, Minnesota and Wisconsin all deploy at less than 30 mile intervals.

4.4 Vendor Practices

Each of the four vendor's studied has similar RWIS sites. Each site contains the following: atmospheric and pavement sensors, remote processing units to read the sensors, and data transmission devices to send information back to a central processing unit. These three components make up the RWIS system. The end user is provided with real-time weather data and road surface condition data.

4.4.1 Vendors

There are four major RWIS vendors in the United States:

- Quixote (SSI & Numetrics) <http://www.qttinc.com/>
- Boschung <http://www.boschungamerica.com/pages/aboutUs.php>
- Vaisala <http://www.vaisala.com/>
- Campbell Scientific <http://www.campbellsci.com/index.cfm>

Other vendors that provide RWIS/weather stations can be found at <http://ops.fhwa.dot.gov/weather/wmv/rwis.cfm>. The four vendors discussed in this section are the leading manufacturers of RWIS sites. Quixote Transportation Technologies and Campbell Scientific are American companies. Vaisala is a Finnish corporation with five manufacturing sites in the United States, and Boschung is based in Switzerland. Each vendor manufactures their own components. Atmospheric sensors utilized at the RWIS sites are the only component that is occasionally outsourced to another company.

4.4.2 Key Sensors

One of the items that distinguish one company from the other is their sensors. Sensors are generally broken down into three categories: atmospheric, non-atmospheric, and pavement sensors.

Atmospheric Sensors

Atmospheric sensors measure current weather conditions in the air. All of the vendors examined in this report had atmospheric sensors to measure the following:

- Temperature
- Humidity
- Dew Point
- Pressure
- Visibility
- Wind speed and direction
- Precipitation accumulation and identifier



Non-Atmospheric Sensors

Non-Atmospheric sensors are any additional devices connected/ mounted to the RWIS sites that do not collect atmospheric weather data. Some examples of non-atmospheric sensors are PTZ cameras, temperature depth probes, and remote microwave traffic sensors which detect the presence and measures traffic parameters in multiple independent lanes.



Pavement Sensors

Pavement sensors measure roadway surface temperature and condition. Pavement sensors are categorized as either active or passive sensors. An active sensor is one in which the sensor emits an energy source to illuminate the target. The most common active remote sensing system is radar imagery but microwave radiometry, altimetry and scatterometry are also used. Most active systems operate in the microwave portion of the electromagnetic spectrum which makes them capable of penetrating the



atmosphere under virtually all conditions. Passive sensors read reflected or emitted radiation of a target which occurs naturally when the target reflects sunlight or emits thermal energy. These types of sensors are multispectral scanners, radiometers, and spectrometers. In the case of passive remote sensing applications, optical infrared and thermal infrared of the electromagnetic spectrum are generally utilized.

The table below displays sensors available for each vendor's RWIS sites.

Weather/Roadway Element	Data Currently Collected by PennDOT	Desired Data by PennDOT	Required Sensors	Quixote	Boschung	Vaisala	Campbell
Air Temperature	√	√	Thermometer	√	√	√	√
Water Vapor (Dew Point or Relative Humidity)	√	√	Hygrometer	√	√	√	√
Wind Speed and Direction	√	√	Conventional and Sonic Anemometer and Wind Vane or combined sensor (Aerovane)	√	√	√	√
Pavement Temperature, Pavement Freeze Point Temperature, Pavement Condition, Pavement Chemical Concentration	√	√	Pavement Sensor	√	√	√	√
Subsurface Temperature	√	√	Subsurface Temperature Probe	√	√	√	√
Subsurface Moisture			Subsurface Moisture Probe				√
Precipitation Occurrence	√	√	Rain Gauge, Optical Present Weather Detector	√	√	√	√
Precipitation Type	√	√	Rain Gauge, Optical Present Weather Detector	√	√	√	√
Precipitation Intensity		√	Rain Gauge, Optical Present Weather Detector	√	√	√	
Precipitation Accumulation		√	Rain Gauge, Optical Present Weather Detector, Hot-Plate Type Precipitation Sensor	√	√	√	√
Snow Depth		√	Ultrasonic or Infrared Snow Depth Sensor	√	√	√	√
Visibility	√	√	Optical Visibility Sensor, Closed Circuit Television Camera	√	√	√	
Atmospheric Pressure	√	√	Barometer	√	√	√	√
Solar Radiation			Solar Radiation Sensor		√	√	√
Terrestrial Radiation			Total Radiation Sensor				
Water Level			Pressure Transducer, Ultrasonic Sensor, Float Gauge, or Conductance Sensor	√			√
Displays of Current Traffic and Weather Conditions		√	PTZ Cameras	√	√	√	
Presence of Fog and Frost			Fog and Frost Detection System or Bofog Sensor		√		
Leaf Wetness			Wetness Sensing Grid or Leaf Wetness Sensor				√
Formation of Ice			Ice Camera	√			
Detection and Measurement of Traffic Parameters		√	Remote Microwave Traffic Sensor	√			

4.4.3 Data Communications

As stated in section 4.2.4, the NTCIP (National Transportation Communications for ITS Protocol) was developed as a communications standard. It was developed because of the growing number of ITS devices installed by proprietary vendors. When these ITS devices, like RWIS, were interconnected with one another they produced break downs in data processing. Each vendor's products were speaking in their own language and not a universally understandable language. The NTCIP requires all vendors to manufacture products with an open-architecture. The table below displays which vendors products are NTCIP compliant.

Vendor	NTCIP Compliant	Product Information	Compliant RPU Models
Quixote	YES	SSI RWIS products are NTCIP-ESS compliant and have been tested by an independent testing authority.	Linux RPU
Boschung	YES	All Boschung RWIS features are NTCIP compliant.	N/A
Vaisala	YES	Vaisala conforms to NTCIP in the U.S. and the ERU protocol in Spain.	DMC586(M)
Campbell Scientific	YES	Campbell Scientific ESS is fully NTCIP compliant.	N/A

NOTE: In regards to NTCIP compliancy, analysis, specification, and testing still need to be completed on each product to assure the fulfillment of project requirements.

4.4.4 Services and Other Products

Each vendor provides a number of software packages to view RWIS data. The software packages include web-based and PC software platforms. Most vendors provide additional software packages that can be integrated with their RWIS software to enhance user capabilities. Anti-icing technology is commonly combined with RWIS stations to determine when anti-icing fluids should be deployed. Companies, such as Vaisala, are using RWIS sites to create thermal mapping and to manage winter treatment for roadways. The table below will examine each vendor's RWIS software and other products relating to inclement weather conditions.

Vendor	Service/Other Product
Quixote	SCAN PC – a software platform that allows the user to view RWIS data from a stand-alone PC. Data can only be viewed by 5 users at one time.
	SCAN WEB – uses a standard web interface to display RWIS data. Data can be viewed from all pavement and weather sensing devices on RWIS as well as anti-icing spray systems, video cameras, traffic monitoring devices, and other sensors. Retains historical weather data to better predict weather trends.
	RWIS ONLINE – provides server hosting, data acquisition costs, and system maintenance. Users can access RWIS data from the password protected web site.
	IntelliZone Motorist Information Software – is an ITS software platform that allows users to manage and deliver real-time messages to motorists in advance of inclement weather or traffic congestion. The software automatically accumulates sensor data and automatically updates dynamic message signs.
	AdvanceWarn Traffic Warning System – is a system that utilizes traffic monitoring sensors, RWIS data, highway advisory radio (HAR), and variable message signs (VMS). The system analyzes weather conditions and automatically updates VMS and HAR.
	Hydroplane Detection/Alert System – manages traffic flow during and after heavy rains by utilizing variable message signs to alert motorists of the upcoming hazard. The system detects ponding water with roadway sensors.

Vendor	Service/Other Product
Boschung	BORRMA – a software platform that allows the user to view RWIS and FAST systems data. Produces real-time information with data storage capabilities for future inquiry.
	BORMMA Web – is a web based platform that displays RWIS and FAST systems data. Produces real-time information with data storage capabilities for future inquiry.
	FAST (Fixed Automated Spray Technology) – is an anti-icing spray system that uses active and passive sensors which are imbedded in the road surface to spray anti-icing fluid on the road surface. FAST systems can be used in coordination with RWIS sites.
	microFAST – uses the same technology as the FAST system except there is less hardware and core drilling of the roadway.
	MDSS (Maintenance Decision Support System) – uses information from RWIS sites, spreader and plow vehicles, mobile road condition sensors, and local forecasts to produce a pro-active treatment recommendation prior to inclement winter weather. This technology is expected to be partially on line by the winter of 2007-2008.
Campbell	BlackTop PC Software – is a web-based platform that provides customer management of data collection and display of atmospheric weather, road surface conditions, custom units of measure, and alarm notifications.
Vaisala	IceView - highly configurable viewing platform displaying <i>IceCast</i> sensor and forecast data.
	IceUpdate – is the communications component of the <i>IceCast</i> suite. The software automatically updates and collects up to 14 days of data.
	IceWeb - creates HTML pages from standard, pre-defined <i>IceCast IceView</i> displays.
	IceMan - is a password-protected, web-based centralized database for winter maintenance service operations. Some of the software's features are the monitoring of winter maintenance and the planning of specific routes for maintenance vehicles.
	IceAlarm – is an alarm system that complements other <i>IceCast</i> software. Alarms can be set for rising wind values and falling surface temperatures.
	IcePager – is an add-on to <i>IceAlarm</i> which forwards an alarm to designated users.
	IceLog - displays and archives a one-page summary of actual and forecasted surface conditions over the previous 24 hours.
	IceCast Thermal Mapping – is software capable of identifying patterns of temperature variation along a road network. Thermal mapping is created by measuring the spatial variation in the minimum night-time road surface temperature.
	TimeStep Thermal Map – offers an hour-by-hour representation and identifies expected changing temperature patterns of a road.
IceCast Route Optimization service – is an impartial and comprehensive winter maintenance consultancy service. It specializes in the development of winter treatment routes to reduce cost and reallocate resources.	

4.4.5 Weather Forecast Providers

RWIS provides weather data at specific locations but does not provide a general weather forecast. To improve the prediction of changing road conditions, weather forecasters can be utilized in coordination with RWIS to fill in the missing data between RWIS sites. Several of the leading weather forecast providers were examined: NorthWest WeatherNet, AccuWeather, DTN/Meteorlogix, and Meridian Environment. Each of the vendors provides similar services:

- 24-hour access to meteorologists
- Site specific weather risks
- Frost and ice formation forecasts
- Advanced warning of pending winter storm
- 24-hour emergency and alert notification
- Real-time weather forecasts and reports
- Web-based software platforms
- Historical weather data
- MDSS system (except for AccuWeather)

AccuWeather

AccuWeather provides products and services to a number of customers: media, utilities, highway departments, emergency management agencies, etc.

Services/Products
Transport Pro – make critical routing decisions using comprehensive, localized weather forecasts.
Consultation Service – make critical decisions after consulting with meteorologists.
SelectWarn – identify threats with timely warnings.
Storm Hawk – ensure the safety of your workers with portable radar.
SkyGuard – enhance safety and reduce costs with mission-critical alerts of weather related business threats.
Snow Warning Service – prepare for winter storms with advance snow and ice warnings.
Severe Weather Digest - Provides storm reports depicting where large hail, high winds, tornadoes, and flooding have occurred.
Forensics – Recreates past weather conditions and offers site specific weather analysis through historical weather research.

DTN/Meteorlogix

DTN/Meteorlogix provides custom weather solutions and information designed to meet the needs of their customers. Their customers include: agricultural, energy, utilities, aviation, and transportation agencies.

Services/Products
RoadCast – provides accurate pavement temperature forecasts without the costs of additional road sensors and RWIS sites.
MxVision WeatherSentry Transportation Edition – encompasses crew scheduling, snow/ice fight strategies, 24/7 weather alert, and storm management.
MxAnalyst – incorporates GIS mapping into real-time weather forecasting.
MxInsight GeoSpatial Systems – integrates weather data with the user’s operational maps and traffic information management operations.

NorthWest WeatherNet

NorthWest WeatherNet provides customized weather reports for each of their customers. Their customers include media, construction firms, agricultural agencies, government agencies, and engineering firms.

Services/Products
Northwest provides route and site specific road weather services. Weather information is customized for each agency. Weather information can be accessed using their website, email, phone, or fax.
24/7, 365 day-a-year phone consultation
24 Hr Emergency Alert Notification – customer will be contacted in case of emergency

Meridian Environmental

Meridian Environmental provides customized weather data to their customers. Government agencies are the primary customers of Meridian Environmental although several private entities utilize their services.

Services/Products
ROADPRO – provides customized weather forecasting for each customer; the customer can acquire significant or minute weather information in regards to their needs. Forecasts are delivered over the web at times specified by the customer.
24/7 meteorologist service

5. Stakeholder Perspectives and Needs

The study team engaged key stakeholder through a variety of approaches in order to identify perspectives and needs. These perspectives and needs were utilized to guide suggested actions.

5.1 Working Group SWOT

The study working group conducted a SWOT (strengths, weaknesses, opportunities and threats) exercise on April 3, 2007. The following summarizes that exercise:

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ Available data ▪ CCTV – picture snapshot ▪ 70+ sites ▪ Public awareness of roadway weather ▪ Independent Report’s findings and recommendations ▪ Value to multiple areas/ departments ▪ TSOP focus ▪ Growth potential 	<ul style="list-style-type: none"> ▪ Public scrutiny ▪ Independent sites ▪ Different technologies ▪ Impedance mismatch (data between systems does not match) ▪ Lack of resources ▪ No clear maintenance owners ▪ Lack of enterprise solutions ▪ Equipment performance ▪ Communications system
Opportunities	Threats
<ul style="list-style-type: none"> ▪ Enterprise solutions/ integration (511, MDSS, RCRS, STMC, asset management) ▪ Improved reliability ▪ Incorporation of standards ▪ Promoting of public acceptance ▪ Partnerships ▪ Better resource utilization ▪ Performance metrics ▪ Identifying functional requirements ▪ Varying data formats ▪ Developing a business practice ▪ Staff training and education ▪ Project piggybacking ▪ Operations funding and mainstreaming 	<ul style="list-style-type: none"> ▪ Budget ▪ Lack of resources ▪ Poor maintenance ▪ Timing – before functional requirements ▪ Lack of interagency/ interdepartmental coordination ▪ Another February 14th ▪ Uninformed stakeholders (lack of experience, understanding, training) ▪ Lack of usage ▪ Apathy ▪ Legislated data requirements ▪ Lack of statewide direction and control

5.2 Management Interviews

Affected Bureaus and key executive management were engaged to solicit their perspectives as they relate to the RWIS program as well as roadway weather management. The following section summarizes the key management that participated in interview sessions.

Tucker Ferguson Bureau of Maintenance and Operations April 10, 2007

- Mr. Ferguson was involved in some of the initial deployments under a previous position. He provided the following insights in historic RWIS deployments.
 - 25-30 sites were deployed initially
 - These locations were selected as weather ‘trouble’ spots
 - Actual site locations were dependent on nearby communication networks
- If functional, RWIS provides a useful maintenance and operations decision making tool.
- If functional, RWIS can be a useful public information tool.
- The Department needs a game plan for maintenance, contracting and funding.



- Staff needs convinced to use (a functional) RWIS program as well as supporting systems such as MDSS.
 - Need to restore confidence in the system
- There are three potential threats
 - Another Valentines Storm
 - System reliability
 - A system that provides unreliable data
- The Department needs a tool that brings RWIS together with other information such as contract weather data.
- An on-site meteorologist may not be feasible in the near future.
- RWIS and other support systems could be integrated with the current Weather Fleet AVL pilot underway using the 800 MHZ system.
 - PennDOT has completed the proof of concept and Phase II will be piloted in District 8-0.
- Ultimately, all Commonwealth data needs to be located in the GATIR system.
- What are other states doing?
 - Deployment guidelines?
 - Types of sensors?
 - Number of in-lane sensors?
- Pan-tilt-zoom (PTZ) cameras would be a good upgrade.
- Active sensors are preferred. Active sensors physically react to a condition versus passive sensors that electronically detect a condition.
- Mr. Ferguson noted that all recommendations would be considered with regard to system management and partnership opportunities.
 - In general, RWIS should be a Central Office initiative.
- Could the RWIS program be partnered with TV stations?

Craig Reed
Bureau of Highway Safety and Traffic Engineering
April 13, 2007

- The future direction of RWIS needs to consider the Clarus Initiative.
- More (enhanced) video would be useful for operational initiatives. Color and pan-tilt-zoom (PTZ) capabilities would be useful upgrades.
- The study should determine what and how many sensors are required.
- The RWIS program should be coordinated with other Transportation Systems Operations Plan (TSOP) initiatives.
- RWIS as well as all operational initiatives need a dedicated funding stream.
 - Appropriation 140 provides \$22 million per year for operational initiatives.
- The future direction of RWIS needs to be coordinated with the statewide telecommunications plan.
- RWIS needs to be integrated into maintenance training programs.
- The RWIS plan needs to provide deployment guidelines?
 - Should they be deployed at trouble spots or at regular intervals?
- RWIS data needs to be integrated with other weather data.
- RWIS and weather data needs to be provided at district, regional and the statewide traffic management centers (TMCs).
- Future maintenance decisions need to be coordinated (collocated) with operations so that roadway weather advisory and maintenance are coordinated.
- Privatization opportunities can be considered, but they don't always result in more cost effective and efficient practices.
- Performance standards for roadway weather management are needed.
- Speed and volume data could be valuable for other operational initiatives

Joni Sharp and Leslie McCoy
Bureau of Planning and Research, Transportation Planning Division
April 18, 2007

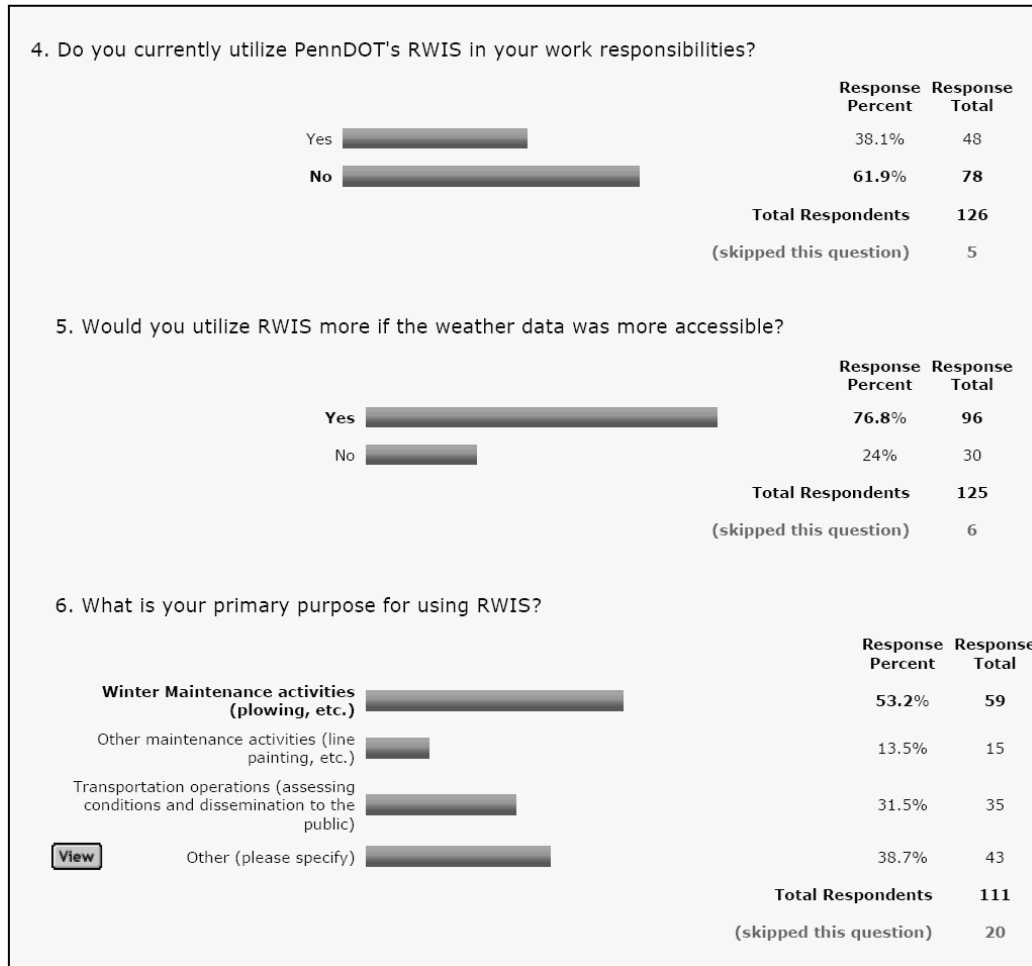
- Speed and volume data from RWIS could help support the Transportation Planning Division.
 - Data would need to have a tolerance of no greater than two percent.
 - Data archiving would be needed.
- There may be an opportunity to collocate sites in the future.
 - Guidance would be needed on maintenance responsibilities.
- The future of the traffic data collection program may include non-intrusive technologies.
- Joni and Leslie noted that there is one state DOT data collection program that includes leasing of data collection sites to the data provider.

Steve Chizmar
Press Office
April 24, 2007

- No excuses.
- Make sure cameras are working.
- Updates need to be quicker. Five minutes minimum.
- More deployments are needed. Every 10 to 15 miles.
- Site locations need to be more definable. Milepost number should be used in addition to current referencing.
- When RWIS was initiated, web hits were high, but now people do not use due to poor reliability.
- A public relations campaign will be needed to bring users back, but only once PennDOT has full confidence in the system.
- The web site needs to be user friendly.
 - The PennDOT website will be upgraded in the near future.
 - It would be useful if weather mapping was integrated with RWIS data on the web site.
 - Manufacturer information is not needed on the website.
- Get rid of black and white cameras. Images need to be color and with better imaging.
- RWIS sites need to be configured to be upgradeable and expandable.
- Public does not need historical data, but archived data may be useful for others.
- An email service would be useful for maintenance personnel.

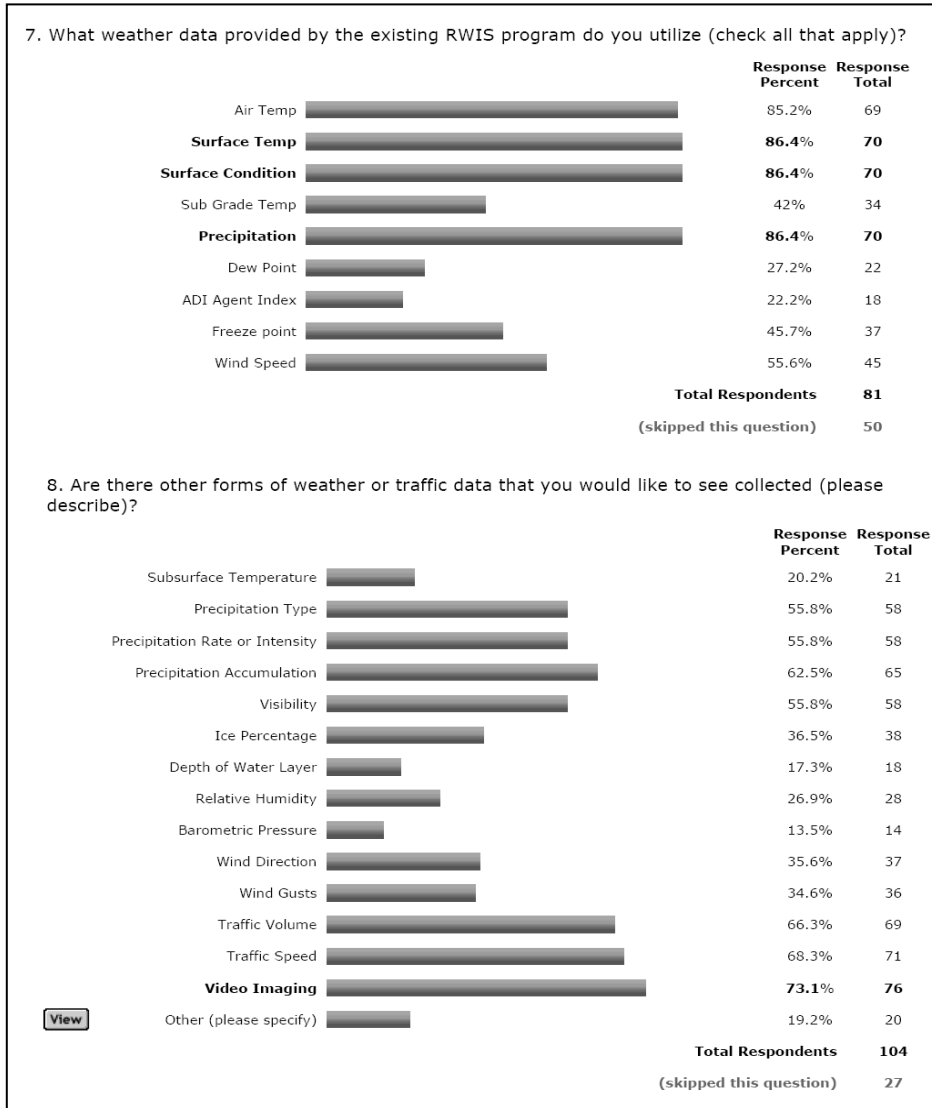
5.3 Stakeholder Survey

In addition to discussions among the study working group and select interviews, a web-based survey was distributed internally to District Executives, District Traffic Engineers, District Incident Management Coordinators, District ITS Coordinators, County Managers, District CRCs, RWIS Coordinators and Caretakers, BOMO, BHSTE, BIS, BPR, and the Press Office as well as to PEMA and PSP. In total, nearly 130 people completed the survey providing additional insight into the current RWIS program and the future directions. Below is a summary of survey responses. A detailed summary is included in **Appendix C**.



While 62 percent of respondents stated they do not utilize RWIS, 77 percent said they would use RWIS if data was more accessible (and reliable). This represents nearly a 40 percent increase in usage.

While RWIS was deployed for primarily winter maintenance purposes, nearly half of respondents indicated they would use RWIS for other purposes, with transportation operations accounting for 32 percent of usage.



Surface temperature and surface condition along with precipitation are the most commonly utilized data currently provided. This is an interesting trend since there are some questions as to the benefits of in-roadway (ground hog) data collection sensors and the maintenance challenges associated with them.

While many desire additional weather data elements including precipitation type, intensity and accumulation, most respondents indicated the need for operational data elements such as traffic volumes, speed and enhanced video. These trends may be an indication of the desire for more elements that can provide situational awareness.

13. Please Rank where RWIS sites should be deployed?				
	First	Second	Third	Response Average
Regular intervals on major freeways and arterials	57% (67)	29% (34)	14% (17)	1.58
Areas with higher than normal weather related crashes	45% (52)	37% (43)	17% (20)	1.72
Co-located sites with other intelligent transportation systems (ITS) such as Dynamic Messages Signs (DMS) and CCTV	24% (27)	29% (32)	47% (52)	2.23
			Total Respondents	119
			(skipped this question)	12

Regarding future deployments, most respondents indicated that RWIS should be deployed at regular intervals, but also at areas with higher than normal weather related crashes.

Open responses to questions were numerous and are provided as **Appendix C**. While there were variations and difference in opinions, there were also several noticeable themes:

- Make the existing RWIS functional and reliable
- Integrate RWIS data with other tools and systems such as RCRS and the TMC's operational environments
- Make RWIS user friendly to Department stakeholders and the public
- Consider enhancements to the RWIS program that promote efficiency such as automatic notification
- Remember that roadway winter maintenance is part science, but also part art

These themes are consistent with themes discussed in the SWOT workshop and during interviews.

5.4 Review of Themes

A review of existing conditions discussed in Section 3 as well as the review of stakeholder perspectives presented in this section resulted in the identification of key themes and trends.

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ Available data ▪ CCTV – picture snapshot ▪ 70+ sites ▪ Public awareness of roadway weather ▪ Independent Report’s findings and recommendations ▪ Value to multiple areas/ departments ▪ TSOP focus ▪ Growth potential Statewide coverage ▪ Data is ultimately available on an easy-to-use public web site ▪ Several years experience with technical infrastructure 	<ul style="list-style-type: none"> ▪ Public scrutiny ▪ Independent sites ▪ Different technologies ▪ Lack of resources ▪ No clear maintenance owners ▪ Lack of enterprise solutions ▪ Equipment performance ▪ Communications system ▪ Roadway Weather Information System (RWIS) currently has 55 sensor sites inoperable out of a total of 75 sites statewide ▪ There are no full-time positions dedicated to the RWIS program ▪ RWIS maintenance has been hampered by maintenance contracts ▪ 3 different proprietary software applications ▪ Slow retrieval because of dial-up connections used for data transfers ▪ Use of dial-up connection to transfer data between PennDOT offices is expensive compared to file-sharing alternatives ▪ Stand-alone systems – No integration at either software level or data level ▪ Web site is outsourced and thus not directly under PennDOT control ▪ Under-utilized equipment – Not collecting traffic data ▪ Under-utilized data: No data archiving for long-term data analysis applications ▪ Under-utilized visual images – Camera images could be useful to Traffic Management Centers and other applications if shared ▪ Lack pan-tilt-zoom (PTZ) control over cameras ▪ Lotus Notes software is out of compliance with PennDOT software development norms ▪ No site system diagnostics. ▪ Field equipment not ruggedized. ▪ Construction activities sometimes impacts in-roadway sensors

Opportunities	Threats
<ul style="list-style-type: none"> ▪ Enterprise solutions/ integration (511, MDSS, RCRS, STMC, asset management) ▪ Improved reliability ▪ Incorporation of standards ▪ Promoting of public acceptance ▪ Partnerships ▪ Better resource utilization ▪ Performance metrics ▪ Identifying functional requirements ▪ Varying data formats ▪ Developing a business practice ▪ Staff training and education ▪ Project piggybacking ▪ Operations funding and mainstreaming ▪ The Bureau of Operations and Maintenance has been directed to have all out-of-service sites operational by September 2007 ▪ Recently, a preventive maintenance contract has been awarded ▪ PennDOT database management systems and technical support are available ▪ PennDOT wide-area network (WAN) is available for data sharing internally, offering a cost-saving alternative to dial-up ▪ Traffic volume data sharing – Investigate sharing traffic data collected from NuMetrics RWIS sites with the Bureau of Planning and Research ▪ Camera image – Investigate sharing camera images with district Traffic Management Centers ▪ Electronic notification capabilities are available in the RWIS monitoring software to automatically alert personnel managing winter storm operations or operating Traffic Management Centers ▪ Use of RWIS data in planning weather-sensitive maintenance and paving operations could be expanded by developing procedures and training for county highway maintenance personnel ▪ RWIS and other support systems could be integrated with the current Weather Fleet AVL pilot underway using the 800 MHZ system. ▪ Ultimately, all Commonwealth data needs to be located in the GATIR system. 	<ul style="list-style-type: none"> ▪ Budget ▪ Lack of resources ▪ Poor maintenance ▪ Timing – before functional requirements ▪ Lack of interagency/ interdepartmental coordination ▪ Another February 14th ▪ Uninformed stakeholders (lack of experience, understanding, training) ▪ Lack of usage ▪ Apathy ▪ Legislated data requirements ▪ Lack of statewide direction and control ▪ PennDOT's representative at the State Emergency Operations Center did not have access to all information available to PennDOT's Traffic Control Center staff. ▪ PennDOT provided flawed information to the public in press releases, on highway electronic message boards and over its telephone information system. Telecommunication cost – Data transfers from RWIS sites currently depend on telephone dial-up connection, which can be costly and sometimes unreliable. ▪ Software integration cost – Extending the usefulness of the data will require potentially costly investment in software development. ▪ Lack of SOPs contributes to under-utilization – Software investment will need to be accompanied organizational changes and training to improve data utilization.

5.4.1 Desired RWIS Program

- An overall game plan for maintenance, contracting and funding.
- Existing system to be functional and reliable
- Restore confidence
- Coordinated planning with TSOP
- Deployment guidelines
- Improved video imaging (Color, PTZ, real-time)
- Collect speed and volume data
- Collect precipitation type, intensity and accumulation
- Alert notification options
- A tool that brings RWIS together with other information such as contract weather data
- To be integrated with other tools such as RCRS, IES, GATIR and PEIRS
- To be widely accessible (including at TMCs)
- A user friendly public interface

5.5 Resulting Operational Vision and Needs

Based on a review of systems stakeholder input, themes and requirements, the following operational vision was established.

1-Reestablish baseline operational conditions

- Need existing system to be functional and reliable
 - Upgrade key elements
 - Upgrade communication systems
 - Upgrade data management practices
- Need to continue proactive/ preventive maintenance practices
- Need to restore confidence of existing system

2-Establish deployment and program guidelines

- Need coordinated planning with TSOP
- Need to develop an “open” system
 - Overcome proprietary issues
 - Consider role of NTCIP
- Need deployment guidelines
 - Consider spacing at logical interval
 - Consider deploying at weather trouble spots
 - Consider co-location
- Need an overall game plan for RWIS program management (maintenance, contracting and funding)
 - Identify organizational structure
 - Identify resource needs

3-Strategically introduce new data elements

- Consider pros/cons of in-roadway data collection elements (intrusive vs. non-intrusive; active vs. passive)
- Pilot new RWIS elements
- Overcome proprietary issues
- Provide improved video imaging (Color, PTZ, real-time)
- Provide speed and volume data
- Provide precipitation intensity and accumulation
- Active (existing) alert notification options

4-Integrate with other data and decision making tools

- Integrate with forecast weather service
- Consider role of pilot snow plow AVL system
- Integrate into TMC’s operational environments (ATMS/IES)
- Consider testing/ implementing / integrating MDSS
 - Is it proven?
 - What are the true benefits/ costs?

RWIS data desired for all sites:

- ID
- Name
- Location
- Weather Data
 - Air Temperature
 - Dew Point
 - Humidity
 - Precipitation type
 - **Precipitation accumulation (desired new element - 63%)**
 - **Precipitation intensity (desired new element - 55%)**
 - Visibility
 - Wind Direction
 - Wind Speed
 - Date/Time Reported
 - Road Surface Data – for each lane
 - Date/Time Last Reported
 - Surface Temperature
 - Surface Condition
 - ADI Agent Index
 - Freeze Point
 - Subgrade Temperature
- Video image (desired upgrades 73%)
 - Real-time
 - PTZ
 - Color
- Traffic data (desired new element – 65%)
 - Traffic volume
 - Traffic speed
- Alert notifications (not currently utilized)

- Consider integrating with RCRS in short-term
- Consider integrating with PEIRS and GATIR

5-Restore confidence in RWIS program

- Test RWIS sites (periodically) to verify site accuracy
- Engaged internal stakeholder to gage successes
- Develop user-friendly portals for stakeholder, public and media
 - Coordinate with traveler information (511) initiatives
- Consider partnership opportunities with the media

6. Relationship to Other Initiatives

The future direction of the RWIS program must be considered in the context of other Department initiatives including key activities taking place in Maintenance as well as in Operations. Ultimately, the RWIS program when combined with other initiatives will allow roadway weather management professionals to coordinate and implement advisory strategies, control strategies and treatment strategies. These strategies rely on gathering accurate information, processing data quickly and efficiently, disseminating that information to stakeholder and providing mechanisms for communication.

6.1 Overview of Maintenance Initiatives

6.1.1 Current Practices²²

PennDOT's winter maintenance program is responsible for maintenance of 95,554 lane miles (number of miles plowed times the number of lanes) and expends approximately \$168 million each year (for the last five years) in winter maintenance activities. Costs include: personnel, materials and equipment. By way of comparison the Pennsylvania Turnpike has approximately 3,000 lane miles.

PennDOT operates 2,250 trucks, plows and salt spreaders, 117 anti-icing trucks and 16 snow blowers. Additionally, PennDOT has access to 543 rental vehicles and has agreements with nearly 749 of the state's 2,655 municipalities to clear state roads within their jurisdiction.

PennDOT used an estimated 793,000 tons of salt and 653,000 tons of anti-skid material per season over the last five winter seasons.

The Department has nearly 5,000 employees who are licensed to operate a snow plow, but the Independent Report noted a lack of experienced winter maintenance personnel within the Department.

The Department has recommended treatment's (as shown in summary on the next page), but the Independent Report noted that District and County's modified individual approaches for snow control and that the quantity of chemical additives in PennDOT's stockpiles is not governed by policy or procedure.

• Anti-icing

Brine is applied to a dry road before snow starts falling. This helps to prevent ice from forming a strong bond with the pavement.



• Pre-wetting

Road salt is sprayed with either brine or liquid magnesium chloride to enhance the salt's melting capability in cold weather. Pre-wetting lowers the melting point of salt to make it more effective in lower temperatures.

• Computerized salt spreaders

PennDOT trucks automatically calibrate the amount of salt being distributed based on the speed. For example, if the truck is going faster, it will spread more salt.



• Infrared temperature sensors

Sensors are mounted on vehicles in the PennDOT fleet to provide the operator with the exact pavement temperature. This helps the operator determine not only when the road will freeze, but what type of winter material is best suited.

• Anti-skid

Crushed limestone or sand is used as an anti-skid material in addition to a salt. The percentage of anti-skid varies by road type.



• Salt

Salt remains the department's primary weapon for fighting winter storms. PennDOT, which has 450 stockpiles around the state, used about 613,000 tons of salt during the 2005-06 winter.

²² Excerpted from PennDOT Winter Brochure, Oct 2006



AT 0-2 INCHES	AT 2-8 INCHES	AT 8 OR MORE INCHES	IN ICE STORMS
<p>Interstates and Expressways We will pre-treat with liquid anti-icers before the winter storm. Then throughout the storm, spread salt or a salt/anti-skid mix over the length of these highways until all lanes are free of snow and ice. Depending on the temperature, we may plow to remove remaining snow or slush.</p> <p>Other Major Routes We will spread salt and anti-skid primarily in the morning and evening rush hours, but will maintain service throughout the storm as needed. Primarily, we will apply salt and anti-skid to bridges, hills, curves and intersections. If we needed, we may also plow to remove snow or slush.</p> <p>Secondary State Roads We apply the same type of treatment as we do to our other roads, but generally we will limit salt and increase the amount of anti-skid, because salt requires higher traffic volumes to work effectively.</p>	<p>Interstates and Expressways We plow and treat these roads with salt and anti-skid throughout the storm to maintain at least two lanes open and passable in each direction. We will continue to plow and spread winter materials until all lanes are free of snow and ice. Shoulder areas are plowed as soon as practical following the storm.</p> <p>Other Major Routes We will plow and spread winter materials over the entire length of these routes. Driving lanes will be maintained reasonably clear of snow and ice. Particular attention is directed to bridges, hills, curves and intersections.</p> <p>Secondary State Roads We apply the same type of treatment as we do to our other roads, but generally we will limit salt and increase the amount of anti-skid, because salt requires higher traffic volumes to work effectively.</p>	<p>Interstates and Expressways During these major winter storms we will plow and often redirect equipment and personnel from other less-traveled roads until all lanes are open. Generally, if it is snowing at a rate of one inch or more an hour, we will limit salt which is ineffective because the continual plowing forces it off the road. We will apply heavier amounts of anti-skid particularly on hills, bridges and ramps.</p> <p>Other Major Routes We will plow and apply winter materials during peak rush hours. However, some roads may be impassable for a period of time due to crews being redirected.</p> <p>Secondary State Roads The same plowing and salting techniques used on other roads apply to the secondary roads. However, these roads may receive significant amounts of snow before equipment and crews can return to their assigned routes.</p>	<p>Interstates and Expressways We will spread salt and anti-skid over the entire length of the road throughout the storm until all lanes are free of snow and ice. We will then plow to remove snow or slush from the highway.</p> <p>Other Major Routes We will spread salt and anti-skid primarily during the morning and evening rush hours. We will apply winter materials primarily to bridges, hills, curves and intersections. However, we may apply winter materials to the entire length of the road as required. We will then plow to remove snow or slush from the highway.</p> <p>Secondary State Roads We apply the same type of treatment as we do to our other roads, but generally we will limit salt and increase the amount of anti-skid, because salt requires higher traffic volumes to work effectively.</p>

6.1.2 Ongoing Initiatives

BOMO is currently working on several winter maintenance initiatives and activities some of which were initiated prior to the development of the Independent Report.

6.1.2.1 Reestablishing RWIS Operational Baseline and Identifying Future Expansion Needs

The Independent Report noted that 55 out of 75 RWIS sites were not operational during the mid-February 2007 storm. The report made a recommendation to immediately repair these sites.

BOMO is currently in the process of contracting to repair RWIS sites and has been directed to have all sites working by September 1, 2007. **The Independent Report also recommended that areas where RWIS technologies are needed (could have helped) be identified. It is worth noting that, this assessment was underway prior to the mid-February storm and release of the Independent Report.**

6.1.2.2 Contract Weather Service

The Independent Report cited that Districts used various forms of weather forecasting services. In particular, the Independent Report noted that District 5-0 had no contract weather forecasting service while District 4-0 had the same service as the Pennsylvania Turnpike which provided them with advance warning that gave them adequate time to prepare. The report made a recommendation to reassess the use of common weather forecasting service.

It was noted that contract weather services and the RWIS network were listed as the fifth and sixth alternatives for early identification of adverse weather conditions in the Snow and Ice Control Manual. BOMO is currently contracting for a statewide contract weather forecasting service for the next year. The initial service will be available for the 2007/2008 Winter Season and will include the following:

- The service is the same contract weather service utilized by the Pennsylvania Turnpike and District 4-0
- A transportation forecast will be provided
- Four forecasts will be provided daily (by state, District and county) during winter months and when rainfall totals of two inches or greater are expected in a 12 hour period
- On-call support will be available
- Website

Many states have begun to integrate RWIS data with contract weather services in order to provide a complete weather picture for employees and customers. The survey of PennDOT employees noted interest in providing a complete weather picture for maintenance and operational decision making. On the public side, the combined weather is fed into state 511 systems. **There may still be an opportunity to integrate RWIS data into a contract weather service for the 2008/2009 Winter Season.**

6.1.2.3 Review of Best and Most Economical Practices for Snow and Ice Removal

The Independent Report noted the differences between how PennDOT and the Pennsylvania Turnpike Commission plan and execute in response to snow and ice storms. The Independent Report noted that the Turnpike has an operating budget financed through the collection of tolls and traditionally has a more aggressive approach to fighting snow which is referred to as a “Bare Pavement” philosophy. “Bare Pavement” philosophy means that every attempt is made to quickly remove accumulated snow and ice from the pavement through the application of chemicals and/or through plowing; however, the practice of applying more chemicals has a direct impact on the cost to fight a snow and ice storm.

PennDOT is currently reassessing the best and most economical alternative for winter (snow and ice removal) maintenance and a final report is expected by July 1, 2007. **New treatment alternatives should consider RWIS data elements in their treatment selection criteria as well as forecast data such that RWIS is utilized as a winter maintenance tool. Also, new treatment alternatives should be integrated into MDSS if utilized.**

6.1.2.4 Winter Maintenance Preparation and Snow Academy Training

PennDOT has a proactive winter maintenance preparation and training program. PennDOT’s winter maintenance preparation program includes after action reviews, equipment repairs, route identification, and route assignments. In the fall, PennDOT conducts dry runs, marks hazards, and familiarizes operators. PennDOT periodically conducts a Snow Academy which familiarizes winter maintenance personnel with winter maintenance policies and procedures. The Academy uses PennDOT’s Maintenance Manual (Chapter 4: Snow and Ice Control) for educational purposes; however, most of the material is presented as guidance.

The Independent Report suggested that PennDOT review their maintenance policies and provide mandated procedure for winter maintenance. Regardless of the final outcome of that recommendation, **awareness of RWIS functionality, weather forecasting opportunities and potential roadway weather management enhancements could be integrated into the training curriculum.**

6.1.2.5 Snow Plow AVL Demonstration

Tucker Ferguson of BOMO noted an ongoing exploration and potential demonstration of snow plow AVL using the 800 MHz communications system. The pilot may be expanded to include some initial testing with vehicles in District 8-0 during the 2007/2008 Winter Season.

Other states have started to integrate snow plow AVL into their winter maintenance and operations programs. The City of Denver has integrated snow plow AVL with FHWA’s MDSS such that the location of vehicles is considered along with maintenance decision making. **As this demonstration advances, the integration of snow plow AVL along with other weather information (including RWIS) and decision making tools should be explored.**

6.2 Overview of Transportation Systems Operations Initiatives

6.2.1 Current Practice

By definition “Transportation Systems Operations” represents technologies and institutional arrangements that allow transportation systems to operate more closely to their maximum design intent. PennDOT has recognized the role of transportation systems operations in promoting a safe and efficient transportation system. Recently, PennDOT adopted the Transportation Systems Operations Plan (TSOP), which defines PennDOT’s operational direction for the next several years.

Roadway weather management (TSOP-06) was identified as one of 19 operational projects at a statewide level. This project augments PennDOT’s existing roadway weather management activities including deploying road weather information systems (RWIS) to monitor road weather conditions throughout the Commonwealth; and establishing a “Winter Road Condition Hotline” for interstate highways. The latter phone service disseminates seasonal statewide road conditions, including road closures, detours, alternative routes, work zone/construction events, and road surface conditions. The purpose of this project is to monitor existing road weather management activities in Pennsylvania and broaden those activities, as necessary. ²³This study is a key product of TSOP-06. Additionally details of TSOP 06 are provided as Appendix G.

Related TSOP Projects

TSOP-01: Inter-Agency Reporting System

- Road weather information will be fed into IRS (or IES).

TSOP-02: Road Closure Reporting System

- Road weather information will be fed into RCRS.

TSOP-03: Interstate Incident Management Program

- Includes Statewide ITS Field Device Master Plan which is a strategy for deploying devices based on a statewide approach with input from regions for local needs.
- There may be opportunities to co-locate RWIS with other ITS deployments or upgrade RWIS sites to include enhanced CCTV where needed.

TSOP-04: IM Traveler Information

- Road weather information will be fed into IM traveler information system.

TSOP-05: Incident Management Processes and Procedures

- Defines processes, procedures, and relationships needed to improve the time required to respond and clear roadway incidents in a safe and efficient manner.
- Project focuses include:
 - (1) Definition and implementation of statewide infrastructure for managing incidents
 - (2) Strengthening relationships among IM partners
 - (3) Refine skills, responsibilities, and procedures used by regional IM Response Teams
 - (4) Monitoring and managing of IM performance regionally and statewide

TSOP-09: STMC and TMC’s

- Includes Optimum Operational Environment assessment and strategy for Traffic Management Centers.
- Includes phased implementation.
- The need for weather information in the TMC must be considered as well as how RWIS sites are integrated with TMC systems.

TSOP-10: ITS Equipment Maintenance

- Project establishes a statewide maintenance inventory of ITS devices, incorporates IT devices into common BIS device maintenance and replacement programs, and defines and establishes cost-effective maintenance contracts or in-house maintenance programs.

²³ PennDOT Transportation Systems Operation Plan

Related TSOP Projects

TSOP-13: ITS and IT

- Project encompasses the elements and practices around ITS and ITS issues.
- For instance, communication from an operations center to roadside equipment or other operation centers requires a telecommunications infrastructure.
- Additionally, the scope of required communications compels PennDOT to determine how best to plan for, process, and maintain record of and maintenance of communication linkages.

TSOP-14: Operations Mainstreaming.

- The mainstreaming of ITS will impact all TSOP projects.
- Mainstreaming activities include planning and programming for operational initiatives. Regional operations plans have begun to identify regional operational needs which in some areas include RWIS and other roadway weather management activities.
- Mainstreaming may ultimately include ITS device management and staff requirements as part of 2007 updates.

TSOP-15: Advanced Planning and Strategy

- All TSOP projects should incorporate new technologies and advanced strategies as applicable.
- BHSTE is currently in the process of forming a steering committee to monitor new technologies and advanced strategies.

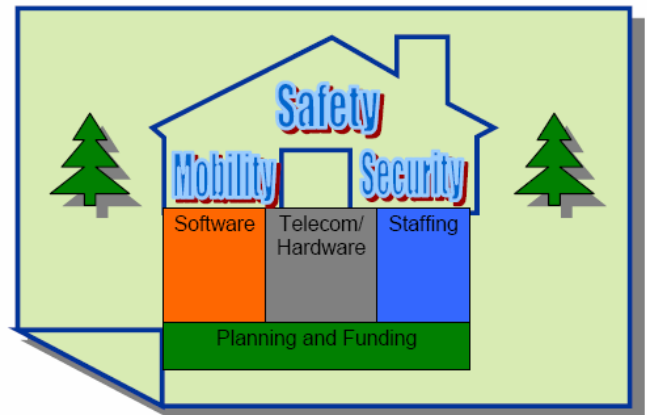
TSOP-16: Data-Acquisition and Archive.

- Performance metrics will be collected and archived for every TSOP project.

Currently, the Department is developing Regional Operations Plans which will define regional needs and projects as well as programming requirements in coordination with statewide initiatives. The number of total projects directly related to roadway weather management was limited in an early screening of potential projects, but many projects related to traveler information and incident management which both have direct relationships to roadway weather management.²⁴

Also, the Department is presently updating the TSOP plan. The updated plan may include a reprioritization/update of current projects as well as new initiatives.

While PennDOT has significant operational deployments (TMC's, DMS, CCTV, HAR, RWIS), especially in urban areas such as District 6-0 and District 11-0, the overall operational program at PennDOT is still in a planning phase. In the near-future, many more deployment projects will be completed and PennDOT will continue to develop the foundation for their operational program.



Statewide Operations Foundation

²⁴ ROP status email 05/24/07

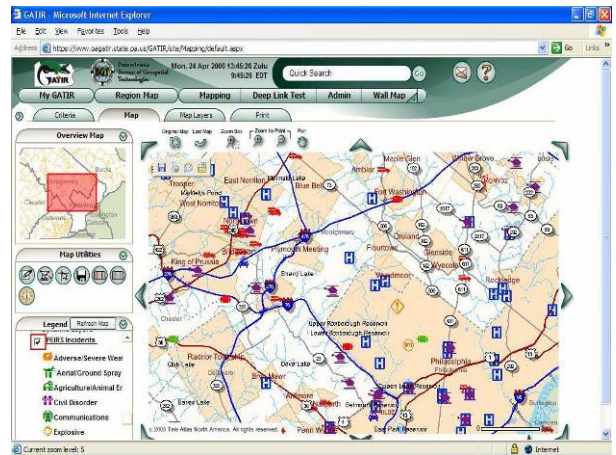
6.2.2 Ongoing Initiatives

Many of the TSOP initiatives have begun to move forward. Below is an update to some as they relate to roadway weather management and the RWIS program.

6.2.2.1 Information Exchange System

The Independent Report noted issues in situational awareness and interagency coordination/ communication. Emergency management (including weather) requires communication and a common understanding of conditions.

TSOP-01 includes the development and deployment of a system for exchanging information concerning incidents within PennDOT and between PennDOT and other stakeholders. The resultant Incident Reporting System (IRS) or Information Exchange System (IES): (1) functions in a flexible environment that supports the timely exchange of information; (2) enables emergency response stakeholders to “subscribe” to and receive the specific data elements of relevance to them; and (3) permits stakeholders to continue using their existing systems and infrastructures. Users will connect to the IRS through a common communications backbone.



Ultimately, this improves emergency management and incident coordination, provides near real time information and reduces duplication of efforts.

IES has the ability to provide an operational awareness above the TMC (ATMS) environment through an integrated user interface that consolidates all essential TMC operator functions, has view-only access to non-PennDOT owned data (PTC, etc.), allow view-only access of PennDOT data by partners and provides a tool for achieving ITS Architecture

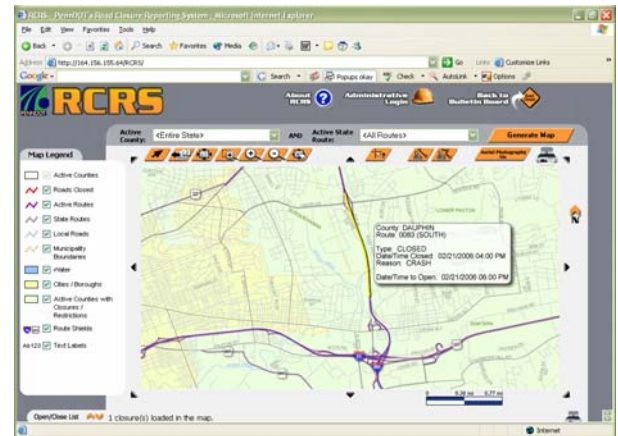
Ultimately, IES is a platform to integrate, coordinate and distribute data from various stakeholders. PennDOT may integrate Road Closure Reporting System (RCRS) and Emergency Detour Routing System (EDRS) as well as use IES as a tool to provide data to the proposed traveler information system. Accurate weather data along with other data can provide situational awareness for roadway weather management, incident management and emergency management activities. **The integration of RWIS data with contract forecast data could be integrated into a weather portal which can ultimately be linked to other systems such as RCRS, EDRS and 511 as well as become a logical component of IES.**

6.2.2.2 Road Closure Reporting System

TSOP-02 included the continued development of the Road Closure Reporting System (RCRS). RCRS was originated by PennDOT Executive Management due to a lack of accurate information during times of adverse weather.

The purpose of RCRS is to effectively and efficiently report real-time road closures/lane restrictions to the motoring public and other agencies, ensure quality and validity of reported data, provide standardized reporting method for closures within PennDOT, and provide statistical analysis of past closures.

RCRS provides a statewide tool to track road closures due to various incidents. Initial efforts included SEOC incidents, winter incidents, and construction incidents. Future enhancements include integration of weather information, coordination with an electronic detour system as well as the development of a public interface. It should be noted that many RCRS users requested the inclusion of weather data as an optional layer in the RCRS portal.



There may be an opportunity to include contract weather reports, RWIS conditions and weather alerts notifications as part of future enhancements to RCRS.

6.2.2.3 Pennsylvania Traveler Information Assessment

PennDOT recently completed a traveler information assessment as part of TSOP-04 activities. Key observations as they relate to the RWIS program are noted below:

PennDOT has two existing activities related/ dedicated to providing roadway weather/ conditions to motorists:

- PennDOT Road Weather Information System (RWIS) – RWIS involves the collection of real time roadway conditions using meteorological and pavement sensors. The sensors report conditions for air temperature, wind speed and direction, relative humidity, dew point, visibility, precipitation type, and precipitation rate. In addition, each site reports pavement temperature, surface characteristics, and amounts of deicing agent on the surface. Newer sites provide traffic volume, average speed, and video data. The information is accessed through PennDOT's website. There are currently 75 sites throughout the state.
- PennDOT Winter Road Condition Hotline – PennDOT provides access to roadway information utilizing the toll free number 1-888-783-6783. This is an automated system that identifies roadway conditions for Interstate roadways only based on information provided by the Districts.

Key traveler information survey results:

- Respondents were most interested in weather related road conditions, driving directions, construction, and incident reporting.
- 80% of respondents have a need for real time traffic information.
- There is an expectation that this type of information will be provided in vehicle as technology progresses.
- Respondents were more likely to use a 511 system if it were free.
- Urban residents were more interested in transit information.
- Anticipated 511 usage is higher for suburban and rural users (96% and 99%) versus urban users (84%).

The study noted that many 511 models utilize weather service providers. Other business models utilized contractors who specialize in providing both traveler information and weather services. The study included weather content/ conditions in the initial role out phase as well as later phases. The current timeline for 511 Pennsylvania Deployment is:

- Web 511 Targeted Turn-On – June 2008
- Voice 511 Targeted Turn-On – June 2009

In the future, the 511 system will replace the PennDOT Winter Road Condition Hotline.

As an outcome of the *Independent Report*, a revised Comprehensive Customer Information Plan will be developed. **There may still be an opportunity to revise the RFP such that contract weather reports, RWIS conditions and weather alerts notifications (from the contract weather service) and transportation alerts (from RCRC and TMCs) are linked into the 511 deployment.**

6.2.2.4 Evolution of Traffic Management Centers and Operations Connectivity

TSOP-09 includes the development of a plan for the development of future TMCs. There are several related initiatives that should be considered as they relate to roadway weather management and the RWIS program.

- **Optimal Environment** – The Department has begun to identify the optimum operational environment for District TMC's, Regional TMC's and a Statewide TMC. The plan includes system redundancy and overlap to address hours of operation and continuity. Upgrades to the District (6-0) and (11-0) TMC's along with a new STMC in Harrisburg are expected to be operational by mid-2011. ATMS will be implemented in all Districts by this time along with IES and 511; it is likely that RWIS weather data will be well integrated into the TMC environment through ATMS and IES.
- **Current and Interim Environments** – TMC's at the District level varying in status and condition. Districts 6-0 and 11-0 have developed TMC's while several other Districts have begun to evolve their TMC's. All Districts will be linked together by C2C communications and three RTMC's, East (6-0), Central (8-0) and West (11-0) will be staffed 24/7. The RTMC's will have control of CCTV, DMS, and HAR in their "member" Districts who do not operate 24/7. Currently, no RWIS capabilities are planned for this environment. RWIS data will only be accessible through the public website for RTMC's and TMC's. The integration of RWIS needs to be considered in the various stages of TMC development.
- **Development of ATMS** – ATMS is intended to provide one integrated platform for the command and control of ITS elements. The proprietary nature of RWIS/ESS data may make it necessary to integrate data at a central location before distributing to TMC's. While the ATMS may be a logical location for this integration, ATMS is not fully developed and in place. Unlike other ITS devices, there is no control of RWIS/ESS sites. Also, the usage of RWIS data extends beyond the TMC environment to other users, especially maintenance; therefore, a web-based weather portal may be a more appropriate tool to disseminate weather data.
- **Connectivity Plan** – The Statewide Operations Connectivity Plan has begun to address C2C and center to field communication needs and options. As was noted, RWIS communication systems have no diagnostics and the connectivity to counties, districts, and Central Office currently includes multiple dial-ups that could be reduced through the utilization of the PennDOT WAN. If the WAN is utilized, then BIS security requirements must be addressed with any communications to field devices. One alternative that was discussed was to utilize call-back modems to authenticate communications. The SOCP will further guide the future direction of the RWIS program.

6.3 Pennsylvania Turnpike RWIS Program

The Pennsylvania Turnpike Commission (PTC) has 11 RWIS sites deployed along the Turnpike system. The PTC RWIS sites can be categorized as stand alone sites or as part of the fog detection system.

- 4 “Stand Alone” RWIS deployments – SSI legacy system/ server
 - MIIST connects to SSI server
 - Considering integration upgrades – estimated \$350K to integrate into MIIST
- 7 Fog Detection RWIS deployments – SSI “open”
 - Sites integrated into MIIST which contains algorithms for variable speed

PTC plans to continue expanding the current RWIS network and plans to install RWIS sites at all weather trouble-spots along the turnpike. Through the Advanced Traveler Information System Project, four more RWIS sites will be deployed. Proposed RWIS deployments can be found on the map below.



Each new RWIS site will supply atmospheric and pavement surface data to the operations center and maintenance facilities where data reduction will be conducted and response schemes designed and implemented. The ultimate condition of the RWIS sub-system will establish RWIS stations at all weather sensitive points within the Turnpike network. The ultimate RWIS system condition will allow for weather data sharing between local agencies, PennDOT, local media and other stakeholders to develop a comprehensive statewide weather forecasting and monitoring system, and augment the turnpike’s available weather data pool.

As PennDOT moves forward, dialogue should be established with PTC to determine if RWIS and other roadway weather data can be shared over a common platform.



7. Suggested Directions

7.1 Overview

The *Independent Report* identified several issues that relate to RWIS and roadway weather management activities as well as Department and interagency communication/ coordination. There are many current initiatives taking place within the Department that may help address these issues. Additionally, other state practices and national initiatives provide some guidance for the future direction of the RWIS program.

Independent Report	Current Initiatives	Operational Vision and Needs
<p>Information Systems and Resources:</p> <ul style="list-style-type: none"> ▪ Roadway Weather Information System (RWIS) currently has 55 sensor sites inoperable out of a total of 75 sites statewide... ▪ Not all districts contract transportation-specific weather forecasting services <p>Maintenance Practices</p> <ul style="list-style-type: none"> ▪ Staffing guidance not followed, particularly in PennDOT's Berks County, and lack of guidance at the district level. ▪ PennDOT allows districts and counties to modify individual approaches for snow and ice control. ▪ Quantity of chemical additives in PennDOT's stockpiles is not governed by policy or procedure. ▪ Turnpike has a "Bare Pavement" philosophy to snow and ice control; PennDOT does not. <p>Transportation Operations</p> <ul style="list-style-type: none"> ▪ PennDOT's representative at the State Emergency Operations Center did not have access to all information available to PennDOT's Traffic Control Center staff. ▪ Emergency operations do not appear to be treated as a core mission of PennDOT ▪ PennDOT provided flawed information to the public in press releases, on highway electronic message boards and over its telephone information system. 	<p>National</p> <ul style="list-style-type: none"> ▪ The Clarus Initiative attempts to create a more complete and reliable weather picture (across state boundaries) by assimilating from a variety of sources, cleansing and checking weather data and disseminating more complete weather data. ▪ MDSS is a tool that merges weather forecasting with roadway maintenance rules of practice and generates treatment recommendations on a route by route basis. ▪ The Aurora Program provides an opportunity to engage other stakeholders on issues relating to roadway weather management. ▪ NTCIP promotes "Open" communication and systems, lessening dependence on proprietary products and services (allowing for flexibility in procurement and maintenance) as well as allow for easier integration into other operational initiatives ▪ FHWA has identified best and proposed practices for the integration of emergency and weather management into TMC's. <p>Other States</p> <ul style="list-style-type: none"> ▪ RWIS is both a maintenance and transportation operations tool ▪ Maintenance per site averaged \$3,500 and more reliable programs spending \$5,000 per site ▪ Some states have begun to deploy NTCIP compliant systems ▪ 77 percent of states contract for other weather forecasting services <p>PennDOT's Winter Maintenance Program</p> <ul style="list-style-type: none"> ▪ Reestablishing RWIS operational baseline ▪ Implementing contract weather service ▪ Identifying best practices for snow and ice removal ▪ Continuing winter maintenance preparation and snow academy training ▪ Exploring snow plow AVL demonstration <p>PennDOT Transportation Operations</p> <ul style="list-style-type: none"> ▪ Coordinating Transportation Systems Operations Planning at statewide and regional-level ▪ Assessing roadway weather management (TSOP-06) needs ▪ Utilizing and expanding Road Closure Reporting System ▪ Planning for Pennsylvania Traveler Information deployment ▪ Guiding the evolution of Traffic Management Centers and Operations Connectivity 	<p>1-Reestablish baseline operational conditions</p> <ul style="list-style-type: none"> ▪ Need existing system to be functional and reliable ▪ Need to continue proactive/ preventive maintenance practices ▪ Need to restore confidence of existing system <p>2-Establish deployment and program guidelines</p> <ul style="list-style-type: none"> ▪ Need coordinated planning with TSOP ▪ Need to develop an "open" system ▪ Need deployment guidelines ▪ Need an overall game plan for RWIS program management (maintenance, contracting and funding) <p>3-Strategically introduce new data elements</p> <ul style="list-style-type: none"> ▪ Consider pros/cons of in-roadway data collection elements (intrusive vs. non-intrusive; active vs. passive) ▪ Pilot new RWIS elements ▪ Overcome proprietary issues ▪ Provide improved video imaging (Color, PTZ, real-time) ▪ Provide speed and volume data ▪ Provide precipitation intensity and accumulation ▪ Active (existing) alert notification options <p>4-Integrate with other data and decision making tools</p> <ul style="list-style-type: none"> ▪ Integrate with forecast weather service ▪ Consider role of pilot snow plow AVL system ▪ Integrate into TMC's operational environments (ATMS) ▪ Consider testing/ implementing / integrating MDSS ▪ Consider integrating with RCRS in short-term ▪ Consider integrating with PEIRS and GATIR <p>5-Restore confidence in RWIS program</p> <ul style="list-style-type: none"> ▪ Test RWIS sites (periodically) to verify site accuracy ▪ Engaged internal stakeholder to gage successes ▪ Develop user-friendly portals for stakeholder, public and media ▪ Coordinate with traveler information (511) initiatives

Ultimately, a plan must be implemented that helps establish the operational vision for the RWIS as identified by system users and stakeholders and as guided by the findings of the *Independent Report* and best practices.

To be successful, the plan must consider the context of PennDOT's Maintenance and Transportation Operations programs, and must allow for a phased implementation of the operational vision. Senior management must provide guidance for the plan as it relates to higher level initiatives, but must also assist in identifying and providing programs resources and overcoming institutional issues associated with a program that spans multiple Bureaus.

The following sections highlight some considerations as they relate to data management, site configurations, deployment considerations and provide some thoughts on program management.

7.2 Data Management

Continuing technological advancements offer opportunities to improve the instrumentation and communications systems used for RWIS at PennDOT. Likewise, advancements in information technologies present opportunities to improve RWIS data acquisition, management, and distribution.

PennDOT has recognized several shortcomings in the current RWIS data management system.

- Proprietary software and data formats complicate data management processes
- Under-utilization of the data due to the current system's limitations on data accessibility and distribution
- Potential delays in acquiring data from the field and delivering it to users, inherent in the chain of multiple sequential dial-up connections.

PennDOT's planning for upgrading RWIS capabilities will need to include steps to improve data management. Complications imposed by having multiple proprietary data collection systems can be alleviated by implementing data standards based on NTCIP. Consolidating the NTCIP-compliant data in a centrally managed and controlled database would enable more effective distribution to a broader population of users, and streamlining the data flow could help improve the timeliness and reliability of the data. Combined, these measures can improve utilization of the RWIS sites and RWIS data, and reduce the overall cost of ownership.

7.2.1 Data Elements and Configurations

RWIS stations are a mix of three types. Each type was procured from a different vendor. While each type of station provides the same basic roadway weather data, they each record the data in a different, proprietary format.

PennDOT should gradually migrate to an open system approach, as opposed to the proprietary solutions. The open system solution, based on National Transportation Communications for ITS Protocol (NTCIP) standards, affords greater flexibility in acquisition and maintenance decisions. It also allows for more efficient administration of the data collection process, and it enables greater opportunities for data integration. An open, standards-based solution provides for greater economies and cost-savings.

PennDOT's profile of RWIS field stations is likely to remain mixed, even in the long term unless replacement upgrades are funded. While PennDOT migrates to open-standard systems, support for the legacy devices will continue to be necessary if they are retained as system components until replacement is required.

Additionally, there is likely to be a substantial amount of diversity among the newer open system devices. All existing PennDOT RWIS stations collect the same basic set of weather data. The NTCIP 1204 standard defines 36 data elements that potentially could be collected. Those that are specifically weather detection data elements are listed on the next page.

RWIS Data currently available at PennDOT Central Office for all sites:

- ID
- Name
- Location
- Weather Data
 - Air Temperature
 - Dew Point
 - Humidity
 - Precipitation (type)
 - Visibility (feet)
 - Wind Direction
 - Wind Speed (mph)
 - Date/Time Reported
 - Road Surface Data – for each lane
 - Date/Time Last Reported
 - Surface Temperature
 - Surface Condition
 - ADI Agent Index (%)
 - Freeze Point
 - Subgrade Temperature
- Video image
 - Still image
 - Date/Time reported

Average Wind Direction	Water Depth	Total Precipitation Past 6 Hrs
Average Wind Speed	Adjacent Snow Depth	Total Precipitation Past 12 Hrs
Spot Wind Direction	Roadway Snow Depth	Total Precipitation Past 24 Hrs
Spot Wind Speed	Roadway Snow Pack Depth	Solar Radiation
Wind Situation	Precipitation Indicator	Total Sun
Wind Gust Speed	Rainfall or Water Equivalent of Snow	Cloud Cover Situation
Wind Gust Direction	Snowfall Accumulation Rate	Terrestrial Radiation
Wetbulb Temperature	Ice Deposit (Thickness)	Solar Radiation v2
Dew point Temperature	Precipitation Start Time	Total Radiation
Maximum Temperature	Precipitation End Time	Total Radiation Period
Minimum Temperature	Total Precipitation Past 1 Hour	Visibility
Relative Humidity	Total Precipitation Past 3 Hrs	Visibility Situation

NTCIP 1204 also has standard definitions for other kinds of ESS data, including pavement treatment and air quality.

PennDOT may choose to combine multiple operational capabilities into a single station at certain locations. For instance, a station could include vehicle detection sensors in addition to environmental sensors to serve the needs of traffic management as well as weather-related operations.

Some of the RWIS stations currently deployed already have similar capability. The SSI devices record traffic counts, and transmit the data from the field in the same stream of data with the weather data. In the current system, however, the traffic data is dropped out of the file that is relayed to the Central Office server.

PennDOT may find it advantageous to equip some new stations with closed circuit television (CCTV) cameras with remotely-controllable pan-tilt-zoom (PTZ) capabilities. CCTV could be deployed in place of, or in addition to, a fixed camera. Streaming video and remote camera control have not been identified as requirements for RWIS, but they are commonly used in traffic operations. This scenario would most likely occur as a result of collaboration between those offices within PennDOT that are responsible for planning RWIS deployments and ITS deployments.

As RWIS stations become more advanced, they should be able to generate more information about their own operational condition. Currently, PennDOT's solar-powered RWIS stations can monitor their own battery status, and transmit the information. As noted above regarding traffic data, the solar battery status information is not relayed up to the Central Office server. More advanced RWIS stations could contain fault-detection components that could communicate self-diagnostic information. The NTCIP 1204 standard identifies three such data elements: Battery status, A/C line voltage, and door status.

7.2.2 Connectivity

The data acquisition process in the current PennDOT RWIS system is accomplished by a series of dial-up connections over land-based telephone lines. There are four "links" in the chain of communications from individual roadside device to consolidation at PennDOT Central Office, and finally on to the vendor that hosts PennDOT's RWIS site on the Internet. Though there are a few exceptions, generally stated, the four links are:

1. County to roadside station – A server and modems at the County Maintenance Office closest to the RWIS station places two separate calls to the site controller at regular intervals. One call collects the RWIS data. The second call collects the camera image. Hardware and software are provided by the RWIS site provider. If multiple vendors have installed RWIS stations in the county, then multiple data collection systems operate in the County Maintenance Office.

2. District to County – The same kind of hardware/software configuration at the District Engineering Office dials the County Maintenance Office server to pull a file of the data and images collected from individual stations since the previous call.
3. Central office to District – Using the same hardware/software configuration, Central Office dials each District RWIS server to pull the accumulated data.
4. Central office to web hosting vendor – Software on each of the three vendor servers at Central Office exports its data to a standard text format. A fourth server, running Lotus Domino software connects to each of the three vendor servers to pull their data, and then transmit it via dial-up to the contracted Web host for presentation on the Internet.

The multiple links in the communications chain are intended to control the per-call cost to the individual RWIS sites. The reasoning is that, in most cases, it is a local call from the county office to the roadside site. Above the county level, the more costly long-distance calls are used for transferring bulk data accumulated from multiple sites.

However, the call-chain method does not scale upward very well. As the number of stations and the amount of data at individual sites increase, it will become more difficult to meet service level goals for data timeliness. The only way to scale upward is to add modems and increase the number of calls. PennDOT is charged on a per-call basis under the current telephone services agreement.

Dial-up is an effective communications method for the RWIS application, if the cost can be controlled. This control can be achieved by purchasing an unlimited service plan from the telephone service provider for a fixed fee. BOMO has already looked into this possibility and found that it has merit. Additionally, the availability of unlimited service plans pertains to telecommunications services other than dialup. Unlimited service plans are typically available for digital cellular service, or CDMA, which is discussed elsewhere in this document.

An economical call plan would make it feasible to consolidate some of the current data collection operations. District offices could initiate the data transfer from roadside stations directly to the district server, eliminating one link in the call chain, albeit the least expensive one.

To further reduce the reliance on dial-up, and greatly speed up the delivery of data, the Districts can take advantage of its high-speed connection on the future PennDOT WAN to post data directly to a central database. This alternative eliminates another link in the call-chain.

There are several other advantages to this alternative data transfer method. It eliminates the need to maintain RWIS servers and modems in the county offices. It also eliminates the need for the RWIS servers and modems in BOMO at Central Office. The District connection to the Metropolitan Area Network (MAN) in Harrisburg is high speed and highly reliable. By posting data directly to a central database, the District can essentially share the data with the rest of PennDOT virtually as soon as they pull it from the roadside device.

There are security concerns which must be addressed if public networks are to be relied upon, however. Precautions must be taken at the District against outside intrusion that could put the PennDOT network at risk. A person with malicious intent could gain access to the District server via the dialup telephone system, and worm their way through to the MAN, potentially exposing the entire Commonwealth network. For this reason, the use of such dial-up modems, when the related computer is connected to the PennDOT intranet, is not in compliance with the security measures stipulated in the OA (Office of Administration) Information Technology Bulletins (ITBs). The Bureau of Information Systems (BIS) in PennDOT recommends replacing these modems, where relevant, with “Call Back” modems. “Call Back” modems are equipped with the functionality of blocking incoming calls, verifying the caller ID against a pre-configured authorization list when called, and subsequently initiating a “call back” connection process if the caller is authenticated. By virtue of this security feature, “Call Back” modems are considered in compliance with the related ITBs security requirement.

Additionally, firewalls should be installed between the District RWIS server and the PennDOT network to detect and prevent intrusion. A firewall is a router that uses software algorithms to enforce rules for allowing access to only trusted resources. A firewall can be an improvement over the call-back modem because the firewall will allow greater flexibility to handle diverse configurations of RWIS communications in the future. Regardless of the mode of communication between the RWIS site and the District RWIS servers, the firewalls would be in place to protect the Commonwealth network.

Ultimately, RWIS communications need to be consistent with the Statewide Operations Connectivity Plan which is under development.

7.2.3 Other Telecommunications Methods

Future RWIS communications will likely be even more diverse than today, in terms of the information technologies involved. In addition to the existing legacy stations and new open-system stations that communicate via dial-up, there will be new deployments that take advantage of high-speed telecommunications systems. In urban areas, certain RWIS deployments could piggyback on ITS projects utilizing T-1, T-3, or fiber-optics. Also some RWIS devices will be equipped with CCTV instead of, or in addition to fixed camera.

Separate polling software, in addition to what was described above, will need to be developed or acquired to pull data from these devices, and deliver to the central database. Software will also be required to capture a frame from a video stream, in order to provide a camera image from sites that have CCTV if used in lieu of a fixed camera.

7.2.4 District Server

The current District servers run proprietary vendor software. This function will continue to be needed as long as legacy devices are sending data from the roadside. However, the District servers will also take on the following additional functions.

- Handle data transfer from “new” open-system RWIS devices, including dial-up, data transfer, and error checking. Digital cellular modems will also be needed to communicate with the new sites.
- Convert non-compliant data from legacy systems to standard format.
- Post data to central database.
- Post images to central database.
- Perform data administration functions, such as data integrity checking, process logging, and disk space management.

Each District will need to be equipped with a new mid-range server, digital cellular modems (or other selected communications equipment), and a firewall. Software will need to be developed or acquired to perform the functions listed above.

7.2.5 Central Database Management

The RWIS/ESS database should be the centralized repository for current RWIS information. It should contain detailed data collected from every RWIS site over at least the most recent 24 hours. Older data would be off-loaded to a separate RWIS Archive database.

The RWIS/ESS database would incorporate a more formally organized structure than the current system. In addition to the RWIS data itself, the database would contain metadata consisting of configuration information on all RWIS devices, and data dictionary definitions of the data elements that comprise the database. Data definitions and formats should comply with NTCIP 1204.

The Bureau of Information Systems (BIS) has extensive experience with databases such as this, and would be responsible for its administration and technical support. These functions include administering security, monitoring performance, and enforcing BIS standards for adequate backup and recovery procedures.

The database should be configured to facilitate the types of access that are most critical to RWIS business applications:

1. Delivering the most recent data and camera image for a requested site to the application.
2. Exporting the most recent data and camera image for all sites to the Web hosting system.
3. Appending new data and camera images in bulk from the District data collection process.

7.2.6 RWIS Data Delivery Systems

The current RWIS data systems have historically been under-utilized in PennDOT. The inability to integrate proprietary software systems and the unreliability of roadside station equipment have contributed to this situation. As these deficiencies are remedied, opportunities will exist to integrate the information gathered by RWIS stations to benefit an increasing number of business processes.

These developments will occur over a period of time. The expansion of RWIS information to new business applications should occur in stages. If the current system is considered the first generation in the development of RWIS software capabilities, then the continuing improvement and expansion of the software system can be viewed as successive generations.

- 2nd Generation – Provide a stable and reliable information technology environment for the acquisition and distribution of near-real-time roadway weather data.
- 3rd Generation – Provide capabilities for using RWIS data in advanced weather-related applications in statistical analysis and modeling.
- 4th Generation – Provide for integration of RWIS with external applications that have limited, but concise need for weather information.

The timeframe of these improvements should be coordinated with other initiatives such as the proposed 511 traveler information system.

2nd Generation

This generation occurs as part of phase concept 2) Establish baseline for program enhancements

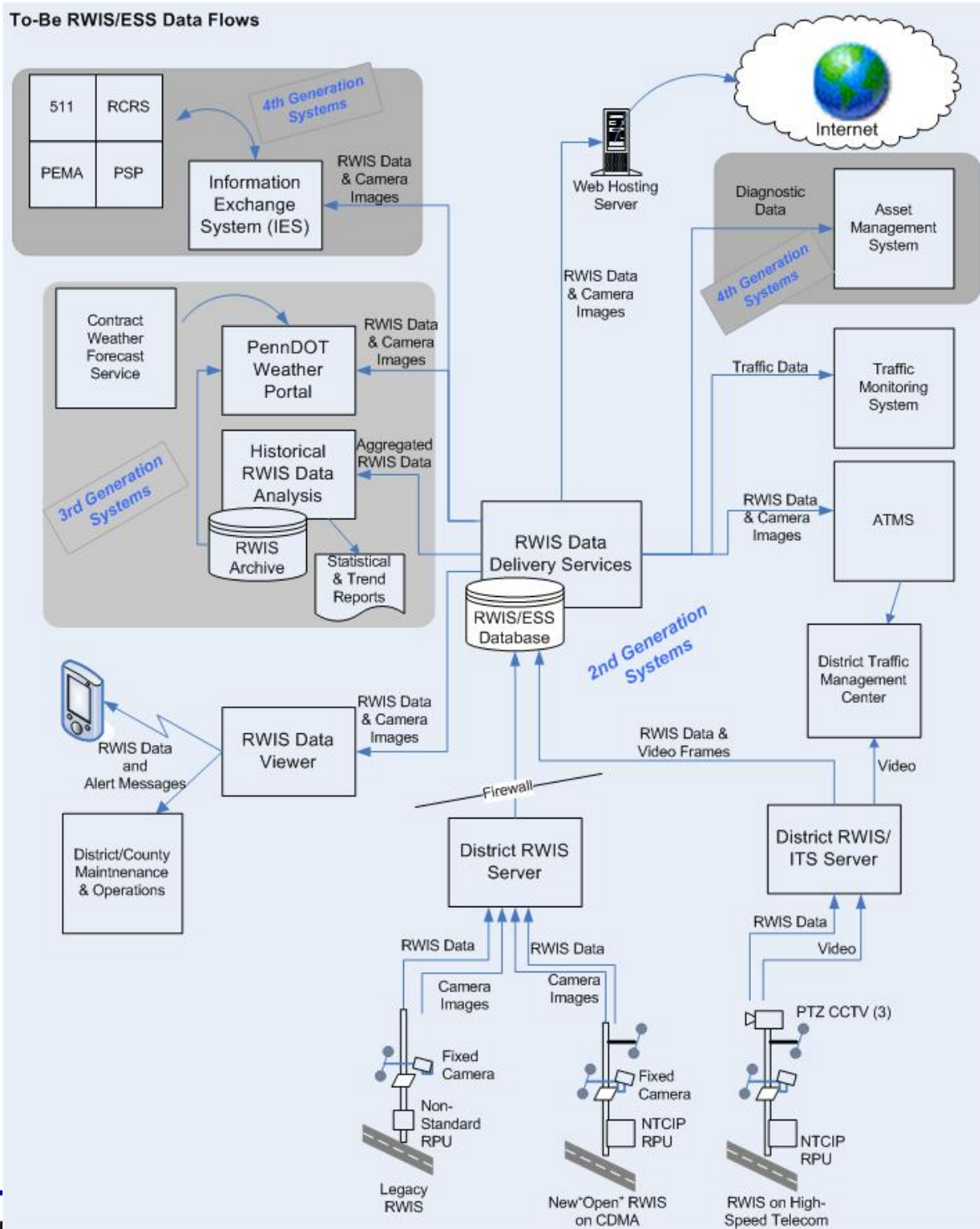
Software applications in the second generation must serve PennDOT Maintenance and Operations personnel at the county, district, and central office levels. They are the current consumers of RWIS data in PennDOT. The second generation RWIS must perform all first generation functions, but must do so in such a way that the users of the data have complete confidence in it.

The system must provide basic data viewing functions similar to that which is provided by the current vendor systems. Unlike the current system, however, second generation RWIS users would have access to the consolidated data from all vendor systems at once, and they would access it over the Internet, through an RWIS Data Viewer application.

This RWIS Data Viewer system must be the top priority. After the RWIS data collection systems are removed from County Maintenance Offices, as described above, county personnel will need this system in order to obtain current roadway weather data for winter operations. The same will be true for users in the Central Office. District personnel will still have the vendor systems onsite. However, they can only access those systems by logging on to the vendor server and using the proprietary software system. They need to log on to

each server separately to obtain data from different vendor devices. All users at the county, district, and central office levels would have simultaneous access to the data through the RWIS Data Viewer.

As a Web-based system, the RWIS Data Viewer would have the advantage of using the consolidated standard data in the central RWIS/ESS database. It also provides the opportunity for PennDOT personnel at any location to obtain the same information. Maintenance and Operations personnel at any location, including in the field, would be able to access the system over a wireless Internet connection. They could do so from a laptop computer in the county office, from their home, or from a plow truck using a hand-held device.



The system would provide an automatic alert function to notify Maintenance personnel when data approaches a given threshold value. For instance, it could automatically send a text message to a cellular telephone when pavement temperature falls to within two degrees of pavement freezing point. This kind of functionality is available in the current vendor systems, but is not being used.

Another key function of the current system is to upload current RWIS data, including camera images to the vendor that is contracted to host the Department's public RWIS Web site. This function must be taken over by the new RWIS system.

Operators in District Traffic Management Centers (TMC) could also receive alert messages. They would be able to access the Web-based RWIS Data Viewer system, as well. Alternatively, the system could deliver RWIS data and camera images to be integrated with the Advanced Traffic Management System (ATMS) that the District TMCs will use to interface with other ITS field elements.

3rd Generation

This generation occurs as part of phase concept 3) Begin to establish complete weather picture

Third generation RWIS systems would provide higher level functions, using advanced statistical methods to analyze aggregate data for use in decision-support applications. This requires archiving RWIS data from the RWIS/ESS Database, into a data warehouse.

The archiving process would perform calculations using the accumulated raw data, and produce a variety of statistics, which would be used in applications to analyze trends or produce mathematical models.

Both the raw data and aggregated statistics would be fed into a PennDOT Weather Portal. This Web-based system would be the central command tool for all PennDOT weather operations. It would incorporate all the capabilities of the RWIS Data Viewer, but it would greatly extend the basic functionality. It would integrate automatic vehicle location (AVL) to monitor plow trucks. It could also exchange roadway weather data with Clarus.

An advanced function of the portal would be to support real-time operational decision-making. It would use historical data plus real-time data to model potential effects of a storm that is in progress. It could model the likely effectiveness of applying alternative mixtures or concentrations of chemical agent to road surfaces at various locations. Once a decision is made, the system could monitor events to compare actual performance versus the model.

4th Generation

This generation starts as part of phase concept 2) Establish baseline for program and enhancements and continues through phase concept 7) Develop integrated/ enterprise solutions

All aspects of the continuous RWIS improvement program will need to be coordinated with the long range plan for the development of PennDOT's intelligent transportation systems (ITS), which is documented in the Transportation Systems Operations Plan (TSOP). Among the TSOP initiatives is the development of business processes and information systems for ITS equipment maintenance, including an Asset Management System (AMS). An AMS would help manage information on all roadside devices and their maintenance history. Each device will have a virtual file folder, containing a complete set of files on the machine's purchase, deployment, usage, and service.

The file would hold information about the manufacturer, model, and configuration. It would record when the device was installed, who installed it, and when warranty period is up. A performance record would contain

information about usage; it would record each time the device was activated or deactivated, when, by whom, for what reason, and any faults or failures.

The maintenance file would track each service activity with data on the type of service call (preventive or repair), when, by whom, what was done, what materials were used, and the cost. A calendar function would report devices that are due for preventive service. The report would be generated in a form that can be shared automatically with the maintenance contractor, perhaps via email or other electronic transfer method.

The system would offer a series of online electronic forms for entering data. Electronic input forms would be available for entering new equipment, modifying maintenance schedules, logging device failures, processing and tracking service requests, and input the results of maintenance activities.

PennDOT management and maintenance personnel will have a battery of reports available for process management, information dissemination, and performance analysis.

In support of another TSOP initiative, RWIS can be the transportation weather information and advisory component of the Information Exchange System (IES). IES is part of PennDOT's ITS vision for inter-agency coordination on incident management and emergency response. IES would facilitate near-real-time information sharing between agencies of Pennsylvania government, potentially including PEMA, State Police, Turnpike Commission, Department of Health, county 911 centers, PennDOT's Traffic Management Centers, and others.

IES would integrate components of many PennDOT software applications and databases, including roadway inventory, Road Closure Reporting System (RCRS), Advanced Traffic Management System (ATMS), and RWIS. RWIS would be able to provide current roadway weather conditions and forecasts.

During an emergency event, the RWIS information could be disseminated immediately by IES to the computer screens of command center operators at PennDOT TMCs, PEMA, State Police dispatch center, the Turnpike Commission, and potentially even similar operations centers in neighboring states.

7.2.7 Requirements Study

In recent years, a number of research projects regarding real-time sensor information gathering and reporting to customers such as RWIS and 511 have been completed. PennDOT may desire to commission a "Requirements Study" to document the current business processes around these programs and recommend a to-be business process complete with the system requirements for the software and hardware that may be needed to support program needs as they relate to ITS, Emergency Management, and Maintenance Decision Support. This is an acknowledged best practice within Information Systems Management and is the recommendation of the OCIO participant on the panel.

7.2.8 Data Management Costs

The material presented here in the *Data Management* section of this document is intended to reflect PennDOT's vision for an information technology infrastructure, databases, and software systems that will support the Department's needs for timely and reliable roadway weather information. The cost estimates below provide an order of magnitude. PennDOT will refine these preliminary estimates based on the course of action taken.

In carrying out the TSOP initiatives for developing its ITS capabilities, PennDOT has adopted a systems management methodology based on FHWA guidance in *Systems Engineering for ITS Projects*. The methodology prescribes a systematic approach to the design and implementation of information technology systems, consisting of eight steps:

- Concept of Operations
- Functional Requirements
- Software Development Plan
- Preliminary System Design
- Detailed System Design
- Integration and Testing
- Training Plan
- Operations and Maintenance

PennDOT should employ this methodology in its RWIS program. At each step in the methodology, estimates for cost to completion would be refined.

Preliminary IT Cost Estimates for Near-Term Needs	
11 district RWIS servers @ \$2,500	\$27,500
11 district firewall routers @ \$1,500	\$16,500
Central Database Server	\$ 8,000
Database software license	\$25,000
Development of 2 nd Generation application software systems	\$78,000
Total	\$155,000

7.3 Site Considerations

The RWIS system can play an important role in preventing weather related traffic incidents throughout the state if properly maintained and operated. Currently the state of the RWIS system has suffered from severe neglect in maintenance and poor design practices. With future PennDOT data management systems moving towards a centralized file sharing database, it has become increasingly important that all vendors comply with the NTCIP protocol formats that allow transferring of data between software programs. This common protocol file sharing can allow useful information gathered from the RWIS sites to be shared with other PennDOT programs such as ATMS, RCRS, 511 systems, or even future improvements such as contract weather forecasting, AVL, MDSS, and the Clarus Initiative being sponsored by the Federal Highway Administration (FHWA).

The following steps outline a standard design concept that may be used in upgrading the current installations and the addition of future installations. These steps are presented as best practices for RWIS designs.

7.3.1 Promoting Reliable Systems Communications

The survey results of the current RWIS system illustrate an immediate need for upgrading the communications to the RWIS sites. The following communications requirements provide guidance for approaching the communication design.

- **Local Connectivity** - The RWIS stations should have the ability for local communication to a laptop computer for system diagnostics and viewing data to facilitate instrument calibration and configuration.
- **District Office to Station Connectivity** - Communications need to allow PennDOT Districts to control the RWIS stations and monitor the information.
- **Centralized Data Server Connectivity** - Communications need to allow statewide RWIS system integration and file sharing among various programs.
- **System Reliability** - Communications must be reliable with minimal down time. Communications system availability goal of 99.9% or greater should be established. The communications system should be equipped with error checking and retransmit data that is received incorrectly. Additionally, communications reliability schemes, where cost effective, may allow a high reliability system to be built with inexpensive, moderate reliability components. Attention should be paid to avoiding single points of failure.
- **Suitable Bandwidth** - Communications bandwidth goals must be set which take into account the sensing platform requirements in addition to the available communications technologies. The existing RWIS stations are currently utilizing dialup telephone communications links which have a usable bandwidth of 30-40 kbps in most installations. This is sufficient for most control communications, however, unsuitable for streaming video.
- **Cost Effectiveness** - The communications design should be cost effective, and minimize long distance or over limit charges to fix costs where possible.
- **NTCIP and other Communications Protocol Compliance** - All communications must comply with the National Transportation Communications ITS Protocols (NTCIP). These protocols include NTCIP 1201, 1204 ESS standards and applicable related TCP/IP and Ethernet standards.
- **System Flexibility** - Communications must allow future expansion or integration of additional features with the changing needs of the RWIS system and utilize commonly accepted data transfer methods (for example, Open DataBase Connectivity ODBC, SQL, FTP, TCP/IP). Additionally, it would be attractive to select mediums which allow upgrade to higher performance. An example is the capability of many dialup telephone installations to allow upgrade to DSL service.

Telecommunication Services

The proliferation of the Internet for personal and business use and the “need for speed” that goes with it has brought previously unavailable data communications services to a much wider area than the analog telephone networks which were built over the last 50 years. Traditional dial-up telecommunications (POTS) in many locations is no longer the best or most cost effective means of digital communication, yet it can provide a good backup to other transmission mediums. The advantage of dialup service is that it is widespread, inexpensive, and reliable. Analog telephone exchanges still maintain battery backup power systems to prevent power loss outages. Dialup is a switched system which can route calls around many types of line failures. While this does not help if the line is down between the end terminal and the telephone switch, it does make for an overall reliable system.

To augment dialup service, we will consider other newer services which can be used for remote data communications. The primary services that will be considered for use are cellular, DSL, private radio, and frame relay (either T1 or fractional).

Cellular

Cellular modems typically utilize a CDMA (Code Division Multiple Access) or TDMA (Time Division Multiple Access) technology. While the technology used is not critical to our discussion, the capabilities of these systems are important to understand. Today’s digital cellular systems are very secure and can be robust and resistant to interference if correctly designed and constructed. Cellular modems can be an excellent choice in remote areas where traditional land lines are not easily accessible. Such is the case for much of the central to western parts of the PA interstate highway system where cellular coverage is good yet land lines may be spaced far apart.

Cellular data services currently available statewide offer data rates of roughly 120 kbps.

Currently the most likely provider for the state would be Verizon Wireless which offers the capability to configure a restricted static IP address for each modem that is installed on their system. They sell a plan which includes unlimited data transmission and continuous availability. Use of this service would allow the RWIS stations to transmit large amounts of data during periods of high demand such as during storm or incident conditions without being penalized for exceeding the bandwidth of the contract. A typical CDMA modem from Airlink with Ethernet capabilities is shown at right.



DSL Communication

For many urban and suburban areas, DSL (Digital Subscriber Line) service may be a viable option. DSL service can be used to provide a high speed connection over dialup telephone lines if a central office for the telecommunication provider is within roughly three wire miles of the station. The DSL service is provided by utilizing the unused bandwidth on a traditional POTS line. DSL can come in several versions: VDSL (Very-high bit-rate DSL), SDSL (Symmetrical DSL), ADSL (Asymmetrical DSL), and RADSL (Rate-Adaptive DSL). VDSL can provide a very fast connection but is only good for short distances. SDSL is mainly used in small business since it does not allow simultaneous voice and data transmission.



RADSL is the most likely connection that would be utilized for the RWIS sites as it allows for the speed of the connection to be adjusted to the length and quality of the land line. An available ADSL modem is shown from Black Box.

Private Radio

Private radio systems are available which could be used to build a communications system to interconnect the RWIS stations; however, this system would be considerably more complex and costly than the RWIS system itself. For this reason, private radio is not considered as a wide area communications option for the RWIS sites but radio can provide a cost effective tail-end link option in locations where cellular and land line installations are available nearby but are not available at the station location. A good example may be the use of radios to wirelessly extend telephone or DSL service across a highway.

The use of wireless radios has become increasingly popular for large distributed point to point or point to multi point networks that cover many miles of geographical area. Unlicensed frequency bands such as 900MHz, 2.4GHz, and 5.8GHz frequencies do not require licenses to be purchased from the FCC. Alternatively, licensed radio systems are available in numerous bands including 150, 450, 800, 900 MHz and the newly available “public safety” 4.9GHz band. One advantage to using radio for communication is not having a contract with a telecommunications provider and therefore no monthly fees are incurred.

In order for radios to effectively communicate there must be a clear line of site between the transmitter and receiver. This becomes a disadvantage in many areas that have high buildings or mountainous areas that have hills or vegetation obstructing the path between sites. Typical data rates can range from 9.6 kbps to 1 Mbps.

Radios are available with interfaces for Ethernet and serial networks. Serial radios are available which utilize a store-forward capability that will reduce the data throughput by one half at the repeater sites. The main consideration of RF for the RWIS sites is to transmit signals from a poor cellular or land line location to a better area of reception or land line service. Another opportunity for wireless use may be to provide PennDOT vehicle sensor platform data uploads to the RWIS site and then transmitted back to the District. An example 900 MHz serial radio system, the TransNET 900 manufactured by Microwave Data Systems is shown.



T1/Frame Relay Service

T1 communications service provides a point-to-point data link that supports digital transmission of information. A full T1 line will transmit 1.54 Mbps. T1 lines are configurable as fractional 1/2T or 1/4T lines for lower cost if a full T1 throughput is not required. There are several commonly available systems used by service providers to provide T1 service to customers. One such service is known as frame relay. Frame relay utilizes communications devices known as Data Terminating Equipment (DTE) and Data Circuit-Terminating Equipment (DCE).

Typically the DTE is owned by the customer and is referred to as a bridge or router located on the customer’s premises. The DCE is owned by the provider and provides clocking and switching of the network. Communication connections can be in two types of configurations Permanent Virtual Circuits (PVC) or Switched Virtual Circuits (SVC). SVCs do not maintain a permanent connection in the network like a PVC and



only forms connections when needed for data transmission. A typical T1 router for frame relay communication is shown.

One of the advantages of T1 service is that it provides a Committed Information Rate or CIR. This means that the service provider guarantees that the link will provide this minimum information rate. A disadvantage of T1 service is its relatively high cost (several hundred to \$1000 per month for each site). T1 service is also not available in many locations unless the service provider is paid to run the service into the area.

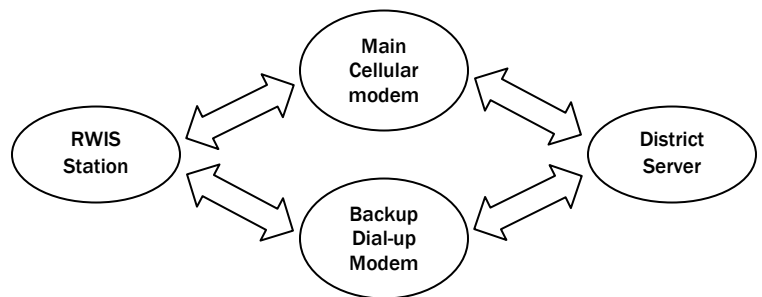
Other Available Communication Technologies

Other communication mediums that could be considered for connection to the RWIS stations include Fiber Optic modems and Satellite modems. Fiber optic requires either construction of a new or use of an existing fiber optic infrastructure. The cost of installing fiber to an RWIS location may not be practical in most cases making this a less desirable option. Satellite communications may be a practical alternative for the rural areas that lack reliable cellular coverage and limited land lines. A satellite modem is available in two-way communications using the ORBCOMM Low-Earth Orbit (LEO) satellite network. Interfaces include serial or TTL and is durable enough for the environmental conditions at a typical RWIS site. Generally, satellite communications are more expensive than cellular or landline based communications of the same speed capabilities. A typical satellite modem from Stellar Satellite Communications is shown on the right.



Telecommunication Redundancy

The current RWIS station to district communication link is via one or two non-redundant dial-up telephone land lines. This type of architecture does not allow for failures within the hardware or on the line connections resulting in a single point of failure. It was noted from the survey feedback that system reliability was a large problem for the current RWIS stations and that if reliability was increased more operators would be interested in using the RWIS data. Loss of communications to an RWIS station makes it useless even though the site itself may be functioning properly. One change that could be implemented at the RWIS stations is communication redundancy. This would allow a backup communications medium to take over in the event of a primary communications failure. This could allow the RWIS site to remain in operation until maintenance forces could remedy the malfunction. A sample diagram shown illustrates the concept of redundant, parallel communication mediums.



This type of configuration could greatly enhance system reliability and provide maintenance forces additional time to repair the faulty hardware without the total loss of communications during a critical storm condition. The cellular and dial-up configuration shown is an example. The system could use other mediums that would best suit the RWIS station location. Further investigation into each existing or new RWIS site should be conducted prior to an installation to confirm the most suitable communication mediums for each individual



site. For the existing RWIS locations that currently have dial-up connections it would be advantageous to maintain at least one of the existing land lines for the backup communication medium as this would not incur additional installation costs.

The following table outlines approximate rates for the different communication mediums discussed previously in this section. The rates shown are based on current estimates and are subject to change.

Communication Medium	Connection Fees	Monthly Contract Fees	Data Throughput	Comments
POTS Dial-Up Land Line	Phone line installation \$40	\$10-\$40 depending on the service contract	Nominally 53kbps or less	Rates negotiated by PennDOT BIS. Throughput depends on land line quality.
Radio	Cost of installation \$1,500 to \$20,000 per site	NA	9.6kbps to 1Mbps Varies per radio selection	Cost varies per radio type, tower and antenna selections
Cellular CDMA	Cost for reserving and setup of restricted static IP approximately \$1,500 per system	Unlimited data transfer approximately \$120	150kbps Varies per modem	Providers Verizon Wireless or Sprint.
ADSL Land Line	Installation & Activation \$300	One year term \$105	384k Uplink 1.5M Downlink	Listed rates from Sprint
T1 Frame Relay	T1 Port = \$342 T1 PVC = \$49 768K Port = \$205 768K PVC = \$49 56K PVC = \$10	Full T1 In Lata = \$419 Across Lata = \$1,104	56Kbps to 1.5Mbps depending on connection selected	Rates are negotiated by PennDOT BIS for. Availability in rural areas will be limited.
Satellite LEO	Data plan approximately \$400	Approximately \$70 depending on data plan selected	512kbps to 1.5Mbps downloads. 40kbps to 100kbps uploads	Wildblue Satellite Internet reference
Fiber Optical Communication	Cost of network connection.	NA	Up to several tens of Gbps	Not feasible where infrastructure is unavailable

Note: Venders are for reference purposes only.

7.3.2 Promoting Open Protocols

NTCIP ESS protocol format compliant

In order to improve the integration of different hardware and software programs within the Districts, PennDOT has begun implementing National Transportation Communications for ITS Protocol (NTCIP). These standards have already been applied to many ITS sites throughout the state. In addition to ITS protocols NTCIP has also broadened the standard to include Environmental Sensor Stations (ESS) known as NEMA TS 3.7. Later, in order to comply with the NTCIP numbering scheme, it has now become largely known as the NTCIP 1204 standard. This standard covers the methods of communication for the environmental sensors connected to a remote processing unit (RPU) and from the RPU back to other related equipment. Since previously no guidance was issued on these communication protocols venders began to develop their on protocol formats causing incompatibility among two proprietary RWIS venders. Such is the case with the existing RWIS systems already located throughout the state. Currently PennDOT has RWIS equipment installed by Numetrics, SSI, and Boschung. All three of these installations have proprietary protocols that prevent communication among themselves or to outside systems such as ATMS.

It is imperative that for RWIS to become an important player in the future of PennDOT roadway maintenance and traffic operations that these existing installations and future sites comply with NTCIP 1204 and other additional NTCIP standards. RWIS sites that comply with the NTCIP standard would allow an “open standard” approach that would easily be integrated to other PennDOT applications and allow future additions or expansion as the needs would develop. All of this could take place without complete dependency on proprietary venders demanding high rates for additional features.

NTCIP has adopted other standards for transmitting data such as:

- Point – to – Point Protocol (PPP) commonly used for dial-up links;
- Internet Protocol (IP) for local or wide area networks; and
- Transport Control Protocol (TCP) provides connection – oriented service on networks.

Remote Processor Unit (RPU)

From the RWIS site survey results it was evident that the current RWIS controllers do not meet the commonly accepted industry standards for information and control systems. The following items are basic best practice design considerations within the information and control system industry that would increase reliability in the existing installations and help guide designs of future RWIS installations.

Open Standard Platform

Much of what has been mentioned for an “open standard” design has been with the communications between the environmental sensors and the RPU and the RPU to the district servers. There is also another area in the “open standard” platform that includes the RPU configuration. This would include common off-the-shelf components that are not proprietary to one particular vendor and can be repaired, upgraded, or replaced by other approved contractors. This “open standard” RPU would help to lower installation costs by using readily available components that are competitively priced on the current market.

The other part of creating an “open standard” platform includes the RPU programming. For increased system flexibility and future upgrades the RPU microcontroller should be programmed with “open source” code using basic programming languages with readily available compilers. The current microcontrollers utilize proprietary source code that requires dependence on the vendor to make improvements or changes to the system. With “open source” programming changes and modifications would be possible by other contractors or internally by the districts. This would also help to lower the costs of making software changes to the RWIS system by allowing multiple approved programmers the ability to alter the source code without dependence on proprietary vendors.

The other advantage to using “open source” programming techniques is preventing software from becoming obsolete in the future. Often vendors will become reluctant to support older versions of their proprietary software in order to push the sales of their newer versions. With the “open standard” and “open source” RPU designs the system could continually evolve with the future needs and provide the flexibility of being integrated into other PennDOT applications and programs.

As future revisions to the NTCIP standards continue to be improved and adopted, there will be an increasing need to provide system flexibility that will easily adapt to these changes.

7.3.3 Promoting System Reliability

Environmental Resistance

Another one of the issues that was noticed in the existing RWIS sites was a lack of proper environmental consideration. Electronics located in an outdoor environment must be able to withstand extreme temperature fluctuations without degrading the integrity of the data being received, processed, and transmitted. The enclosures should be adequately sized and provide reasonable protection from the outdoor elements such as rain and rapid temperature changes. Some key considerations include the following:

- Component temperature range from -55° Celsius to 85° Celsius;
- Shock and vibration resistance;
- EMI/RFI component shielding;
- Low power consumption for lowering component operating temperatures;
- Moisture resistance with operating humidity range of 90%;
- Rodent and Insect barriers;
- Rust and corrosion prevention;
- Minimum enclosure rating Nema 3R; and
- Surge protection for Power supplies and telecommunication lines.
- Spline ball lighting protection

These key considerations are not inclusive of all the possibilities that should be taken into account but they do outline a basis for improvements and guidelines for future RWIS installations.

Panel Heating and Ventilation

Each RWIS enclosure should include ventilation slots sealed with bug filters and a thermostatically controlled ventilation fan with 100 CFM and 0.18 amps at 120VAC to maintain a controlled temperature below 40° Celsius. Additional temperature control would include equipping each enclosure with a heavy duty UL-listed radiant electric heater with a minimum output of 500 watts with a power consumption of not more than 5 amps. The addition of panel heaters would require utility service as the primary power supply instead of solar.

The enclosures should also be equipped with thermal insulation lining on the inside of the enclosure, including the front door and top of the enclosure to help maintain consistent temperatures for the electronic equipment.

Plug and Play Design Configuration

One key consideration for RWIS designs should include the ability to remove key items that are found or reported to be faulty from the site and easily replaced with the down time only a matter of unplugging the failed component and plugging in the new component without requiring it to be a specific brand. This plug and play method of repairing the RWIS sites could be conducted by any individual without needing a full understanding of the system design and operation.

Any repairs that need to be made on an RWIS site should be as quick and simple as possible to minimize troubleshooting circuits and hardware in an uncontrolled outdoor environment. Components that would need to be taken apart and repaired could quickly be replaced in the field and returned to a repair shop where it could be disassembled, repaired, and tested before being placed back into operation in another RWIS location.

Wiring & Connector Practices

All wiring, connectors, and other RWIS appurtenances should follow the NFPA-70 requirements and industry standards. Some of these guidelines are listed below, but are not inclusive of all the requirements that may apply to these installations.

- No exposed wiring
- Barrier type terminal blocks approved by NEMA must be identified and readily accessible
- Connections should be insulated spade terminals
- All cables and wires must be identified with permanent cable tags, neatly routed, and secured using cable ties
- Additional slack in cables and wires should be removed
- Power and communications wiring should never be run in the same location
- Protect all wiring and cables against sharp edges
- External cabling should be routed through approved conduit

Power & Telecommunication TVSS Protection

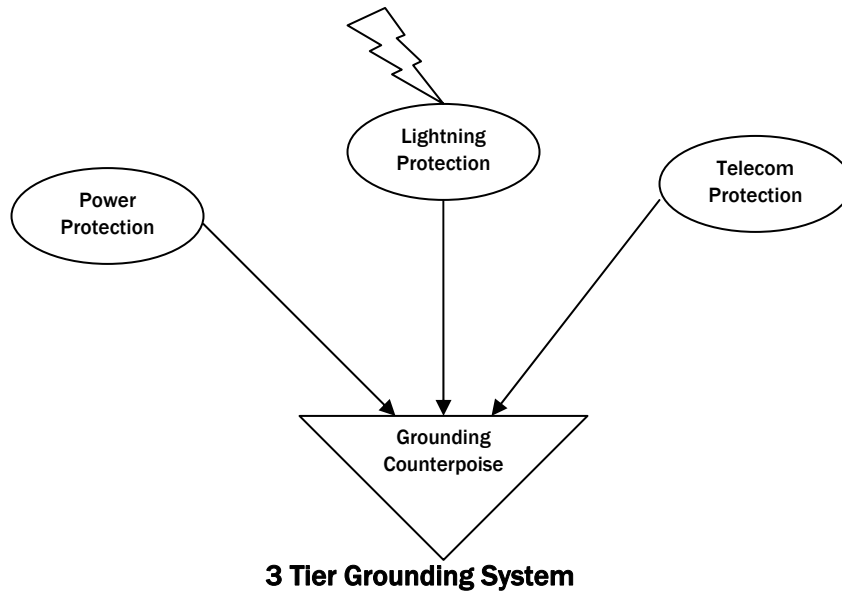
Power and communication surge protection is very essential to unmanned sites that are required to be reliable in adverse weather conditions. Many of the current installations do not have adequate protection to avoid damaged components in the advent of amperage or voltage spike.

The following table shows typical surge protection parameters that would be suitable for each RWIS site.

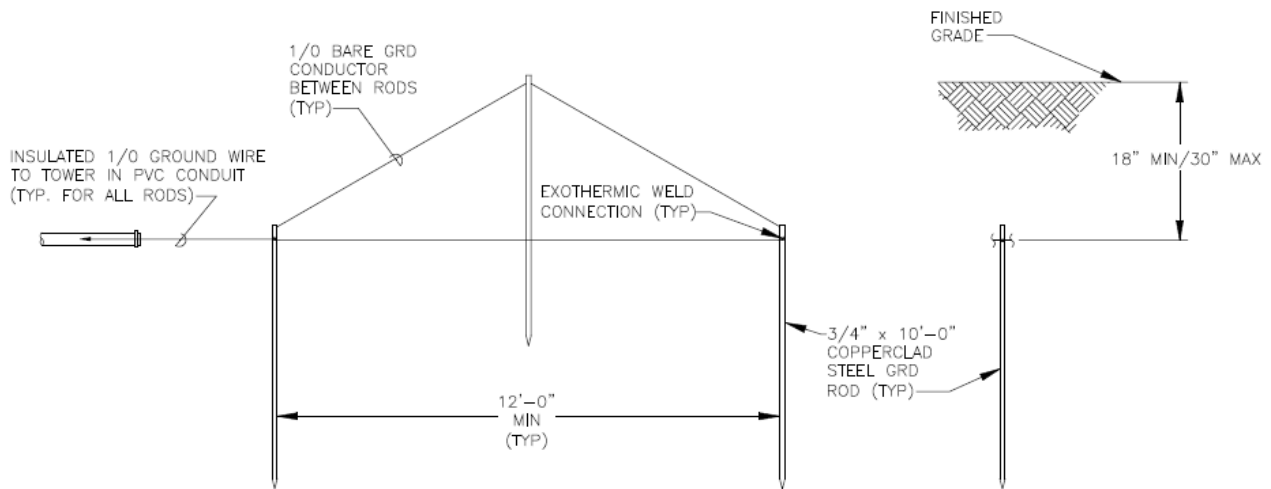
TVSS SCHEDULE			
TYPE	DESCRIPTION	CONDUCTORS	MODEL
AC Power TVSS	120VAC, IEEE C62.41 CLASS A, 10KA MIN	2	CITEL DS210D-120, LEVITON 42000
AC Power TVSS	120VAC, IEEE C62.41 CLASS B, 30KA MIN	2	CITEL DS230G-120, LEVITON 42000
Telecom TVSS	ANALOG TELEPHONE LINE	2	CITEL DLU170
DC TVSS	4 TO 20ma @ 35VDC MAX	3	CITEL DLU-24D3, LEVITON 3420-035
DC TVSS	24VDC		CITEL DLU-24D3, LEVITON 3824-DIN
Telephone TVSS	T1 OR FT1 TELEPHONE LINE, FRAME RELAY	4	CITEL DLU2-06DBC, BOURNS 1831
CAT5 TVSS	CAT5	8	CITEL ZS-CAT5 , LEVITON 3861-ETH
Serial TVSS	EIA/TIA RS232	4	CITEL DLU2-12D3
Serial TVSS	EIA/TIA RS485/RS422	6	CITEL DLU-06D3, LEVITON 3803-485
Coaxial TVSS	50-OHM 1GHz	1	POLYPHASER 1S- B50LN-C2-MA
Coaxial TVSS	50- OHM 2-6GHz	1	POLYPHASER AL-LSXM- MA
Coaxial TVSS	75-OHM	1	CITEL P8AX09-BW- FF75/BK-A, BOURNS 1740-35

Place the TVSS as close as possible to the equipment ground bus, terminate the ground terminal of the TVSS to the equipment ground bus using multi-strand.

The following illustrates a 3 tier grounding system that would provide sufficient protection for each RWIS site.



The grounding counterpoise system is shown next in the figure below with the best practice design considerations indicating preferred distances and cable sizes.



DETAIL EARTH GROUND
NO SCALE

All grounding should be in compliance with NFPA-70 and all other applicable codes and standards.

Power Supply

There are two basic options for providing power to each of the RWIS sites. The preferred method is to have utility power connected to the sites for reliability. The site would then have a UPS backup capable of providing minimum of 72 hours of backup.

The other alternative is to have a solar panel for generating photovoltaic power for the RWIS sites. Although this may be an option for some locations it was noticed that the current lack of maintenance has allowed trees and other vegetation to grow over the solar panels and render them useless. Since these sites are unmanned and should require low maintenance, solar power should only be considered if diagnostic tools are utilized.

A third option would be to include solar power as a redundant source to the utility. The advantage to this option would be when the utility power is lost the solar could provide additional storage to the UPS increasing the backup time more than the basic 72 hours without any additional power source.

Status Meters

When conducting maintenance on a RWIS station a useful diagnostic tool to aid in the determining of the status would be to have fixed meters to display the voltage, current, UPS power supply condition, and communication status. These meters could be fastened internally to the enclosure that would quickly display if the site has lost outside utility power, the UPS is failing, or if the communications from the modem is not functioning. For further diagnostics a laptop could be connected to the controller.

7.3.4 Promoting and Enhancing Data Collected

Video Processing

Video processing has many different capabilities that can make it a specialized tool for many applications. Currently the RWIS video consists of low resolution snap shot images that are suited for transmission across low bandwidth dial-up connections. Currently every 10 to 15 minutes the system dials in and downloads the snap shot image. Most of the time this may be all that is necessary for viewing roadway conditions, but during severe storm conditions it would be useful to see increased transition of the images or possibly see real-time changes.

One possibility would be to use a higher speed connection other than a dial-up line that would transmit video images at decreased rate during normal weather conditions and then during a storm the transmission rate would increase to near real-time to keep the maintenance personal up to date with the current changes in the weather. This system flexibility could easily be accommodated by using a high speed cellular or digital connection that would provide the increased bandwidth for transmitting 4 CIF (704 x 480 pixels) at minimum 12 frames per second. Other functionality would be PTZ uploads to manually adjust the viewing angle and initiating presets for the camera to automatically rotate through. The video processor would then require a triggering source to communicate the desired transmission levels, which could be manually or automatically activated.

Since many of the RWIS locations are in rural areas that currently do not have any ITS installations it would be useful to install additional CCTV cameras at some of the RWIS sites with PTZ abilities that would have presets for viewing traffic conditions and relaying the video back to the ATMS at the local TMC. This would provide the ATMS with a much broader coverage than is currently available and would help to increase traffic management operations across the state. For these type of installations the communication medium would require high speed connections of minimum 768kbps or higher to decrease latency issues in the PTZ controls and minimize operator induced oscillations when repeated commands are initiated by the operator. Some of these affects can be minimized by pre-programming a preset time delay into the video feedback.

As an alternative to the PTZ installations for the ATMS some of the locations could use the fixed cameras already installed on the RWIS towers to view traffic information. By adjusting the angle of the fixed cameras from viewing only the road surface to a longer area of the roadway more information could be gathered in regards to traffic congestion and approximate velocity. Since the cameras would then be used by both RWIS and ATMS systems the refresh rate would need to increase to a minimum 1 fps on a dial-up line or 12 fps on high speed connection. The dial-up connections can greatly restrict view images from cameras. For example, a 50kB downloaded over a 9600 baud modem would take 50 seconds, but it would only take 0.5 seconds for an Ethernet user over a 100kBps connection. For fixed cameras that are being used by the ATMS for traffic surveillance, a minimum 100kBps connection would be available using the cellular modem.

Data Reliability

The main purpose of the RWIS sites is to provide reliable data that can help predict maintenance operations. With better sensor technology the data would have increased precision and therefore become a better tool for treating weather related conditions. But with all of this information, there may be a time when there is too much data or the data is not being correctly displayed. The following table issued by Aurora outlines the minimal requirement that should be the basic considerations for each RWIS installation.

Parameter	Unit	Accuracy and Range	Update Frequency	Comment
Pavement Temperature	Celsius	Tenths of a degree (-1000..1001)	N/A	1001 indicates a missing field
Air Temperature	Celsius	Tenths of a degree (-1000..1001)	N/A	1001 indicates a missing field
Relative Humidity	Percentage	Integer percent (0..101)	N/A	101 indicates a missing field
Average Wind Speed	Meters per second	Tenths of a meter per second	Every two minutes	65535 indicates a missing field
Average Wind Direction	Degrees	Integer degrees (0..65535)	Every two minutes	65535 indicates a missing field
Precipitation Situation	Numeric code	Codes range from 1-15	N/A	N/A
Dew Point	Celsius	Integer (-1000..1001)	N/A	1001 indicates a missing field
Precipitation Accumulation	Kilograms or millimeters per square meter	Tenths of a kilogram or millimeter (0-65535)	24 hours	65535 indicates a missing field Different time period option.
Visibility	Meters	Tenths of a meter given as an integer (0-1000001)	N/A	1000001 indicates a missing field

ESS Parameters and Attributes

Road Weather Information Systems (RWIS) Data Integration Guidelines, Aurora Final Report; Page 36 Table 16; October 2002, Accessed June 8, 2007

Implementing New Sensor Technologies

Since sensors are the heart of the RWIS system it only makes sense to ensure that they are accurately gathering data that is relevant to the purpose of the RWIS system. Some of the sensor upgrade possibilities include strategically installing precipitation accumulation, type and intensity sensor, rain gauge, optical present weather detector, and hot-Plate type precipitation sensor.

One of the key sensors to the RWIS sites is the roadway sensors or surface sensors. How these sensors work is by installing the puck shaped sensor into the roadway surface. The disadvantage to this approach is that when road maintenance is done the sensor gets either ground off by the construction crew or paved over with new blacktop and destroys the sensor. An alternative to this type of installation is the infrared sensor technology. This type of sensor could be mounted on the RWIS tower and monitor road surface temperature. The accuracy of these sensors has not been fully tested. A picture of a Vaisala infrared sensor is shown on the right.



The following table outlines the available sensor technologies considered for the RWIS sites along with the current and desired sensors by PennDOT.

Environmental Sensors	Data Currently Collected by PennDOT	Desired Data by PennDOT	Suggested Sensors for Upgraded/New RWIS Sites
Thermometer	√	√	√
Hygrometer	√	√	√
Conventional and Sonic Anemometer and Wind Vane or combined sensor (Aerovane)	√	√	√
Pavement Sensor	√	√	√
Subsurface Temperature Probe	√	√	√
Subsurface Moisture Probe			
Rain Gauge, Optical Present Weather Detector	√	√	√
Rain Gauge, Optical Present Weather Detector, Hot-Plate Type Precipitation Sensor		√	
Ultrasonic or Infrared Snow Depth Sensor		√	√
Optical Visibility Sensor, Closed Circuit Television Camera	√	√	√
Barometer	√	√	√
Solar Radiation Sensor			
Total Radiation Sensor			
Pressure Transducer, Ultrasonic Sensor, Float Gauge, or Conductance Sensor			
PTZ Cameras		√	√
Fog and Frost Detection System or Bofog Sensor			
Wetness Sensing Grid or Leaf Wetness Sensor			
Ice Camera			
Remote Microwave Traffic Sensor		√	√

For further information regarding sensor availability and vender information see section 4.4.2 Key Sensors.

Sensor Testing and Calibration

RWIS sensors vary in accuracy and precision. Although this is an accepted condition of sensor operations, sensor errors must be minimized to ensure quality observations. Calibration standards are procedures for testing the accuracy of these observations. They compare the performance of the sensor with established

criteria and performance measures. Calibration standards apply to how sensors function: in laboratory settings (initial calibration), when first installed in the field (onsite calibration), and over a period of routine maintenance (recalibration).

Currently, most state and local agencies use calibration procedures developed by the vendor for the sensor, or they accept sensor data without verification or validation. Calibration standards provide the agencies with guidelines for developing their own testing program, ensuring that the data being generated by their network of sensors are accurate, reliable, and uniform within an acceptable margin of error.

Calibration standards can also serve as the foundation for a quality control/quality assurance program for sensor operations. In addition, an agency can use a mesonet (mesoscale environmental monitoring network) to further bolster such a program. A mesonet defines both the technical and institutional arrangements for collecting and sharing weather data among a range of public and private end users. Information exchanged within a mesonet can help an agency identify irregularities in data collection and measurement. This can greatly enhance the quality of its calibration program.

Calibration standards lead to the following benefits:

- Verification and validation of the level of accuracy of RWIS sensors
- Certification of results (with a common agreement and understanding of the criteria that must be met for certification)
- Better reliability of data, which should lead to wider use of the data by public and private users of weather data

Applicable Codes and Standards

Each RWIS installation should be in conformance to the following list of codes and standards.

- National Transportation Communications for ITS Protocol – NTCIP/Current
- Institute of Electrical Electronics Engineers – IEEE
- National Fire Protection Association – NFPA
- National Electrical Code – NEC
- PennDOT Publication 408/Current
- American National Standards Institute – ANSI
- Telecommunication Industry Association – TIA
- Electronics Industry Alliance – EIA
- American Association of State Highway and Transportation Officials – AASHTO
- Institute of Transportation Engineers – ITE
- National Electrical Manufacturers Association – NEMA
- American Society for Testing & Materials – ASTM
- Society of Automotive Engineers – SAE
- Underwriters Laboratories – UL standards

7.3.5 Site Layout and Design²⁵

Site layout and design are critical in the acquisition of pertinent, accurate weather information. The following criteria should be evaluated before selecting a site location:

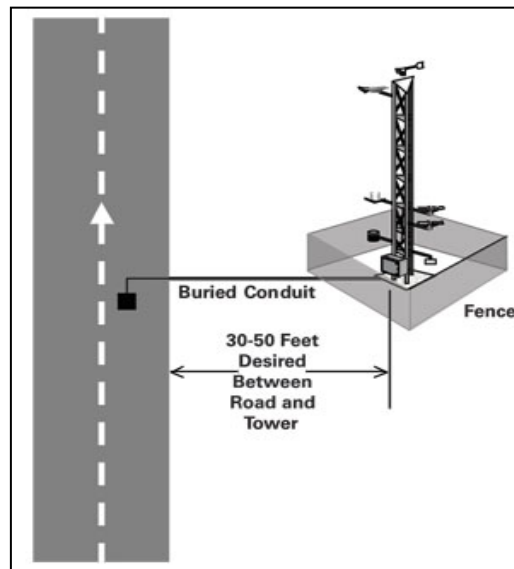
- Road right-of-way
- Power/communication access
- Potential obstructions to sensors
- Site access for maintenance
- Geography
- State, County, and City codes

Once a location has been selected, documentation of the site location and sensors utilized should be recorded. Site layout and design criteria have been split into two sections: observation tower and sensor location.

Observation Tower

The following criteria are considerations that should be utilized in the selection of towers and their location:

- Tower should have an open matrix (lattice structure) construction with instrument booms to reduce contamination of sensor data from wind. If a wind sensor is utilized, the tower should be at a height of 33 feet.
- Towers are frequently located within 30-50 feet of the edge of the roadway. No studies have been conducted to confirm these distances at this time.
- Tower should be installed on top of a concrete pad to provide a solid foundation.
- Terrain surrounding the tower should be low vegetation or soil, approximately a perimeter of 50 feet is necessary.
- Folding towers should be considered for ease of maintenance.
- If vandalism is present, a perimeter fence should be utilized. A distance of at least 15 feet from the tower should be utilized to prevent contamination of sensor data.
- If possible, locate tower base at the elevation of the roadway surface.
- If possible, place towers upwind of roadway based on the predominant wind direction for the season of most interest.



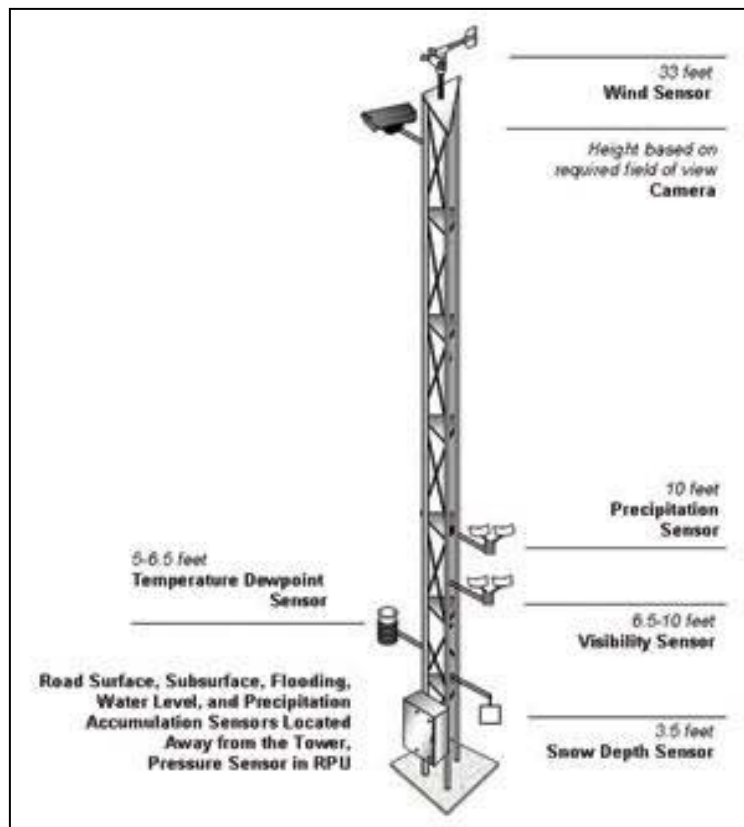
**Tower Location Relative to
Roadway**

²⁵ FHWA-HOP-05-026 Road Weather Information System Environmental Sensor Station Siting Guidelines

Sensor Location

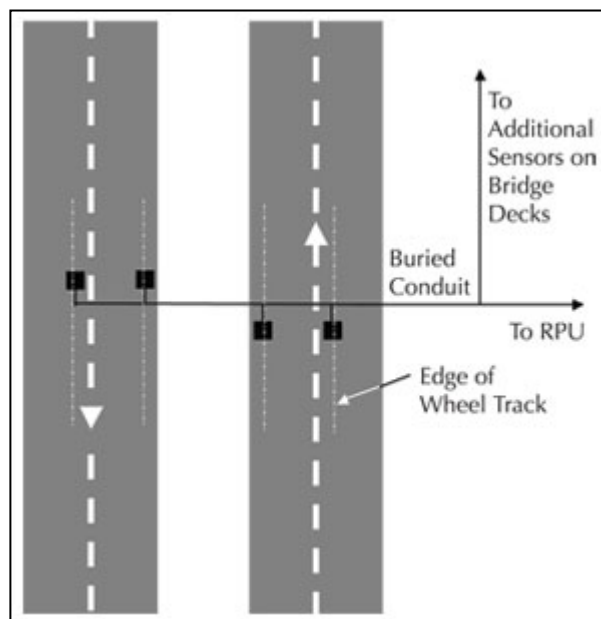
The following are recommended guidelines for sensor locations, adjustments may need to be made in areas of heavy snowfall for non-atmospheric and atmospheric sensors:

- Air temperature/dew point sensors should be located within a radiation shield in a well ventilated area mounted approximately 5-6.5 feet above ground level. The sensor should be attached to a boom extending 3 feet from the tower towards the predominant wind direction.
- Wind speed/direction sensors should be positioned at the top of the tower.
- Optically based precipitation sensors should be installed 10 feet above ground level. Optical based sensors should be installed to avoid direct light from the sun and other light sources.
- Visibility sensors should be installed approximately 6.5-10 feet above ground level. Install sensor away from direct light sources.
- Precipitation accumulation sensors can either be installed separately or on the tower. If mounted on the tower, the sensor should have an unobstructed view above it.
- Barometric pressure sensor can be installed at any height and should be encased in a protective shelter.
- Snow depth sensors should be installed perpendicular to the surface at a height of 3.5 feet above ground level.
- Cameras (visible and infrared) should be installed where a clear line of sight can be obtained and not interfere with the operation of other sensors. Cameras should be installed as close as possible to the driver's level of sight.



Typical Location of Sensors

- Pavement sensors can provide representative and specific road surface information depending on their location. For a representative sample, sensors should be located in unshaded areas to represent the surrounding road segment under maximum cooling conditions. In areas of prevalent shade, additional sensors may be utilized to provide an improved indication of local weather conditions. When installing pavement sensors on multilane highways, sensors should be installed in each lane. If only one sensor is to be installed the travel lane is utilized. Pavement sensors should be installed near the edge of the inside wheel track. Avoid installing sensors in wheel track depressions to prevent contamination of sensor readings due to ponding water. Placing pavement sensors in the center of the lane is not recommended. Pavement temperatures can be as much as 2°F higher in lane centers. Sensor should be installed flush with the road surface.
- Subsurface temperature and moisture sensors should be installed at a depth of 12 or 18 inches depending on the manufactures specifications.



Typical Pavement Sensor Siting

7.3.6 Steps to Providing System Improvement

In the following, three step suggestions are given on improving the RWIS sites along with the anticipated timelines for each phase to be completed.

Step 1) Upgrade Existing Legacy RWIS sites

The current RWIS sites require much needed maintenance that would address all the concerns listed in the site survey and in the previous sections. In addition to the maintenance there is a definite need to have regular scheduled maintenance every 3 months including a site visit and conducting a complete systems check.

All failed or obsolete components should be removed and replaced. Grounding should be improved to meet the requirements previously outlined. TVSS and surge protection should be tested and replaced if faulty. See table "Summary of Site Conditions" in section 3.4.5 for further maintenance issues.

The other improvement to the sites would include installing CDMA cellular communications to the sites with self diagnostics that provides feedback on the health of the modems. The dial-up connections could be maintained as backup to the cellular modem in the event of a complete failure. This would increase the system reliability considerably more than it is now.

The time line for these improvements should begin immediately to provide the state with a functional RWIS system by September 2007.

Step 2) Upgrade Existing Legacy RWIS sites with CCTV/PTZ

The other addition to the upgrades at the legacy sites includes installing CCTV cameras with PTZ control back to the TMC and controlled by ATMS. Since not all locations would require this addition a study should be conducted to determine which sites would be beneficial for adding the CCTV cameras.

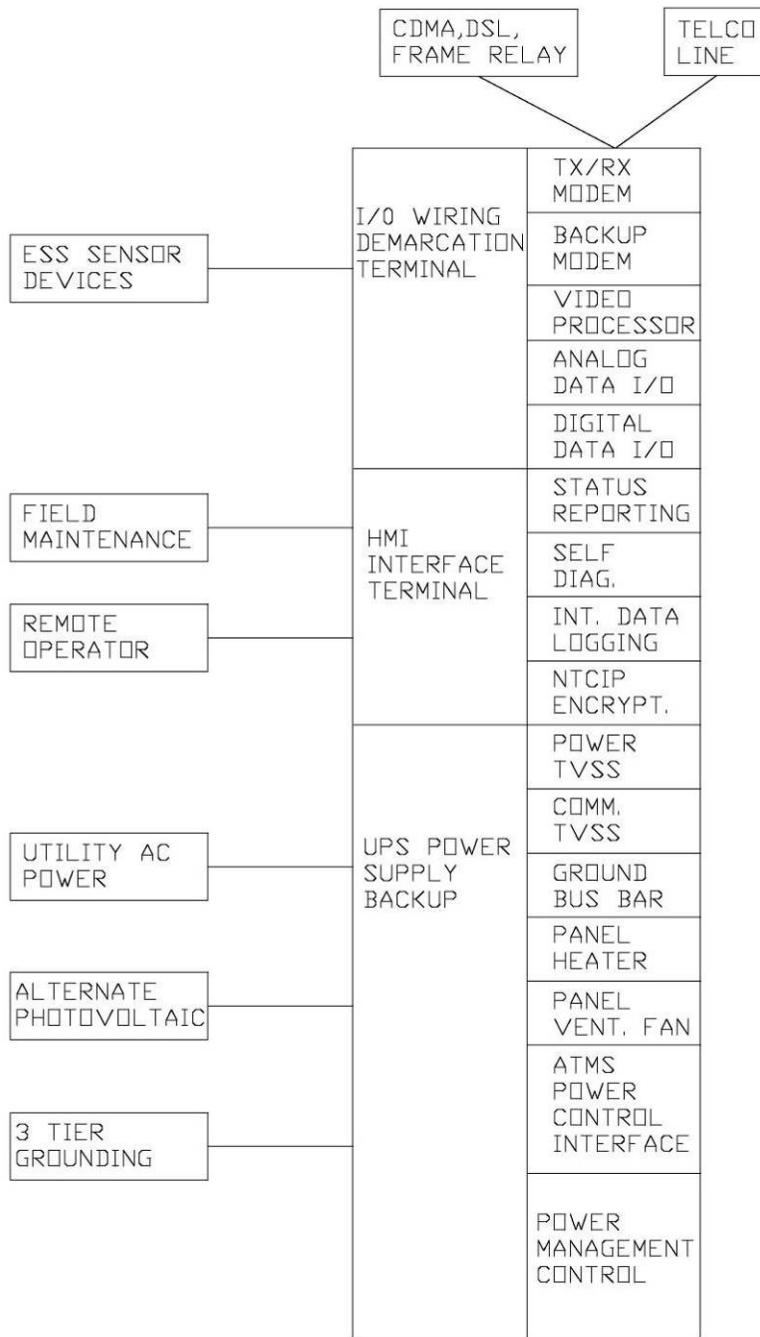
For this addition, high speed connections would have to be added to each site as discussed previously. If the cellular modems are implemented as in the previous step with the dial-up connection used as backup the cellular connection would provide sufficient bandwidth for the CCTV camera. If a failure in the cellular communication occurs, the manual PTZ functionality could be removed with only automatic presets allowed and frame rates reduced to allow for snap shots of the video images to be passed over the dial-up connections. Refresh rates for the images should be less than 5 minutes for dial-up CCTV data transmission.

Self diagnostics for the cellular modems would provide health status of the modems for preventive maintenance.

The time line for this integration could take place within a 1-7 year period that could begin during the 2007 RWIS site upgrades.

Step 3) Install New Open Standard RWIS site

Future installations of RWIS sites should follow the open standard design steps laid out in the previous sections. A sample of this architecture is shown below.



RWIS Controller Architecture

This system could be designed around the “open standard” platform that would allow off-the-shelf current technologies to be utilized instead of proprietary OEM contracts. The programming would be “open source” code that could be easily reconfigured and upgraded to meet the evolving needs of each RWIS site. The site maintenance could easily be supported by multiple contractors instead of proprietary vendors.

The new system design should also include self diagnostic tools that monitor the health of the RPU and sensors at each new RWIS site and provide feedback to the proper personnel warning them of a failing or failed component. This increased interaction with each RWIS location would provide reliable and accurate data to the maintenance operators.

The time frame for introducing these new installations could approximately take place over a 1-10 year period in phases that would not interrupt the current installations.

7.3.7 Site Maintenance Practices

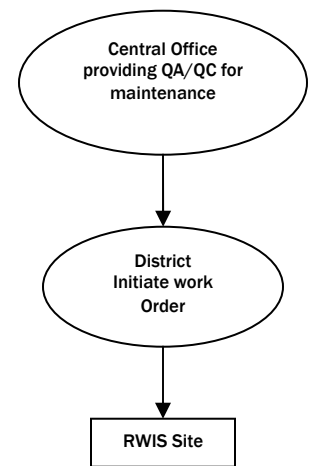
Site maintenance of the existing ITS deployment is initiated by District ITS Units. This maintenance program has met with varied success in the ITS program. Since the RWIS sites are becoming an integrated system that is taking on some of the functionality of an ITS site it would seem logical that they both fall under the same maintenance procedure.

Currently there is no “Systematic Maintenance Procedure” in place for the maintenance of these sites. Future direction could include writing a “Set of Standard Procedures” that would be documented and overseen by a central body to provide direction to each district regarding the maintenance for RWIS and other sites. Then if a failure occurred at one of the RWIS sites, District ITS Units would be notified and a work order for the repair could then be given to the districts initiating the maintenance procedure.

Regular scheduled maintenance should still be conducted every 3 months to verify that the sites have not suffered physical damage due to extreme weather conditions or vandalism. Areas close to wooded areas or other vegetation should be cleared of over growth once in the spring and once in the fall seasons. A comprehensive check list should be issued for the quarterly site visit that lists all the items that need to be check therefore maximizing the time spent at each site.

All maintenance contracts that are signed by PennDOT with an outside contractor should state that the contractor is responsible for the entire site regardless of whether they provided the equipment or not. Site maintenance is for keeping the sites operational and includes all the components of the RWIS site installation. Once site maintenance has been conducted, a quality assurance and quality checking (QA/QC) review should be conducted to verify that the conditions of the contract have been met. The QA/QC could be conducted internally with the department or by a third party. Some of the consideration should include:

- does the site have good communications,
- does the check list indicate the status of each component in the RPU,
- does the checklist indicate the status of the sensors,
- are the sensors within calibration requirements,
- is the site clear of any obstructions that would hinder proper operation,
- if any damage at the site has been detected was it repaired,
- have all connections and wiring been inspected for damage or poor contact, and
- has the site been rated as excellent, good, or fair condition and reason for the rating.



7.3.8 Site Upgrade Cost Estimate

The estimated cost of upgrading the existing and installing new sites is shown in the table below.

ROADWAY WEATHER INFORMATION SYSTEM (RWIS)
Maintenance & Upgrades
Construction Cost Estimate

Cost Basis
2007

Item	Site Index						Total Quantity		Material Unit Cost	Labor Unit Cost	Total Unit Cost
	1	2	3	4	5						
Unlicensed RF Radio, Antenna, ect							0	EA.	\$ 4,000	\$ 1,000	\$ 5,000
Dial-Up modem	1	1	1	1	1		5	EA.	\$ 40	\$ 100	\$ 140
Cellular modem	1	1	1	1	1		5	EA.	\$ 2,000	\$ 100	\$ 2,100
DSL modem							0	EA.	\$ 300	\$ 100	\$ 400
T1 Bridge							0	EA.	\$ 1,000	\$ 100	\$ 1,100
RPU (processor, I/O cards, communcations hardware, ect)			1	1	1		3	EA.	\$ 15,000	\$ 2,000	\$ 17,000
RPU Operating Software (Open Standard)			1	1	1		3	EA.	\$ 2,000	\$ 500	\$ 2,500
Surface sensor (In roadway)			1	1			2	EA.	\$ 4,600	\$ 2,000	\$ 6,600
Surface sensor (Remote roadway surface & environmental)					1		1	EA.	\$ 28,000	\$ 300	\$ 28,300
Sub Surface sensor			1	1			2	EA.	\$ 700	\$ 300	\$ 1,000
Wind speed and direction sensor			1				1	EA.	\$ 1,500	\$ 300	\$ 1,800
Air Temperature sensor			1				1	EA.	\$ 700	\$ 200	\$ 900
Relative Humidity sensor			1				1	EA.	\$ 600	\$ 200	\$ 800
Barometric Pressure sensor			1				1	EA.	\$ 800	\$ 200	\$ 1,000
Infrared Snow depth sensor			1				1	EA.	\$ 2,100		\$ 2,100
Precipitation sensor			1				1	EA.	\$ 1,500	\$ 200	\$ 1,700
Visibility sensor			1				1	EA.	\$ 3,600	\$ 200	\$ 3,800
Precipitation Accumulation sensor (Tipping bucket)			1	1			2	EA.	\$ 600.00	\$ 200.00	\$ 800.00
Optical Present weather sensor (Type and Intensity sensor)							0	EA.	\$ 8,500	\$ 200	\$ 8,700
Traffic sensor							0	EA.	\$ 1,000	\$ 300	\$ 1,300
Fixed camera (Enviromental conditions)			1	1			2	EA.	\$ 1,000	\$ 200	\$ 1,200
PTZ CCTV camera for ATMS applications		1	1	1			3	EA.	\$ 4,000	\$ 300	\$ 4,300
30' self supporting tower for sensor & camera mt.			1		1		2	EA.	\$ 5,000	\$ 2,000	\$ 7,000
Lightning Protection, Rods, TVSS, Ground	1	1	1	1	1		5	EA.	\$ 200	\$ 500	\$ 700
Conduit and wire for power			40	40	40		120	L.F.	\$ 1.50	\$ 5.00	\$ 6.50
Other conduit and wire			80	80	80		240	L.F.	\$ 2.00	\$ 5.00	\$ 7.00
Subtotal per Site	\$ 2,940	\$ 7,240	\$ 56,260	\$ 37,160	\$ 58,560	\$					

Notes:

- 1) Estimate does not include telecommunication connection fees or monthly costs.
- 2) Estimate does not include maintenance to repair the current malfunctioning equipment
- 3) Cost estimates from SSI, Campbell Scientific, Vaisala, Envirotech
- 4) Remote surface sensor provide enviromental sensing technology and is listed as alternative to the open traditional sensor technology

7.4 Deployment and Upgrade Guidelines

Historically, the Departments 75 RWIS sites and 10 RWIS/FAST sites (85 total) were deployed at perceived weather trouble spots and with input from engineering districts and county maintenance. As a result, there are various deployment densities by engineering district. This creates a non-uniform perspective of statewide roadway weather conditions. While the unique and varying weather patterns make a completely uniform spacing impractical, some consideration to consistent deployment guidelines should be considered.

Consideration	National Guidance	Suggested Pennsylvania Direction
<p>Regional Needs</p>	<p>Regional sites support broad, real-time monitoring of weather and road conditions across a geographic area. Equally important, these sites can also be used to provide data to improve the accuracy of surface transportation specific forecasts (e.g., pavement temperature forecasts). Installing regional sites across an area lacking sensors helps define the initial environmental conditions necessary to run road weather prediction models. These sites can also provide ground truth for comparing surface transportation specific forecasts with real-time observations to evaluate the accuracy of the forecasts. Additionally, locating a regional ESS in an isolated area where no other weather observations are available or in a location upstream of an area of interest can improve the ability to anticipate changes in the road weather environment in a specific area of interest.</p> <p>The size of the area for which road weather observations from a regional ESS site can be considered representative is influenced by a number of factors including topography, climate, and the time and space scale of the weather event under observation. There are no studies that define the optimal separation between regional ESSs to monitor road weather events and to support weather models. Some weather forecasting models include a grid spacing as low as 2.5 miles (4 kilometers (km)). While installing regional ESSs with a 2.5 mile (4 km) separation may be desirable to contribute to more accurate weather forecasts, doing so may be cost prohibitive. A spacing of approximately 20-30 miles (30-50 km) along a road is recommended as a guide²⁶</p>	<p>Deploy on National Highway System (Interstates and US Routes) at typical intervals of 20-30 miles/site depending on climate</p>
<p>Local Needs</p>	<p>Local sites are those that require siting of sensors in areas that are specifically designed to satisfy a road weather information requirement along a short segment of roadway or a bridge. Examples of these requirements include: (1) road surface conditions such as historically cold spots that create slippery conditions or a location where significant blowing, drifting, or heavy snow accumulation occurs, (2) surface flooding on low lying road segments, (3) visibility distance where the local environmental conditions contribute to low visibility (e.g., a large local moisture source), or (4) high winds such as those occurring in hurricanes and terrain-induced crosswinds along a confined valley or ridge top. These local requirements may require the use of additional sensors or the siting of sensors in a location that is specifically selected to detect and/or predict a local roadway condition or weather phenomenon. At local sites, the primary consideration is detecting the road weather condition of specific interest to transportation operations and maintenance activities.²⁷</p>	<p>Deploy at locations with above average weather-related crashes including lower classifications of roadways</p>
<p>Operational Coordination</p>	<p>Little national guidance exists on the concept of co-locating RWIS with other ITS devices. Most RWIS images still include fixed snapshots of conditions. There may be potential savings if RWIS sites can be co-located with planned ITS deployments.</p> <p>Wisconsin locates RWIS at trouble spots, but also attempts to co-locate with other ITS devices</p>	<p>Coordinate and deploy in RWIS "gap" areas when other ITS elements (CCTV) are being deployed</p> <p>If a CCTV site is proposed in RWIS gap area, implement combined RWIS/ CCTV configuration</p>

²⁶ FHWA, Road Weather Information System Environmental Sensor Station Siting Guidelines

²⁷ FHWA, Road Weather Information System Environmental Sensor Station Siting Guidelines

7.4.1 Suggested Deployment Criteria

While regular intervals are suggested for forecasting purpose, the need for RWIS is not as strong in areas with lower snow and ice accumulations. Additionally, while coverage of all state roadways would be desirable, it may not be practical to deploy RWIS at the same densities on lower classification roadways. Using national guidance and an understanding of the extensive transportation network under the jurisdiction of the Department, the following deployment criteria were developed.

Roadway Classification	Winter Snowfall Totals		
	<30 inches	30-60 inches	>60 inches
Interstates	30 mile/ site	25 mile/ site	20 mile/ site
Freeway/ Expressways (US Routes)	30 mile/ site	25 mile/ site	20 mile/ site
Other Principal Arterials	As warranted based on local conditions, assumed 400 mile/ site		
Minor Arterials	As warranted based on local conditions, assumed 800 mile/ site		
Major Collectors	As warranted based on local conditions, assumed 1,200 mile/ site		
Minor Collectors/ Local Roads	As warranted based on local conditions and funded by others		

7.4.2 RWIS Deployment Demands

When these general numbers are applied to statewide road miles the following total demand is estimated.

Roadway Classification	Macroscopic RWIS Demand Assessment		
	Road Miles	Assumed Spacing Criteria (mi/site)	Total RWIS Demand
Interstates	1,758	25	70
Freeway/ Expressways (US Routes)	546	25	22
Other Principal Arterials	4,801	400	12
Minor Arterials	8,421	800	11
Major Collectors	1,2581	1,200	10
Minor Collectors	7,256	NA	NA
Local Road	85,305	NA	NA
Total	120,667	NA	Total 125 Current 75 Additional demand 50

This macroscopic assessment indicates that an additional 50 RWIS are needed to provide adequate coverage.

For a more detailed comparison, demands were generated for each county based on road miles (by class) and snow fall. The total demands were compared with existing deployments to identify additional deployments required which are summarized by District below and are detailed (by county and class) in **Appendix H**.

District	District RWIS Demand Assessment		
	Total RWIS Demand	Current RWIS Deployed	Additional RWIS Demand
1-0	5	14	1
2-0	3	9	0
3-0	3	5	2
4-0	8	7	3
5-0	9	5	6
6-0	13	0	13
8-0	12	7	7
9-0	5	8	3
10-0	3	6	0
11-0	9	5	5
12-0	8	9	5
Total	78	75	45

The District (county by county) analysis indicates that an additional 45 RWIS sites are needed. The large number of additional RWIS sites is attributable to improper spacing and poor location of current RWIS sites. If located properly, the number of additional RWIS sites needed for adequate coverage would be greatly reduced. The inconsistencies between the Total RWIS Demand and Current RWIS Deployed may be attributed to the deployment of RWIS sites in high crash or extreme weather locations. In addition, the high number of Additional RWIS sites may be attributable to denser deployments in some districts while other districts have limited or no deployments.

While winter maintenance and operations is critical on all roadways, interstates and US routes carry a significant portion of the total vehicular demand. Interstates roadways account for only 1.5 percent of state road miles, but carry 24 percent of the total daily vehicle miles of travel²⁸. The National Highway System accounts for only 4.5 percent of state road miles but carry 45 percent of the total daily vehicle miles of travel²⁹.

The table on the next page illustrated RWIS demands for interstate roadways and US Routes. Many of the US Routes include freeway or limited access sections where denser deployments were calculated as well as arterial sections with less dense deployment criteria.

Based on this analysis key roadways may warrant an additional 40 RWIS deployments. Again, this higher number may be attributable to denser deployments in some areas while other areas have limited or no deployments.

Summary of Deployment Demands

Based on the analysis presented above, it is estimated that an additional 45 to 50 RWIS sites may be warranted to provide adequate system coverage.

²⁸ Pennsylvania Highway Statistics 2005

²⁹ Pennsylvania Highway Statistics 2005



ROUTE	TOTAL LINEAR MILES	MEAN AADT	CURRENT RWIS DEPLOYMENTS	CURRENT AVG SPACING	ESTIMATED SPACING CRITERIA	TOTAL RWIS DEMAND	ADDITIONAL RWIS REQUIRED
I 70	80.69	32,386	2	40.3	30	3	1
I 76	349.62	37,691	3**	-	28	12	9
I 78	75.49	43,349	1	75.5	29	3	2
I 79	182.91	31,027	4	45.7	25	7	3
I 80	311.07	29,947	13	23.9	25	12	0
I 81	232.60	45,797	9	25.8	25	9	0
I 83	50.52	63,629	1	50.5	30	2	1
I 84	54.89	22,468	1	54.9	23	2	1
I 86	7.00	8,813	0	-	20	0	0
I 90	46.39	28,981	2	23.2	20	2	0
I 95	51.08	117,247	0	-	30	2	2
I 99	51.12	16,716	1	-	25	2	1
I 176	11.32	19,580	0	-	30	0	0
I 180	28.84	27,908	0	-	27	1	1
I 276	32.65	81,845	0	-	30	1	1
I 279	19.52	75,849	0	-	30	1	1
I 283	2.91	61,435	0	-	30	0	0
I 376	14.70	76,616	1	14.7	30	0	0
I 380	24.44	22,663	1	24.4	22	1	0
I 476	129.61	43,428	0	-	27	5	5
I 579	1.57	64,432	0	-	30	0	0
I 676	2.55	112,230	0	-	30	0	0
INTERSTATE SUBTOTAL	1,761.49		36.00	37.89	27.09	65.00	28.00
US 1	92.37	39,536	0	-	252	0	1
US 6	404.58	6,445	4	101.1	374	1	0
US 6N	27.93	3,761	0	-	400	0	1
US 11	246.98	12,644	0	-	288	1	1
US 13	43.55	18,061	0	-	308	0	1
US 15	192.19	13,177	2	96.1	124	2	0
US 19	186.75	9,071	0	-	358	1	1
US 20	45.38	11,436	0	-	324	0	1
US 22	321.81	18,655	4	80.5	190	2	0
US 30	328.39	18,500	1	328.4	263	1	0
US 40	82.69	7,866	1	82.7	400	0	0
US 62	118.53	5,237	1	118.5	343	0	0
US 119	125.52	10,577	1	125.5	250	1	0
US 202	61.25	37,312	0	-	289	0	1
US 206	0.40	8,200	0	-	30	0	0
US 209	140.73	8,542	0	-	370	0	1
US 219	208.05	7,107	3	69.4	297	1	0
US 220	226.09	5,678	0	-	212	1	1
US 222	93.49	24,390	0	-	241	0	1
US 224	8.06	9,250	0	-	400	0	0
US 322	363.38	8,394	4	90.8	325	1	1
US 422	203.29	19,966	1	203.3	251	1	0
US 522	126.98	3,934	0	-	398	0	1
US ROUTE SUBTOTAL	3,648.39		22.00	129.63	290.74	13.00	12.00
TOTAL INTERSTATES AND US ROUTE	5,409.88		58.00	167.52	317.83	78.00	40.00

** 7 RWIS sites are within 7 miles of one another for the fog detection system, recorded as 1 RWIS site
Each US Route of at least 25 miles should have a minimum of 1 RWIS site

7.4.3 Deployment and Upgrade Prioritization

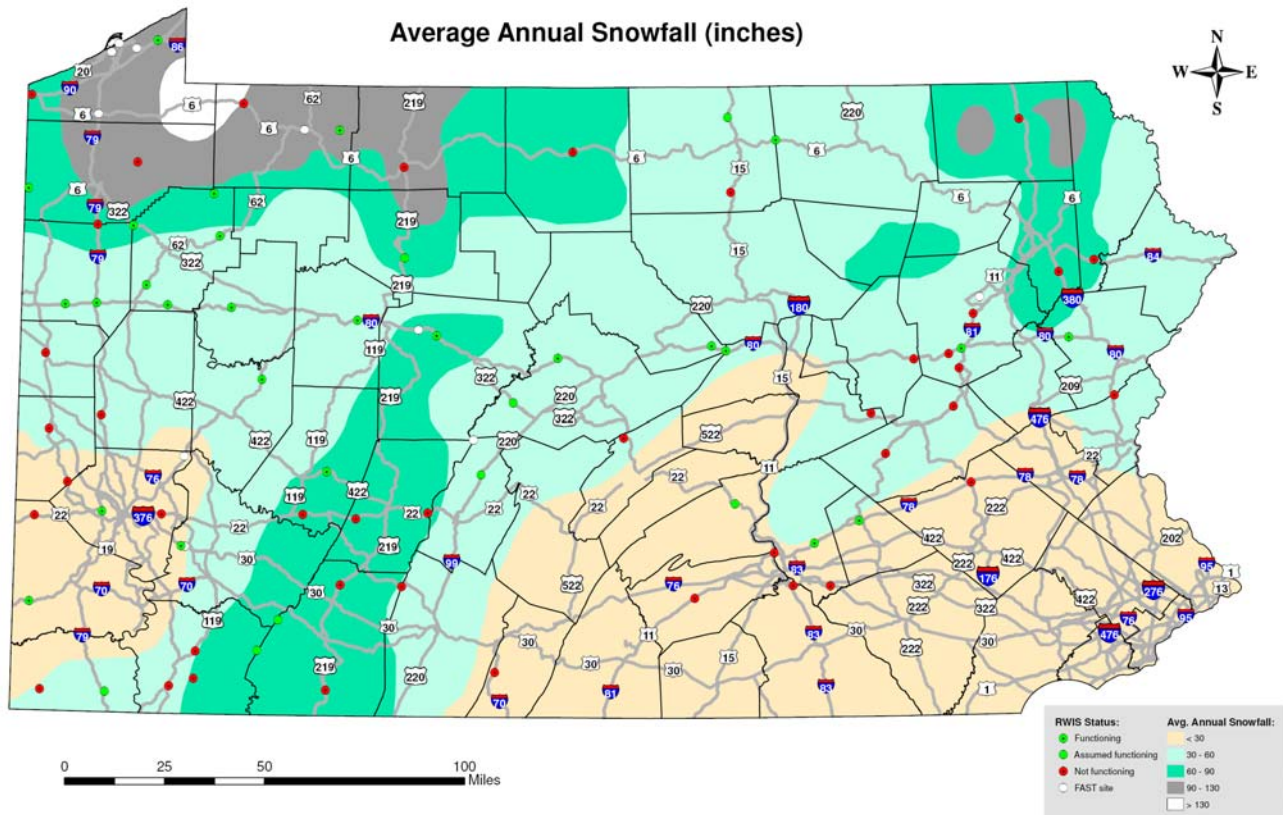
Many of the upgrade activities associated with repairing baseline conditions and establishing a baseline for program enhancements may be best served by completely updating the existing system in order to maximize contract resources. As phase concept 5) *Expand/ upgrade data elements being collected* and phase concept 6) *Fill RWIS gap areas* begin to be introduced, upgrades and future deployments should be prioritized based on several issues.

1. Local needs such as weather related crashes
2. Regional needs
 - a. Consider daily vehicle miles
 - b. Consider roadway class
 - c. Consider average snowfall
3. Ability to coordinate with other projects/ needs
 - b. Deploy RWIS in needed area if other ITS elements are being deployed
 - c. Deploy RWIS in areas coinciding with key detour routes established in the EDRS

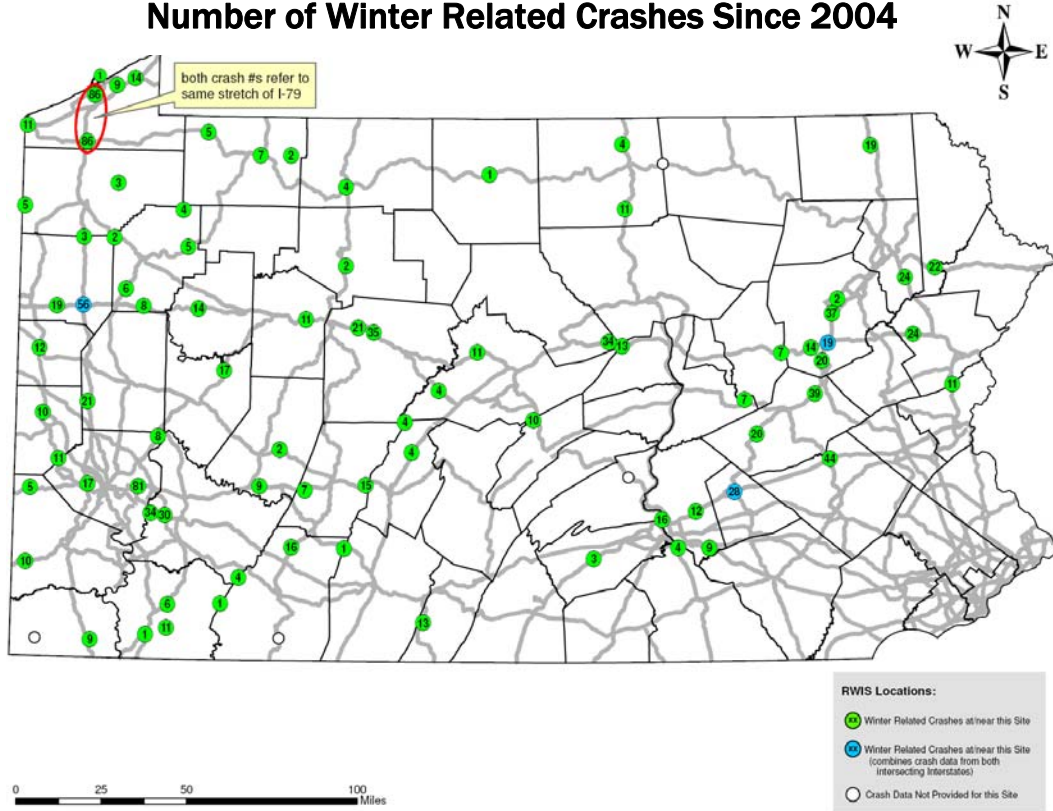
7.4.4 Other Deployment Considerations

Weather-related crashes

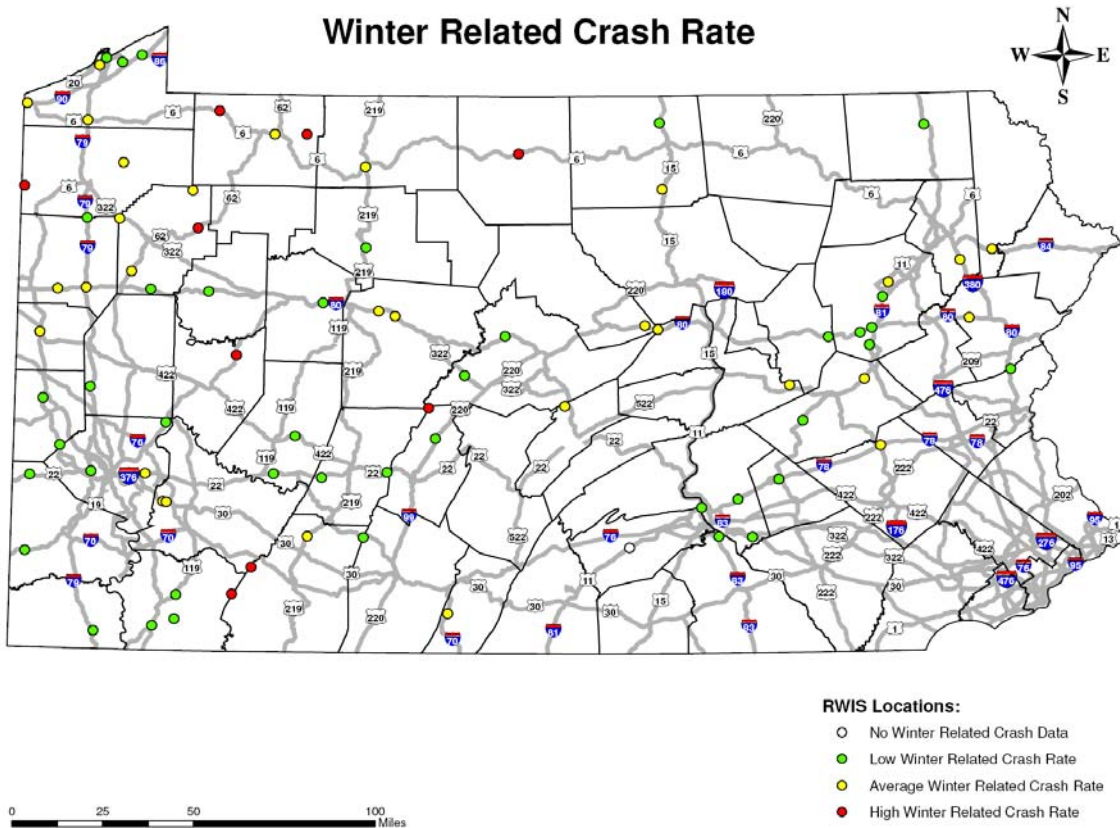
When the RWIS program was initialized, site locations were primarily chosen because of unique weather conditions or high weather related crashes. This methodology still applies today in site deployments; RWIS site spacing guidelines and high weather related crash areas should be examined concurrently to determine the most effective site location and to prioritize existing RWIS upgrades.



Number of Winter Related Crashes Since 2004



Winter Related Crash Rate



District Perspectives

As part of this evaluation, each district was surveyed to identify specific RWIS needs. While several districts noted the benefit of and need for additional RWIS deployments, three districts provided specific needs.

District 6-0

- SR 309 – to be deployed as part of ongoing project
- I-95 Northern end
- I-95 Southern end
- US 422 middle of route
- US 30 near Route 10
- US 202 near West Chester

District 8-0

- PA 581 near I-81 interchange mm1. - the sound walls create a wind tunnel in this location
- I-83 near I81 interchange
- I-81 near Progress Avenue

District 9-0

- US 220 - Mason - Dixon Line - near MD Border (Bedford County)
- US 30 - Ship Mountain - near Somerset County line (Bedford County)
- I-99 - Sproul Mountain – segment 160-170- near Bedford County line (Blair County)
- PA 271 - Laurel Summit - top of mnt. -near Somerset County line (Cambria County)
- PA 869 / 164 - Blair Line - near Bedford County line (Cambria County)
- US 219 - Galleria Ramps - east of Johnstown (Cambria County)
- US 219 - New Germany- at interchange (Cambria County)
- US 30 - Sideling Hill – segment 120 - near Bedford County line (Fulton County)
- US 30 - Franklin Line- segment 450/2250 -near Franklin County line (Fulton County)
- PA 26 - Pine Grove Mnt. - top of mnt. -near Centre County line (Huntingdon County)
- US 40 - Addison - near the MD Border (Somerset County)
- US 219 - Salisbury - near the MD Border (Somerset County)

District 10-0

- SR 422 around the Armstrong / Butler County line.
- SR 68 at the top of Brady Hill in Clarion County.
- SR 66 in Northern Clarion County.
- SR 28 Brockway, Jefferson County.
- SR 119 near Indiana / Jefferson County Line.
- SR 422, top of Nolo Hill in Indiana County

Thermal Mapping - Pennsylvania has already deployed a significant amount of RWIS sites. Some states have utilized thermal mapping in identifying deployment locations. Thermal mapping is the use of vehicle-mounted, downward-pointed infrared radiometers to survey a selected road segment to map the position of warm and cold spots along the roadway. This analysis can (1) better define the thermal characteristics of road segments (e.g., cold spots) and aid in the selection of locations to site roadway sensors for monitoring and forecasting surface icing conditions and (2) help identify locations that are representative of other locations, thereby possibly reducing the number of ESS installations required. The thermal mapping data are usually collected in the early morning, before sunrise, when surface temperatures are the coldest. Data are usually collected under clear sky, cloudy sky, and wet pavement conditions, as roadway temperature patterns differ under each condition.

Virtual RWIS Deployments - One vendor offers “virtual” RWIS deployments through a patent algorithm that interpolates data from neighboring sites. While this service is available for charge, it is believed that non-proprietary algorithms could be developed and integrated into a weather portal.



Anti-icing Systems – Pennsylvania currently has 10 FAST sites deployed. Anti-icing systems can be utilized to provide additional atmospheric weather data to reduce gaps in coverage. Caution should be taken when analyzing roadway temperature and surface conditions from a FAST site to determine correct roadway treatment. Surface conditions can vary significantly between the bridge deck and roadway. Anti-icing systems should continue to be utilized on bridges and interfaced with the RWIS program to provide a better overall weather picture.

7.5 Program Management

PennDOT's RWIS program was established primarily for winter maintenance purposes. Maintenance decision makers at the county level were able to use RWIS to gauge weather conditions and make maintenance decisions. In many cases, maintenance decisions were made at the county level with minimal consideration or awareness of regional ramifications and conditions.

The *Independent Report* identified several issues that relate to RWIS and roadway weather management activities in Pennsylvania.

- RWIS itself was not functioning and program guidance is needed
- Other weather forecasting and maintenance tools were not available
- There was a failure in Department and inter-agency communication /coordination
- There was a failure in public notification

A survey of PennDOT stakeholders noted that while 62 percent of respondents stated they do not utilize RWIS, 77 percent said they would use RWIS if data was more accessible (and reliable). This represents nearly a 40 percent increase in usage. Also survey findings noted that while RWIS was deployed for primarily winter maintenance purposes, nearly half of the respondents indicated they would use RWIS for other purposes, with transportation operations accounting for 32 percent of usage.

Nationally, roadway weather management has evolved beyond just maintenance practices. Roadway weather management includes strategies to **advise** agencies and motorists, **control**/regulate roadway conditions, and **treat** roadways efficiently. All of these strategies rely on gathering accurate information, processing data quickly and efficiently, and disseminating that information to stakeholders in a format that supports their needs.

Eighty-three percent of the states surveyed noted that their RWIS and roadway weather management programs include maintenance as well as transportation operations. As was noted in FHWA's *Integration of Emergency and Weather Management into Transportation Management Centers*, many states have begun to co-locate winter maintenance and transportation operations decision makers at traffic management centers so that coordinated decision making can take place.

To be prepared for "all hazard," PennDOT must provide coordinated command of and control of all resources across Bureau boundaries. In the case of roadway weather management, maintenance, transportation operations and emergency management should have the same situational awareness and should be able to communicate.

7.5.1 Program Facilitation

Nationally, most of the best practices with respect to winter maintenance and operations highlight the need for shared responsibility between winter maintenance and transportation operations. Over 80 percent of states responding noted that RWIS data is used by both maintenance and transportation operations. Additionally, program management activities are divided with nearly one-third of states reporting having maintenance manage their RWIS program, one-third having operations manage their RWIS program, and one-third having multiple departments manage their RWIS program.

Senior management must provide direction to the Department's roadway weather management program as it cuts across traditional "Bureau" boundaries. Specifically, senior management should consider the RWIS program in the context of other maintenance and transportation operations initiatives as well as each group's



mission and provide guidance regarding program funding and “ownership” as well as deployment, data management and maintenance.

Funding, planning and deployment should be a shared responsibility between BOMO and BHSTE with input from the district and county level. Data management practices should be initiated by BOMO and BHSTE with guidance and support from BIS. Maintenance may be best served if it is made less proprietary in nature, then coordinated and combined with District/ Central Office ITS maintenance with oversight and specialty expertise provided by BOMO. This shift in maintenance practices may not be possible until “proprietary” sites have been converted to an “open” system. To maintain and enhance the RWIS program, responsible groups must be allocated additional resources.

Ultimately, an enhanced RWIS program would be utilized by multiple stakeholders addressing roadway weather management and could be used for other non-roadway weather purposes as well.

Stakeholder Group	RWIS Program Management					Roadway Weather Management Activities			Non-winter Traffic Conditions Usage
	Funding Responsibility	Program Strategic Planning	Site Upgrades and Future Deployments	Data Management and Enterprise Solutions	Preventative System Maintenance	Advisory (notify and advise public)	Control (control of access to roadways)	Treatment (winter maintenance activities)	
BOMO and county maintenance	TBD (note 1)	Lead (note 2)	Lead (note 3)	Lead (note 4)	Lead (note 5)	Input	Input	Primary	
BHSTE and district traffic operations/ TMC		Input (note 2)	Input (note 3)		Support (note 5)	Primary	Input/Support	Aware	Primary
BIS				Support (note 4)	Support (note 5)				
BPR (traffic data collection program)			Input	Input					Second
Public Relations and CRCs with output to: ■ Municipalities ■ Public				Input		Support	Aware	Aware	
Emergency Management (including PSP and PEMA)			Input	Input		Aware	Primary	Aware	

- 1) Program funding needs to be identified and directed by senior management recognizing that while BOMO may be the primary lead, there may be opportunities to piggyback deployments and upgrades with BHSTE operational initiatives.
- 2) The primary use of the RWIS program is winter maintenance; however, transportation operations will be a significant user and should have significant input as it relates to operational initiatives. The relationship should be similar to the relationship established as part of this project.
- 3) It is appropriate for BOMO to provide program leadership with respect to site upgrades and future deployments, but these efforts should be coordinated with ongoing ITS deployment activities such that deployment and O&M resources are maximized.
- 4) Data management and enterprise solutions should be developed in such a way as to support multiple user needs and to allow for common situational awareness. BIS should provide guidance as it relates to identifying business requirements and developing solutions.
- 5) As the RWIS system transitions to an “open” system, proprietary maintenance practices may be less necessary. This would allow for preventive maintenance to be coordinated with District ITS maintenance. Specialty maintenance may still need to be led by BOMO with BIS provided support for data management and enterprise solutions.

- TBD – to be determined by management
- Lead – should provide leadership with input and support from other groups
- Input – should provide input to lead party
- Support – provide support/ assistance to primary party
- Primary – primary usage
- Second – secondary usage
- Aware – should be aware of conditions

7.5.2 Resources, Needs and Opportunities

The existing investment in the RWIS program has been facilitated by BOMO. It is estimated that this investment has been approximately \$6M largely allocated from 1997 through 2006. Many deployments were funded as part of winter maintenance budgeting while other deployments have been funded as part of other projects. The RWIS maintenance program has been funded utilizing winter maintenance and other discretionary funding.

Within BHSTE, there is approximately \$22M a year to fund ITS programs and maintenance activities. While this amount seems substantial, the Transportation and Funding Reform Commission noted that \$53M is needed annually to preserve the existing system (level A), \$115M is needed annually to incrementally improve the existing system (level B) and \$171M is needed annually to improve mobility (level C). The transportation funding situation in Pennsylvania is still being resolved, but based on Transportation and Funding Reform Commission findings, additional funds are needed to support ITS and signal system initiatives. RWIS should be considered as part of other operational initiatives.

In the future, ITS funding should be centralized similar to the current Interstate Management Program. ITS would then be considered a statewide asset and funds would be distributed statewide after a technical review had been completed. A monetary budget would be established for statewide ITS projects annually, and PennDOT Districts would still be responsible for project management.

An enhanced RWIS program may provide modest, but tangible savings in winter maintenance expenditures by assisting maintenance personnel in more proactively and efficiently implementing treatment strategies. Additionally, an enhanced RWIS program may provide indirect savings to the motor public due to enhanced safety and improved winter mobility.

To achieve these savings, resources will need to be directed toward system enhancements and upgrades. These resources need to be dedicated to upgrading the program's data management structure, introducing more reliable communications and integrating RWIS data with other resources. Additionally, resources should be dedicated to the introduction of non-proprietary sites which will permit more proactive maintenance programs.

It is estimated that the investment required to enhance the RWIS program would be approximately \$6M over the next 7 years and then \$410K per year for operations and maintenance.

Funding Category	Description/Use
Winter Maintenance Funds	<ul style="list-style-type: none"> ▪ Some RWIS deployed using maintenance funds ▪ May provide return on investment
Surface Transportation Program (STP)	<ul style="list-style-type: none"> ▪ Most flexible funding category ▪ Can be used on any federal-aid road
National Highway System (NHS)	<ul style="list-style-type: none"> ▪ May be used for projects only on NHS roads
Highway Safety Improvement Program (HSIP)	<ul style="list-style-type: none"> ▪ New category established in SAFETEA-LU to address safety concerns ▪ May be appropriate for localized weather-related crash concern sites

Other Funding Opportunities

- **Clarus Initiative Grants** - FHWA anticipates the announcement of a "Collection Incentive Program" to be announced in June 2007 that will be available to all U.S. transportation agencies that operate a

network with one or more RWIS/ESS who want to contribute data to Clarus. Funds will be provided as a Federal Aid Grant, and funding is based on a sliding scale dependent on the number of RWIS/ESS in the network. This grant opportunity should be explored as it may provide an opportunity to implement future enhancements to the RWIS program as it relates to metadata required for connection to the Clarus Initiative.

- **Transportation Funding and Reform Outcomes** - This report should be used to justify allocation of future revenue streams to address safety and mobility.

7.5.3 Public and Internal Outreach

There has been much scrutiny of the RWIS program by the media and the public, but also by internal stakeholders as noted in the survey of PennDOT employees. Outreach to internal stakeholders and the public should be conducted at logical phases of enhancement, but only after the upgrades have been tested and proven to be reliable. Outreach is needed to restore system confidence and usage.

7.5.4 Partnership Opportunities

Partnership opportunities should be explored when possible to minimize resource demands and maximize return on the investment. Additionally, partnership opportunities may allow for better dissemination of advisory conditions. Some examples of possible partnership include:

- Partner with local media outlets similar to video sharing for access to RWIS data
- Attempt to leverage RWIS to contract weather providers
- Partner with the Clarus Initiative to gain access to additional weather data

7.5.5 Training

Program enhancements will need to be included in training programs by winter maintenance and transportation operations personnel in order to promote usage and awareness of the RWIS program and other roadway weather management resources.

8. Action Plan

The future direction of the RWIS program must consider what is needed in order to manage roadway weather maintenance and transportation operations including emergency management activities. Decision makers need to have access to the same information and resources so that they can introduce the right combination of strategies. Communication, coordination tools and management practices need to be adopted that allow advisory, control and treatment strategies to be implemented in a coordinated manner. This guided the suggested direction presented below.

The operational vision is not achievable over night. The program direction must be phased in such a way that phases produce success within available resources while establishing an opportunity for future enhancements. The suggested direction is based on seven key concepts:

- 1) Repair existing RWIS sites to baseline conditions – Need to fix what we have before we can make it better
- 2) Establish baseline for program enhancements – The current system, even if operational, may not be capable of supporting future enhancements
- 3) Begin to establish complete weather picture – RWIS data is one piece of the weather picture. It needs to be combined with other sources of information such as contract weather data and provided to all users
- 4) Begin to transition to an “open” RWIS system – The proprietary nature of the existing system have resulted in maintenance issues and a lack of flexibility in use of RWIS data. By transitioning to an “open” system, maintenance can be enhanced (and costs reduced) and there would be more flexibility in how data is managed.
- 5) Expand/ upgrade data elements being collected – Other information would be helpful in winter maintenance and transportation operations. Precipitation intensity and accumulation sensors could aid in maintenance decision making. In-roadway sensors assist in maintenance decision making, but could provide valuable traffic data to transportation operations decision makers. Enhanced and updated CCTV systems can improve situational awareness for all parties.
- 6) Fill RWIS gap areas – To complete the picture, gaps in coverage must be filled. These gaps should be coordinated with other initiatives in order to maximize resources.
- 7) Develop integrated/ enterprise solutions – Ultimately, weather information must be shared with other parties and combined with other information tools.

Below outlines a phased approach to reestablish the existing system, strategically upgrade and expand and to introduce an open architecture system that can be integrated with other activities.

Phase Concept	Phase Task	Considerations	Suggested Timeframe	Resource Requirements
1. Repair existing RWIS sites to baseline conditions	1. Reestablish baseline operations	<ul style="list-style-type: none"> ▪ Reestablish existing dial-up communication ▪ Make repairs to RWIS elements ▪ BOMO actively working 	Directed to be complete by September 2007	Estimated at \$6K per site \$450K total
2. Establish baseline for program enhancements	2.A Revise data management system and conduct requirements study	<ul style="list-style-type: none"> ▪ Current system has dial-up from CO to District to County to device ▪ Proposed interim system would be on WAN and dial-up from District to device ▪ All data would first be pulled to CO for integration/ processing before distribution ▪ Provide basic data viewing functions like current vendor systems ▪ Conduct requirements study to determine system requirements for software and hardware 	0-2 years	District IT hardware upgrades: \$44,000 Systems integration: \$46,000 Total: \$90,000



Phase Concept	Phase Task	Considerations	Suggested Timeframe	Resource Requirements
	2.B Introduce RWIS/ESS Database and Server at Central Office	<ul style="list-style-type: none"> Pull data sets from SSI, NU, Boschung, other, open protocols and integrate into one data set Metadata – device configuration information Data dictionary based on NTCIP Data security and integrity administration Post data to central database Post images to central database 	0-2 years	Database software license: \$25,000 IT Hardware: \$8,000 Systems integration: \$32,000 Total: \$65,000
	2.C Introduce new communications to promote system reliability, diagnostic and to support RWIS sensors and upgraded CCTV	<ul style="list-style-type: none"> Hardwire, CDMA, DSL or practical alternative Existing dial-up could be used as a back-up Address BIS security concerns and coordinate with SOCP 	1-3 years	Estimated at \$3K per site Total: \$28,000
	2.D Develop an asset management and maintenance tool	<ul style="list-style-type: none"> Collect Metadata Maintenance and operations 	1-3 years	IT Hardware: \$12,000 Systems integration: \$150,000 Total: \$162,000
	2.E Establish future funding for maintenance and operations	<ul style="list-style-type: none"> Existing costs per site were \$3K to \$4.2K per year, but were limited by contract Other states spend \$3.5K Continue current funding level 	NA	\$250K per year \$410K per year with future sites Estimated at \$4M over next 10 years
3. Begin to establish complete weather picture	3.A Integrate RWIS data with contract weather data	<ul style="list-style-type: none"> BOMO awarded a statewide weather forecast for the next winter season Is an amendment to the contract an option 	1-2 years	System integration: \$15,000
	3.B Develop weather portal - a new PennDOT and public website with both RWIS and contract weather data	<ul style="list-style-type: none"> Develop web portal functional requirements 	1-3 years	IT Hardware: \$4,000 Systems integration: \$70,000 Total: \$74,000
	3.C Explore usage of existing notification systems	<ul style="list-style-type: none"> Include as part of 3.B planning 	1-3 years	NA
4. Begin to transition to an "open" RWIS system	4. Introduce NTCIP open protocol RPU's at existing sites	<ul style="list-style-type: none"> Open, NTCIP communication Rugged hardware Less RWIS vendor dependency and shared maintenance contracting with other ITS devices Establish standard specifications for "open" RWIS system 	1-4 years	Estimated at \$37.2K per site Total: \$2,828,000
5. Expand/upgrade data elements being collected	5.A Utilize existing traffic data not being transmitted	<ul style="list-style-type: none"> Traffic volume, class and speed data could be collected at NU sites 	0-2 years	NA
	5.B Install "missing" in-roadway sensors to collect surface conditions as well as traffic volume, speed and class	<ul style="list-style-type: none"> Maintenance staff desire surface conditions data Other staff requested traffic data Sensor maintenance issues exist with in-roadway devices 	1-4 years	Estimated at \$6.6K per site Total: \$766,000
	5.C Reassess fixed CCTV systems settings	<ul style="list-style-type: none"> Reduce refresh times to <5 minutes Adjust fixed camera view angles to consider surface, roadway perspective and sun 	1-4 years	Estimated at \$1.5K per site Total: \$114,000
	5.D Install PTZ CCTV at strategic locations	<ul style="list-style-type: none"> Install PTZ CCTV at locations consistent with ITS deployment plans and based on District input Integrate into District TMC 	1-7 years	Assume 50% of RWIS sites upgraded \$4.3K per site Total: \$164,000



Phase Concept	Phase Task	Considerations	Suggested Timeframe	Resource Requirements
	5.E Strategically install precipitation accumulation, type and intensity sensors	<ul style="list-style-type: none"> Rain Gauge, Optical Present Weather Detector, Hot-Plate Type Precipitation Sensor 	3-7 years	Estimated at \$8.7K per site Total: \$662,000
	5.F Pilot/ explore and introduce non-intrusive methods to measure surface and traffic data.	<ul style="list-style-type: none"> Road Surface Spectroscopic Sensor (for surface conditions) Traffic data collection are more well proven (video, radar, etc) Alternative to traditional RWIS sensor technology utilizing remote sensor technology Eliminates need for in-road sensors and most atmospheric sensors 	3-7 years	Estimated at \$58.6K per site Total: \$4,454,000
6. Fill RWIS gap areas	6.A Strategically introduce new RWIS sites	<ul style="list-style-type: none"> Recurring intervals based on deployment guidelines Consider trouble spots, needed recurring coverage, etc Piggyback with ITS and traditional construction projects Consider using (FHWA) ITS checklist for highway projects 	1-10 years	Estimated at \$56.3K per site Total (50 total): \$2,815,000
7. Develop integrated/ enterprise solutions	7.A Coordinate with information exchange initiatives	<ul style="list-style-type: none"> Weather data may be needed by PEMA, PSP, etc 		
	7.B Integrate RWIS data with contract weather data into 511 phone and web services	<ul style="list-style-type: none"> Web 511 Targeted Turn-On - June 2008 Voice 511 Targeted Turn-On - June 2009 	1-3 years	Incorporate in 511 RFP
	7.C Integrate RWIS data with contract weather data into RCRS as a geospatial layer	<ul style="list-style-type: none"> RCRS requested the ability to see weather information 	1-3 years	Systems integration: \$10,000
	7.D Integrate Snowplow AVL into complete weather picture	<ul style="list-style-type: none"> Pilot ongoing using 800 MHZ system 		Systems integration: \$25,000
	7.E Monitor Clarus opportunities	<ul style="list-style-type: none"> Monitor for Grant opportunity in summer 07 Integrate into weather solution 	TBD	TBD
	7.F Monitor MDSS opportunities	<ul style="list-style-type: none"> Test free version Integrate into weather portal? 	TBD	TBD

Recurring communication costs for existing and future conditions should be considered for planning and programming purposes.

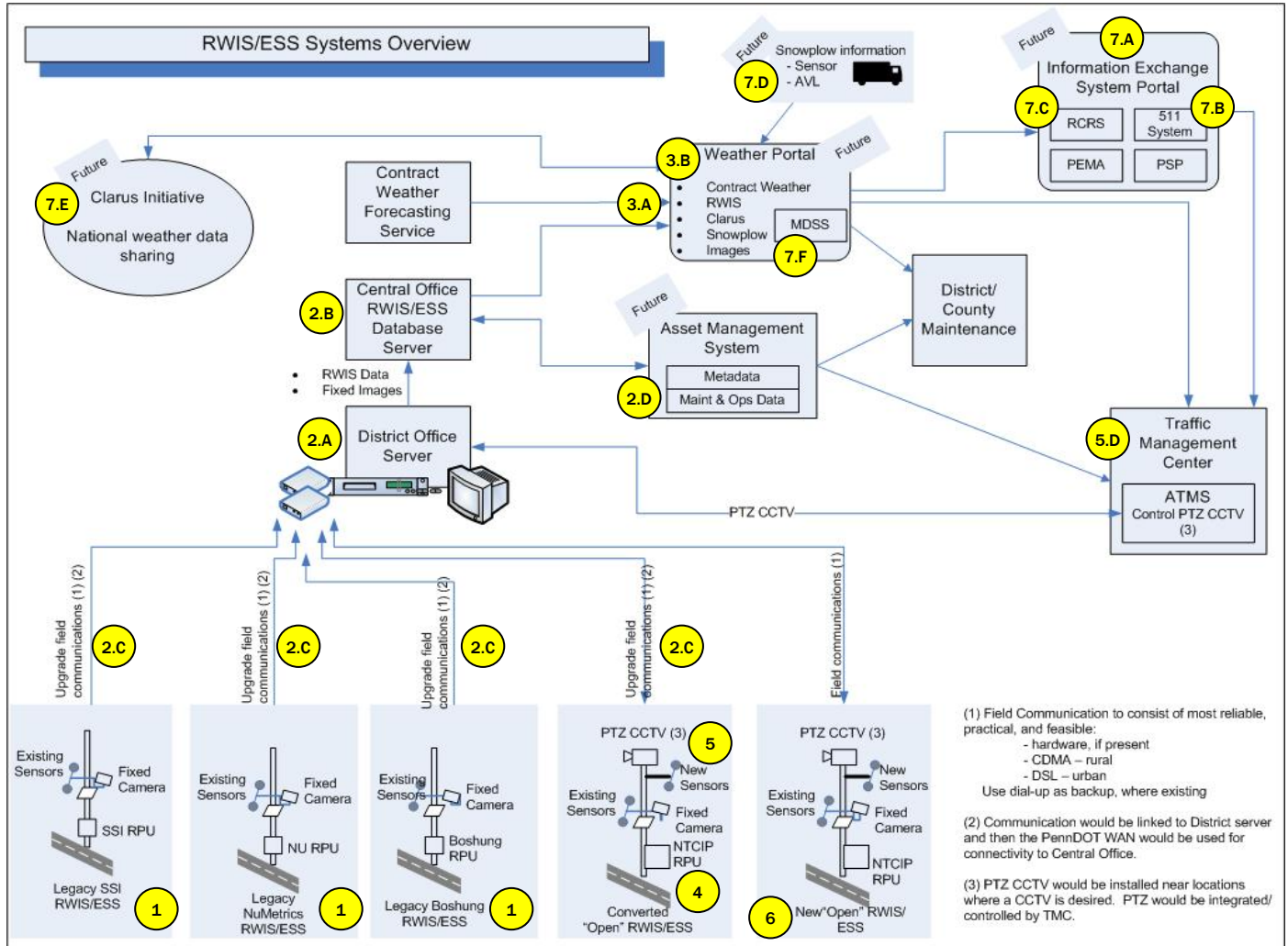
	Existing	Future
RWIS Sites	75	130+
Communication Type	POTS	Combination (CDMA, DSL, etc.)
Estimated Monthly Cost (per site)	\$40	\$120 - \$210 *
Estimated Annual Cost	\$3,000	\$15,600 - \$27,300 *

* Subject to outcome of SOCP

In addition to the action plan presented above, the following actions should be considered in order to better manage, operate and maintain:

- Review program management and funding responsibilities per section 7.5.1
- Eliminate proprietary contracts and coordinate with District-led ITS maintenance activities
- Identify potential partnership opportunities
- Provide outreach internally and to the public when proven enhancements are made
- Integrate RWIS program into winter maintenance and transportation operations training programs
- The findings of this report should be included in planned development of standard specifications for ITS systems and consider the connectivity plan. The specifications should include guidance on device design and deployment and should include an "open" architecture interface enabling the integration of emerging technologies.

It is estimated that the total program investment would be \$10.5M over the next 10 years; however, the plan is estimated at \$7.5M if additional deployments are excluded from the total.



9. Performance Considerations

9.1 Benefit to Cost

9.1.1 National Research

NCHRP Report No. 20-7(117), *Benefit/Cost Study of RWIS and Anti-icing Technologies: Final Report* documented several benefits of RWIS programs (noted below), but report findings were largely based on input from maintenance personnel.

Performance Measures	Road Weather Information System (RWIS) Benefits
Mobility	<ul style="list-style-type: none"> ▪ Reduced travel times. ▪ Improved traveler information.
Safety	<ul style="list-style-type: none"> ▪ Reduced accident frequency. ▪ Less disruption of emergency services.
Productivity	<ul style="list-style-type: none"> ▪ More efficient response strategies (right resources, in right place, at right time). ▪ Reduced maintenance costs (staff, equipment and materials). ▪ Assisted with crew scheduling. ▪ Facilitated data sharing.
Environmental Quality	<ul style="list-style-type: none"> ▪ Improved quality as a result of reduced salt usage
Other / Indirect	<ul style="list-style-type: none"> ▪ Reduced infrastructure damage (roads, bridges, guardrail, etc.). ▪ Assisted in planning of operations other than winter maintenance (e.g., paving).

While little research exists quantifying the benefits of the RWIS program, early test results from several state highway agencies showed that **snow and ice control costs could be reduced by as much as 10 percent** using RWIS technologies³⁰. Other research using computer models found that when using only RWIS sensor systems, the B/C ratios are small and range from -1.5 to almost 1.0. However, when **RWIS systems are combined with other data such as forecast weather data, the model produced a B/C ratio of approximately 5.0** and average computed level of service improvements were on the order of 20 percent.³¹

³⁰ NCHRP Benefit/Cost Study of RWIS and Anti-Icing Technologies and Transportation Research Board, Transportation Research Record 1352, Washington DC. Benefit-Cost Assessment of the Utility of Road Weather Information Systems for Snow and Ice Control

³¹ Transportation Research Board, Transportation Research Record 1352, Washington DC. Benefit-Cost Assessment of the Utility of Road Weather Information Systems for Snow and Ice Control

9.1.2 Pennsylvania

While Pennsylvania has invested significant resources in the deployment of its RWIS program, the proprietary nature of the systems deployed, maintenance contracts that limit proactive maintenance and limited maintenance resources have resulted in a program that provides little benefit since approximately two-thirds of sites are not functioning.

Upgrading the program's data management structure, introducing more reliable communications and integrating RWIS data with other resources will begin to provide more benefit. Furthermore, the introduction of non-proprietary sites will permit more proactive maintenance programs which can be coordinated with other ITS maintenance activities as well as establish a baseline for future program expansion and integration with other systems.

Phase	Time Period (1)	Sites Assumed	Cost of Investment (2)	Yearly Cost of Operations and Maintenance (3)	Estimated Cost Per Year (4)	Approx Yearly Winter Maintenance Cost	Estimated Savings Due to Program (5)	Estimated Benefit to Cost
Existing	10	75	\$3,000,000	\$270,000	\$570,000	\$150M	0 (2/3 of system not functional and 2/3 of staff do not use)	0
Enhanced RWIS Program	10	125 (30 new)	\$10,500,000	\$410,000	\$1,090,000	\$150M	\$3,000,000 (assumes only 2 percent of winter maintenance when research indicates 10 percent)	>2.0 (may be as high as 5.0 based on national research)

(1) Only 13 sites deployed before 1997, therefore 10 years (1997-2006) assumed. Future plan can be adjusted, but 10 years assumed.

(2) Assumes old sites value was \$40K

(3) It is believed that the same maintenance \$3,500 per site per year will yield a more reliable outcome with proactive and decentralized maintenance contracting.

(4) Dollars not adjusted for inflation since exact time of expenditure was not known.

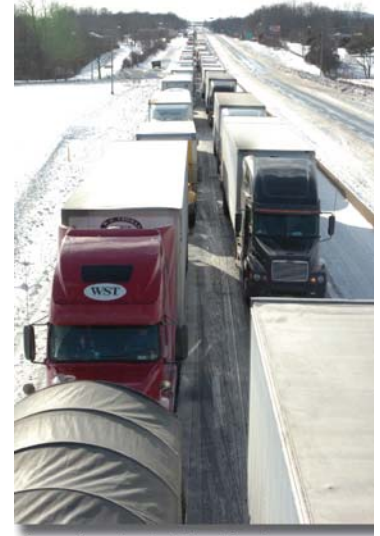
(5) Does not include savings due to enhanced safety and mobility.

9.2 Performance Metrics

To document a program's success, performance metrics should be implemented and measured in order to document the program benefits versus program costs. By measuring performance, the RWIS program can address the following issues:

- Document successes – Has the program provided a realized benefit?
- Rationalize investments versus the benefits – Do the financial benefits of the program outweigh the costs?
- Identify potential improvements – Can the program be modified to maximize benefits and minimize costs?

Performance metrics should be kept simple and easily measurable, when possible. Performance metrics may be best developed if they are linked to roadway weather management strategies; however, safety and mobility are overarching principles that supersede strategy areas. These metrics can be historically referenced for the life of the RWIS program and through implementation of the proposed program enhancements.

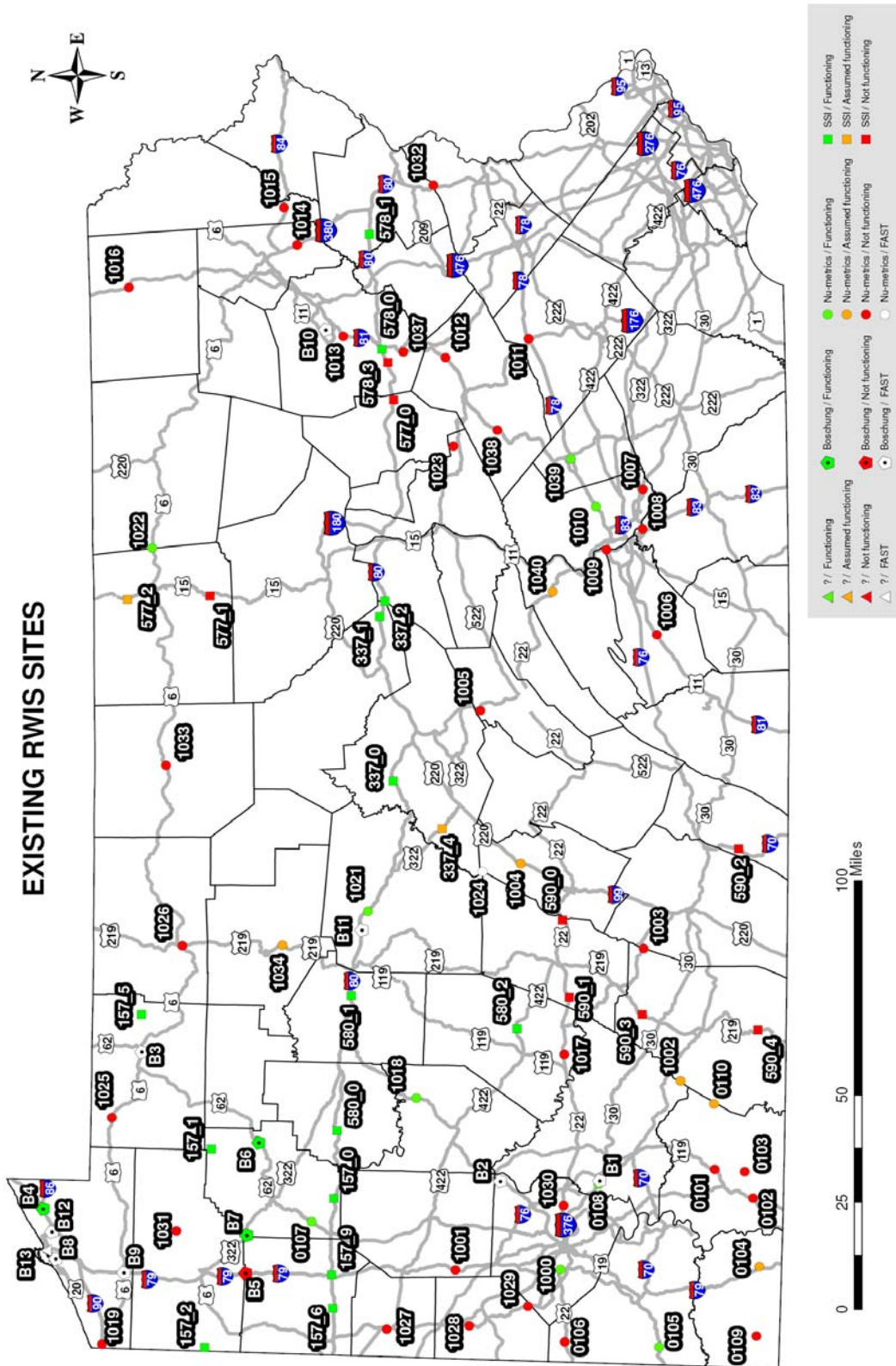


Source: Pennsylvania National Guard

Roadway Weather Management Strategy Areas	Suggested Performance Metrics
Safety and Mobility	<ul style="list-style-type: none"> ▪ Statewide weather-related fatalities ▪ Statewide weather-related crashes ▪ Winter road closures
Advisory - Provide information to transportation officials and transportation managers as well as the public	<ul style="list-style-type: none"> ▪ Customer usage (satisfaction) ▪ Transportation operations staff usage (satisfaction)
Control - Provide transportation officials with weather data such that they can coordinate or implement control strategies	<ul style="list-style-type: none"> ▪ TBD
Treatment - Treatment strategies include road maintenance activities	<ul style="list-style-type: none"> ▪ Maintenance staff usage (satisfaction) ▪ Maintenance costs

In addition to the performance measures listed above, up-time metrics (% of system that is functional) should be monitored as part of maintenance and asset management activities and in order to justify and monitor the benefit of operations and maintenance expenditures.

Appendix A Summary of Existing RWIS Systems



Appendix B References and Literature Review Summary

Key Literature Review Documents

RWIS

1. Road Weather Information System Environmental Sensor Station Siting Guidelines (Publication Number: FHWA-HOP-05-026) ([HTML](#), [PDF 2.44MB](#))
2. [REVIEW OF THE INSTITUTIONAL ISSUES RELATING TO ROAD WEATHER INFORMATION SYSTEMS \(RWIS\): FINAL REPORT](#) Publication
3. [UTILIZING ROAD WEATHER INFORMATION SYSTEM \(RWIS\) DATA TO IMPROVE RESPONSE TO ADVERSE WEATHER CONDITIONS](#) Publication
4. [BENEFIT/COST STUDY OF RWIS AND ANTI-ICING TECHNOLOGIES](#) Publication

Roadway Weather Management/ Winter Operations

5. Evaluation of Utah Department of Transportation's Weather Operations/RWIS Program: Phase I http://www.coe.montana.edu/wti/wti/pdf/4W0892_Final_Report.pdf
6. Integration of Emergency and Weather Elements into Transportation Management Centers (Publication Number: FHWA-HOP-06-090) ([HTML](#), [PDF 1.7MB](#))
7. Prototype Weather Response System (WRS) for Transportation Operations (Publication Number: FHWA-HOP-06-106) ([HTML](#), [PDF 1.1MB](#))
8. Maintenance Decision Support System - Key Documents http://www.rap.ucar.edu/projects/rdwx_mdss/index.html
9. [The Winter Maintenance Decision Support System \(MDSS\): Demonstration Results And Future Plans](#)
10. Clarus Initiative - Key Documents <http://www.clarusinitiative.org/> and <http://www.its.dot.gov/clarus/index.htm>
11. Final Report of the Operation and Demonstration Test of Short-Range Weather Forecasting Decision Support within an Advanced Transportation Weather Information System (#SAFE) http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//14348_files/14348.pdf
12. Best Practices for Road Weather Management http://ops.fhwa.dot.gov/Weather/best_practices/CaseStudiesFINALv2-RPT.pdf

Other Documents Reviewed

RWIS

13. Road Weather Information Systems (RWIS) Data Integration Guidelines http://www.aurora-program.org/pdf/RWIS_Data_Integration_rpt.pdf
14. NTCIP 1204:1998 v01.13 National Transportation Communications for ITS Protocol Object Definitions for Environmental Sensor Stations (ESS) <http://www.ntcip.org/library/documents/> NTCIP 1204 v02.23 National Transportation Communications for ITS Protocol Environmental Sensor Station Interface Standard – Version 02
15. [ROAD WEATHER INFORMATION SYSTEM \(RWIS\): ENABLING PROACTIVE MAINTENANCE PRACTICES IN WASHINGTON STATE](#) Publication
16. [Final Evaluation Report: Evaluation of the Idaho Transportation Department Integrated Road-Weather Information System](#) http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//14267.htm
17. EVALUATION OF ODOT ROADWAY/WEATHER SENSOR SYSTEMS FOR SNOW AND ICE REMOVAL OPERATIONS. PART I, RWIS <http://www.dot.state.oh.us/research/2003/Maintenance/14758-Part%20I-FR.pdf>
18. NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL CASE STUDY REPORT NTCIP 9008 v01.06 Minnesota DOT Statewide R/WIS Project <http://www.ntcip.org/library/documents/pdf/9008v01-06.pdf>
19. NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL CASE STUDY REPORT NTCIP 9009 v01.05 Washington State Department of Transportation Statewide ESS Procurement

Roadway Weather Management/ Winter Operations

20. [An Overview Of Federal Highway Administration Road Weather Management Program Activities](#)
21. [USE OF PAVEMENT TEMPERATURE MEASUREMENTS FOR WINTER MAINTENANCE DECISIONS](#) Publication
22. [Evaluation Of The FORETELL Field Operational Test: Weather Information For Surface Transportation](#)
23. FHWA ITS Benefit-Cost website <http://www.itsoverview.its.dot.gov/>



Document Name	1: Road Weather Information System Environmental Sensor Station Siting Guidelines
Published By	Federal Highway Administration
Date	April 2005
Electronic Source	http://ops.fhwa.dot.gov/publications/ess05/ess05.pdf
Abstract	The document proposes a set of guidelines for siting a RWIS Environmental Sensor Station (ESS) and its associated environmental and pavement sensors. These sensors measure atmospheric, pavement, soil, and water conditions. After reviewing a set of published documents and conducting interviews with about two dozen road weather experts, the authors designed the guidelines to satisfy as many road weather monitoring, detection, and prediction requirements as possible.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ Planning for the installation of ESSs requires a team of weather and road experts including a meteorologist and maintenance personnel. <ul style="list-style-type: none"> ▫ The meteorologist can evaluate certain deployment sites for obstructions or other influences that could compromise the validity of the ESS data. ▫ The maintenance personnel have knowledge regarding the conditions of the areas they maintain. They could provide information about recurring weather problems or locate areas where the ESS might be vulnerable to hazardous conditions. ▪ Before deploying an ESS, an agency should have an idea of the requirements of the road weather information: <ul style="list-style-type: none"> ▫ How will the road information be used? ▫ Will the ESS be used to measure a site-specific condition or provide data that may represent the conditions of an entire area? It is possible to have an ESS monitor a region and have a few sensors monitor conditions at that site, but this practice requires considerable planning. ▫ What needs to be measured at each site? ▪ A typical ESS includes the following: <ul style="list-style-type: none"> ▫ a sensor to measure wind speed and direction, ▫ sensors to measure air temperature and moisture, ▫ sensors to measure the temperature of pavement and determine whether the pavement is dry, wet, or frozen, and ▫ sensors to measure the type and intensity of precipitation. ▫ Auxiliary sensors include solar radiation sensors, hygrometers, and optical visibility sensors, to name a few. ▪ The following criteria should be considered for the construction of an ESS tower: <ul style="list-style-type: none"> ▫ The tower should be sturdy to minimize the impact of turbulence and wind flow on the reliability of collected data. ▫ Although there have been no studies to determine the optimal distance for towers to be placed near the roadway, towers are usually constructed 30 to 50 feet (9 to 15 meters) from the edge of the pavement. ▫ If possible, the tower base should be at the same height as the roadway surface. ▫ The tower height should depend on the sensors installed on the tower. For example, if the tower includes a wind sensor, the tower should be at least 33 feet (10 meters). ▫ Towers should be installed on a flat terrain. Wind measurements could be affected if there are steep slopes within 300 feet of the tower. ▫ Towers should be constructed upwind of the roadway based on the predominant wind direction for the season of most interest. ▫ There should be low vegetation in a circle of 50 feet (15 meters) from the tower. ▫ ESS towers should be installed such that it is not affected by ponding water. ▫ If the threat of vandalism is present, the tower should be surrounded by fencing. The distance between the fence and the tower should be at least 15 feet (5 meters) so that the fence does not affect sensors on the tower. Additionally, anti-climb panels may be installed to deter vandals from climbing up the tower. ▫ The tower should be located such that it is easily accessible to maintenance personnel. ▫ If right-of-way limitations prevent a tower from being constructed, sensors may be installed on utility poles and sign bridges. ▪ The following criteria should be considered for the installation of sensors on the ESS tower: <ul style="list-style-type: none"> ▫ Air Temperature/Dewpoint Sensor – This sensor should be installed in a radiation shield in a well ventilated area. The sensor should be mounted on a boom such that the sensor is at least 3 feet (1 meter) from the tower and 5-6.5 feet (1.5-2 meters) above ground level. ▫ Wind Speed and Direction Sensor – This sensor should be installed 33 feet (10 meters) above ground level, or 10 times the height of the nearest large obstruction. The wind direction sensors should be set on true north, as opposed to magnetic north. ▫ Optically-based Precipitation Sensors – These sensors should be installed 10 feet (3 meters)



	<p>above the ground and away from traffic such that the vibrations do not interfere with the sensors.</p> <ul style="list-style-type: none"> □ <u>Visibility Sensors</u> – Visibility sensors should be placed 6.5 to 10 feet (2 to 3 meters) above the roadway to accurately monitor visibility deficiencies due to local moisture, smoke, and dust sources. Placing the sensors any closer to the pavement would degrade their performance due to interference from salt spray and passing vehicles. □ <u>Snow Depth Sensors</u> – These sensors should be installed perpendicular to the surface at a height of 3.5 feet (1 meter). □ <u>Shortwave Solar Radiation Sensor</u> – These sensors should be installed at least 10 feet (3 meters) above the ground surface. This is to avoid radiation from reflective surfaces. □ <u>Longwave Radiation Sensors</u> – These sensors determine the potential for nighttime cooling, and should be installed 10 feet (3 meters) above the ground. □ <u>Cameras</u> – Cameras should be installed so that they have a clear line of sight and do not interfere with other sensors. □ <u>Pavement Temperature and Pavement Condition Sensors</u> – Pavement sensors may be installed in shaded areas to represent the roadway under maximum cooling conditions. Usually operations and maintenance practices limit where the sensors should be placed. On multilane highways a sensor could be placed such that traffic conditions are minimally impacted. Pavement sensors should be installed on the edge of the inside wheel track and flush with the pavement. □ <u>Subsurface Temperature and Moisture Sensors</u> – These subsurface sensors should be installed 12 or 18 inches (30.5 or 45.5 centimeters) underground, depending on the guidelines. Multiple sensors could be installed at different depths for more in-depth analysis. □ <u>Precipitation Accumulation Sensor</u> – The precipitation sensor should be placed in as open an area as possible and away from the road. A windshield may be utilized to increase the accuracy of the measurement. □ <u>Barometric Pressure Sensor</u> – The barometric pressure sensor can be installed at any height but should be enclosed to avoid the elements and any drastic temperature changes. □ <u>Water Level Sensors</u> – These sensors are installed in a standpipe, and the standpipe should be placed in a steady flowing portion of a creek near a flood-prone road segment. <ul style="list-style-type: none"> ▪ If the primary reason for selecting an ESS location is data collection, then the secondary reasons would be to satisfy power and communications requirements. <ul style="list-style-type: none"> □ The most economical and reliable power source is a commercial connection. Solar power is not capable of sustaining heavy power loads for long periods of time, but requires less installation costs. Additionally, wind power has been successfully implemented in ESS stations in North Dakota. □ Different communications options exist such as hardwired telephone, cellular, copper wire, fiber optic cable, wireless, radio, microwave, and satellite. The amount of data that needs to be transmitted is an important factor in deciding which communications method to implement. This includes how much data is included in each observation and how often each observation is sent to the information center. For low data volumes, wireless communications may be more economical than hardwired options. For higher data volumes, wired or fiber optic communications should be considered. □ ESSs could be installed near other ITS devices so that both share the same power and communications source.
Guidance on Maintenance and Operations	None
Guidance on Program Management (public, private, other)	None
Guidance on Integration with Other Weather Data	<ul style="list-style-type: none"> ▪ Before deploying an ESS, an agency should research opportunities to partner with other agencies and share data. These partnerships could avoid the agencies collecting duplicate data, which would cut down on costs. <ul style="list-style-type: none"> □ The first partnership a DOT should consider is one with the National Weather Service. ▪ Partnerships may also allow organizations to share existing towers, power, and communications to support ESS installation.
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and	None



Dissemination to the Public	
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ Organizations looking to install ESS towers need to carefully weigh the costs and benefits of virtually every aspect of the installation process. The agencies must consider what sensors should be included in the tower, where the tower should be place (including purchasing right of way), and what power and communications connections are needed to collect and distribute the data. ▪ DOTs should consider forming partnerships with other agencies, like the National Weather Service, to decrease costs and increase the availability of information.
Summary	<p>It is crucial that organizations looking to install Environmental Sensor Stations (ESS) spend plenty of time planning the design and location of the towers. The agencies must answer questions to determine how the road information will be used, whether the ESS will be used to measure a site-specific condition or to measure the conditions of an entire area, and what needs to be measured at each site. Detailed planning will allow the agency to decrease initial costs and possible maintenance costs in the future.</p>
Other Notes and Observations	None

Document Name	2: Review of the Institutional Issues Relating to Road Weather Information Systems (RWIS): Final Report
Published By	Aurora Program
Date	August 1998
Electronic Source	http://www.aurora-program.org/pdf/inst_issues.pdf
Abstract	This paper identified and documented the issues with developing and implementing Road Weather Information Systems (RWIS). The authors define RWIS as a collection of technologies used to assist agencies in determining road and weather conditions. The authors reviewed and summarized existing literature of RWIS institutional issues. The issues could be broken into four categories: funding, staffing, partnerships, and the expandability, transferability, and compatibility of RWIS. The authors also conducted telephone and in-person interviews to document first-hand experiences in implementing RWIS.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ Before deploying a RWIS, organizations must address funding for the system. <ul style="list-style-type: none"> ▫ If multiple agencies are involved in creating a RWIS, the financial responsibilities of the agencies must be clearly defined during the planning process. ▫ Agencies could look for creative funding schemes like “using a state infrastructure bank, industrial revenue bonds, lease arrangements with payments tied to financial performance of private sector partners, and profit sharing on the sale of value-added products and services.” ▫ Additionally, initial costs could be Federally funded to promote a standard, nationwide RWIS.
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ An in-house meteorologist, working part- or full-time for the agency, may have benefits in dealing with weather-related issues and providing useful advice which would fully utilize the RWIS technologies effectively.
Guidance on Program Management (public, private, other)	<ul style="list-style-type: none"> ▪ In order for an agency to properly manage RWIS, all levels of the particular agency must be properly trained. <ul style="list-style-type: none"> ▫ Usually, some behavioral changes are required on the part of decision makers to transfer from the reactive decisions process to the proactive decision process to anticipate necessary decisions based on RWIS information. ▫ Educating all levels of the agency, from maintenance workers to management, on RWIS and the benefits of the system would create more understanding and support for RWIS. ▪ RWIS should be user-friendly, flexible, and intuitive to be accepted by users. ▪ If a RWIS is being developed by partnerships, there must be open paths of communication and understanding. <ul style="list-style-type: none"> ▫ One way to facilitate communication is to consider a multi-agency oversight board. This board could ensure that needs are being met and the partnership is beneficial to everyone involved. ▪ Private sectors may be interested in RWIS if it is shown that the market is strong. <ul style="list-style-type: none"> ▫ Performing market research may facilitate the involvement of private companies in some RWIS components. ▫ It should be noted that a public/private partnership to deploy RWIS has been attempted only in Minnesota (within the United States) and has proved to be unsuccessful. <ul style="list-style-type: none"> ▪ This failure could be attributed to concerns over liability, ownership issues, and assumption of risk.
Guidance on Integration with Other Weather Data	None
Guidance on Role In Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	<ul style="list-style-type: none"> ▪ For RWIS to be successful in the future, data formats and specifications must be standardized between agencies. <ul style="list-style-type: none"> ▫ For standardization to occur, agencies must consider what systems and processes are already in place.
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ Although finding funding for RWIS is difficult, most of the agencies the authors interviewed agreed that RWIS is a valuable tool for keeping the public safe during winter conditions. ▪ According to the survey responses, the greatest challenge in implementing RWIS was training the operations and maintenance staff, the shortage of funds, and meeting the public's expectations.
Summary	In order for Road Weather Information Systems to be successful, agencies should be able to obtain more funding more easily, data formats and specifications must be standardized to bring down costs, and partnerships should be explored only when agencies know their own roles in the system and there are open paths of communication. Also, the system must be user-friendly to be accepted by maintenance and operations workers. Overall, the agencies that were surveyed agree that there are numerous benefits to RWIS, and that RWIS should be implemented to protect the public during unsafe winter conditions.



Other Notes and Observations	None
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Document Name	3: Utilizing Road Weather Information System (RWIS) Data to Improve Response to Adverse Weather Conditions
Published By	Federal Highway Administration
Date	N/A
Electronic Source	http://ops.fhwa.dot.gov/weather/best_practices/UtilizingRWIS.pdf
Abstract	In this paper, the authors investigated the potential of Road Weather Information Systems to improve the identification of adverse weather factors and improve the information provided to response teams prior to or during the detrimental weather conditions. During this investigation, the authors discovered that there are several significant issues with RWIS. First, due to the categorical nature of some of the collected data, RWIS is limited in providing useful guidance to response teams. Also, RWIS data are limited with their ease of accessibility. Lastly, RWIS data are spatially localized, such that there are discrepancies between officer-reported crash data and RWIS-reported crash data.
Guidance on Design and Deployment	None
Guidance on Maintenance and Operations	None
Guidance on Program Management (public, private, other)	None
Guidance on Integration with Other Weather Data	None
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	None
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ The authors concluded that the Road Weather Information System has three distinct limitations. <ul style="list-style-type: none"> □ First, some RWIS data is categorical. For example, the pavement surface is categorized as dry, wet, damp, chemical wet, or snow/ice. The presence of precipitation is indicated with a yes or a no, instead of a measure of the rate of precipitation. This categorical nature of the RWIS data does not make the data advantageous over existing crash reporting in its ability to determine the weather conditions. □ Second, the RWIS data has a limited historical timeline, which limits its usefulness over traditional crash report data. □ Lastly, RWIS data is highly localized. For example, pavement sensors only report the status of the road in the vicinity of the sensor, but different road surface conditions may exist from lane to lane.
Summary	The authors of this study aimed to develop a crash severity model which will be used to determine the crash, roadway, traffic, and weather characteristics that significantly impact crash severity. The authors focused on weather-related variables to develop a multinomial logit model and an ordered probit model. Both models used the same dependent variable, crash severity, of which had three different categories: property damage only, injury, and fatality. Through investigation of these models, the authors found that there are some limitations when using RWIS data.
Other Notes and Observations	None

Document Name	4: Benefit/Cost Study of RWIS and Anti-icing Technologies
Published By	National Cooperative Highway Research Program
Date	March 2001
Electronic Source	http://www.sicop.net/NCHRP20-7(117).pdf
Abstract	The American Association of State Highway and Transportation Officials identified the need for documenting the costs and benefits of RWIS and anti-icing strategies. This report describes these technologies, summarizes the current state of the practice, and describes different agency initiatives regarding RWIS. In particular, the benefits and costs of RWIS and anti-icing technologies are outlined.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ An auxiliary weather radar sensor would be helpful to examine the character of precipitation during a storm. <ul style="list-style-type: none"> ▫ Snow normally occurs in bands and these bands sometimes show up well on radar. ▪ Before deploying a RWIS and anti-icing system, an agency should contact another organization that is currently involved in this practice. <ul style="list-style-type: none"> ▫ The practicing agency could provide insight on the required resources, the budgeting process, any environmental concerns, and dealing with the public and agency personnel.
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ Using RWIS information to decide not to anti-ice is as important as deciding to anti-ice. <ul style="list-style-type: none"> ▫ If the pavement temperature dips below a threshold to anti-ice, it may still be wise not to apply liquid anti-icing chemicals. Pavement surfaces should be dry in blowing snow conditions, not wet. Even when blowing snow is not expected, it is not advisable to leave pavement bare and wet.
Guidance on Program Management (public, private, other)	<ul style="list-style-type: none"> ▪ An agency should develop a list of performance measures for snow and ice control so that the agency can document the adequacy of the system. Using this list, the organization can assess the need for implementing different strategies, and keep track of the costs and benefits for the RWIS/anti-icing system.
Guidance on Integration with Other Weather Data	None
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	None
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ A previous benefit to cost model that was developed during initial RWIS research portrayed a benefit to cost ratio of 5 for RWIS deployment. <ul style="list-style-type: none"> ▫ The model inputs included the cost of RWIS hardware and weather forecasting services, the road network being maintained, and the resource costs for snow and ice control. ▪ The weather index, which compares the costs of snow and ice control to weather severity and frequency of snow and ice, showed that snow and ice control costs are reduced when RWIS is implemented. ▪ Using RWIS data to conscientiously decide whether or not to anti-ice could cut down on an agency's operational costs. ▪ The following is a categorized listing of the reported benefits for RWIS. <ul style="list-style-type: none"> ▫ <u>Level of Service</u> – safer travel, improved driver information, and help for local agencies and public service functions (through data sharing). ▫ <u>Cost Savings</u> – save agency money, reduce staff and equipment requirements, reduce the use of salt, and reduce patrolling. ▫ <u>Maintenance Response to Information</u> – get the right resources at the right place at the right time, assist with crew scheduling, increased efficiency, implement better response strategies, helps make maintenance more effective, and helps with “do nothing” decisions. ▫ <u>Environmental Quality</u> – improved environmental quality due to the reduction of salt usage. ▫ <u>Indirect Benefits</u> – shorter travel times, reduced accident rates, reduced workplace absenteeism, and less disruption of emergency services. ▫ <u>Other Benefits</u> – reduced wear on equipment and bridges, helps in pavement operation planning, and assists in avalanche risk assessment. ▪ The FHWA asked agencies to document the potential cost savings from RWIS. <ul style="list-style-type: none"> ▫ The Maryland DOT estimates that a \$4.5M system will pay for itself in 5-7 years with just reduced standby time. ▫ The Massachusetts Highway Department saved \$53,000 in the first year with nine RWIS in Boston (\$21,000 in one storm alone), and estimated savings of \$150,000 to \$250,000 over a typical winter.



	<ul style="list-style-type: none"> □ The Minnesota DOT estimates a future 200-1300 percent return on RWIS. □ The Nevada DOT projects a \$7M savings over 25 years in the Lake Tahoe region due to reduced chemical usage, more efficient scheduling, and less damage to the environment. □ The New Jersey DOT has cut snow and ice costs by 10-20 percent or more. □ The North Dakota DOT has saved \$10,000 to \$15,000 on one bridge in four storms with reduced sand usage. □ The Texas DOT reports the savings in labor, equipment, and materials in the first three storms have paid for the RWIS deployments. □ West Virginia saved \$2,300 per storm in labor, \$6,500 of salt per storm, and \$200,000 per year for typical winter weather. The RWIS installation paid for itself in one year. ▪ Anti-icing, when used in conjunction with RWIS information, can save 10-20 percent of an agency's snow and ice control budget. Also, the snow and ice control costs per lane mile can be cut by as much as 50 percent.
Summary	<p>It has been well-documented that a number of DOTs and agencies have had considerable savings in implementing RWIS. RWIS has a number of level of service, cost saving, maintenance, and environmental benefits. Specifically, using RWIS in conjunction with an anti-icing scheme can increase cost saving within an agency by analyzing the correct times to anti-ice, if anti-icing is needed at all. To keep track of the benefits and decide whether to implement new strategies, an agency should develop a list of performance measures related to the Road Weather Information System.</p>
Other Notes and Observations	<p>None</p>

Document Name	5: Evaluation of Utah Department of Transportation's Weather Operations/RWIS Program: Phase I
Published By	Utah Department of Transportation
Date	February 2007
Electronic Source	http://www.coe.montana.edu/wti/wti/pdf/4W0892_Final_Report.pdf
Abstract	In this paper, the authors examined the Utah Department of Transportation (UDOT) RWIS program. UDOT's RWIS program provides detailed, area-specific weather information to assist operations, maintenance, and construction operations. UDOT also employs staff meteorologists to provide weather analysis and quality control of weather forecasts. The authors examined resource costs for the winter season of 2004-2005. The authors created a neural network to establish the winter maintenance cost as a function of UDOT weather service usage, level of maintenance, seasonal vehicle-miles traveled, anti-icing level, and winter severity index. The model estimated that the UDOT RWIS saved 11-25 percent of the labor costs and 4-10 percent of the materials cost for winter maintenance.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ When implementing RWIS, an agency should be sure to train personnel well, and to make the transition easy to implement within the different sectors of the organization. <ul style="list-style-type: none"> ▫ When the authors interviewed UDOT maintenance personnel, 80 percent responded that they change their approach to winter maintenance by using weather forecasts.
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ UDOT emails detailed text forecasts twice a day and more often as weather conditions worsen. These forecasts can be broken into three time periods: pre-storm, during-storm, and post-storm. <ul style="list-style-type: none"> ▫ Pre-storm forecasts provide information on the onset of weather events, whether precipitation will be rain or snow, and temperature trends. These forecasts are applicable to anti-icing operations. ▫ During-storm forecasts provide information on the intensity and duration of weather events and temperature trends. This information is applicable to snow and ice removal operations, such as de-icing, snowplowing, and sanding. ▫ Post-storm forecasts provide information on the exit timing of weather events, blowing snow, and temperature trends. This information is applicable to snow and ice cleanup operations. ▪ UDOT incorporates ITS technologies including bridge spray systems, high wind alerts, and fog warnings.
Guidance on Program Management (public, private, other)	<ul style="list-style-type: none"> ▪ By keeping meteorologists on staff, agencies can have year-round weather support for winter maintenance, construction and rehabilitation projects, operations, planning, risk management, training, and incident management. Also, the expert meteorologists ensure quality control of all weather forecasts.
Guidance on Integration with Other Weather Data	None
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	<ul style="list-style-type: none"> ▪ Weather and road conditions may be distributed in real-time using pager, email, radio, 511 telephone systems, and variable message boards. ▪ Web pages could provide pertinent adverse weather information, in real-time, to the public.
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ The benefits of RWIS are clear when they are compared to the costs due to inaccurate weather information. Some of the costs include: <ul style="list-style-type: none"> ▫ excessive use of chemicals and materials ▫ failure to respond efficiently to a storm event (resulting in greater crash risk and user delay) ▫ an unplanned use of overtime staffing. ▪ There are numerous benefits for using RWIS for winter maintenance. <ul style="list-style-type: none"> ▫ Reduction of worker call-outs and staff overtime. ▫ Reduction in unnecessary use of snow and ice control materials. ▫ Better planning in advance of a winter storm. ▫ Increased use of anti-icing practices. ▫ Winter maintenance activities could be practiced at lower costs. ▫ Increased level of safety for motorists. ▫ Improved planning for the annual winter maintenance budget. ▫ Decrease incident response time. ▫ Decrease construction project costs by better planning based on storm forecasts. ▪ Pavement sensors used with RWIS can be helpful in forecasting the timing of pavement icing, but not all RWIS use these sensors due to their high costs. ▪ There are significant costs associated with maintaining, calibrating, powering, and communicating with RWIS networks.



	<ul style="list-style-type: none"> ▪ In an attempt to quantify the benefits of the UDOT RWIS, the authors constructed two models to predict the labor and materials costs for annual winter maintenance for a particular maintenance shed. <ul style="list-style-type: none"> ▫ The authors predicted that the labor and materials cost would be a function of the overall usage of UDOT services during the winter season, the overall evaluation of the UDOT services, the level of anti-icing practiced in the shed, the level of maintenance of the winter roadways in the shed, the vehicle-miles traveled during the winter on the roadways that the shed manages, and the winter severity index for the area managed by the shed. ▫ One model that was predicted was a linear regression model. The authors concluded that a linear regression was not a good predictor for the labor and materials costs for annual winter maintenance for a particular maintenance shed. ▫ The second model predicted was an artificial neural network (ANN). ANNs can model non-linear systems, are robust, and can produce generalizations even if some of the data are incomplete. The authors found that the ANN predicted the labor and materials cost much better than the linear regression model, and can be used to quantify the benefits of the UDOT RWIS program. <ul style="list-style-type: none"> ▪ Based on the model, UDOT has saved between \$5.9 and \$13.3 million per year by using RWIS. ▪ Through the use of the weather program, UDOT has saved between \$1.4 and \$3.1 million per year just on labor and materials cost savings. ▪ There is potential to save between \$0.5 and \$1.2 million per year more by increasing usage of the program. ▪ Overall, the benefit to cost ratio for the UDOT weather maintenance program is 10. ▪ The authors interviewed 80 UDOT maintenance personnel including maintenance engineers, area supervisors, and station supervisors. <ul style="list-style-type: none"> ▫ Many of the 80 said that RWIS impacted their maintenance costs, but none would comment on how much the costs were affected. ▫ All respondents ranked the UDOT winter management system as their most useful source of weather information. Other sources included television broadcasts, traffic cameras, Accuweather, airports, ski reports, satellite, and Utah Highway Patrol. ▫ Among the station supervisors, 91 percent of respondents said they use the UDOT weather service daily during the winter season. As a storm approaches, this number increases to 97 percent, while 58 percent said they use the service more than twice a day. ▫ 60 percent of all survey respondents said they liked receiving forecast information for a future timeframe of 12 to 24 hours. 22 percent said they would like information for a timeframe of three to five days. ▫ 90 percent of UDOT station supervisors said that the UDOT RWIS system provided better service than other weather service providers.
Summary	<p>Utah has a model winter weather management program. A majority of the users report that the system is the best source for weather information, provides a better service than other service providers, and the users rely on the system on a day-to-day basis. Utah employs meteorologists to properly analyze forecast information and provide insights on handling adverse conditions. Utah also uses a variety of media to disseminate weather information, and incorporates ITS solutions as part of the program. The authors of the article developed a model to investigate the benefits of the winter weather management program on the costs of labor and materials, and found that the benefit to cost ratio is 10.</p>
Other Notes and Observations	<ul style="list-style-type: none"> ▪ Weather information can be broken into two categories: observations and forecasts. Observations reflect current conditions, while forecasts predict future conditions. Forecasts may be broken into subcategories. <ul style="list-style-type: none"> ▫ Micro – less than one hour ▫ Meso – one to six hours ▫ Synoptic – six hours to one week ▫ Climatic – numerous weeks and beyond ▪ The forecast scales correspond to different types of activities. A micro-scale analysis could help an agency decide an application rate, while a synoptic-scale analysis could be helpful for resource allocation.

Document Name	6: Integration of Emergency and Weather Elements into Transportation Management Centers
Published By	Federal Highway Administration
Date	February 2006
Electronic Source	http://ops.fhwa.dot.gov/weather/resources/publications/tcintegration/finalrpttmc22806.pdf
Abstract	This document focuses on using integration as a tool to improve the efficiency of Traffic Management Centers (TMC). Weather integration supports a TMC's ability to handle weather-related emergencies, manage traffic, and dispatch maintenance crews. This form of integration is accomplished by providing up-to-date weather forecasts, road conditions, and decision support to the TMC operators. Weather integration in TMCs is still in preliminary stages, but it has the potential to greatly improve transportation operations, safety, and driver satisfaction. The authors of this report interviewed 38 TMCs across the country to gain an understanding of the current best practices of integration. Ten of these TMCs were selected by the authors for site visits.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ When designing a weather information system, planners should include information from multiple information sources and subsystems. <ul style="list-style-type: none"> □ The Maryland CHART system uses one vendor to provide a GUI of all ESS information while another vendor provides remote weather imagery. □ Salt Lake City uses three different servers to provide ESS information. ▪ It is helpful and intuitive to present weather information graphically. <ul style="list-style-type: none"> □ Cherry Hill, NJ, uses a magnetic whiteboard map to track and organize their maintenance operations for snow removal. □ Salt Lake City uses a web-based GUI to show the driving impacts of weather and specific route closings throughout the state. □ Houston TranStar has an automated wall map with warning lights for each of the flood gauges in the region. The map shows the flood level thresholds and is replicated on the network with GIS software. ▪ It is advisable to have predefined routines in place related to the primary type of weather events in the region. <ul style="list-style-type: none"> □ Houston TranStar has the power to its light rail shut off if the water depth level reaches a certain threshold near a transit underpass. ▪ Before deploying a weather information system, managers should conduct a self-assessment and develop an integration plan, including a set of guidelines, to be organized and prepared at the time of deployment.
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ Weather triggers allow TMC staff members to set thresholds for certain weather events. When these events pass the thresholds, TMC personnel are notified, allowing the operators to take appropriate actions. Some examples of weather triggers are: <ul style="list-style-type: none"> □ Alarms such as the Flood Emergency Warning System □ Activation of the Emergency Operations Center □ A "heads-up" call from a weather service for road weather conditions beyond a threshold ▪ Maintenance personnel and weather forecasters can use traffic data to confirm weather events and improve response times. <ul style="list-style-type: none"> □ Salt Lake City utilizes CCTV images and road condition reports to tweak weather forecasts provided to maintenance dispatchers. □ In Los Angeles, traffic operations personnel track traffic incidents and provide maintenance personnel with reports. These maintenance personnel use these reports to deploy incident response teams. □ Minneapolis monitors the traffic system during the off-hours using CCTV. □ The Maryland CHART program keeps maintenance near the TMC control room so that they are in close contact with each other and lines of communication are open.
Guidance on Program Management (public, private, other)	None
Guidance on Integration with Other Weather Data	None
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	<ul style="list-style-type: none"> ▪ Not only can weather information be used for roadway maintenance itself, but the information can be used to monitor emergency personnel and dispatch responders in a safe manner. <ul style="list-style-type: none"> □ Austin studies different routes a helicopter air ambulance can take to avoid localized thunder cells. □ Houston TranStar relocates towing vehicles in case of flooding and alters transit routes in



	<p>anticipation of underpass flooding.</p> <ul style="list-style-type: none"> ▪ In Salt Lake City and Minneapolis, each workstation in the TMC has situational flip cards. These cards contain information related to field conditions that require response, criteria for contacting service providers, operational checklists, and contact numbers.
<p>Guidance on Data Formats and Dissemination to the Public</p>	<p>None</p>
<p>Benefit and Cost Considerations</p>	<p>The content of the weather information used by a TMC may not always be reliable or accurate.</p> <p>The following is a list of integration methods and the benefits and consequences associated with each method.</p> <ul style="list-style-type: none"> ▪ Intra-TMC committee put in charge of weather information coordination. <ul style="list-style-type: none"> □ Pro – This is a good start for deploying a weather information system □ Pro – An intra-TMC committee can initiate the needs analysis process and utilize minimal extra effort. □ Con – This method will not present any improvement in the TMC operations if the weather events present a complex situation. ▪ Identify an individual to coordinate weather information at the TMC. <ul style="list-style-type: none"> □ Pro – This method requires no additional staffing, and provides a go-to person when issues regarding information coordination arise. □ Con – The go-to person may already have responsibilities, and the effectiveness of that person may decrease with additional tasks. ▪ Hire a dedicated weather operations supervisor. <ul style="list-style-type: none"> □ Pro – This is a good strategy for coordinating weather information at the TMC to meet complex organizational needs. □ Con – There may not be enough demand to justify creating this position. ▪ Have weather information continuously available through the internet, public access forecasts, weather radar, or satellite images. <ul style="list-style-type: none"> □ Pro – Low cost, maintenance, and effort. □ Pro – Utilizes information from a number of public sources. □ Con – Public forecasts may not be precise enough for TMCs. □ Con – If a TMC is using satellite or radar information, the personnel must be trained so that information from these sources can be interpreted correctly. <hr/> <ul style="list-style-type: none"> ▪ Obtain weather information through Cable Channel or non-surface transportation specific subscription weather information vendors. <ul style="list-style-type: none"> □ Pro – Low cost, maintenance, and effort. □ Pro – The interpretations from satellite and radar information are provided by meteorologists. □ Con – The provided information is not specific to operational needs. ▪ Hire a contractor to provide surface transportation weather forecasts targeted at the operational needs of the TMCs. <ul style="list-style-type: none"> □ Pro – This method is contractual and can be customized to the needs of the TMC. □ Con – This requires a dedicated weather operations supervisor to handle the RFP development and contract management. ▪ Deploy field observers or probes to routinely report weather and road condition information for the entire network. <ul style="list-style-type: none"> □ Pro – This method could be implemented with low technical deployment. □ Pro – Routine forecasts provides information for treatment decisions. □ Pro – This method provides continuous coverage, and not just adverse weather coverage. □ Con – It must be frequent enough to provide valuable information. □ Con – This method requires considerable planning and commitment. ▪ Hire a meteorology staff located within the TMC to interpret and forecast weather information. <ul style="list-style-type: none"> □ Pro – This method requires no training of TMC personnel. □ Pro – Provides high operational benefits through physical integration. □ Con – This method has high costs and it requires a detailed benefit/cost analysis to realize the need for a dedicated staff. <hr/> <ul style="list-style-type: none"> ▪ Use a web-page or email to notify personnel of escalated adverse weather conditions or automatic thresholds. <ul style="list-style-type: none"> □ Pro – Low cost, maintenance, and effort. □ Con – Uncertain reliability and not specific to the TMC's needs. ▪ Use road weather systems like RWIS or ALERT to generate specific notifications when weather conditions escalate. <ul style="list-style-type: none"> □ Pro – This method is customizable for a TMC's needs. □ Con – Requires dedication to on-going maintenance and is virtually impossible to cover all



	<p>locations of the transportation network.</p> <ul style="list-style-type: none"> ▪ Hire a vendor to provide personal email/phone notification when weather conditions escalate. <ul style="list-style-type: none"> □ Pro – Effective solution that has low tech requirements. □ Pro – Allows the TMC transportation staff to focus on the network and maintenance personnel to focus on mobility. ▪ Utilize an in-house meteorology staff to provide daily briefings of weather forecasts. <ul style="list-style-type: none"> □ Pro – This is a non-technical solution that meets the advisory needs of the TMC operational staff. □ Con – This method has high costs and it requires a detailed benefit/cost analysis to realize the need for a dedicated staff. ▪ Provide geographic visualization of road conditions, personnel positions, and precipitation, wind, and visibility. <ul style="list-style-type: none"> □ Pro – Easily understandable by personnel and a high level of training and knowledge is not required. □ Con – Geographic visualization requires expert design and careful planning. ▪ Use focus groups or gatherings of local professionals from the transportation management and weather communities to create community awareness. <ul style="list-style-type: none"> □ Pro – An easy way for institutional integration at the local level. □ Con – Requires local professionals to take the extra time to form the local activities. ▪ Create national meetings to exchange operational method ideas. <ul style="list-style-type: none"> □ Pro – Creates a national awareness and provides professional development opportunities. □ Con – Different communities have different national associations with little reason for collaborating and creating a joint meeting. ▪ Hold training courses that highlight different communities' operations. <ul style="list-style-type: none"> □ Pro – This method provides an open exchange of the state of the art practices for weather information management. □ Con – Requires leadership at the federal level to facilitate funding and assist training development. ▪ Use quick reference cards at operators' workstations for decision support. <ul style="list-style-type: none"> □ Pro – Low cost and technology and training requirements. □ Con – Limited to recurring events and decisions not requiring involved operational integration. ▪ Utilize software to supply decision support solutions based on traffic and weather modeling. <ul style="list-style-type: none"> □ Pro – The software provides experience and knowledge beyond the operator's capabilities. □ Pro – Allows what-if scenarios and learning situations to take a preventative role in maintenance management. □ Con – Requires real-time traffic and weather modeling that is not yet developed
Summary	<p>Planning for weather integration in a Traffic Management Center is a delicate process. Managers must perform considerable amounts of assessment and planning in order to properly design a system that performs well for that region. It is not advised to copy another region's system, because different areas have different needs when it comes to how weather impacts traffic safety and mobility. Even though it is not advised to copy another region's system, it may be helpful to examine another integration system to gain insight to the integration process. This paper presents the pros and cons of some integration methods, and gives examples of different methods for different regions.</p>
Other Notes and Observations	<ul style="list-style-type: none"> ▪ There are three types of mitigation strategies in dealing with severe weather events using integrated weather information: advisory, treatment, and control. <ul style="list-style-type: none"> □ Advisory is the most practiced and integrated mitigation strategy. Here, all parties (TMC staff and the public) are better informed. TMC staff are informed and prepared for any operational or safety incidents that may occur and the public are more informed through the use of DMS, web sites, 511, and Highway Advisory Radio (HAR). □ Treatment is used to alter the effects of the weather on traffic operations by applying resources to the physical infrastructure. Forecasts and CCTV images can provide the TMC staff with up-to-date conditions in the area. □ Control is a strategy that allows the TMC to regulate traffic flow using variable speed signs or traffic signal timing.

Document Name	7: Prototype Weather Response System (WRS) for Transportation Operations
Published By	Federal Highway Administration
Date	November 2006
Electronic Source	http://ops.fhwa.dot.gov/publications/wrs/wrsflyernov06.pdf
Abstract	In conjunction with the Federal Highway Administration, the Missouri Department of Transportation (MoDOT) developed a piece of prototype software to support weather-related transportation responses. This web-based application, the WRS, obtains weather information from the National Weather Service (NWS). MoDOT personnel in Kansas City tested the software and found it to be useful in scheduling activities and managing operations before and during adverse weather conditions.
Guidance on Design and Deployment	None
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ The WRS has the capability to: <ul style="list-style-type: none"> □ Provide real-time weather information □ Support effective response to the impacts of adverse weather on the transportation network □ Assist agencies in analyzing operational and maintenance needs based on the provided weather information ▪ The WRS can increase operation and maintenance efficiency by allowing personnel to easily visualize upcoming weather events. The program also has the ability to allow users to filter weather-related criteria, letting the person focus on areas of concern.
Guidance on Program Management (public, private, other)	None
Guidance on Integration with Other Weather Data	None
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	None
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ Since the program is still in its preliminary phase, there are no cost listings for the WRS software.
Summary	Although the application is still in the preliminary phase, the Weather Response System has the ability to become a staple in RWIS. The WRS has a user-friendly interface, which will allow it to become mainstream in RWIS practices. The Planner and Graph modules of the program allow users to plan for upcoming weather events, specifically weather events that are of particular concern to the agency.
Other Notes and Observations	<ul style="list-style-type: none"> ▪ The WRS includes several modules: <ul style="list-style-type: none"> □ <u>Home Page</u> - this page includes a general description and contact information. □ <u>National</u> - this module displays weather maps of the continental United States. □ <u>State</u> - this page shows weather maps centered on 11 central U.S. states. □ <u>Local</u> - the Local page displays local weather forecasts for metropolitan areas in Missouri. □ <u>MapShow</u> - MapShow shows the latest national, state, and/or local weather maps in a series of map displays. □ <u>Planner</u> - Planner allows a user to select a particular map location and displays parameters that meet user-specified criteria. The results are portrayed in time periods for each weather criteria or the criteria can be combined to show which time period satisfies all of the weather parameters. For example, a user can specify time periods when the temperature will be below 40° F, wind gusts will be greater than 10 mph, and the chance of precipitation will be at or above 75%. The planner will show time periods when each individual parameter is met, or when all are simultaneously met. □ <u>Graph</u> - the Graph shows the results of the Planner module in a set of time-series graphs. □ <u>Radar</u> - this module allows a user to select NWS Doppler radar images from any radar station in the nation. ▪ The detail provided by the Planner and Graph can help operations staff to better plan and react to specific weather conditions.

Document Name	8: Maintenance Decision Support System (MDSS) – The National Center for Atmospheric Research Projects
Published By	The National Center for Atmospheric Research Projects
Date	May 19, 2005
Electronic Source	http://www.rap.ucar.edu/projects/rdwx_mdss/index.html
Abstract	The Maintenance Decision Support System (MDSS) is a prototypical tool for decision support during winter road maintenance activities. The MDSS is based on leading weather research and road condition algorithms. The ultimate goal of this project, which is still in the preliminary stages, is to produce a standardized application that will be used by various agencies and will be generally supplied by private vendors (Value Added Meteorological Services).
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ The developers of MDSS have identified several factors for supporting maintenance decisions. Support systems should include: <ul style="list-style-type: none"> □ start and stop times for weather events □ precipitation characteristics, such as the type, amount, and rate □ road conditions, such as the temperature, chemical concentration, and coverage by liquid phases □ the snow status, with respect to the depth on the road and drift patterns □ a level of risk associated with the provided information (confidence or probabilities associated with the information)
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ MDSS will be able to generate diagnostic and predictive maps of roadway conditions with emphasis on the one hour to two day forecast horizon. <ul style="list-style-type: none"> □ Historical information from the previous two days will also be available. ▪ MDSS will also have a decision support tool, which provides advice on road maintenance activities during certain weather conditions. ▪ MDSS focuses on three types of decision groups based on a time period prior to the winter event. <ul style="list-style-type: none"> □ <u>Monitor Conditions</u> – Agencies should start monitoring conditions starting at two days before the start time of the event. □ <u>Activate Staff</u> – Agencies should start activating staff starting at 15 hours before the event begins. This includes putting supervisors on the schedule, splitting crew shifts, and calling in personnel. □ <u>Mid-Storm Management</u> – Organizations need to manage operations during the storm starting between one to three hours before the storm. During this time, the agencies should dispatch crews to treat roadways, request resources from other jurisdictions, coordinate emergency management, coordinate public information, manage incidents, close roads, monitor crew conditions and working times, re-evaluate storm conditions, and determine when the level of service goal is reached.
Guidance on Program Management (public, private, other)	None
Guidance on Integration with Other Weather Data	<ul style="list-style-type: none"> ▪ The MDSS project hopes to capitalize on existing weather data to reduce the costs of implementing MDSS.
Guidance on Role in Transportation Operations	None
Guidance on Integration in Maintenance Decisions	<ul style="list-style-type: none"> ▪ Current technologies exist to assist in maintaining road conditions during adverse weather conditions, but there are some needs that are not addressed by these existing technologies.
Guidance on Data Formats and Dissemination to the Public	None
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ Some potential benefits of MDSS include: <ul style="list-style-type: none"> □ Increased safety □ Decreased user costs □ Decreased work hours □ Decreased material use □ Decreased equipment use □ Decreased environmental impact ▪ Some potential costs of MDSS include: <ul style="list-style-type: none"> □ Costs for software □ Costs for instrumentation □ Increased data processing □ Costs for training ▪ Since the program is still in the preliminary stage, there are no prices associated with the MDSS



	software.
Summary	The Maintenance Decision Support System is a promising tool for agencies looking for assistance with winter road maintenance decisions. MDSS looks to provide weather information such as event durations, precipitation characteristics, road conditions, snow status, and the level of risk associated with the provided information. This information will help agencies monitor conditions, activate staff, and manage operations during storms.
Other Notes and Observations	None

Document Name	9: The Winter Maintenance Decision Support System (MDSS): Demonstration Results and Future Plans
Published By	Federal Highway Administration
Date	2003
Electronic Source	http://ops.fhwa.dot.gov/weather/best_practices/MDSSpaperAMS2004.pdf
Abstract	The Maintenance Decision Support System (MDSS) is a prototypical tool to link available weather information with the decisions made by winter maintenance managers. MDSS was deployed at several maintenance garages in Iowa during the 2002-2003 winter season. 15 routes and three maintenance garages around Des Moines and Ames participated in the study. The authors document the deployment process, summarize lessons learned, and document plans for a more extensive demonstration during the 2003-2004 winter season.
Guidance on Design and Deployment	None
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ MDSS uses a rule-based module to provide treatment recommendations to supervisors. These recommendations include: <ul style="list-style-type: none"> □ timing information for the length of precipitation □ precipitation type and accumulation □ optimized treatment times □ recommended chemical types and application rates ▪ MDSS features a “what-if” scenario tool. The user can modify treatment times, chemical types, or application rates, and investigate how the road conditions will change over time. For example, through a chemical composition display, a user can check how the chemical concentrations on the road surface last for different treatment scenarios. ▪ Garage supervisors and plow operators who participated in the MDSS deployment study said that the recommendations from the MDSS were reasonable.
Guidance on Program Management (public, private, other)	<ul style="list-style-type: none"> ▪ The following list provides a summary of the results from the Iowa deployment study. <ul style="list-style-type: none"> □ MDSS requires very specific precipitation forecasts, which limits predictability. □ The rule-based module must be refined to handle a wider variety of weather and road condition scenarios and treatment solutions. □ The availability and quality of real-time data are very poor. □ During a heavy winter storm, managers usually do not have enough time to enter the treatments for each route into MDSS. In this instance, MDSS loses track of some roadway conditions. □ Light and intermittent snow storms are important to DOT operations and are harder to predict than heavier storms. □ Users have a need for tactical (zero to two hour) decision support. □ Since weather cannot be perfectly predicted, probabilistic products should be developed and implemented. □ MDSS is not designed to provide advice for blowing snow conditions. □ MDSS does not have the capacity to identify specific road segments that may need treatment due to frost. □ There should be a forecast level of confidence reported with all weather information in MDSS. ▪ The following list is a summary of enhancements planned for the next field demonstration. <ul style="list-style-type: none"> □ Add plow-only and pre-treat with brine treatment options. □ Add the ability for users to reset road conditions to zero for snow depth and chemical concentration. □ Create a treatment option to alert when blowing snow conditions may exist. □ Modify treatment options that utilize road drying times. □ Work with the Iowa State University to add frost deposition forecast support. □ Install real-time snow gauges for better liquid equivalent information. □ Revise the system to support hourly forecasts (currently the system is based on three hour forecasts). □ Create probabilistic information for certain data fields, such as precipitation occurrence, precipitation type, and air temperature. □ Add the ability to observe current RWIS data. □ Add the ability to view recent history on the display, so that more than just the latest 48 hours is available.
Guidance on Integration with Other Weather Data	None
Guidance on Role in Transportation Operations	None
Guidance on Integration In	None



Maintenance Decisions	
Guidance on Data Formats and Dissemination to the Public	None
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ Since the MDSS system is still in the preliminary deployment phase, there are no costs associated with the system.
Summary	The MDSS was deployed and tested in the Des Moines and Ames areas of Iowa. A number of shortcomings of the system were identified, but the participating supervisors agreed that the system has tremendous potential. The supervisors said it would be worthwhile to continue to improve the system. A number of enhancements have been notified and will be implemented before the second field demonstration.
Other Notes and Observations	None

Document Name	10: Clarus Initiative – A National Surface Transportation Weather Observing and Forecasting System
Published By	Federal Highway Administration
Date	January and March, 2007
Electronic Source	http://www.clarusinitiative.org/ - Last updated January 11, 2007 http://www.its.dot.gov/clarus/index.htm - Last updated March 20, 2007
Abstract	Clarus is an initiative to provide transportation managers with information to alleviate the affects of adverse weather events. Officials working on Clarus will achieve this by developing an integrated surface transportation weather observing, forecasting, and data management system. The Clarus initiative also hopes to create a Nationwide Surface Transportation Weather Observing and Forecasting System.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ Clarus will establish an Initiative Coordinating Committee to guide the development and deployment of new technologies related to weather information management. ▪ The ideal deployment for Clarus is to have an open, flexible system that can be implemented by any agency and that can accept data from new sources (like vehicle-infrastructure integration). ▪ The FHWA would like to make Clarus as easy as possible to implement, so that its use is extended throughout a number of agencies. ▪ Clarus will utilize the following technologies: <ul style="list-style-type: none"> □ Environmental Sensor Stations □ CCTV □ Mobile Sensing such as truck-mounted sensors □ Remote Sensing like a radar or satellite system ▪ The FHWA will create a manual to provide step-by-step instructions on how to deploy Clarus in different parts of the country. ▪ The Clarus development also includes plans for a network deployment cost estimation tool for agencies aiming to deploy the system.
Guidance on Maintenance and Operations	None
Guidance on Program Management (public, private, other)	<ul style="list-style-type: none"> ▪ One of the goals of Clarus is to eventually involve the private sector in this project. <ul style="list-style-type: none"> □ It is hoped that by involving the private sector, the quality of the collected weather information will increase. □ Officials in the private sector will not necessarily think in terms of political boundaries. □ The government and private sector must overcome data sharing boundaries to effectively work together with this initiative. ▪ The following stakeholders will benefit from the Clarus initiative: <ul style="list-style-type: none"> □ State and Municipal DOTs □ Public Weather Forecasting Agencies □ Public Weather Consumer Agencies □ Private Weather Information Providers □ Electronic and Print Media □ Road Users □ Mass Transit □ General Public
Guidance on Integration with Other Weather Data	<ul style="list-style-type: none"> ▪ The Clarus initiative hopes to develop partnerships between transportation and weather communities to share resources and information for research and operations. Specifically, officials involved with the Clarus initiative will work closely with the National Oceanic and Atmospheric Administration to build off each other's data and avoid duplication of information. ▪ Officials developing Clarus want to build a database to collect the nation's current and future transportation weather and road condition observations. Then, they want to provide this data as input to advanced weather models. ▪ Clarus will work by providing access to existing RWIS sensors, and fill in the gaps between the sensors by obtaining information from satellites and vehicle-based sensors.
Guidance on Role In Transportation Operations	None
Guidance on Integration In Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	None
Benefit and Cost Considerations	<ul style="list-style-type: none"> ▪ The potential benefits of Clarus include: <ul style="list-style-type: none"> □ Reliable access to transportation-related weather data



	<ul style="list-style-type: none"> □ Nonstop quality control of weather information with feedback to transportation agencies □ Creating standards for data formats and communications networks □ Providing real-time data for weather and traffic models and decision support systems □ Applications of new technologies like vehicle-based sensors and low-cost, high-resolution weather radar sensors. ▪ While Clarus hopes to share data with other organizations, officials do not exactly know how to develop solutions to enable data sharing with the World Meteorological Organization.
<p style="text-align: center;">Summary</p>	<p>Clarus is a governmental initiative to develop an open-source weather information system. Eventually, this system will coordinate with other agencies to share data for research and operations, allow any agency to utilize the system, and open the system to the private sector to increase the reliability of the collected data.</p>
<p>Other Notes and Observations</p>	<p>None</p>

Document Name	11: Final Report of the Operation and Demonstration Test of Short-Range Weather Forecasting Decision Support within an Advanced Transportation Weather Information System (#SAFE)
Published By	Federal Highway Administration
Date	April 2006
Electronic Source	http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//14348_files/14348.pdf
Abstract	The Advanced Transportation Weather Information System (ATWIS) was proposed in 1995 by the University of North Dakota Regional Weather Information Center. Its purpose was to provide weather forecasts and road condition information to motorists. ATWIS used Intelligent Transportation Systems Integration to be the first system to develop and produce an operational rural system to provide information to motorists across vast, open spaces. ATWIS successfully transferred into a sustainable operational system through a public-private partnership. ATWIS was the first major road weather research tool and proved to be extremely useful for paving the way for this new field. This report includes a summary of the current technologies in weather information systems.
Guidance on Design and Deployment	<ul style="list-style-type: none"> ▪ ATWIS in North and South Dakota included a quality control process to identify and flag suspicious data that was collected from ESSs. This suspicious data was then excluded from data assimilation processes. ▪ Satellite imagery was used during the daytime to study fog conditions in certain areas. ▪ After the initial program deployment, it was realized that there needed to be better automation in information assimilation. <ul style="list-style-type: none"> ▫ The states developed a definition matrix to standardize the descriptive nature of the road and weather conditions along each roadway segment. ▪ ATWIS developed a Steering Committee to provide insight and leadership from transportation and meteorological professionals to create a plan for ATWIS implementation.
Guidance on Maintenance and Operations	<ul style="list-style-type: none"> ▪ A Forecast Decision Support System (FDSS) was developed to manage forecasts to assess and analyze weather conditions for specific corridor segments.
Guidance on Program Management (public, private, other)	<ul style="list-style-type: none"> ▪ ATWIS used lightning detection networks from the private sector to obtain short-range weather forecasts. ▪ Following a Congressional mandate, ATWIS successfully transferred into a sustainable system through a public-private partnership.
Guidance on Integration with Other Weather Data	<ul style="list-style-type: none"> ▪ The ATWIS system utilized Doppler weather radar data from the University of North Dakota.
Guidance on Role In Transportation Operations	None
Guidance on Integration in Maintenance Decisions	None
Guidance on Data Formats and Dissemination to the Public	<ul style="list-style-type: none"> ▪ ATWIS initially disseminated information to the public through VMS, highway advisory radio, and AM side-band radio. ▪ Through time, ATWIS implemented the ability to access information through cellular phones. <ul style="list-style-type: none"> ▫ To implement this as a free service, the program developed relationships with cellular service providers across North and South Dakota. ▫ Users could dial #SAFE to connect to a computer telephony system and request road and weather information.
Benefit and Cost Considerations	None
Summary	The ATWIS and #SAFE systems have resulted in new research initiatives and technologies. For example, the current 511 system in rural areas owes its beginnings to ATWIS and the #SAFE technologies. The ATWIS that was proposed by the University of North Dakota included innovative quality control processes, public-private partnerships, and methods for disseminating road and weather information to the public.
Other Notes and Observations	<ul style="list-style-type: none"> ▪ Initial deployment of ATWIS was supported by the public so much that there was a larger demand for broader coverage of information provided through #SAFE.

Document Name	12: Best Practices for Road Weather Management
Published By	Federal Highway Administration
Date	May 2003
Electronic Source	http://ops.fhwa.dot.gov/Weather/best_practices/CaseStudiesFINALv2-RPT.pdf
Abstract	This report contains 30 case studies of weather management systems in 21 states that improve roadway conditions under adverse weather. Each study contains a general description of the system, system components, operational procedures, transportation outcomes, implementation issues, and contact information and references. The listings below are summaries from selected case studies that are applicable to this project.
Alabama DOT Low Visibility Warning System	<p>The need for a low visibility warning system was made apparent after a 1995 fog-related crash that involved 193 vehicles. The crash occurred on the Bay Bridge on Interstate 10.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ Six sensors with forward-scatter technology are used to measure visibility. ▪ The sensors are installed in one-mile intervals along the bridge. ▪ A Closed Circuit Television (CCTV) system monitors traffic flow. ▪ Sensor data is transmitted to a tunnel control room, which controls 24 variable speed limit (VSL) signs and five dynamic message signs (DMS). <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Two operators are in the tunnel control room 24 hours a day. ▪ When fog is visible through the CCTV, the operators check the visibility measurements through the central computer. ▪ The operators may display messages through DMS and change speed limits through VSL. ▪ When operators change the speed limits, the DOT division office, Highway Patrol, and local law enforcement agencies are automatically notified. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ The system improves safety by reducing speed and minimizing crash risk. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ Backscatter technology sensors were initially installed, but problems with accuracy and reliability forced the DOT to install new forward-scatter sensors. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Gerald Criswell, Alabama DOT, Tunnel Maintenance Supervisor, ccriswell@dot.state.al.us ▪ M.R. Davis, Alabama DOT, Division Maintenance Engineer, davisr@dot.state.al.us
California DOT Motorist Warning System	<p>The California DOT (Caltrans) installed an automated warning system on southbound Interstate 5 and westbound State Route 120. The system warns travelers of driving hazards attributed to low visibility conditions.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ 36 vehicle detection sites and nine Environmental Sensor Stations (ESS) are deployed along the freeways. ▪ Detection sites are made up of paired inductive loop detectors and Caltrans Type 170 controllers. ▪ Each ESS includes a rain gauge, a forward-scatter visibility sensor, wind speed and direction sensors, a relative humidity sensor, a thermometer, a barometer, and a remote processing unit. ▪ Dedicated phone lines transmit data from the field to a Traffic Management Center (TMC). ▪ A central computer automatically shows messages on nine DMS. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Three central computers control the warning system. ▪ ESS data is displayed by a meteorological monitoring computer. ▪ A traffic monitoring computer records and processes traffic volumes and speed data. ▪ The DMS computer has the ability to access the recorded data and assess traffic conditions. Using automated software, warning messages can be displayed on the DMS. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ The warning system improves traveler safety by reducing the frequency of low-visibility crashes. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ Incandescent DMS are used because of their readability in low visibility conditions. ▪ After the system components were installed and calibrated, maintenance schedules and contracts were developed, and personnel were trained. ▪ The system was designed so that it may be expanded in the future. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Clint Gregory, Caltrans District 10, Electrical Systems Branch Chief, clint_gregory@dot.ca.gov ▪ Ted Montez, California Highway Patrol, Public Information Officer, tmontez@chp.ca.gov
City of Palo Alto California Flood Warning System	The City of Palo Alto, California, developed a web-based flood warning system after heavy rain in 1998 caused the city to flood. Residents and emergency officials had no advanced warning of the flood.



	<p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ Water level sensors, rain gauges, flood basin detectors, tide monitors, and a CCTV are used to monitor field conditions. ▪ Five bridge locations have ultrasonic sensors to detect flood conditions. ▪ Radio and telephone networks carry water level readings to the water, gas, and storm drain Supervisory Control and Data Acquisition system. ▪ Video images of one bridge are transmitted to the Emergency Operations Center. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Video images and water level readings are posted on the City's website. These readings are updated every three minutes. ▪ In the event of a flood threat, an automatic telephone system calls all residents and businesses that are in a threatened area and notifies them of the weather conditions. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ Before the system was installed, management personnel had to drive to the bridges to monitor the storm drain system and check water levels. ▪ Residents may access the information and make decisions regarding safety and travel. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The sensors were installed and integrated with existing systems. ▪ Non-intrusive sensors were installed such that floating debris could not damage the equipment. ▪ After the system was installed and running, officials decided to add the web-based feature to better serve the public. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ John Ballard, City of Palo Alto, California, Public Works Operations
<p>City of Aurora, Colorado Maintenance Vehicle Management System</p>	<p>The City of Aurora, Colorado, deployed a system to monitor the status of maintenance vehicles. The system improves public relations, productivity, and the real-time communication between drivers and maintenance managers.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ The Maintenance Vehicle Management System is composed of in-vehicle devices, central control systems, and a wireless communication system. ▪ 20 snowplows are equipped with integrated display, messaging and communication devices. ▪ Data transmission devices send position data to a central computer every 20 seconds. ▪ The vehicles are equipped with Global Positioning Systems (GPS) to keep track of vehicle locations. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Centralized computers allow managers to send messages to single plows, or multiple plows. ▪ Managers can monitor road treatments through maps. These maps allow users to assess which roads have been plowed, determine if a plow is off its route, and plan route diversions. ▪ The system is used for treatment strategy planning, real-time operations monitoring, and post-event analysis. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ Using the system, costs have been reduced and productivity has been improved by 12 percent. ▪ Managers can easily provide information to residents who call in to ask about the plow status of a particular street. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The City used a private vendor to install in-vehicle and central components of the system. ▪ The City's information systems staff was involved with the planning and design of the system. ▪ The City also hired a local system integrator to resolve issues related to the various component and communications providers. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Lynne Center; City of Aurora, Colorado Public Works Department, lcenter@ci.aurora.co.us
<p>Florida DOT Motorist Warning System</p>	<p>The Florida DOT installed an automated motorist warning system on an exit ramp between the Florida Turnpike and Interstate 595 to notify travelers of wet pavement conditions.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ A sensor is embedded in the pavement to monitor pavement condition. ▪ A microwave vehicle detector is installed to collect traffic volumes and speeds. ▪ A precipitation sensor verifies rainfall measurements. ▪ A dedicated telephone line transmits data from the system to the turnpike operations center. ▪ A remote processing unit (RPU) is connected to flashing beacons atop of speed limit signs. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ When pavements become damp, the RPU activates the flashing beacons to alert motorists of the posted speed limit. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ The warning system improved safety by reducing vehicle speeds and promoting more uniform traffic

	<p>flow during rainy conditions.</p> <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The project was a joint effort between the Florida DOT, the University of South Florida, and a private vendor. ▪ The university collected all data at one-minute intervals to evaluate the system performance. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Michael Pietrzyk, University of South Florida, Center for Urban Transportation Research (CUTR), pietrzyk@cutr.eng.usf.edu
<p>Idaho DOT Motorist Warning System</p>	<p>The Idaho DOT installed a motorist warning system on a section of Interstate 84 in southeast Idaho and northwest Utah. This segment was prone to crashes when blowing snow or dust reduced visibility.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ Sensors collect road, weather, and traffic condition data and transmit the data to central computers. ▪ Environmental Sensor Stations (ESS) detect pavement condition, wind speed and direction, precipitation type and rate, air temperature, and relative humidity. ▪ Sensors with forward-scatter detection technology measure visibility distance. ▪ Inductive loop detectors record vehicle length, speeds, and travel lane. ▪ Warnings are posted on four DMS. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ The central computer records sensor readings every five minutes. ▪ When visibility has fallen below a predetermined threshold or when conditions are deteriorating, the computer in the control center alerts traffic managers. ▪ Traffic managers decide which messages to display on the DMS. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ The agency performed a system evaluation and found that average vehicle speeds decreased when adverse conditions were present and DMS were activated. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ Since leased telephone lines in the rural area where the system was deployed were not reliable for transmission of sensor data, a dedicated telephone cable was installed from the system location to the control center. ▪ Numerous power outages, shortages, and surges damaged field and central components. Uninterruptible power supplies were installed to solve these problems. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Bob Koeberlein, Idaho Transportation Department, ITS Program Manager, rkoeberl@itd.state.id.us ▪ Bruce Christensen, Idaho Transportation Department, District 4 Traffic Engineer, bchriste@itd.state.id.us ▪ Clyde Dwight, Idaho Transportation Department, Information Technology Systems Coordinator, cdwight@itd.state.id.us
<p>Idaho DOT Anti-Icing/Deicing Operations</p>	<p>In 1996 maintenance managers with the Idaho DOT started an anti-icing program on a section of US Route 12. An anti-icing chemical is applied to road surfaces instead of applying large volumes of abrasives.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ Trucks with 1,000-gallon (3,785-liter) and 1,500-gallon (5,678-liter) tanks were had spray controls attached to dispense liquid magnesium chloride. ▪ Idaho DOT has a chemical storage facility with two 6,900-gallon (26,117-liter) storage tanks and an electric pump to load the trucks with the anti-icing formula. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Maintenance managers use the Internet to identify adverse winter conditions. ▪ When managers identify adverse conditions, trucks are deployed to spray small amounts of the anti-icing chemical on road surfaces before the winter event begins. ▪ Maintenance personnel regularly check the road to be retreated to ensure that chemical concentrations are high enough to prevent freezing. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ Mobility was improved, as the application of the anti-icing formula was typically effective at improving traction for three to seven days ▪ Since the DOT cleared snow and ice at faster rates, operation costs were reduced and productivity was enhanced. ▪ The system also included safety improvements because of the reduced frequency of wintertime crashes. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ Trucks that were previously used to spray weed-killing and other chemicals were modified to dispense liquid magnesium chloride. ▪ The DOT trained crews in all aspects of anti-icing procedures. They learned about various anti-icing

	<p>chemicals and their properties, chemical application rates, and equipment operation.</p> <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Bryon Breen, Assistant Maintenance Engineer, bbreen@itd.state.id.us
<p>Minnesota DOT Access Control</p>	<p>Since 1996, Minnesota Department of Transportation (DOT) has worked with the Minnesota State Patrol and county sheriffs to prevent traffic from driving on the freeways when there are unsafe winter conditions. After maintenance vehicles have cleared snow and ice, freeways are reopened to traffic.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ Two types of gates are used to restrict freeway access. <ul style="list-style-type: none"> □ One maintenance district installed gate arms swing into place when needed and block traffic from access. These arms have amber lights. □ Other districts deployed upright gate arms, with red lights, that are lowered into position. Warning signs are located in advance to notify motorists of freeway closures. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Factors that maintenance managers consider when deciding to restrict freeway access are: <ul style="list-style-type: none"> □ Storm duration □ Storm Severity □ Visibility □ Pavement condition □ Time of day □ Day of the week □ Seasonal travel patterns □ Capacity of towns to accommodate diverted motorists ▪ When all organizations decide to restrict access, DOT personnel travel to gate locations to open warning signs and activate gate arm lights. ▪ During closure, law enforcement personnel are located at gate locations to prevent motorists from interfering with winter maintenance operations. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ The Minnesota DOT researched this program during a storm event and over a six-month period indicated that productivity, mobility, and safety were improved. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ A consultant hired by the DOT analyzed the costs and benefits of deploying the gate arms for access control. The consultants concluded that there were considerable reductions in travel time delay and crash frequency. ▪ Snowdrifts could block swinging gates so they may need to be shoveled before the gates could be positioned in the road. ▪ In some cases, the pulley on the upright gates failed causing the gate arm to slam down unexpectedly. ▪ The DOT plans to test remote operation of gates and CCTV at one interchange. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Farideh Amiri, Minnesota DOT, ITS Project Manager, farideh.amiri@dot.state.mn.us
<p>Minnesota DOT Anti-Icing/Deicing System</p>	<p>A few Minnesota DOT districts have installed fixed automated anti-icing systems on bridges that regularly have slippery pavement conditions. The system deposits anti-icing chemicals automatically, as needed.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ The automated anti-icing system is comprised of: <ul style="list-style-type: none"> □ A small enclosure which houses the pump, a 3,100-gallon (11,734-liter) chemical storage tank, a 100-gallon (379-liter) water storage tank, and control mechanisms □ Storage tanks □ A pump and delivery system □ Environmental sensors □ Four motorist warning signs with flashing beacons □ A control computer located in the district office ▪ 38 valve bodies are installed in the median barrier to direct the anti-icing chemical to 76 spray nozzles. ▪ An ESS has air and subsurface temperature sensors, pavement temperature and pavement condition sensors, and precipitation type and intensity sensors. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ The environmental sensors continuously send data to the control computer. This data is used to predict the presence of black ice or snow. ▪ When the sensors predict that there will be ice, the computer automatically activates flashing beacons to alert motorists, checks the chemical delivery system for leaks, and begins one of 13 spray programs.



	<ul style="list-style-type: none"> □ Each spray program consists of different valves spraying the chemicals at different frequencies based upon prevailing environmental conditions. ▪ At the end of each winter season, personnel inspect the anti-icing system. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ In the first year of the program, winter crashes were reduced by 68 percent. ▪ The automated system also improved productivity by lowering material costs and enhancing winter maintenance operations throughout the district. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The DOT hired a private vendor to design and install the system and to provide system documentation, training, and support. ▪ Nozzles often became blocked due to plowed snow and sand. ▪ A filter failure in the pump enclosure caused a chemical spill, which reacted with galvanized metals and seeped through building foundations. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Cory Johnson, Minnesota DOT, Office of Metro Maintenance Operations, cory.johnson@dot.state.mn.us
<p>Nebraska Road Weather Information for Travelers</p>	<p>The Nebraska DOT and the Nebraska State Patrol in conjunction with a private company, partnered to provide the public with road weather information using 511. Information provided via 511 is also posted on agency web sites.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ The private company, Meridian Environmental Technology, operates a system that inputs data from a wide array of sources. ▪ The data are transmitted to central computers that perform processing for weather forecasts. ▪ The data is disseminated through an interactive telephone system and the Internet. ▪ The DOT has installed road signs along highways to notify travelers of the 511 service. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Travelers can dial 511 and obtain pavement conditions for their specific route and a forecast for 60 miles in their direction of travel. ▪ Information provided via 511 is also available on the Internet. <ul style="list-style-type: none"> □ Travelers can also access weather data for neighboring states. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ During severe weather conditions, the 511 service improves efficiency by relieving officers of reporting duties. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The DOT has negotiated agreements with telephone companies and cellular service providers to provide the 511 service free of charge to the public. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Jaimie Huber, Nebraska Department of Roads, 511 Operations Manager, jhuber@dor.state.ne.us ▪ Bryan Tuma, Nebraska State Patrol, Major, Administrative Services, btuma@nsp.state.ne.us ▪ Leon Osborne, Meridian Environmental Technology, Chief Executive Officer, leono@meridian-enviro.com
<p>New Jersey Turnpike Authority Speed Management</p>	<p>The New Jersey Turnpike Authority (NJTA) operates an Advanced Traffic Management System (ATMS) to control a significant portion of the turnpike. Various subsystems are utilized to monitor road and weather conditions, manage traffic speeds, and notify motorists of hazardous conditions.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ ATMS control computers are located at the turnpike Traffic Operations Center (TOC). ▪ Data is transmitted to the central control systems wirelessly using Cellular Digital Packet Data technology. ▪ Inductive loop detectors and Remote Processing Units make up a vehicle detection subsystem to collect speed and volumes and to detect traffic congestion. ▪ The system also uses CCTV to verify road conditions. ▪ 30 ESS are used to collect road weather data. <ul style="list-style-type: none"> □ Nine ESS detect wind speed and direction, precipitation type and rate, barometric pressure, air temperature and humidity, and visibility distance. □ 11 ESS collect pavement temperature and condition data. □ Ten ESS only monitor visibility distance. ▪ 113 DMS, 12 Highway Advisory Radio (HAR) transmitters, and a Variable Speed Limit (VSL) subsystem convey information to motorists. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Management personnel in the TOC monitor weather data to determine when speed limits should be lowered.



	<ul style="list-style-type: none"> ▪ When personnel decide to lower speeds, management manually activates the sign assemblies to decrease speed limits in five-mph increments. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ Speed management and traveler information dissemination have improved safety by reducing the frequency and severity of adverse weather-related crashes. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The turnpike's VSL subsystem is one of the oldest in the country. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Solomon Caviness, NJTA Operations Department, caviness@turnpike.state.nj.us
<p>City of Charlotte, North Carolina Weather-Related Signal Timing</p>	<p>The City of Charlotte DOT decided to implement weather-related signal timing plans in the central business district. These plans are utilized to reduce traffic speeds during adverse weather conditions.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ The traffic signal control system is comprised of the following: <ul style="list-style-type: none"> □ A CCTV system □ A fiber optic cable communication system □ A signal system control computer in the TOC □ CCTV images from major routes are transmitted to the TOC ▪ Different timing plan patterns can be selected and downloaded to field controllers using the communication systems. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ Operators receive weather forecasts and the CCTV images and assess traffic and weather conditions. ▪ When operators deem the weather conditions to be unsafe, they access the signal computer and manually implement weather-related timing plans to slow the progression speed of traffic. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ It has been shown that travel speeds decrease by five to ten mph (eight to 16kph) when weather-related signal timing is utilized. This decreases the chance for a weather-related crash. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ The City's TOC is typically staffed during AM and PM peak periods, but managers may extend the hours of operation when storm events are in the forecast. ▪ Operators change the signal timings only when weather impacts numerous intersections. ▪ There are plans to establish a fiber optic cable communication link with the North Carolina DOT TMC. Once this link is established, the City can access 30 CCTV cameras. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Art Stegall, City of Charlotte DOT, Signal System Supervisor, astegall@ci.charlotte.nc.us ▪ Bill Dillard, City of Charlotte DOT, Chief Traffic Engineer, wdillard@ci.charlotte.nc.us
<p>Oklahoma Environmental Monitoring System</p>	<p>Oklahoma manages an information system called OK-FIRST. OK-FIRST allows public safety officials and various agencies to accurately identify weather threats and make effective public safety decisions. OK-FIRST provides emergency managers with web-based, real-time environmental data.</p> <p><u>System Components</u></p> <ul style="list-style-type: none"> ▪ OK-FIRST allows managers to obtain agency-specific, county-level weather data from the environmental monitoring network and various radar systems. ▪ The environmental monitoring network includes over 110 ESS. ▪ The Oklahoma Department of Public Safety maintains a digital communication network called the Oklahoma Law Enforcement Telecommunications System (OLETS). ▪ Over 200 participants access the OK-FIRST system through OLETS including law enforcement, emergency management, and fire service agencies. <p><u>System Operations</u></p> <ul style="list-style-type: none"> ▪ The environmental data is packaged into five-minute observations and transmitted via OLETS and a radio communication system to the University of Oklahoma for quality assurance, integration with National Weather Service data, and dissemination via the web. <p><u>Transportation Outcome</u></p> <ul style="list-style-type: none"> ▪ OK-FIRST enhances safety and improves productivity by reducing the need for maintenance personnel working overtime during adverse winter conditions. <p><u>Implementation Issues</u></p> <ul style="list-style-type: none"> ▪ OK-FIRST was originally funded by a grant from the Technology Opportunities Program. ▪ After the system was installed, all participating agencies had the opportunity to acquire training for the system. <p><u>Contacts</u></p> <ul style="list-style-type: none"> ▪ Dale Morris, Oklahoma Climatological Survey, University of Oklahoma, dmorris@ou.edu
<p>Virginia DOT Weather-Related Incident Detection</p>	<p>The Virginia DOT operates an ATMS to control the highway network in Northern Virginia. This system includes an Incident Detection subsystem and a CCTV subsystem, both of which are used for traffic and</p>

road condition surveillance on Interstate 66 and Interstate 395.

System Components

- The Incident Detection subsystem includes:
 - Inductive loop detectors
 - Type 170 controllers housed in roadside cabinets
 - A central incident detection computer.
- The CCTV subsystem includes:
 - Over 50 cameras
 - Video transmission devices
 - Three monitor walls for the display of video images.
- Fiber optic cable and coaxial cable communication systems transmit data and video from the field to computers in the Smart Traffic Center (STC).

System Operations

- Incident detection computer software continuously analyzes data to identify traffic flow disruptions caused by incidents.
- The CCTV subsystem is used to visually verify incidents and support incident management decisions.

Transportation Outcome

- The system improves roadway mobility and safety by facilitating incident detection under adverse conditions.

Implementation Issues

- A consulting firm was hired by the Virginia DOT to design, install, and integrate the ATMS components and subsystems.
- In the future, the DOT plans to expand incident detection capabilities to Interstate 495 and plans to integrate the ATMS with research facilities at the University of Virginia.

Contacts


- Marlowe Dixon, Virginia DOT, dixon_mk@vdot.state.va.us
- Jimmy Chu, Virginia DOT, chu_tf@vdot.state.va.us

Appendix C FHWA MDSS Roadshow

U.S. Department of Transportation
Federal Highway Administration
Road Weather Management Program

Pennsylvania DOT


MDSS Executive Brief



The Maintenance Decision Support System (MDSS) *transforming the world of winter maintenance*

Ray Murphy
ITS Specialist
Resource Center

Road Weather Management Program
MDSS RoadShow




MDSS Executive BRIEF

awareness... benefits of the MDSS technology...
making the **investment!**

Managing winter maintenance activities is a complex endeavor. Snow & Ice Control managers must know:

- regulations about chemical applications,
- environmental impacts and
- be able to analyze & make sense of multiple/often contradictory weather forecasts.

All of these factors come together, challenging public agencies to meet the traveling public's high expectation that roads be kept free of snow and ice. Thus, today's maintenance managers require the ability to efficiently handle multiple tasks & process high volumes of information.



MDSS Executive Brief

- Software
 - Data Integration
 - System Integration
 - Future modifications
 - Wide scale Deployments
 - Scenario/Treatment Options
 - Training & User Acceptance
 - After Action – Strategy Refinement
 - Deployment Cost & Potential Savings
- 

MDSS Executive Brief

- **PennDOT RWIS Interview...**
**a reliable, communicating, & calibrated
ESS/RWIS system is needed to have an
effective, functional MDSS**
- **Clarus Initiative...**
all Weather Data for Decision Support
- **MDSS technology...**
**the ultimate in system integration
a smart investment**



5.1.2 Management Interviews

...*Snow Plow – AVL/GPS*

Bureau of Maintenance and Operations

...*Decision Making Tool*

- If functional, RWIS provides a useful maintenance and operations decision making tool.
- Staff needs convinced to use (a functional) RWIS program as well as supporting systems such as MDSS.

...*Real-Time Data*

Bureau of Highway Safety and Traffic Engineering

...*Integration*

- The future direction of RWIS needs to consider the Clarus Initiative.
- RWIS needs to be integrated into maintenance training programs.
- The RWIS plan needs to provide deployment guidelines?

...*Clarus Initiative*

- RWIS data needs to be integrated with other weather data.
- RWIS and weather data needs to be provide at district, regional and the statewide traffic management centers

...*System Reliability*

... *RWIS value is realized
when it's combined with
other data sources*

...*Increase Accuracy &
Reliability --> Increase
Use & Usefulness*

Focus areas captured from the PennDOT RWIS Interview

Focus areas captured from the PennDOT RWIS Interview

...*Accuracy*

...*System Reliability &
Strategically located*

...*Accessible
Current Data*

...*better handle on
Precipitation*

...*Manage Work Force*

...*Integration &
Communications*

...*Material Usage
Database*

...*All Weather Data*

...*Changes in state*

...*Neighboring Data*

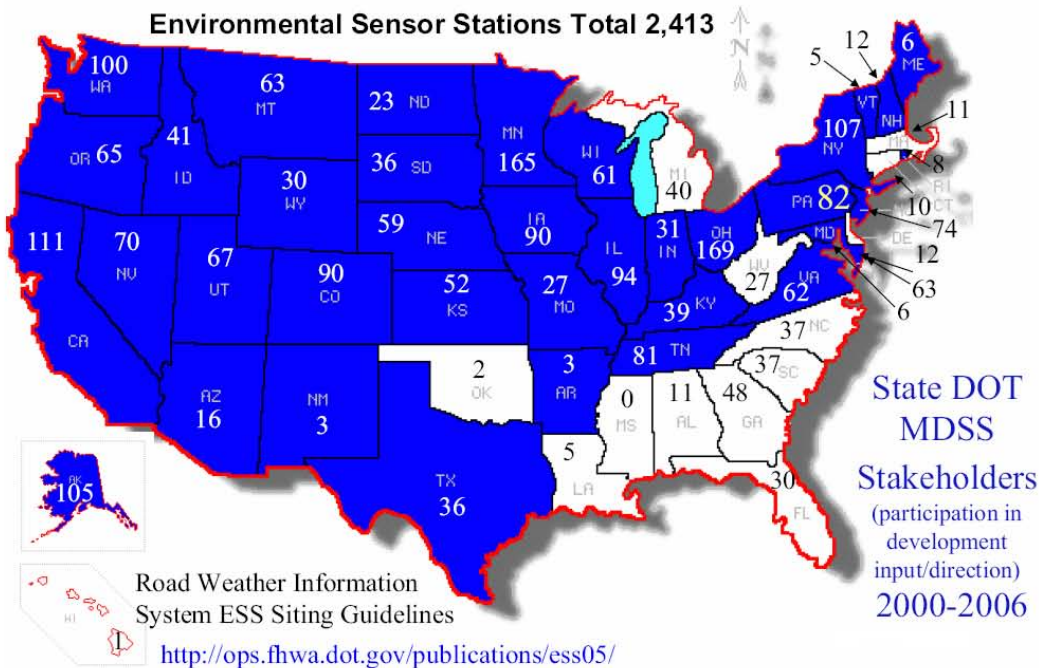
...*Ground Conditions*

...*All Weather
Information for
Decision Support*

...*Comprehensive Data
Collection -RWIS alone is NOT
a solid strategy, it's only one
part of the puzzle*



ESS owned by State Transportation Agencies



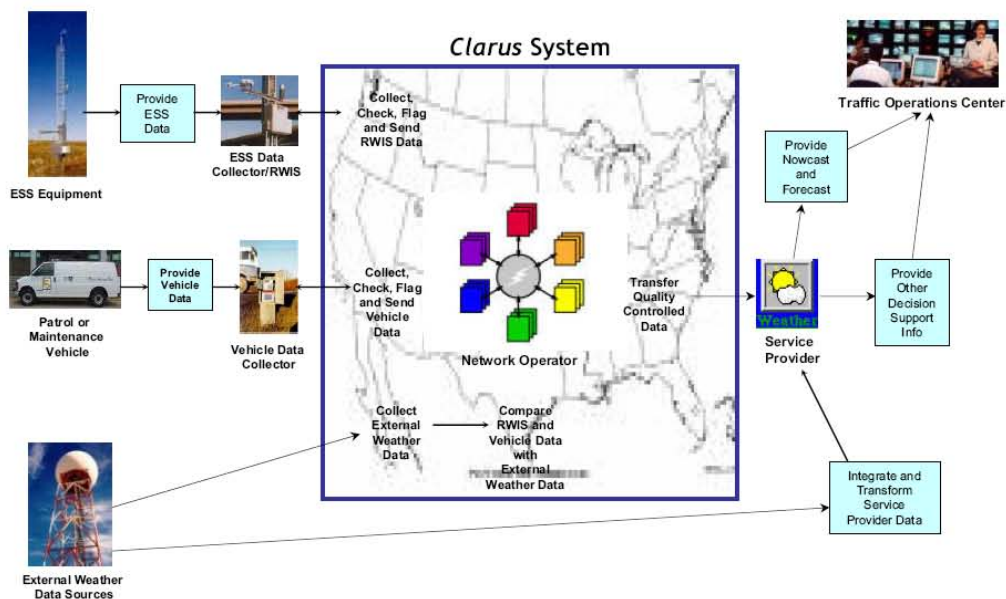
The *Clarus* Initiative

- *Clarus* is an ITS initiative to demonstrate and evaluate the value of “Anytime, Anywhere Road Weather Information” that is provided by both the **public and private weather enterprise** to the breadth of transportation users and operators.
- To do so, we needed to create a robust
 - data assimilation,
 - quality checking, and
 - data dissemination system**that can provide near real-time atmospheric and pavement observations from the collective states’ investments in environmental sensor stations (ESS).**

Clarus Initiative Objectives

- Design, develop and demonstrate these capabilities, as captured within the *Clarus* System
- Maximize transportation agency **investments in ESS/RWIS**
- Educate the community about the **importance of data sharing, metadata & proper ESS siting**
- Work with our public and private partners to **develop and evaluate the value-added road weather information products that *Clarus* enables**
- Establish partnerships to **move from demonstration to deployment of a nationwide network**

Clarus – The Initiative vs. The System



Clarus System

Prototype - 3 State DOTs: Alaska, Minnesota & Utah are available.

As more transportation agencies contribute to the initiative, more links will become active.

Reports and Subscriptions

Get Observations by:

[Contributor](#) [Geospatial Coordinates](#)

[View Metadata](#) [View Subscriptions](#)

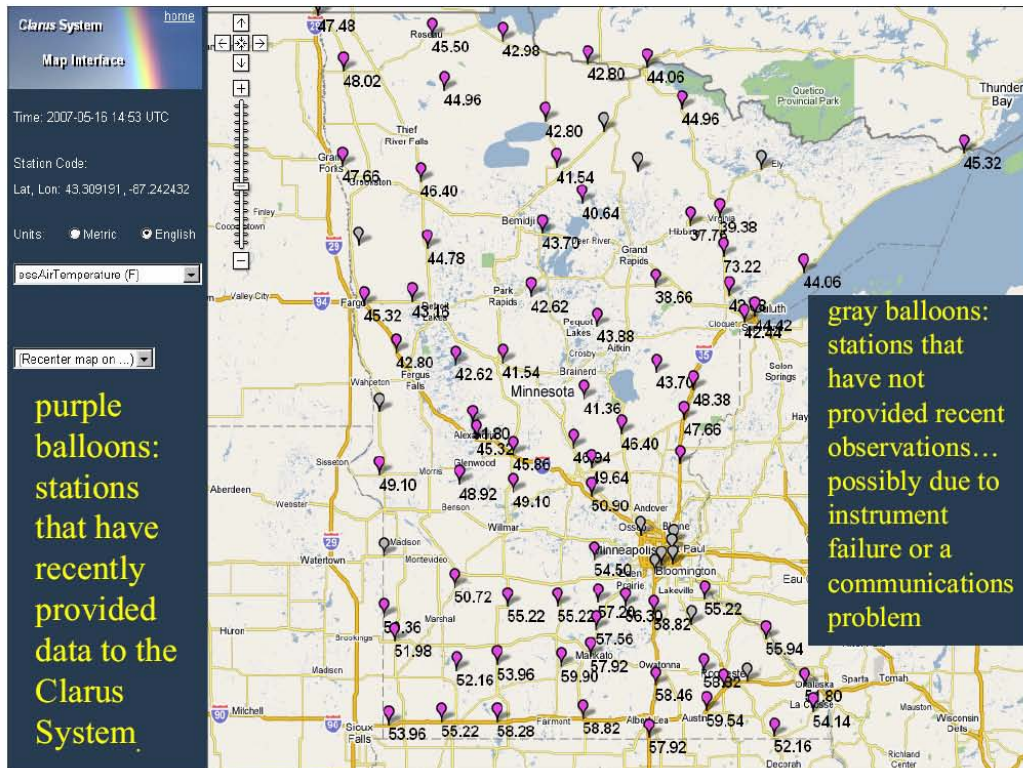
Data can be retrieved in comma delimited, XML formats directly through the web portal or Users can "subscribe"

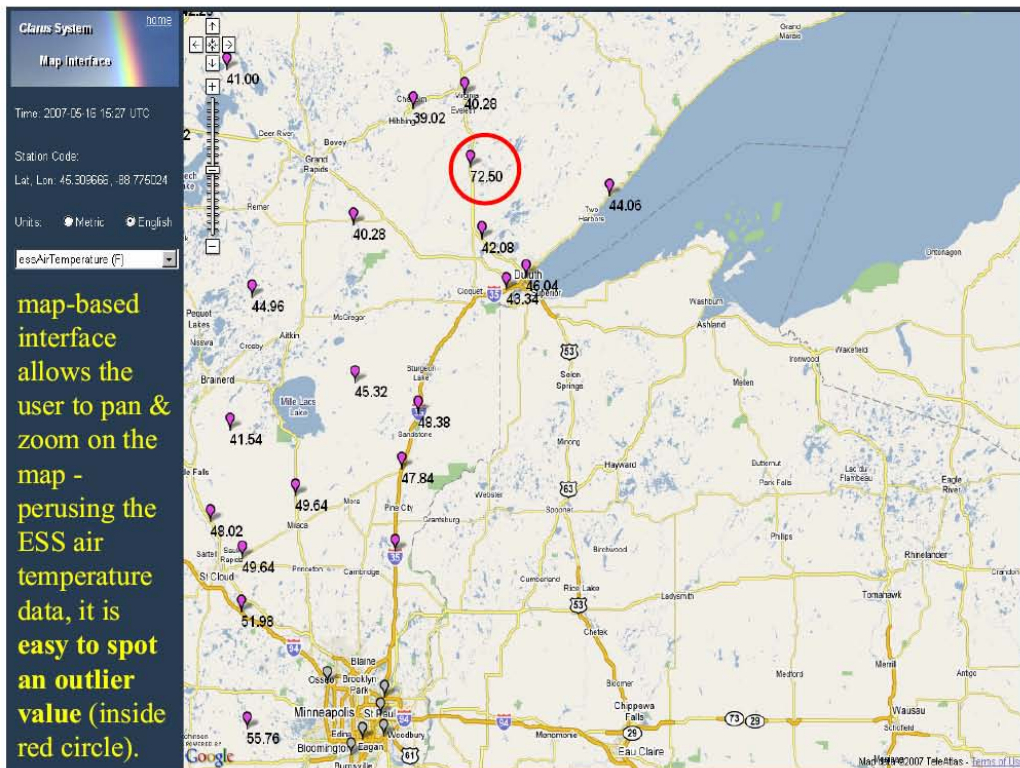
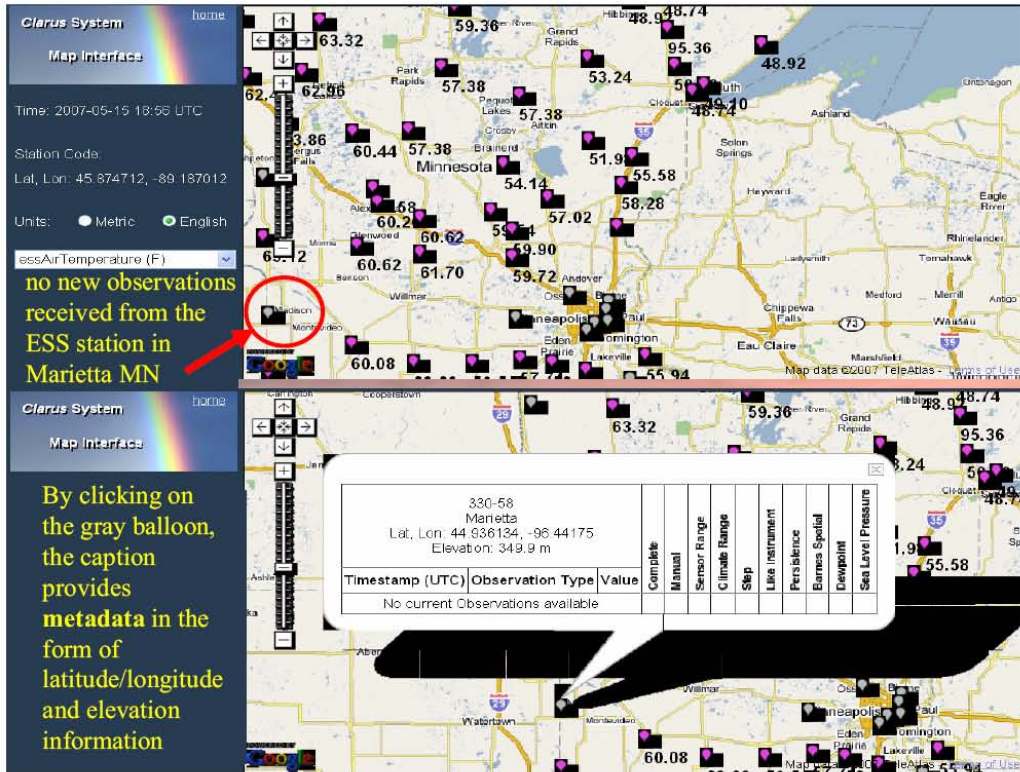
United States

Alabama	Hawaii	Massachusetts	New Mexico	South Dakota
Alaska	Idaho	Michigan	New York	Tennessee
Arizona	Illinois	Minnesota	North Carolina	Texas
Arkansas	Indiana	Mississippi	North Dakota	Utah
California	Iowa	Missouri	Ohio	Vermont
Colorado	Kansas	Montana	Oklahoma	Virginia
Connecticut	Kentucky	Nebraska	Oregon	Washington
Delaware	Louisiana	Nevada	Pennsylvania	West Virginia
Florida	Maine	New Hampshire	Rhode Island	Wisconsin
Georgia	Maryland	New Jersey	South Carolina	Wyoming

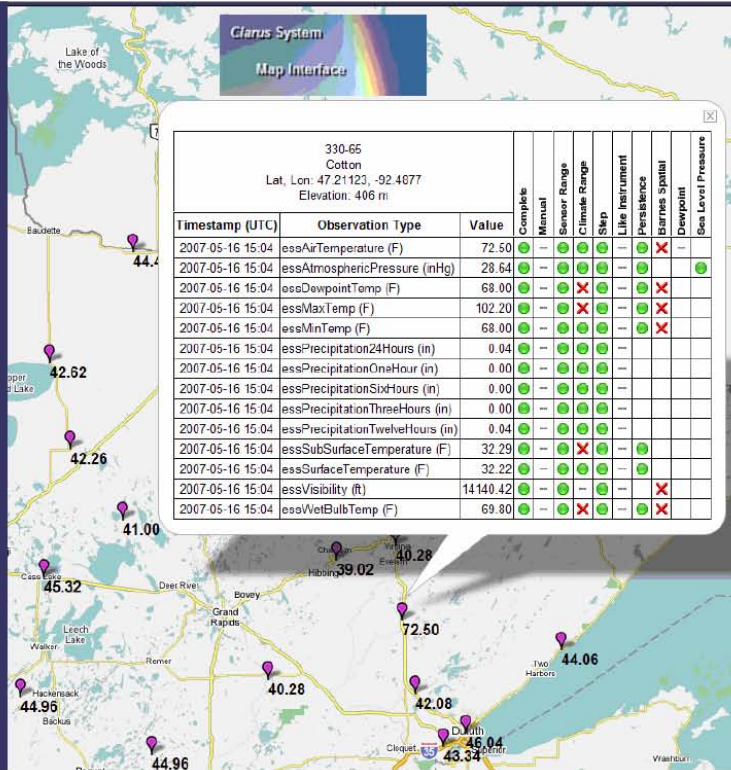
Canada

Alberta	Quebec
British Columbia	Saskatchewan
Manitoba	Yukon Territory
New Brunswick	
Newfoundland &, Labrador	
Northwest Territories	
Nova Scotia	
Nunavut	
Ontario	
Prince Edward Island	





- By clicking on the balloon, one can quickly see each ESS data element along with the results of the quality checking algorithms.
- The green circles show when quality tests had expected results.
- The red x's show when the quality checks had a failure condition.
- The dashes mean that a quality check was not run for this element.



Clarus System ...the interface allows system users to access data through a graphical interactive system.

Reports and Subscriptions

- Get Observations by:
 - Contributor
 - Geospatial Coordinates
- View Metadata
- View Subscriptions

...data can be obtained through each contributor

United States

- Alabama
- Alaska
- Arizona
- Arkansas
- California
- Colorado
- Hawaii
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Massachusetts
- Michigan
- Minnesota
- Mississippi
- Missouri
- Montana
- New Mexico
- New York
- North Carolina
- North Dakota
- Ohio
- Oklahoma
- South Dakota
- Tennessee
- Texas
- Utah
- Vermont
- Virginia

Canada

- Alberta
- British Columbia
- Manitoba
- New Brunswick
- Newfoundland & Labrador
- Northwest Territories
- Quebec
- Saskatchewan
- Yukon Territory

Clarus System
Observations by Contributor

Contributors

Select one or more contributors from the **All Contributors** listbox and 'add' them to the **Selected Contributors** listbox by pressing the **[>>]** button. To remove a contributor from the **Selected Contributors** listbox, select it and press the **[<<]** button.

You may select more than one item in the list by pressing the **Ctrl** or **Shift** key when making your selection.

All Contributors

- AK_State_DOT
- MI_State_DOT
- UT_State_DOT

Selected Contributors

This lower screen shows that data can be obtained from any (or all) of the 3 available states.

Clarus System Observations

2007-05-15 19:29 UTC

Observation Type: All Observations

- essAtmosphericPressure
- essDewpointTemp
- essInstantaneousSolarRadiation
- essMaxTemp
- essMinTemp
- essPrecipitation24Hours
- essPrecipitationOneHour
- essPrecipitationSixHours
- essPrecipitationThreeHours
- essPrecipitationTwelveHours
- essRelativeHumidity
- essSubSurfaceMoisture
- essSubSurfaceTemperature
- essSurfaceConductivityV2
- essSurfaceFreezePoint
- essSurfaceIceOrWaterDepth
- essSurfaceSalinity
- essSurfaceStatus
- essSurfaceTemperature
- essTotalRadiation
- essVisibility
- essWetBulbTemp
- precip10min
- windSensorAvgDirection
- windSensorAvgSpeed
- windSensorGustDirection

Observations

Specify the observation type to retrieve by selecting it from the **Observation Type** listbox, or leave it on "All Observations" to retrieve all observations.

When you select a specific observation type, you will be presented with optional entry fields for the minimum and maximum values, as well as listboxes for each of the Quality Checks that are valid for that observation type. Supplying values for the minimum and/or maximum will filter the observations retrieved to those values that are within the specified range.

You may also filter an observation based on its Quality Checks by selecting "P" (Pass) or "N" (Not Pass) from its respective drop-down list.

Once the contributors have been identified, the GUI provides a series of pull-down menus to specify the kinds of data fields to display – in this example by observation type

Clarus System Time Range and Format

2007-05-15 19:27 UTC

Start Time: 2007-05-15 17:00

End Time: 2007-05-15 20:00

Output Format: CSV

Time Range and Format

Specify the time range for the observations you wish to retrieve.

You may also select the output format for the report.

Run Query

The interface provides the ability to control the **time window** and the **output format** (comma delimited or XML, as seen in the top window).

The bottom window provides an example of **text output** beginning with a header field and followed by comma delimited observational elements.

Clarus System Query Results

Time: 2007-05-15 19:29 UTC

Saving the Query Results

You may save the query results by clicking on the link below. This will reissue the query and display the results in a plain browser window. You can then save the entire page by selecting the proper option from your browser's File menu.

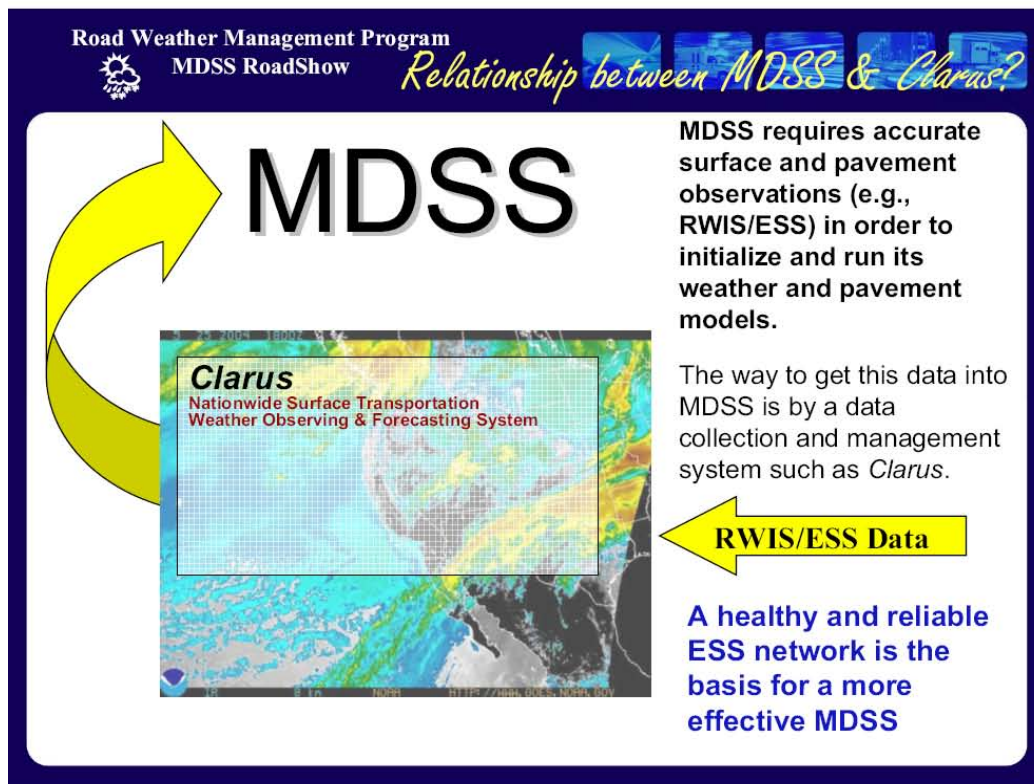
Note: Because the query is reissued, the results you see on the next page may be different than the results you are currently viewing.

```

ObsTypeID,ObsTypeName,ClarusSensorID,ClarusSensorIndex,ClarusStationID,ClarusSiteID,C
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554,essAtmosphericPressure,830,0,613,42,42,2,MN_State_DOT,330-0,2007-05-15 17:00,43.5
554,essAtmosphericPressure,1285,0,642,71,71,2,MN_State_DOT,330-31,2007-05-15 17:00,44
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554,essAtmosphericPressure,936,0,624,53,53,2,MN_State_DOT,330-12,2007-05-15 17:02,46.
                    
```


Connection Incentive Program

- Available to all U.S. transportation agencies that operate a network with one or more ESS who want to contribute data to *Clarus*
- Funds will be provided as a Federal Aid Grant
- Expect posting in June 2007
- Funding is based on a sliding scale dependent on the number of ESS in the network
- Funding can be used for local travel, to collect metadata and for associated equipment such as a handheld GPS or video camera



Road Weather Management Program
MDSS RoadShow

What is MDSS?

The Maintenance Decision Support System

... an integrated solution

The MDSS is a **tool** that merges **weather forecasting** with roadway maintenance **rules of practice** and generates **treatment recommendations** on a route by route basis.

Computer-based, customizable tool that provides winter maintenance personnel with:

- Route-specific weather forecast information
- Road treatment recommendations
 - anti-icing, deicing
 - chemical applications
 - optimized treatment times

...a Smart Investment in Winter Maintenance

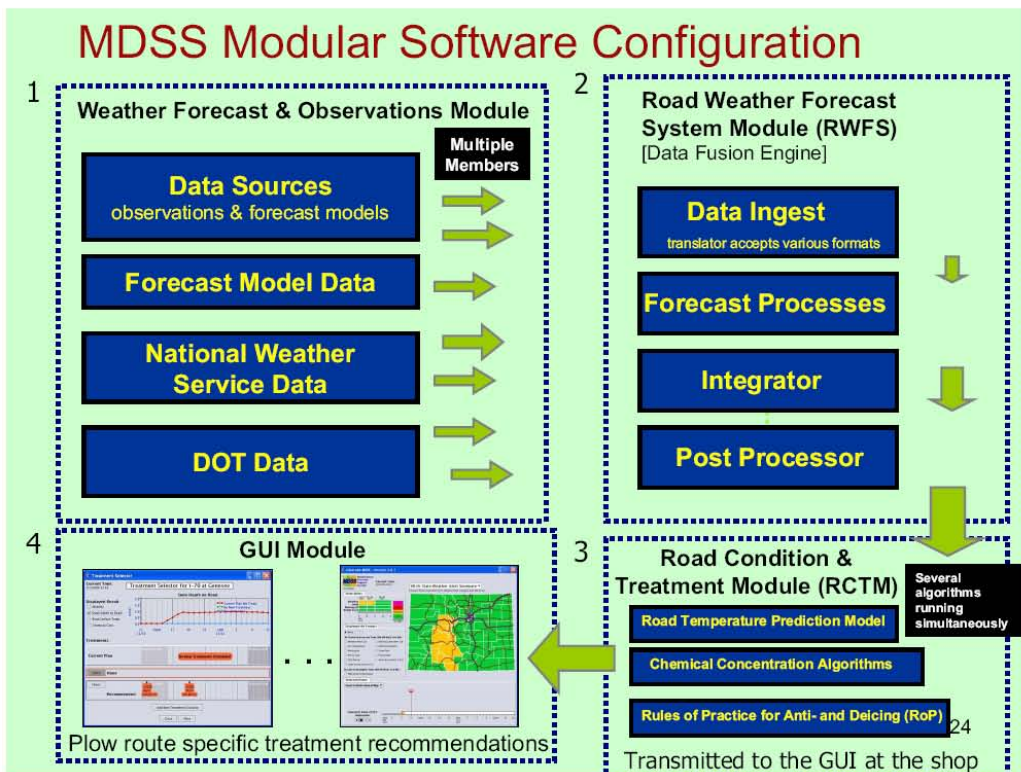
Major Contributors to the Development of MDSS

- ❖ National Center for Atmospheric Research 
- ❖ MIT Lincoln Laboratory 
- ❖ Cold Regions Research & Engineering Lab 
- ❖ NOAA Forecast Systems Laboratory 
- ❖ State DOT Stakeholders
- ❖ Pooled Fund Study Program
- ❖ AASHTO 
- ❖ Field Demonstration Host – Iowa DOT

Road Weather Management Program
MDSS RoadShow

Essential Elements of MDSS

- Report:
 - ✓ actual road surface conditions
 - ✓ actual maintenance treatments
- Assess:
 - ✓ past & present weather conditions
 - ✓ present state of the roadway
- Predict:
 - ✓ storm-event weather
 - ✓ road surface behavior
- Recognize resource constraints
 - Identify feasible maintenance treatments
- Communicate recommendations to supervisors & workers



The MDSS Main Screen Display is composed of 4 main parts:

Road & Weather Alerts

Weather & Road Parameters

State Alerts and Local Routes

Time Selection and Animation

Release 4.0 can be found at:
http://www.rap.ucar.edu/projects/rwx_mdss/release3/index.html

Modules are provided on a non-exclusive basis.

Release 5.0 will be available this Fall.

Selected Maintenance Area: Colorado

Colorado Alerts:

	0-12 Hrs	12-24 Hrs	24-48 Hrs
Weather	OK	OK	OK
Road	OK	OK	OK
Blowing SN	OK	OK	OK
Bridge Frost	OK	OK	OK

Map Products:

- State Zone Alerts: County Weather
- Weather Forecasts: Weather Alerts
- Road Forecasts: Mobility Alerts
- Point Observations: Air Temperature
- Area Observations: Radar Reflectivity
- Watches/Warnings: None

The State is plotted into county forecast zones

Route views are selected from the pull down menu

48 Hr State Weather Alert Summary

- 48 Hr State Weather Alert Summary
- E-470 Road Conditions
- West Denver Road Conditions
- South Denver Road Conditions
- Vail Pass Road Conditions

Area Observations submenu

Map Products:

- State Zone Alerts: County Weather
- Weather Forecasts: Weather Alerts
- Road Forecasts: Mobility Alerts
- Point Observations: Air Temperature
- Area Observations: Radar Reflectivity
- Watches/Warnings: None
- Satellite Infrared
- Satellite Visible
- Satellite Water Vapor
- Radar Reflectivity

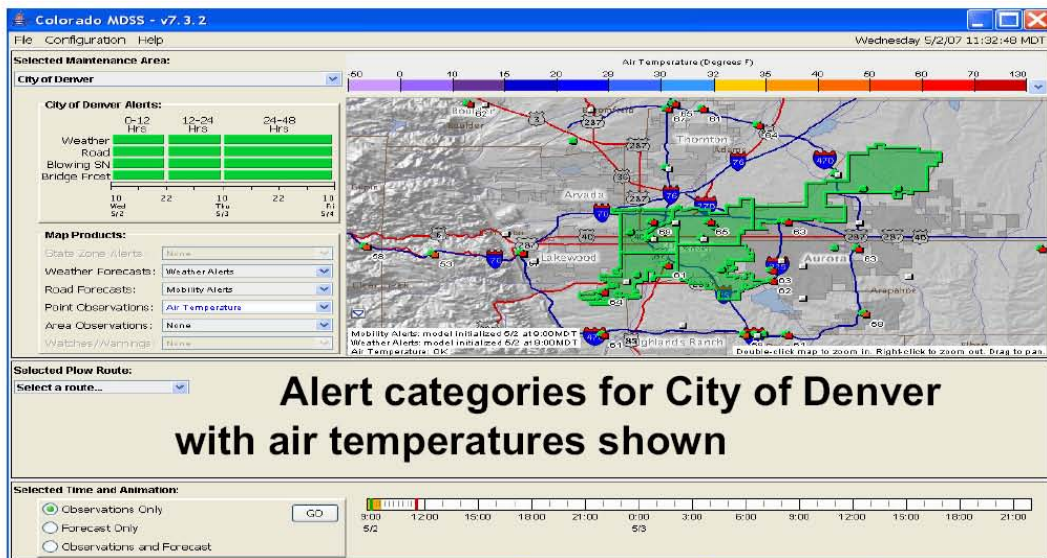
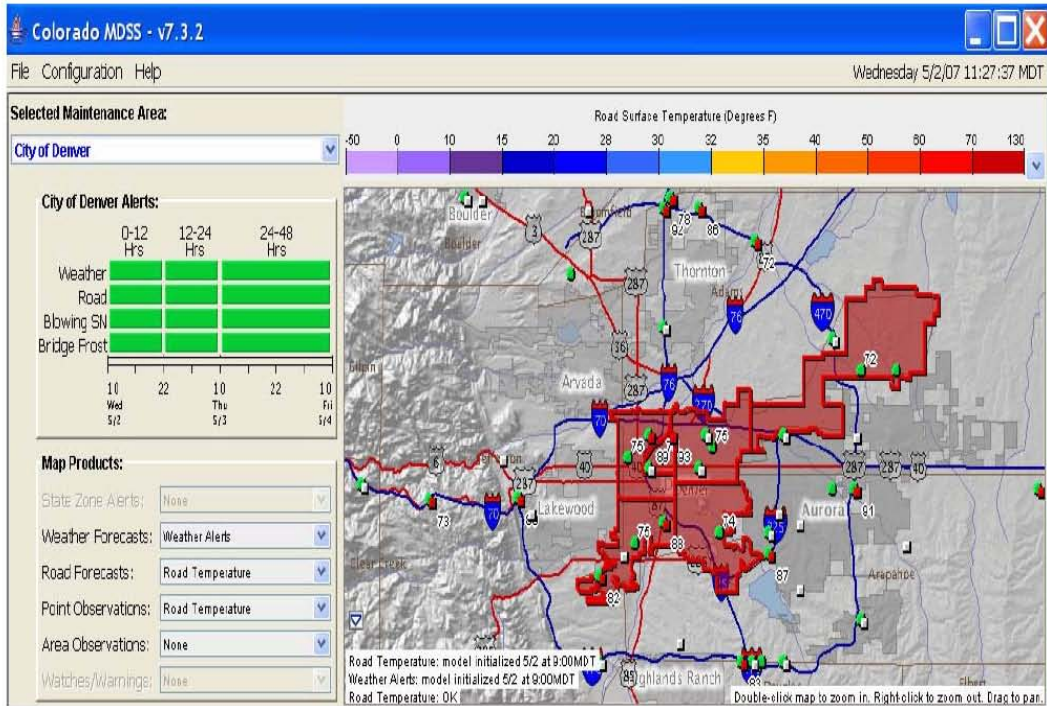
Point Observations submenu

Map Products:

- State Zone Alerts: County Weather
- Weather Forecasts: Weather Alerts
- Road Forecasts: Mobility Alerts
- Point Observations: Air Temperature
- Area Observations: None
- Air Temperature
- Road Temperature
- Relative Humidity
- Wind Speed

Main Display with radar & air temperatures

City of Denver Road Temperatures and Alerts



Alert categories for City of Denver with air temperatures shown

Weather Forecast submenu

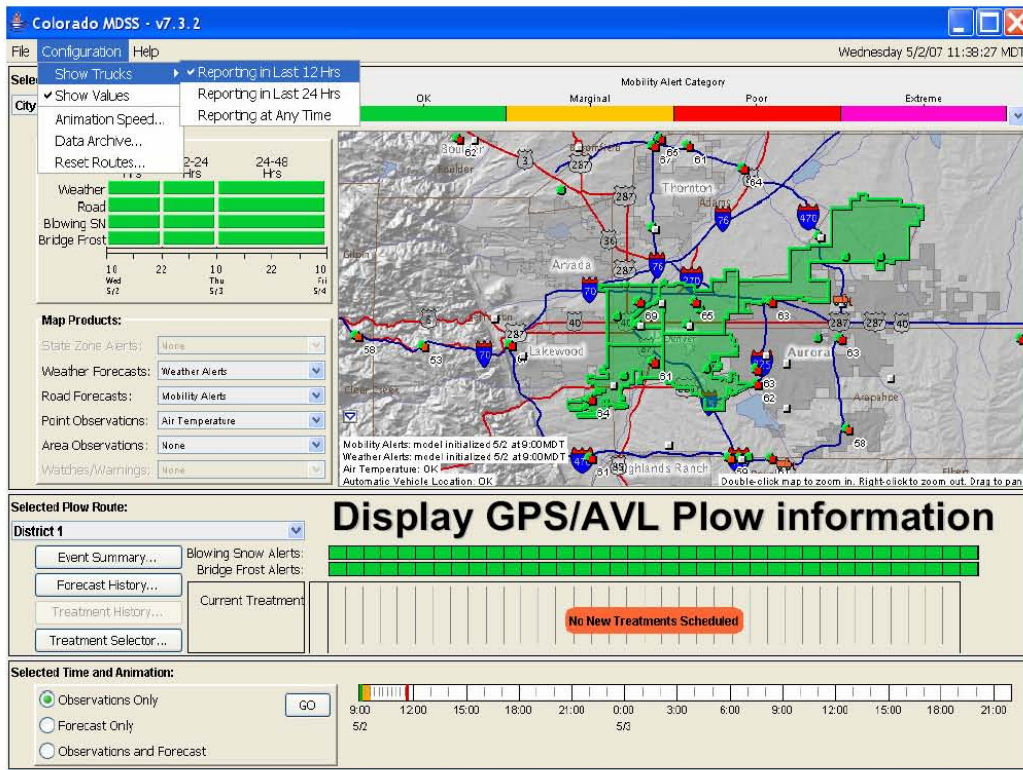
Map Products:

- State Zone Alerts: County Weather
- Weather Forecasts: Weather Alerts
- Road Forecasts: Weather Alerts
- Point Observations: Blowing Snow Alerts, Air Temperature, Relative Humidity, Wind Speed
- Area Observations: Precipitation Rate, Snow Rate
- Watches/Warnings: Precipitation Type

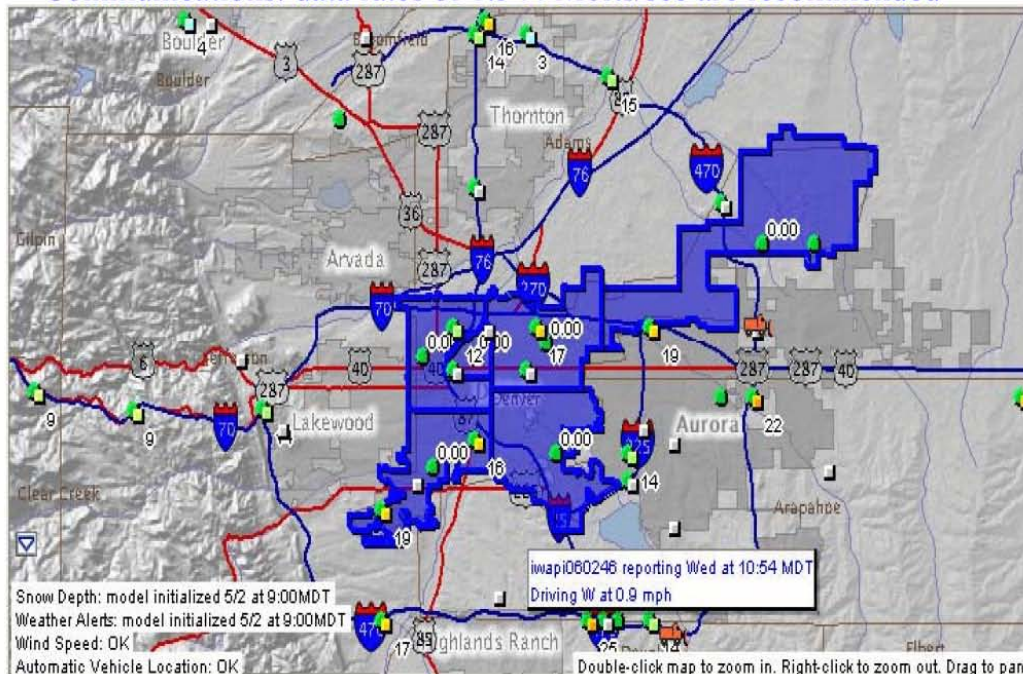
Road Forecast submenu

Map Products:

- State Zone Alerts: County Weather
- Weather Forecasts: Weather Alerts
- Road Forecasts: Mobility Alerts
- Point Observations: None, Mobility Alerts
- Area Observations: Road Temperature, Bridge Temperature
- Watches/Warnings: Snow Depth



Shows Snow Depth, Wind Speed & Plow information
Communications: data rates of 1.544 Mbits/sec are recommended



Additional MDSS Functionality

Buttons along the top of the “Route Selection” tab.

Event Summary: Provides a weather and treatment recommendation summary for the user in time series graphics

Forecast History: Show actual measured data compared to predicted conditions for air and road temperature, humidity, and windspeed

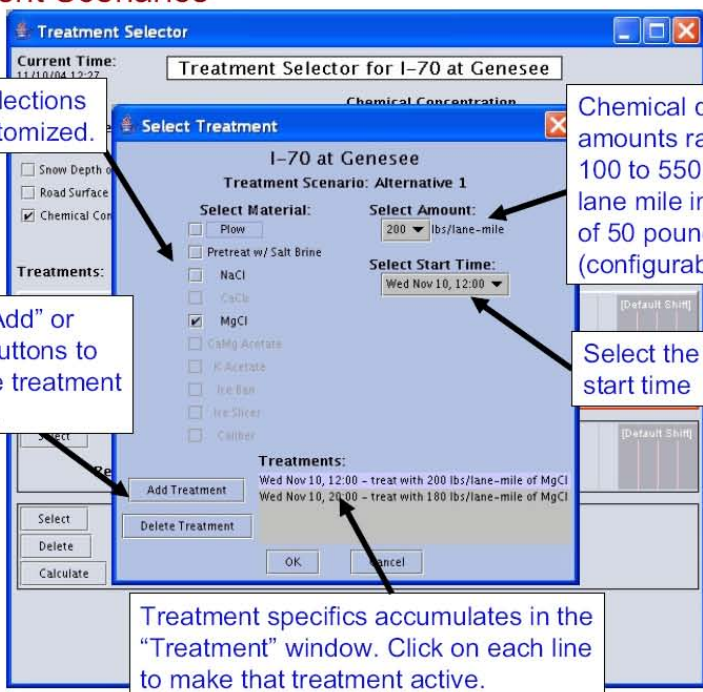
Treatment History: Shows the treatment recommendations and selections for the last several model runs

Treatment Selector: Opens the treatment selection window

Configuration: Allows changing of shift scheduling and shift splitting

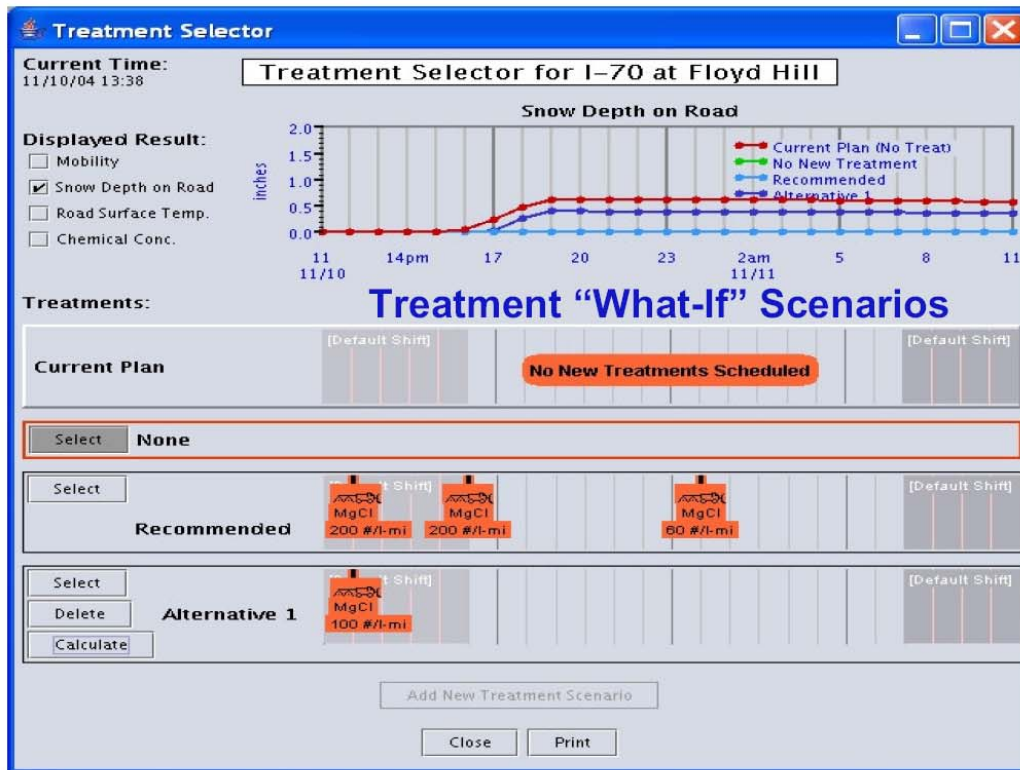
MDSS as a training tool

Treatment Scenarios



The screenshot shows the 'Treatment Selector' window for 'I-70 at Genesee'. It includes a 'Select Treatment' sub-window with a list of materials (Plow, NaCl, CaCl₂, MgCl₂, CaMg Acetate, K Acetate, Ice Ban, Ice-Slicer, Caliber) and a 'Treatments' list. Callouts provide the following information:

- Material selections can be customized.
- Chemical dispersion amounts range from 100 to 550 pounds per lane mile in increments of 50 pounds (configurable).
- Use the “Add” or “Delete” buttons to control the treatment directives.
- Select the treatment start time
- Treatment specifics accumulates in the “Treatment” window. Click on each line to make that treatment active.



Road Weather Management Program MDSS RoadShow

Vendor Capabilities

Disclaimer: FHWA does not endorse the commercial vendors discussed in this presentation.

Focus on accurate and updated FORECASTS

DTN only offers a web-based application

Focus on MAINTENANCE

Current Status

Dynamics

DOT Maint. Info

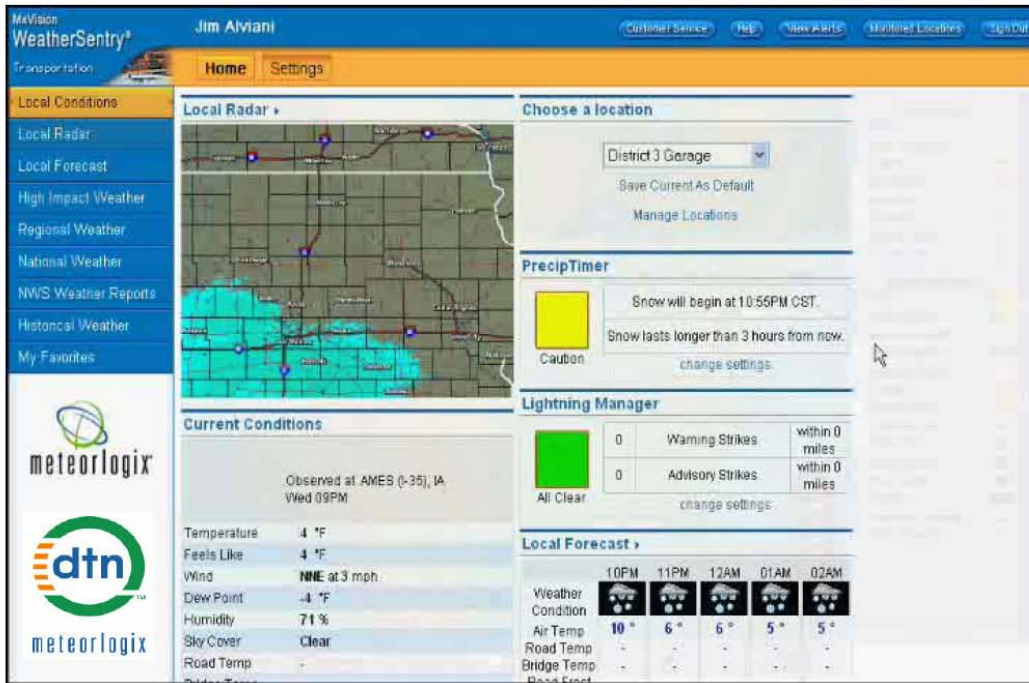
- RWIS
- Road Reporting
- Activity Tracking

Resources

Meridian is a client-based system (one that runs on your PC)

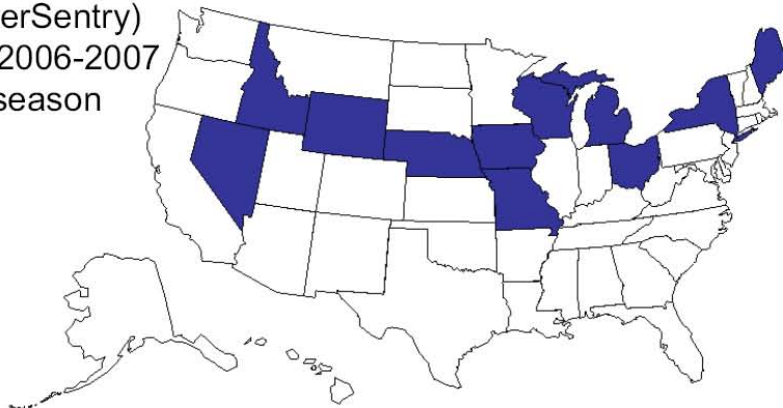
GIS & Weather Layers

Disclaimer: FHWA does not endorse the commercial vendors discussed in this presentation.



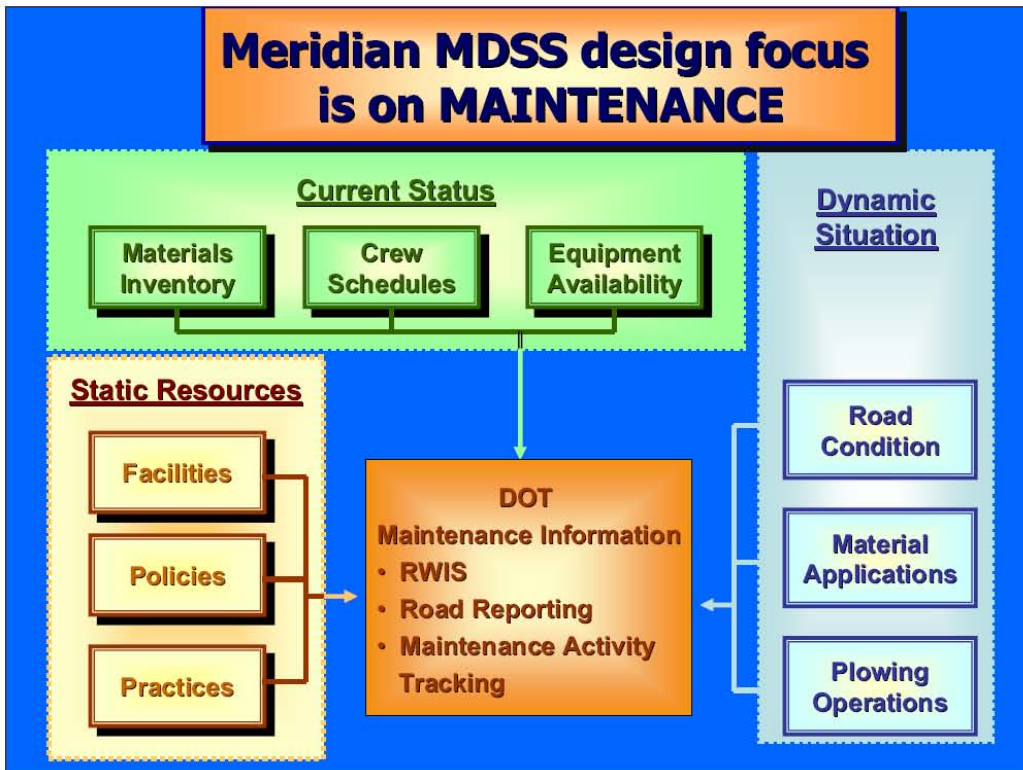
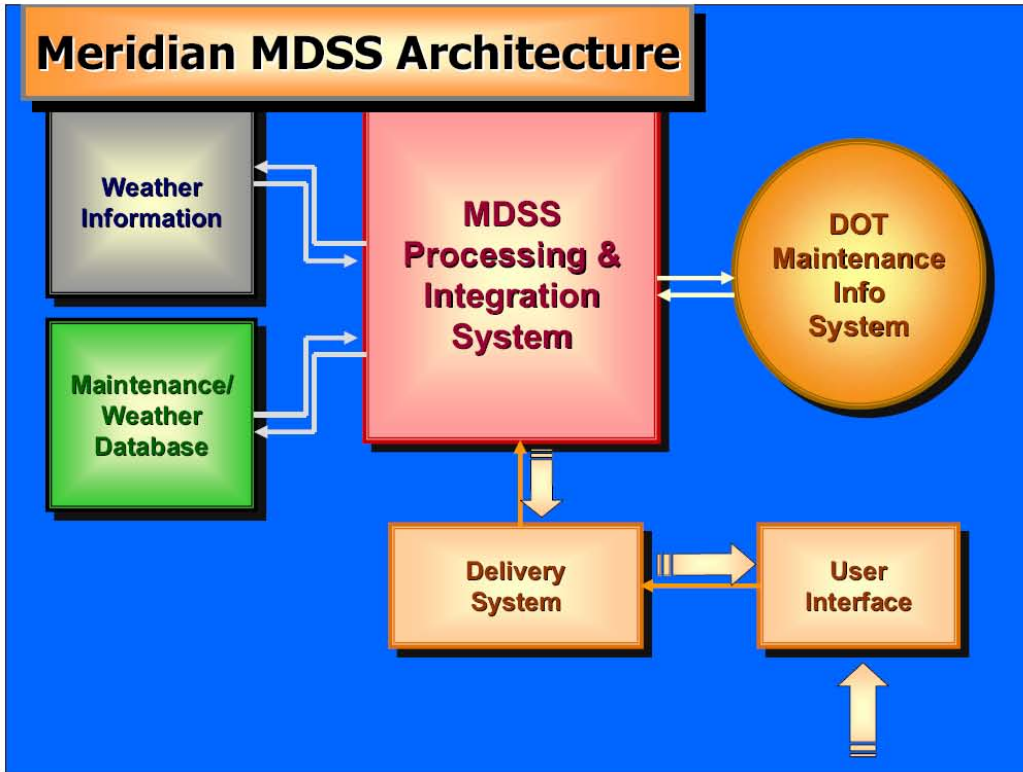
DTN MDSS Pilot Project Participants 2006-2007

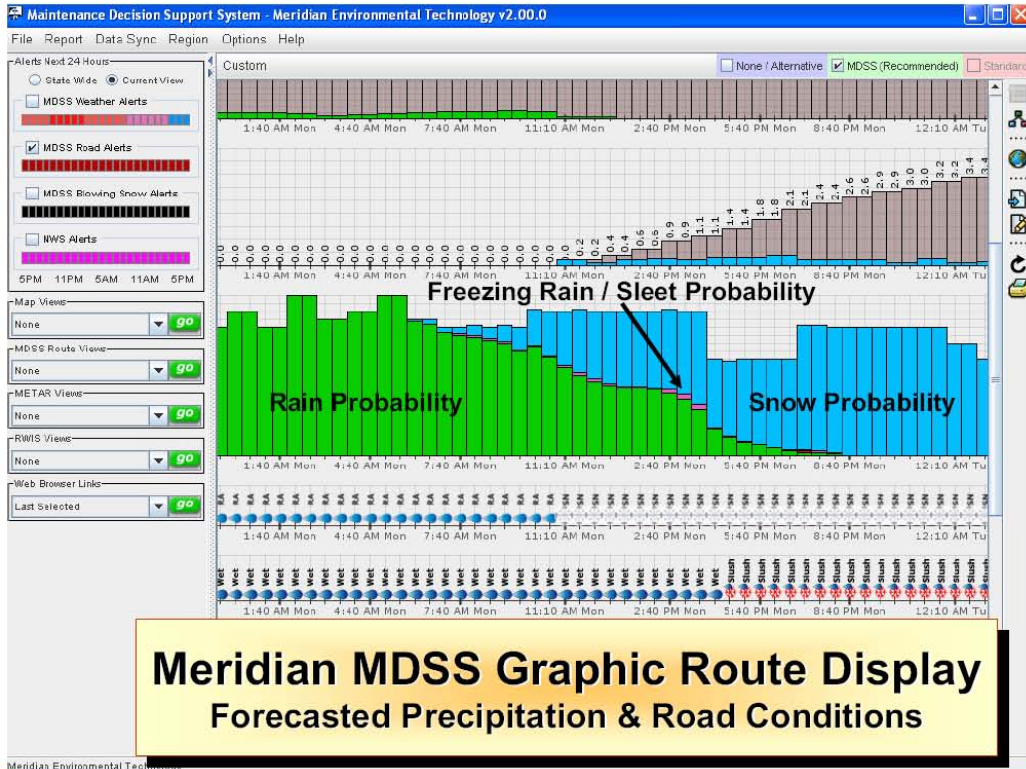
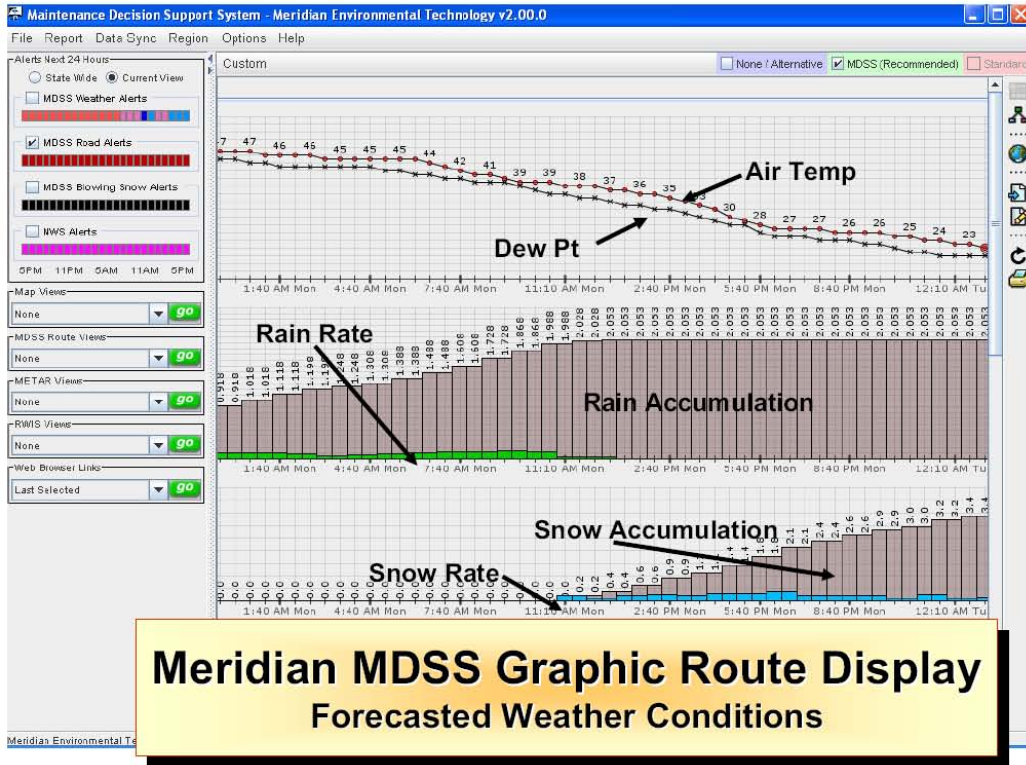
State DOT participants NV, ID, WY, NE, IA, MO, WI, MI, OH, NY, ME that purchased the DTN/Meteorlogix Web-based MDSS System (WeatherSentry) for the 2006-2007 winter season

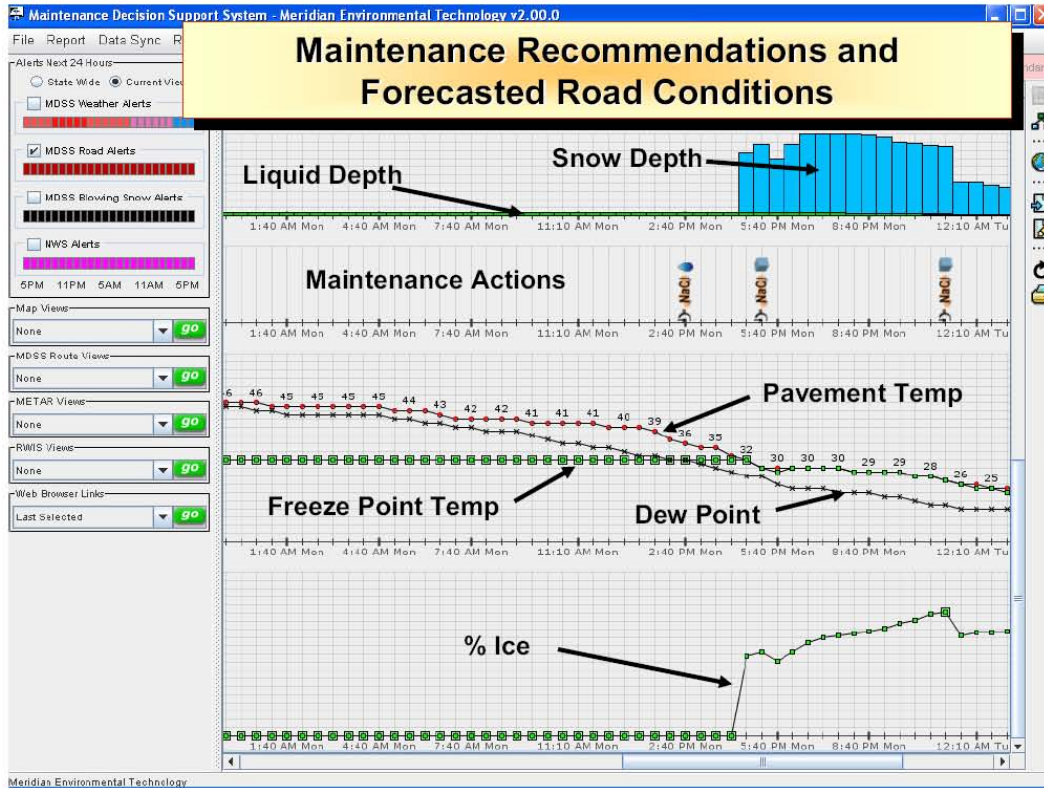


- IA is also in the Pooled-Fund
- ME is host for MDSS Cost/Benefits Analysis
- NYS Thruway Authority also participated

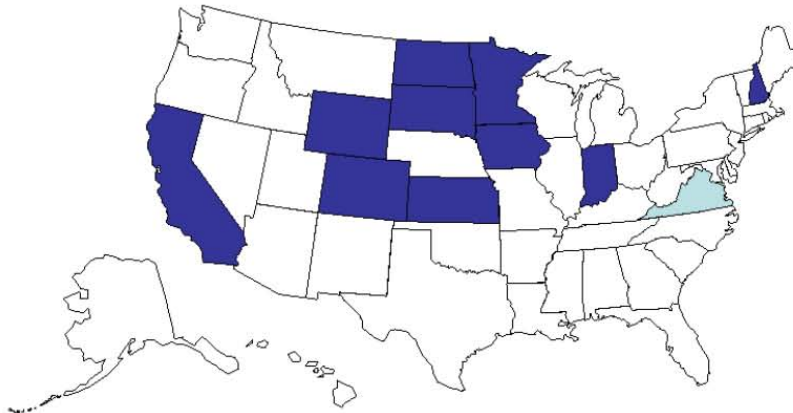
75 Cities & Counties also
Subscribe to DTN's MDSS







Pooled-Fund MDSS Participants 2007 South Dakota DOT Lead State



Pooled-Fund membership: CA, WY, CO, KS, ND, SD, MN, IA, IN, NH. The light blue state is VA which is not yet a member but is interested in joining. *VA is actively seeking membership

Road Weather
Management



**Iowa DOT
Experience
with MDSS**



- FHWA Prototype Development (3 Garages)
- Pooled Fund Study program (+ 6 Garages)
- All garages within every County in Iowa (+110 Garages)

43

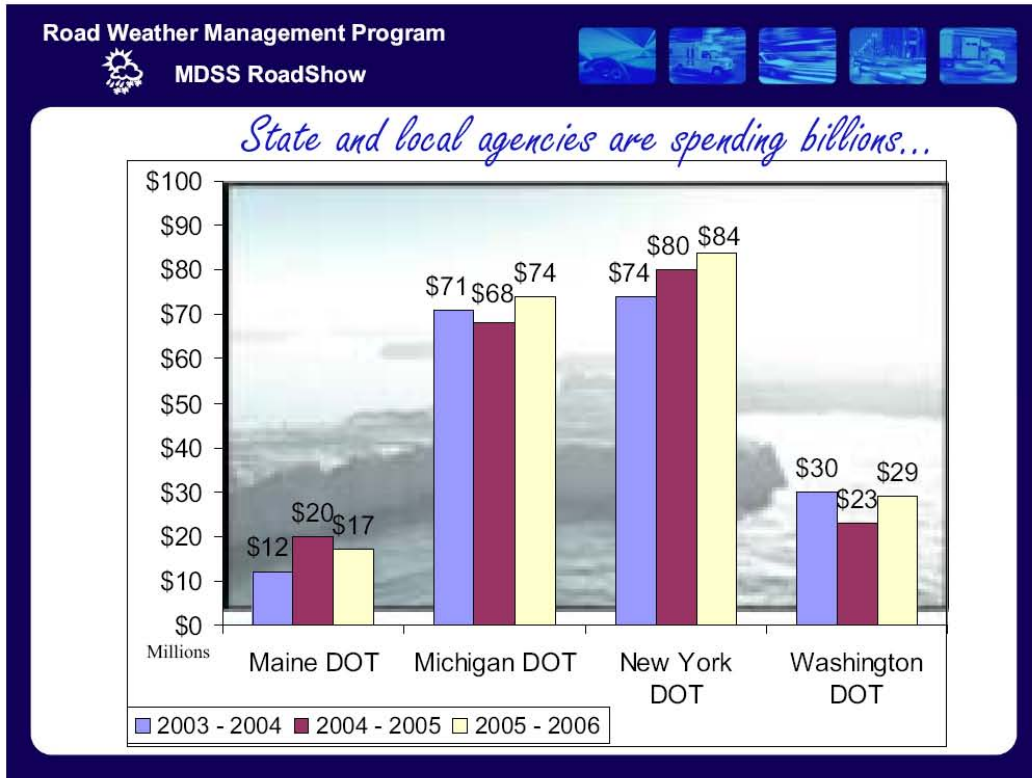
Road Weather Management Program
MDSS RoadShow

Value - Added Benefits

**Iowa DOTs
experience has
identified a number
of Value-Added
Benefits that can be
achieved by
deploying MDSS**



- Estimate **10%** savings in operational costs
~\$3 to \$4 million annual savings in
labor, materials & equipment
- Operate more efficiently
- Stewards of the environment



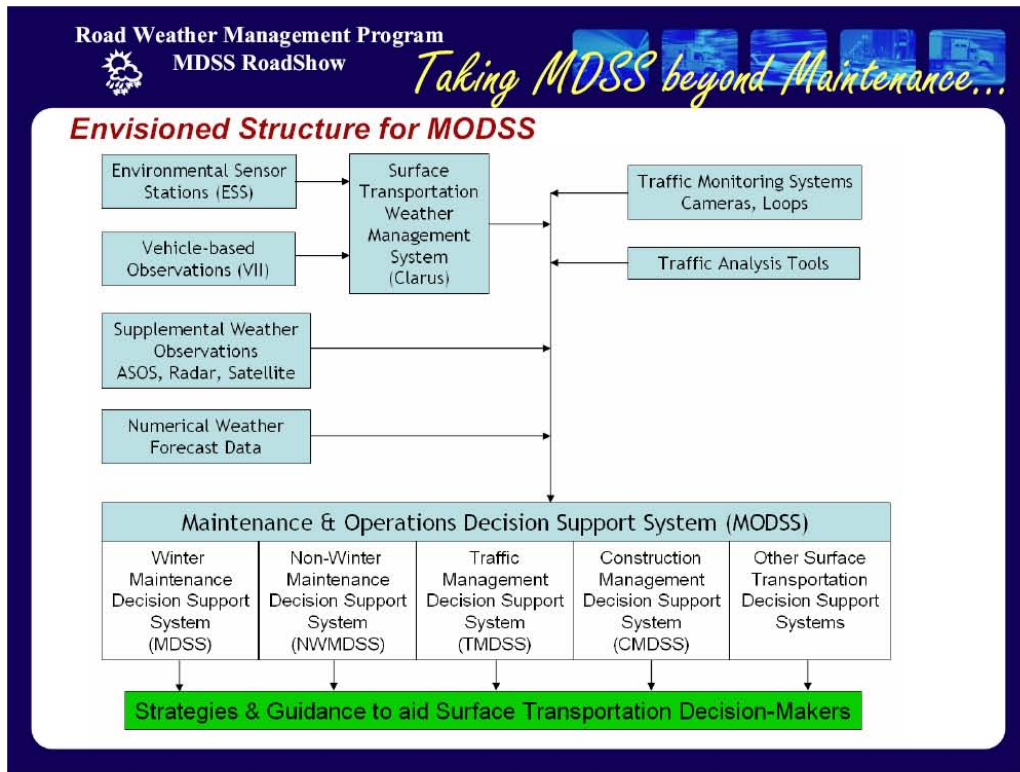
PennDOT Snow & Ice Control



Activity includes all necessary labor, equipment, materials, rentals & service contracts used for snow and ice control operations.

Crawford, Erie, Forest, Mercer, Venango, Warren, Centre, Clearfield, Clinton, Cameron, McKean, Potter, Mifflin, Juniata, Elk, Columbia, Lycoming, Montour, Northumberland, Snyder, Sullivan, Tioga, Union, Bradford, Lackawanna, Luzerne, Pike, Susquehanna, Wayne, Wyoming, Berks, Carbon, Lehigh, Monroe, Northampton, Schuylkill, Bucks, Chester, Delaware, Montgomery, Philadelphia, Adams, Cumberland, Franklin, York, Dauphin, Lancaster, Lebanon, Perry, Bedford, Blair, Cambria, Fulton, Huntingdon, Somerset, Armstrong, Butler, Clarion, Indiana, Jefferson, Allegheny, Beaver, Lawrence, Fayette, Greene, Washington, Westmoreland

Next steps...



Road Weather Management Program
MDSS RoadShow *Add MDSS to your Tool-Box*

**MDSS... A Smart Investment in Winter Maintenance
...saving lives, time and money!**

SOLUTION - by adding an MDSS to your tool-box, you will make a smart investment in the future of your own Winter Maintenance Program:

- Potential cost savings can be achieved
- Managers & supervisors will more effectively employ their resources
- Improve your snow fighting techniques & material application rates.

Benefit Areas

- > Safety
- > Mobility
- > Productivity
- > Efficiency
- > Energy & Environment
- > Customer Satisfaction

Road Weather Management Program
MDSS RoadShow



We are pleased to announce the next **MDSS Stakeholder meeting** will take place 18-19 September, 2007 and the **Clarus ICC meeting** will take place on 20-21 September, 2007 in Kansas City, MO. The meeting will be held at the new National Weather Service Training Center which is located by the Kansas City International Airport.

FHWA will pay for one state representative to attend.

On behalf of FHWA, thank you Pennsylvania DOT
for your time and attention!

- FHWA **Road Weather Management** Web Page
– www.fhwa.dot.gov/weather/





Appendix D Other States Web-based Survey Summary

Summary of a **web-based state of the practice survey distributed to other state DOT's** including state traffic engineering and ITS contacts as well as state roadway weather management contacts. The survey resulted in 26 responses and was used as a basis for follow-on interviews.



1. What Department of Transportation do you represent?	2. What is your title?	3. What is your name (optional)?	4. What is your phone number (optional)?	5. What is your email address (optional)?	6. Do you mind if PennDOT contacts you regarding your RWIS program?	7. How many RWIS sites do you have deployed?	8. How many staff positions are assigned to your RWIS program?	Sites Per Staff Position	9. What department manages your RWIS program?	10. What is your annual operations and maintenance budget?
Open-Ended Response	Open-Ended Response	Open-Ended Response	Open-Ended Response	Open-Ended Response	Yes/ No	Adjusted Data	Adjusted Data	Calculated Data	Adjusted Data	Adjusted Data
Arizona	State Traffic Engineer	Mike Manthey	602 712-8888	mmanthey@azdot.gov	No	20	NA	NA	Operations	NA
California	Senior Transportation Electrical Engineer	Steve Hancock	916-654-6007	steve.hancock@dot.ca.gov	No	106	1	106	Both	NA
Delaware	TMC Operations Manager	Gene Donaldson	302-659-2401	gene.donaldson@state.de.us	No	10	NA	NA	Operations	NA
Idaho	Winter Maintenance Coord.	Kent Wetzstein	(208) 334-8472	kent.wetzstein@itd.idaho.gov	No	33	1	33	Maintenance	\$50,000
Indiana	Snow and Ice Supervisor	Kirk Carpenter	317-234-5048	kcarpenter@indot.in.gov	No	28	2	14	Maintenance	NA
Iowa	RWIS Coordinator	Tina Greenfield	515-233-7746	tina.greenfield@dot.iowa.gov	No	58	1	58	Maintenance	\$150,000
Kansas	Staff Engineer	Peter Carttar	785-296-3576	carttar@ksdot.org	No	53	1.5	35	Both	NA
Kentucky	Transportation Engineer Branch Manager	Glenn Anderson	502-564-3020	glenn.anderson@ky.gov	No	39	0	NA	Both	NA
Maine	ITS Program Manager	Clifton Curtis	207 624-3600	clifton.curtis@maine.gov	No	6	0.5	12	Maintenance	\$20,000
Michigan	Traffic and Safety Engineer	Dawn Gustafson	906-786-1800	gustafson@michigan.gov	No	NA	NA	NA	NA	NA
Mississippi	State Traffic Engineer	Wes Dean	601-359-1454	wdean@mdot.state.ms.us	No	NA	NA	NA	Operations	NA
Montana	Traveler Information Coordinator	Brandi Hamilton	406-444-0468	brhamilton@mt.gov	No	66	NA	NA	Multiple	\$100,000
Nebraska	Maintenance Engineer	Dalyce Ronnau	402-479-4544	dronnau@dor.state.ne.us	No	60	NA	NA	Operations	\$125,000
New Hampshire	Special Projects Manager	Stephen Gray	603 271-4185	sgray@dot.state.nh.us	No	12	NA	NA	Both	NA



1. What Department of Transportation do you represent?	2. What is your title?	3. What is your name (optional)?	4. What is your phone number (optional)?	5. What is your email address (optional)?	6. Do you mind if PennDOT contacts you regarding your RWIS program?	7. How many RWIS sites do you have deployed?	8. How many staff positions are assigned to your RWIS program?	Sites Per Staff Position	9. What department manages your RWIS program?	10. What is your annual operations and maintenance budget?
North Dakota	ITS Engineer	Ed Ryen	701.328.4274	eryen@nd.gov	No	23	2	11.5	Maintenance	\$25,000
Ohio	RWIS Coordinator	Abner Johnson	614-466-4859	abner.johnson@dot.state.oh.us	No	169	13	13	Maintenance	\$80,000
Rhode Island	Chief Highway Maintenance Supervisor	Thomas Kesson	-222-2378 Ext. 4	tjkesson@dot.ri.gov	No	9	1	9	Maintenance	NA
Nevada	Asst. Chief Operations Engineer	Denise Inda	775-888-7867	dinda@dot.state.nv.us	No	70	NA	NA	Both	\$280,000
Utah	Weather Operations/RWIS Manager	Ralph Patterson	801 887-3735	ralphpatterson@utah.gov	No	58	5	11.6	Weather Operations	\$300,000
Virginia	Senior ITS Engineer	Gene Martin	804-786-4168	e.martin@vdot.virginia.gov	No	42	1	42	Operations	\$500,000
Washington	State ITS Operations Engineer	Bill Legg	360 705 7994	legg@wsdot.wa.gov	No	91	NA	NA	Operations	\$273,000
West Virginia	ITS Coordinator/System's Mgmt Engineer	Bruce Kenney	304 558 9449	Capitol Complex, Bldg 5, Rm 550, Charleston WV 25313	No	0	1	0	Operations	\$100,000
Wisconsin	RWIS Program Manager	Mike Adams	608-266-5004	michael.adams@dot.state.wi.us	No	57	1	57	Operations	\$300,000
Summary							31 Total	13 Avg		\$175,250 Avg



1. What Department of Transportation do you represent?	Yearly Expenditure Per Site	17. What third-party weather providers do you utilize?	18. Is RWIS data integrated with other third-party data?		MDSS Status of Respondants (from Ray Murphy of FHWA)	19. Has your agency considered any public-private partnerships for more effective roadway weather management?	
			Adjusted Data	Open-Ended Response		Adjusted Data	Open-Ended Response
Open-Ended Response	Calculated Data	Open-Ended Response	Adjusted Data	Open-Ended Response	Supplied	Adjusted Data	Open-Ended Response
Arizona	NA		No		Unknown		
California	NA	varies region by region	No		Meridian Environmental MDSS - pooled fund	No	
Delaware	NA				Unknown	No	
Idaho	\$1,500.00	We did not have good success with third party weather providers.	No		Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Indiana	NA		Yes		Meridian Environmental MDSS - pooled fund	No	
Iowa	\$2,600.00	DTN/Meteorlogix Meridian Environmental Technologies	Yes	They both use our RWIS to provide pavement temperature forecasts and they both have current RWIS obs on some of their weather maps on their websites.	Participating in pooled fund but utilizing DTN (Weather Sentry)		I don't know
Kansas	NA	DTN provides site-specific forecasts and statewide forecasts and Meridian provides statewide radar.	Yes	RWIS feeds our 511 system which integrates RWIS, road condition reporting and forecasts	Meridian Environmental MDSS - pooled fund		
Kentucky	NA	Accuweather provides images for kiosks but this is not part of the RWIS program	Yes	Data is ingested into NOAA MADIS	Unknown	No	
Maine	\$3,300.00	DTN Meteorlogix	Yes	We have incorporated the RWIS stations to compare to their pavement forecasting.	Utilizing web-based MDSS by DTN (Weather Sentry) -analysis lead for B/C	No	
Michigan	NA		No		Utilizing web-based MDSS by DTN (Weather Sentry)		
Mississippi	NA				Unknown		
Montana	\$1,500.00	Northwest Weather Net (contracted through Meridian I believe)	Yes	RWIS data integrated with Northwest Weather Net. Also integrated with 511 to provide roadway specific forecast information.	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Nebraska	\$2,100.00	Not certain, this is handled by the districts	Yes	It is used for our 511 and Road Condition Reportings system	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
New Hampshire	NA	Home Time Weather Forecasting Nashua, NH	No	Currently is not for weather forecast but is being shared with Plymouth Stae University meteorology department.	Meridian Environmental MDSS - pooled fund	No	No interest yet from third parties but department would consider any proposals that might be put forth.



1. What Department of Transportation do you represent?	Yearly Expenditure Per Site	17. What third-party weather providers do you utilize?	18. Is RWIS data integrated with other third-party data?		MDSS Status of Respondants (from Ray Murphy of FHWA)	19. Has your agency considered any public-private partnerships for more effective roadway weather management?	
North Dakota	\$1,100.00	Meridian Environmental Technology, Inc.	No		Meridian Environmental MDSS - pooled fund	Yes	We are currently involved with a multi-state MDSS pooled fund study that is a partnership with a private company.
Ohio	\$500.00	1. Meridian Environmental Technology, Grand Forks, N.D. 2. DTN/Meteorlogix, Minneapolis, Mn.	?	Question is unclear. Our RWIS data is ingested by the NWS and our weather service vendor and used in our forecasts.	Utilizing web-based MDSS by DTN (Weather Sentry)	Yes	See Question 17.
Rhode Island	NA	Private local weather forecast.	No	Our private weather service can access our web page.	Unknown	Yes	Rhode Island Turnpike & Bridge Authority has two RPU's on the Pell Bridge, and will share the data. The Providence Water Supply Board is looking into adding a RPU inside the Scituate Water Shed area.
Nevada	\$4,000.00	Northwest Weathemet provides a weather forecast that is road and crew specific. It is specifically tailored to our winter maintenance procedures.	Yes	NW Weathemet gets our RWIS data and utilizes it in their forecasting. We are working to improve the data sharing and pavement temperature forecasting for next winter.	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Utah	\$5,200.00	We use NorthWest Weathemet... We have their forecasters (hand picked) stationed inside our TOC facility.	Yes	Only to the affect that they use it in their operations to help them provide better service to me. We also have been known to use their Meteorologists in the field working on stations or assisting in RWIS deployment siting...	Unknown	Yes	As previously stated we have or Vendor supply the forecasters who work under my direction... We also let them forecast for adjacent states out of my office to help us offset costs of having an inhouse staff...
Virginia	\$11,900.00		No		Pursuing Meridian Environmental MDSS - pooled fund	No	
Washington	\$3,000.00	We use NW Weathemet to provide customized regional forecast as needed on an on-call basis.	Yes	The 3rd party mentioned above receives our RWIS data.	Unknown	Yes	We are a member on two of the recently announced CLARIS initiative project selection. We view this as a public-private partnership. Also, we will provide our RWIS data to anyone who needs it at now cost.
West Virginia	NA				Unknown		
Wisconsin	\$5,300.00	Meridian Environmental, Meteorlogix.	Yes	Limited MDSS from Meteorlogix.	Utilizing web-based MDSS by DTN (Weather Sentry)	No	
Summary	\$3,445 Avg \$5300 Max		40% Yes 9 total			17% Yes 4total	



1. What Department of Transportation do you represent?	1A Please describe your status of participation in the Maintenance Decision Support System (MDSS).	2A If you plan to participate in MDSS, what is your estimate as far as deployment and recurring costs? Other thoughts?	3A If you are currently utilizing third party weather data, what is your subscription fee?
Open-Ended Response	Follow-up Email May 14, 2007	Follow-up Email May 14, 2007	Follow-up Email May 14, 2007
Arizona			
California			
Delaware			
Idaho			
Indiana			
Iowa			
Kansas	Although KDOT has participated in the conceptualization and development of MDSS from the first OFCM - STWDSR meetings years ago, we have only operated the Pooled-Fund Study (PFS) version of MDSS in Dodge City for two winters and in the Topeka area for one winter. We hope to run it in the Kansas City area next winter.	Beyond the cost of membership in the Pooled-Fund Study (PFS), MDSS, each truck involved in the study has been equipped with an Iwapi smart modem device (SMD) to communicate location and truck operational data back to MDSS (approx. \$1700 per unit) and has communicated over cell phone air cards (\$48/mo. for unlimited data plan). That has proved to be the greatest additional direct cost of the project. There would be additional costs, of course, for statewide deployment. Statewide deployment would involve costs of communicating (we would use our state radio system) and storing (servers, etc) truck operational data. There would be training costs, SMD installation and maintenance costs as well as on-going IT maintenance and system oversight costs.	KDOT RWIS also incorporates RWIS from other organizations such as Kansas Turnpike Authority, City of Topeka, and Sedgwick County. These organizations are given access to KDOT RWIS and RWIS forecasts in exchange for the data from their weather stations. Access to MDSS PFS is not part of this agreement.
Kentucky			
Maine			
Michigan			
Mississippi			
Montana			
Nebraska			
New Hampshire	1. NHDOT is participating in MDSS on a limited basis to evaluate the technology and usefulness of the system. Presently one interstate maintenance facilities is actively taking part in the program. The departments representative is Pamela Mitchell who is a district engineer for District 5.	2. We are currently evaluating MDSS and are not making future commitments until the system has been used for several seasons and a thorough review completed.	3. NHDOT is used SSTs scan cast forecast last winter which was included in our recent RWIS deployment. We also utilize the services of a meteorological firm here in NH. They operate under the name of Hometown Weather. Their bid for last year was \$8500.00 for 6 months of forecasts (November thru April) This item is bid each year.



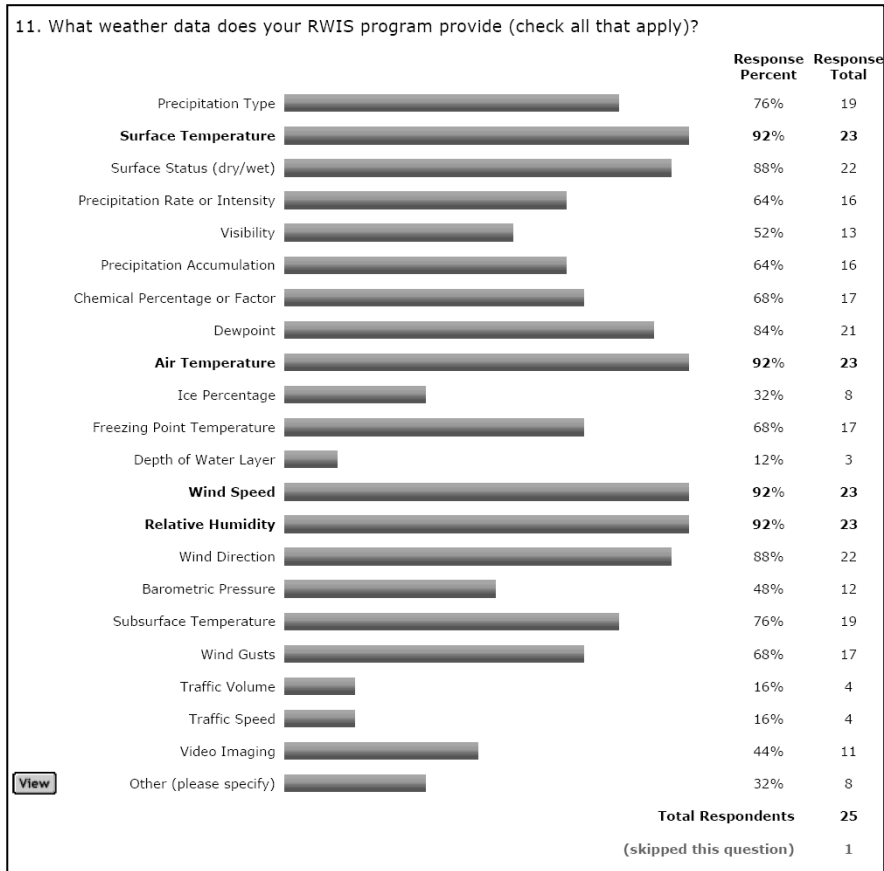
1. What Department of Transportation do you represent?	1A Please describe your status of participation in the Maintenance Decision Support System (MDSS).	2A If you plan to participate in MDSS, what is your estimate as far as deployment and recurring costs? Other thoughts?	3A If you are currently utilizing third party weather data, what is your subscription fee?
North Dakota			
Ohio			
Rhode Island			
Nevada	<p>NDOT is interested in pursuing MDSS but all of the conditions are not yet right for us to move forward: 1) We need to fine-tune and improve our RWIS system to ensure that the data is consistently available and accurate on a statewide basis before moving to MDSS 2) Maintenance staff in certain regions are familiar with forecasting, but others are not. We want to get the majority of Maintenance staff comfortable with weather and pavement forecasts before moving completely into MDSS. We feel that buy-in from Maintenance is critical in successfully using MDSS. 3) We are waiting for MDSS to mature and develop a little bit more before moving to this new technology.</p>	<p>Not quite this far along yet. Cost will depend on the product/vendor chosen.</p>	<p>We have our own RWIS data...over 70 sites statewide. We are paying approximately \$125,000.00 per year to have a meteorologist (Northwest Weathermet) provide forecasts (weather and pavement temperature) for us statewide. The forecasts are customized to the regions/crews and address their specific needs and maintenance practices. Our consultant is working closely with the 3 Districts to ensure that he is meeting the needs of the Maintenance staff, both for snow and ice removal procedures as well as summer maintenance activities that are weather and temperature sensitive.</p>
Utah			
Virginia			
Washington			
West Virginia			
Wisconsin	<p>We have been a stakeholder in the project since day 1. But we did not join the MDSS pooled fund effort due to a lack of funding and some serious questions about the direction of the project. On the surface, we think MDSS is an excellent idea. But the devil is in the details. To make MDSS fully functional, we would have to come up with a way to get feedback into the system on what maintenance activities were undertaken on each stretch of roadway. That means GPS/AVL or some other likely expensive technology. We simply don't have the resources to go there right now. We did pilot test the Meteorologix MDSS this past winter, but were not overly impressed. It gave only initial treatment recommendations, and these were often illogical.</p>	<p>See above. The cost would be enormous for the supporting technologies, not necessarily for MDSS itself. If you already have real-time logging of activities and actions, MDSS implementation might not be terribly costly.</p>	<p>We use Meridian Environmental. They provide us weather and pavement temperature forecasts for every county every three hours. They also provide a storm alert service that warns us 2 hours in advance of an event of any magnitude. We pay approximately \$76,000 for this.</p>
Summary			



1. What Department of Transportation do you represent?	4A Briefly describe how (and who) RWIS data, third party weather data and MDSS will (or is) integrated.	5A If you plan to utilize third party weather data as well as MDSS, please describe your philosophy regarding RWIS deployments (RWIS not needed? regular intervals?, trouble spots?, co-located with ITS devices?, etc)
Open-Ended Response	Follow-up Email May 14, 2007	Follow-up Email May 14, 2007
Arizona		
California		
Delaware		
Idaho		
Indiana		
Iowa		
Kansas	<p>PFS MDSS GUI incorporates RWIS and various other weather sources and displays in an integrated display product. See the MDSS PFS website for GUI views. KDOT RWIS data includes (by agreement) the data from our non-KDOT RWIS data partners. This data is loaded to an FTP site for transfer to the National Weather Service and others, to help build weather data archives and to allow external partners to incorporate our data into integrated weather products.</p>	<p>RWIS is needed, at regular intervals, to represent regional weather trends (best for forecasters and climatological archive. RWIS is also useful at trouble spots to solve specific problems for DOT personnel. See siting guidelines, refer to FHWA publication FHWA-HOP-05-026.</p>
Kentucky		
Maine		
Michigan		
Mississippi		
Montana		
Nebraska		
New Hampshire	<p>4. RWIS and weather forecasts are available to the section foreman and by the MDSS group. Suggested decisions are based on these predications and real time weather reports.</p>	<p>5. Philosophy to date is to make RWIS data available to all sections of NHDOT as well as the public thru NHDOT web site and the Traffic Management Center that is scheduled to open this fall. We will continue to place RWIS in areas that reflect general conditions as well as a few critical trouble spots. presently we feel that RWIS is a valuable tool that our field personnel can utilize in making everyday maintenance decisions.</p>

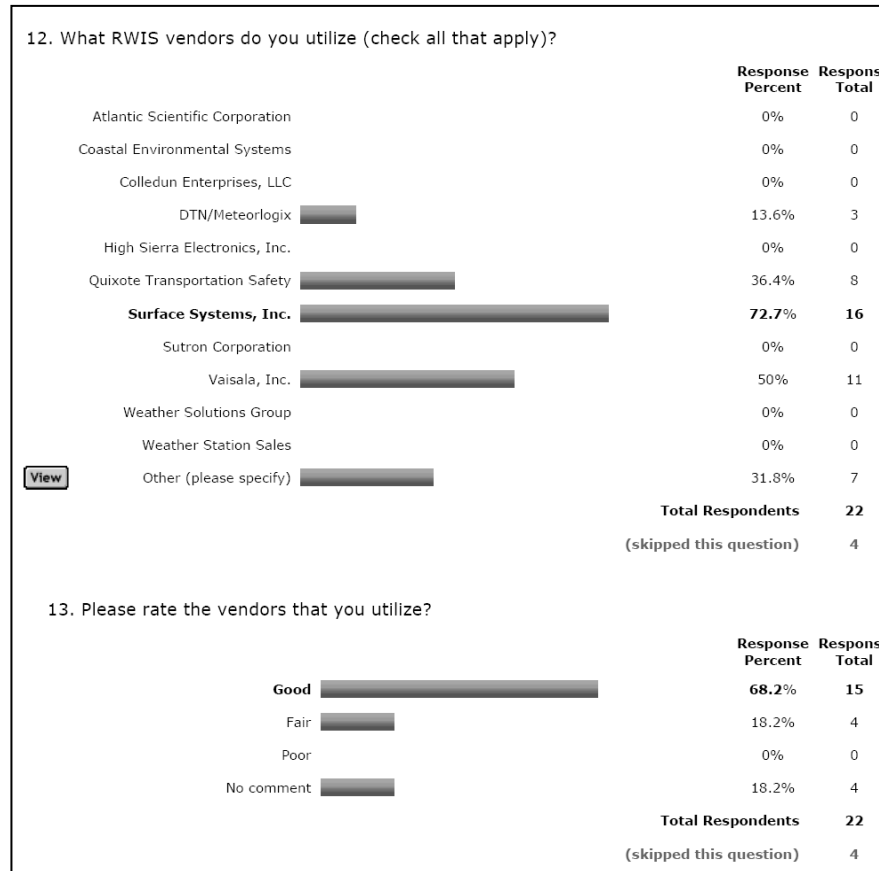


1. What Department of Transportation do you represent?	4A Briefly describe how (and who) RWIS data, third party weather data and MDSS will (or is) integrated.	5A If you plan to utilize third party weather data as well as MDSS, please describe your philosophy regarding RWIS deployments (RWIS not needed? regular intervals?, trouble spots?, co-located with ITS devices?, etc)
North Dakota		
Ohio		
Rhode Island		
Nevada	<p>Currently our consultant (meteorologist) has access to our RWIS data, but availability is sometimes sporadic. We are working to solve these problems. This will improve the accuracy of the pavement temp forecasts that we receive from him.</p>	<p>We did thermal mapping on our roads to assist with locating appropriate sites for RWIS. While we will continue to add a few more sites in areas that do not have RWIS, the bulk of our installations are already in place. The thermal mapping was done in the mid-nineties, well before I began my position at the District. I do not know what the cost was. I think that the prices may have gone down since them....at the time, Vaisala had to ship their special car over to map the roads. Now, I believe they have a vehicle in North America. I'm sure that Vaisala could provide some general pricing if you want better information than what I'm able to provide.</p>
Utah		
Virginia		
Washington		
West Virginia		
Wisconsin	<p>We have no real plans for MDSS, so I'll drop that one. Our RWIS and other weather data is all web-based. All our RWIS are SSI, and they display all data on a web site that we pay them to administer. RWIS data is also available through the Meridian web site. Meridian also displays a lot of third party (National Weather Service) data. Many of our shops also use the DTN satellite service for radar and weather data, and some use the Meteorogix web-based Weather Sentry product for this purpose. We have no dictates on what they can use for this type of information.</p>	<p>In this context, I'm not sure what you mean by "third party weather data." Our RWIS currently consists of 57 sites across the state. We are mainly adding to it through improvement projects that place new sites in both trouble spots and representative areas. If possible, we want to co-locate with ITS devices, though we have only a couple sites that do this.</p>
Summary		



Other Responses to Question 11:

1. Note, different sites have different sensor suites, not all sites provide all of the provided data.
2. traffic and video only at a couple sites. Also measure sunlight intensity and wetness (off pavement)
3. 1 location provides traffic volume and speed. Plans are under way to add cameras to all locations.
4. Pan / Tilt and Zoom cameras that take still pictures at each site
5. We have not employed RWIS, but will later this year
6. N/A
7. Our RWIS cameras take still shots every 15 minutes...
8. Snow Depth

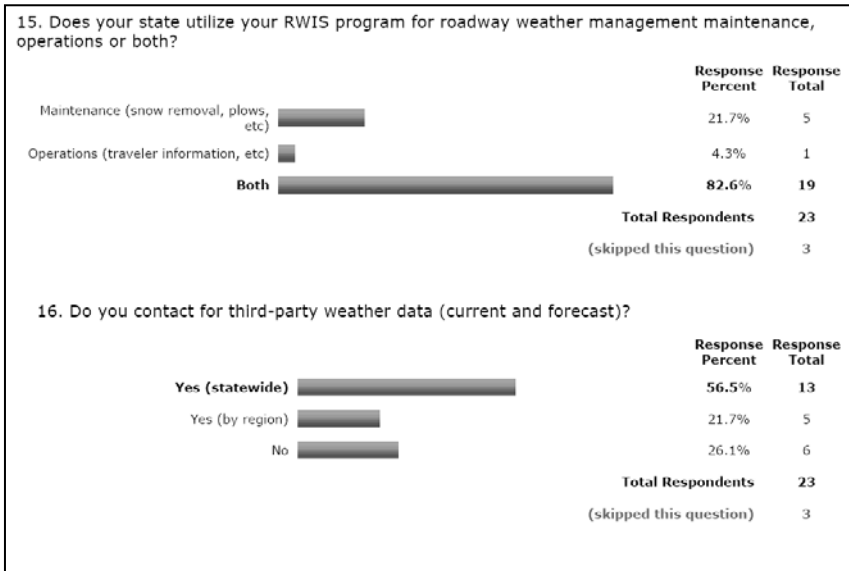


Other Responses to Question 12:

1. Hardware is from QTT/SSI, forecasts and radar are from DTN and Meridian Environmental
2. Campbell Scientific
3. Boschung (used for a bridge spray system)
4. N/A
5. Campbell of Logan Utah
6. Campbell Scientific out of Logan Ut. We have utilized this company for over 20 years in our avalanche safety program, and now we are migrating to Campbell for our RWIS as well. I like to use Vaisala instrumentation with the Campbell RPU...
7. DTN/METEORLOGIX IS NOT AN RWIS VENDOR

Other Comments Related to Question 13 (Question 14):

1. Very little maintenance required with Campbell Scientific equipment.
2. SSI has been relatively good while Vaisala was good during installation but has been only fair in addressing maintenance issues.
3. Maintenance is good, much better than SSI but software development is poor.
4. I would rate Vaisala as "good" I would not rate SSI in the same category
5. Very response to my needs
6. I represent Virginia at Aurora, an RWIS oriented pooled-fund project. I do not have direct contact with Virginia's RWIS, but support the need for and use of RWIS for system and maintenance operations. Atmospheric weather information is available all over the web, but only RWIS will give you information about weather's affect on the road surface.
7. Good relationship with their maintenance technician, but dealing with St. Louis leaves much to be desired.
8. Some problems with timely service
9. Field support from the vendors for commissioning of new sites and for preventive or response maintenance is very expensive. Therefore, we don't use the vendors for field support.
10. It depends on how you use them. We like Campbell and Vaisala the best. SSI seemed not to be all that responsive for what we wanted.
11. Not satisfied with their surface sensors for detecting chemical concentration.
12. As with all vendors dealing with State government, RWIS vendors are as good as the contracts they're accountable to and the oversight that is provided for them by the State.



17. What third-party weather providers do you utilize?

1. DTN provides site-specific forecasts and statewide forecasts and Meridian provides statewide radar.
2. We use NW Weathernet to provide customized regional forecast as needed on an on-call basis. Typically used for operations related to upcoming large storms or during the storm. They are part of our EOC team (via phone) during weather related activations.
3. Accuweather provides images for kiosks but this is not part of the RWIS program
4. varies region by region
5. Home Time Weather Forecasting Nashua, NH
6. Private local weather forecast.
7. Northwest Weather Net (contracted through Meridian I believe)
8. We did not have good success with third party weather providers. The District's did not find the service to be of value.
9. DTN Meteorlogix
10. Northwest Weathernet provides a weather forecast that is road and crew specific. It is specifically tailored to our winter maintenance procedures and is also utilized during the warmer months for temperature/weather sensitive work (slurry seals, etc.) Our 511 vendor (Meridian Environmental Technology) provides a road-specific 6-hour forecast that is available to the public via our 511 traveler information website and phonenumber.
11. Meridian Environmental, Meteorlogix.
12. Not certain, this is handled by the districts
13. Northwest Weathernet based in Seattle, Washington We do customized forecasts (as well as continuous updates during winter storms) for each of UDOT's 88 maintenance stations. NW Weathernet provides reduced fees in exchange for work space in our Traffic Management Center
14. We use NorthWest Weathernet... We have their forecasters (hand picked) stationed inside our TOC facility. This creates better communication and enhances relationships amongst disparate groups...
15. Meridian Environmental Technology, Inc.
16. DTN/Meteorlogix Meridian Environmental Technologies
17. 1. Meridian Environmental Technology, Grand Forks, N.D. 2. DTN/Meteorlogix, Minneapolis, Mn.

18. Is RWIS data integrated with other third-party data?

1. RWIS feeds our 511 system which integrates RWIS, road condition reporting and forecasts
2. The 3rd party mentioned above receives our RWIS data.
3. Data is ingested into NOAA MADIS
4. Currently is not for weather forecast but is being shared with Plymouth State University meteorology department.
5. Our private weather service can access our web page.
6. RWIS data integrated with Northwest Weather Net. Also integrated with 511 to provide roadway specific forecast information.
7. We have incorporated the RWIS stations to compare to their pavement forecasting.
8. NW Weathernet gets our RWIS data and utilizes it in their forecasting. We are working to improve the data sharing and pavement temperature forecasting for next winter.
9. Limited MDSS from Meteorlogix.
10. It is used for our 511 and Road Condition Reporting System
11. We have access to MesoWest instrument data
12. Only to the affect that they use it in their operations to help them provide better service to me. We also have been known to use their Meteorologists in the field working on stations or assisting in RWIS deployment siting...
13. They both use our RWIS to provide pavement temperature forecasts and they both have current RWIS obs on some of their weather maps on their websites.
14. Question is unclear. Our RWIS data is ingested by the NWS and our weather service vendor and used in our forecasts.

19. Has your agency considered any public-private partnerships for more effective roadway weather management?

1. We are a member on two of the recently announced CLARIS initiative project selection. We view this as a public-private partnership. Also, we will provide our RWIS data to anyone who needs it at now cost.
2. No interest yet from third parties but department would consider any proposals that might be put forth.
3. Rhode Island Turnpike & Bridge Authority has two RPU's on the Pell Bridge, and will share the data. The Providence Water Supply Board is looking into adding a RPU inside the Scuate Water Shed area.
4. I am not sure.
5. We issued an RFP for private contractors to work under our direction in our building. There is some element of partnership in that we provide facilities in exchange for reduced consulting fees.
6. As previously stated we have or Vendor supply the forecasters who work under my direction... We also let them forecast for adjacent states out of my office to help us offset costs of having an inhouse staff...
7. We are currently involved with a multi-state MDSS pooled fund study that is a partnership with a private company.
8. I don't know
9. See Question 17.

20. Please describe your training practices?

1. yearly expo, computer based training, district and local training programs
2. We have a RWIS focused 3 day maintenance training class typically once a year, based on need, for our signal/electronic techs.
3. All DeITrac systems when contracted include training for maintenance and operations.
4. Most of the RWIS work has been done under contract. We have done some training on the central software setup and configuration.
5. Just finished giving an 8 hour winter maintenance course to highway maintainers which had heavy emphasis on RWIS and anti-icing theory. Also have the AASHTO computer based training in RWIS and Anti-icing available at all maintenance sections.
6. RIDOT up-graded our system 3 years ago and all maintenance field supervisors were trained at that time.
7. Include RWIS in winter maintenance training
8. Once a year I have the vender come in for a week and travel the state giving Weather classes for maintenance workers. In 2006 we had classes for 110 folks total.
9. To date very little has been done with regard to training.
10. Basic computer introduction for crew and dispatchers
11. Ask Gene Martin
12. The RWIS system is fairly established in about 1/2 of the state. We are in the process of improving our system and ensuring the the rural maintenance crews have access to the RWIS data. Training occurs mostly at the District level within the Maintenance crews.
13. We do some level of training, mainly on forecast services, for each region each Fall.
14. Data entry to update the road conditon reporting system
15. We have sent maintenance crews to Campbell factory for training on RWIS instruments Contract meteorologists are trained by the consultant
16. Typically I put on some sort of training at the TOC for the Engineers and Operations staff. As far as the maintenance personnel go I usually present at their annual snow schools that the Regions put on (4), as well as area supervisor meetings and shed foreman meetings... but the training that seems the most effective is when someone from my staff and I go to each maintenance shed and show them how things work at their own computers in their own offices...
17. We haven't had a training session since we installed our ESS 12 years ago. Most of it is on-the-job.
18. Training has been ongoing since the first RWIS in 1989. Training included classroom and hands-on training for RWIS maintenance and use of RWIS and forecasts. Recently we've done more computer based training. Vendors and DOT personnel have conducted training.
19. We provide annual training to all winter maintenance front line managers and first responders as to the location, capabilities and possible uses of our RWIS sites as well as familiarization on how to access and interpret weather forecast data. We provide year round live technical support for all aspects of the program.

21. Please describe your maintenance practices?

1. KDOT has own RWIS technician who follows manufacturers recommendations
2. Maintenance is provided by our signal/electronic techs who repair and maintain all of the various electronic/ITS infrastructure we own and operate. RWIS work is just one of their many tasks, we have no one who supports RWIS exclusively.
3. Break fix with a statewide general ITS maintenance contract.
4. AL DeITrac systems are monitored 24/7 and are dispatched to either DeIDOT maintenance forces or contractors. We have a maintenance contract with the RWIS vendor.
5. Unsure what you are asking for in this question. Miantenance practices is a pretty large subject.
6. RIDOT has a yearly maintenace agreement with our vendor.
7. Servers - 4 year cycle Equip - on failure
8. Call!
9. Up until now the RWIS maintenance has been largely left to the District's to provide with HQ providing some finicial back-up. The State's Communications personnel have provided nearly all the nescicary maintenance. We have begun to have conversations about the need for a Statewide Maintenance Agreement.
10. Yearly calibration to update and replace equipment
11. Contract with Vaisala. See Gene Martin for copy of contract.
12. Vaisala performs a pre-season check of all of our sites and works with the District Communication Tech staff to replace parts and fix other issues as necessary. Comm. Tech. staff troubleshoots and fixes individual problems as they occur throughout the year. One of our goals is to better manage our system and ensure that all of our sites are in working order.
13. We have a service contract with SSIU for about \$130K per year. it requires on-site response within 48 hours of a reported outage or liquidated deductions can be levied. it requires annual PMs in August and September.
14. Maintenance is contracterd to a private source.
15. We have two ITS maintenance crews. They maintain CCTV, VMS, and TMS in addition to RWIS. The weather operations personnel monitors instrument data and issues work orders to crews when necessary. We concentrate on PM and repairs in summer and early autumn in anticipation of getting RWIS stations fully operational before winter. Managers track status of open work orders and turn-around time.

16. We use RWIS data in conjunction with Meridian Environmental Technologies Weather Services and MDSS for maintenance decisions and recommendations.

17. I assume this statement is in regard to RWIS? We have developed a preventative maintenance program... We like to send our technicians to get trained by the 'factory' if possible...

18. Our division works with our IT division to do a yearly check on each ESS. Most of our budget however, is for communication to the ESS.

19. RWIS and weather info is used by pretty much everybody for every storm – particularly for chemical application amounts and storm timing. They also use their in-vehicle IR pavement sensors, which are installed on the majority of plow trucks.

20. RWIS Maintenance. We have a performance based maintenance contract that provides for State oversight at the county, District and Statewide levels at our discretion. The vendor is paid in monthly increments based on system availability. The new agreement adds pro rating of daily performance to the monthly installment

22. Do you have any guidance relative to your RWIS and roadway weather management programs that is of particular interest?

1. It is easier to get funding to install stations than it to fund the ongoing maintenance of the stations. However, over time the maintenance needs will far exceed the initial installation costs. Using the data from the systems to provide operations support requires buyin from the folks doing winter operations and training (both initial and ongoing). After the excitement of the sites going in becomes old news, you may see maintenance folks reverting back to historical practices and experience and ignoring the data.

2. The trend towards pre-treatment (salt brine in our case) tends to make RWIS less useful and weather forecasts more important. Our sites cost about 12K installed.

3. We are currently looking at initiating a program.

4. Use NTCIP compatible systems

5. NHDOT is still in the learning curve as it pertains to RWIS. We have established a terrific partnership with Plymouth State University's Meteorology Department which looks very promising for both agencies.

6. RIDOT obtains a "Pavement Temp. Forecast" for the winter season (6 months). This has proved to be most help full during winter storm maintenance operations.

7. no

8. Call!

9. It is very important to educate the Maintenance personnel who will be requesting any new equipment on what the industry has to offer. There have been great strides in RWIS instrumentation. Educate yourself as to what your needs are first.

10. RWIS is the only information system that produces the affect of weather on the road surface. The information is archived which allows information to be used to forecast future road temperatures. It is essential to support a maintenance decision support system (MDSS), which can give your agency guidance on chemical treatment of roads during snow events.

11. Custom forecast services are a must, as is maintenance of equipment.

12. 1. Having weather operations in TMC is valuable for several reasons. Weather forecasters have access to all of the traffic CCTV's as well as state radio system. They are able to monitor snowplow radio traffic and talk to drivers on state radio. They assist TMC with web and 511 updates, advice on VMS messages, and answering phone calls in winter weather. They have face to face contact with ITS RWIS maintenance crews and with UDOT snow maintenance personnel. By being in UDOT facilities, they are accepted as part of DOT 'culture' 2. We provide custom forecasts to each station across all districts of the state. This is necessary because Utah weather varies greatly due to elevation that ranges from 4,500 in desert valleys to 8,000 + on mountain passes. Forecasters provide written forecasts each day, and do group conference call briefings 2 days in advance when they anticipate a major storm. They call individual station supervisors in advance of approaching winter storms to give latest on timing and severity. Forecasters will stay in touch with maintenance personnel during storms to give latest updates. 3. Our weather forecasters do not give snow removal advice, but do concentrate forecasts on what they call "road snow". Considering surface and air temps, and precip intensity, they try to anticipate conditions on paved surfaces.

13. Consistent preventative maintenance program and installation oversight program.

14. I am not sure what you are getting at with this question... You can give me a shout if you want any additional info...

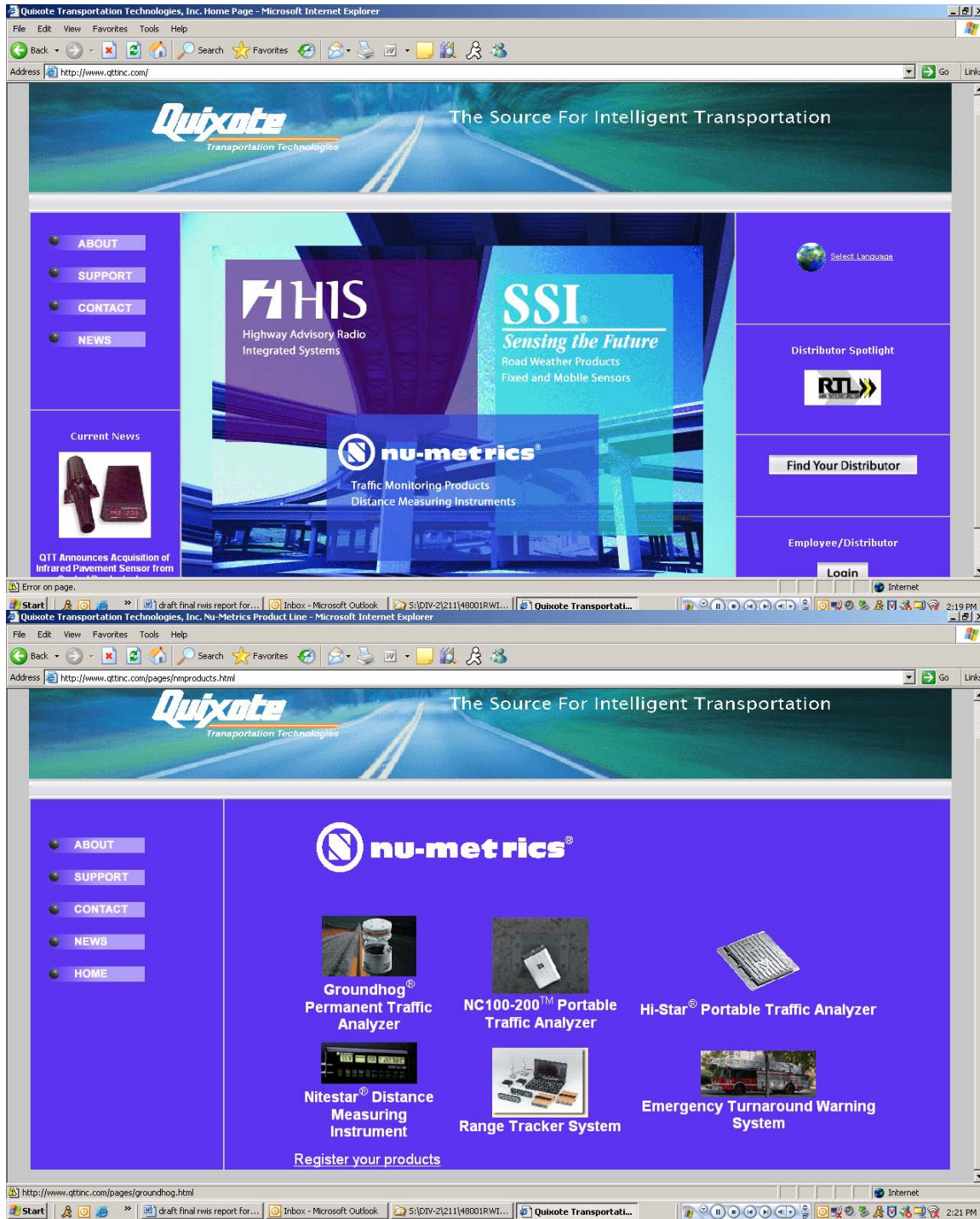
15. We are in the process of conducting research into developing a open architecture/system to break our dependance on proprietary equipment. We also have research project underway with one of our universities to test various ESS components, which will assist us in developing specifications for an open architecture system.

16. There are many different ways RWIS can be implemented in a state so you are doing good to look around at what a lot of people are doing. With that info you should be able to find a RWIS setup that best fits PennDOT. RWIS is not 'one size fits all'.

17. The best recommendation we can make for a successful RWIS program is ownership. Someone with influence has to be the champion of the system or you wasted your money. It will need to be maintained and improved and front line users will need to be trained and motivated for buy-in. It's not 'plug-n-play'.

Appendix E Vendor Products Summary

Screen captures of each vendor's RWIS page along with pictures and a brief descriptions of a few of their sensors.





Atmospheric Instruments

Wind Speed / Wind Direction

The Wind Speed/ Wind Direction Sensor determines the speed and direction of wind.



Relative Humidity / Air Temperature

The Relative Humidity / Air Temperature sensor determines air temperature and the level of humidity relative to the ambient temperature.



Precipitation Identifier / Classifier

The Precipitation Identifier / Classifier detects the occurrence of precipitation, identifies the precipitation type (rain, snow, drizzle), and measures precipitation rate and short-range visibility.



The Precipitation Occurrence sensor provides a (Yes/No) signal to indicate if precipitation, in any form, is occurring or not.

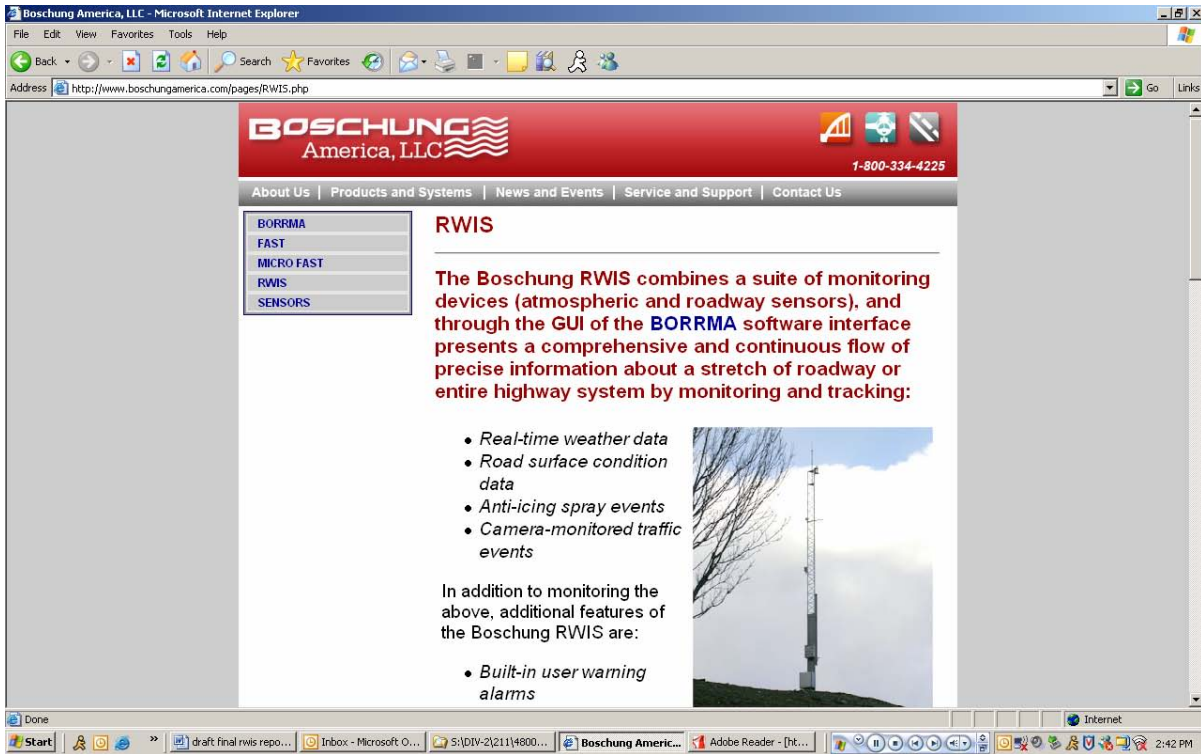


Pavement Sensors

Passive Surface Sensor

The flush-mounted FP 2000® has no moving parts, requires no maintenance, and is durable enough to withstand heavy traffic, tire-chains, snowplows and extreme temperatures for many years.





Pavement



ARCTIS

The ARCTIS, working along with the BOSO III sensor, cools itself by up to 27°F below the road surface and displays the actual freeze point via the BORRMA software, regardless of chemical on the roadway, eliminating the need for chemical algorithms and look up tables.



BOPAS

The BOPAS sensor used in combination with an RWIS allows the measuring and condition of the pavement status as well as pavement temperature (dry, wet, salted, black ice, frost).



BOSO III

The BOSO III system uses an active/ passive sensor design. The passive element measures pavement temperature, road wet/dry and water film thickness. The active element cools itself by 3.6°F below road surface temperature to determine a freeze point, alerting the user, via the BORRMA software, to a possible icy condition. This sensor also is capable of spraying a Boschung FAST or micro-FAST system.

Atmospheric

Windspeed and Wind Direction



- High Precision Sensor
- Light Construction
- Analogue outputs for easy interface with all kinds of electronics
- Separated Construction of both sensors for easy maintenance
- Conformity to CE norm
- Integrated heating for accurate operation in extreme conditions

Optical Precipitation Sensor



- Detection of rain and/or snow at 3 levels of intensity
- Optical measuring process, with years of proven accuracy
- Automatic Contamination detection (Dirty Probe Detection)
- Integrated ambient temperature measurement

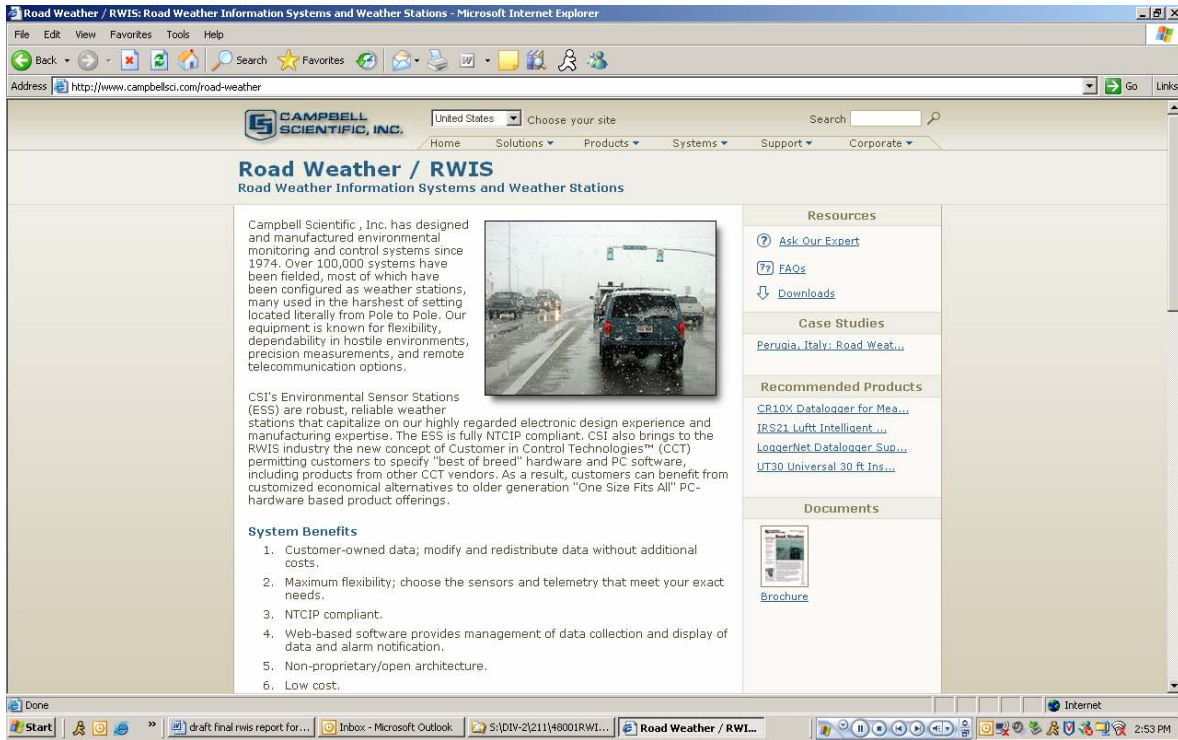
Air Temperature and Humidity



- Combined measurement of Humidity and Air Temperature
- Measurement of relative humidity by capacitive principle
- Measurement of Air Temperature using PT100 1/2 Dia Sensor



- High accuracy
- Automatic snow depth measurement
- Exact measurement of all types of snow
- Connect with a Measuring Station or function as a stand alone sensor



Temperature and Relative Humidity Probe Model CS215

The CS215 uses the Sensirion SH175, a combined relative humidity and temperature element, to provide accurate, stable measurements. The probe outputs an SDI-12 signal that our dataloggers can directly measure. Please note that our CR7 and CR9000X dataloggers are not SDI-12 compatible.

The Sensirion SH175 element is field-replaceable, eliminating the downtime typically required for the recalibration process.



Precision Infrared Radiometer Model IRR-P

The IRR-P is a precision, infrared radiometer that makes continuous measurements in field conditions. Infrared temperature sensors provide a non-contact means of measuring the surface temperature of an object or surface by sensing the infrared radiation given off by the subject. This unique sensor is manufactured by Apogee Instruments Inc. (Logan, UT).

Typical applications include:

- Road surface temperature
- Plant canopy temperature for irrigation scheduling and crop water stress
- Soil, snow, and water surface temperatures
- Sky temperature (net longwave radiation)

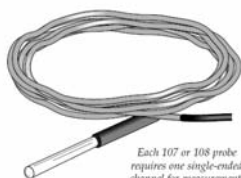
The IRR-P is comprised of a thermopile, which measures surface temperature, and a thermistor, which measures sensor body temperature. The two temperature probes are housed in a rugged aluminum body that contains a germanium window. When compared with the silicon window of its predecessor, the germanium window facilitates correction of target emissivity, reduces the effect of atmospheric humidity, and allows the sensor to be used at greater distances from the target.



Temperature Probes Models 107 and 108

The 107 and 108 are rugged, accurate probes that measure air, soil, and water temperature in a variety of applications. These probes consist of a thermistor encapsulated in an epoxy-filled aluminum housing. The housing protects the thermistor allowing the probes to be buried or submerged. The 107 measures from -35° to +50° C, the 108 from -5° to +95° C.

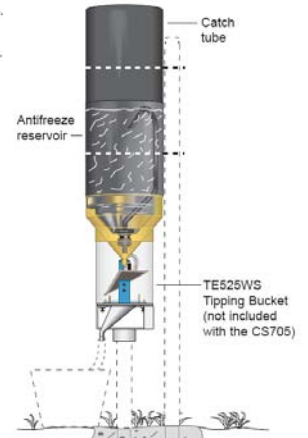
Please note that the 107 and 108 are not compatible with the CR200-series dataloggers. However, a similar thermistor, the 109, has been developed specifically for our CR200-series dataloggers.



Each 107 or 108 probe requires one single-ended channel for measurement.

Snowfall Conversion Adapter Model CS705

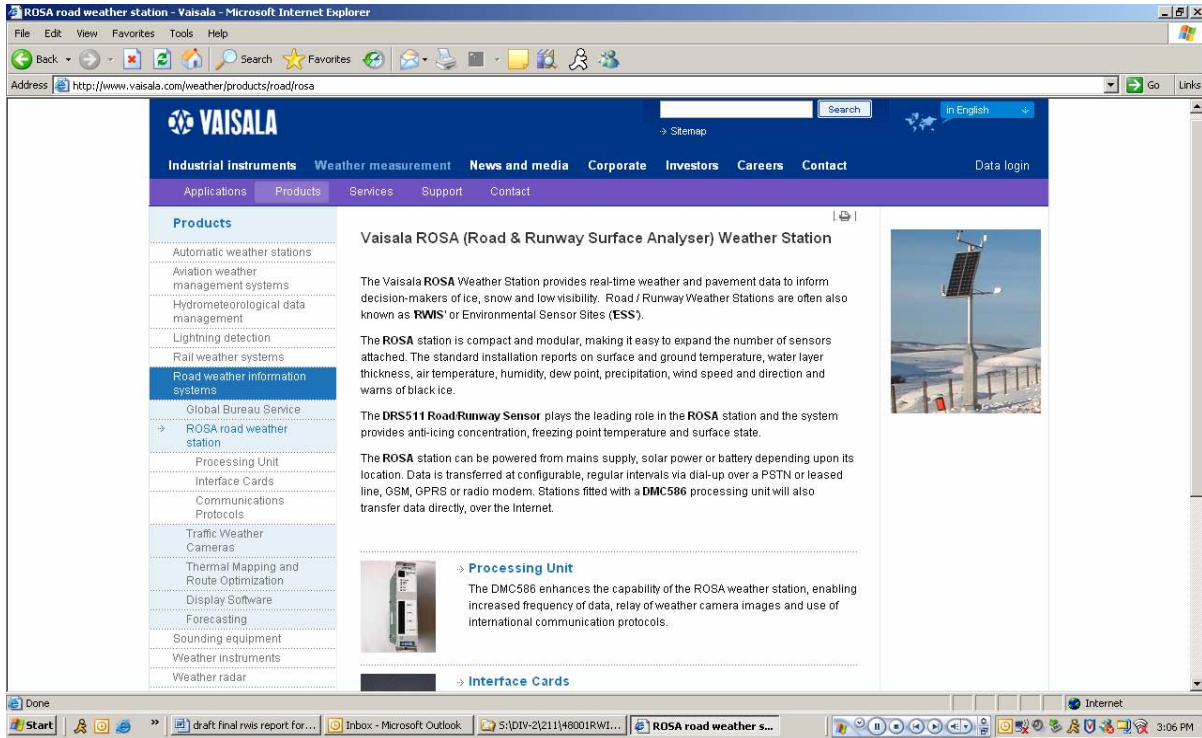
Campbell Scientific's CS705 consists of an antifreeze reservoir, overflow tube, and catch tube. Snow captured in the catch tube dissolves into the antifreeze. The melted snow raises the level of the antifreeze and water solution. The mixture flows through the overflow tube into the tipping bucket where it is measured by the tipping bucket mechanism.



Intelligent Road Surface Sensor Model IRS21

Lufft's IRS21 is a passive sensor that monitors road surface temperature, freezing temperature for NaCl (others on request), road condition (dry/damp/wet/ice or snow/residual salt/freezing), and water film level (up to 4 mm). This intelligent road surface sensor is a primary component of our Road Weather Information Stations (RWIS). When used in an RWIS application, the IRS21 is connected to a CR1000 or CR10X datalogger via the 18080 Lufft Interface and our SDM-SIO4 Serial Data Interface Module.





Weather instruments



Ceiliometers

Vaisala provides high quality ceilometers which measure cloud heights at 25,000 feet or 40,000 feet. These sensors offer a super measurement accuracy which has been documented in international intercomparisons.



Barometers

Vaisala's barometers offer excellent performance in a variety of applications. In meteorology, barometric pressure is measured in weather stations, data buoys, GPS meteorology and other environmental data logging.



Humidity, dewpoint and temperature

Vaisala relative humidity and air temperature sensors provide excellent accuracy and stability. These products meet even the most exacting demands.



Precipitation

Vaisala precipitation sensor selection comprises rain gauges and rain detectors that provide fast and accurate precipitation detection. Integrated into automated weather stations, they offers economical and reliable precipitation measurements.



Present weather

Vaisala provides optical sensors for measuring cloud height, visibility and present weather. They offer a superior measurement accuracy and range which has been documented in international intercomparisons.

Surface sensors

These sensors accurately detect and measure surface temperature and condition, chemical concentration and black ice.



Remote Surface State Sensor

Provides an accurate reading of surface conditions, including water, ice and snow amounts and a high resolution value for grip level. Pole mounted roadside set-up eliminates the disruption caused by slot-cutting, making installation and maintenance relatively easy. Can be used as a stand alone system on bridge decks, in remote locations or as part of an existing ROSA weather station.



Remote Surface Temperature Sensor

Measures surface temperature via emitted infrared radiation. Pole mounted roadside set-up eliminates the disruption caused by slot-cutting, making installation and maintenance relatively easy. Can be used as a stand alone system on bridge decks, in remote locations or as part of an existing ROSA weather station.



Road / Runway Surface and Depth Sensor

This thermally passive multi-variable sensor measures road / runway surface and subsurface temperatures, as well as water layer thickness, black ice and chemical levels.

Overhead Wire Sensor

A non-contact multi-variable sensor measuring overhead wire temperature and state (water / ice layer thickness, presence of snow etc).



Bridge Surface Sensor

A sensor with shallower physical dimensions to enable installation on bridge decks.



Conductor Rail Sensor



Appendix F Pennsylvania Web-based Survey Summary

Summary of **web-based survey to Pennsylvania (PennDOT)** including: District Executives, District Traffic Engineers, District Incident Management Coordinators, District ITS Coordinators, County Managers, District CRCs, RWIS Coordinators and Caretakers, BOMO, BHSTE, BIS, BPR, and the Press Office as well as to PEMA and PSP.

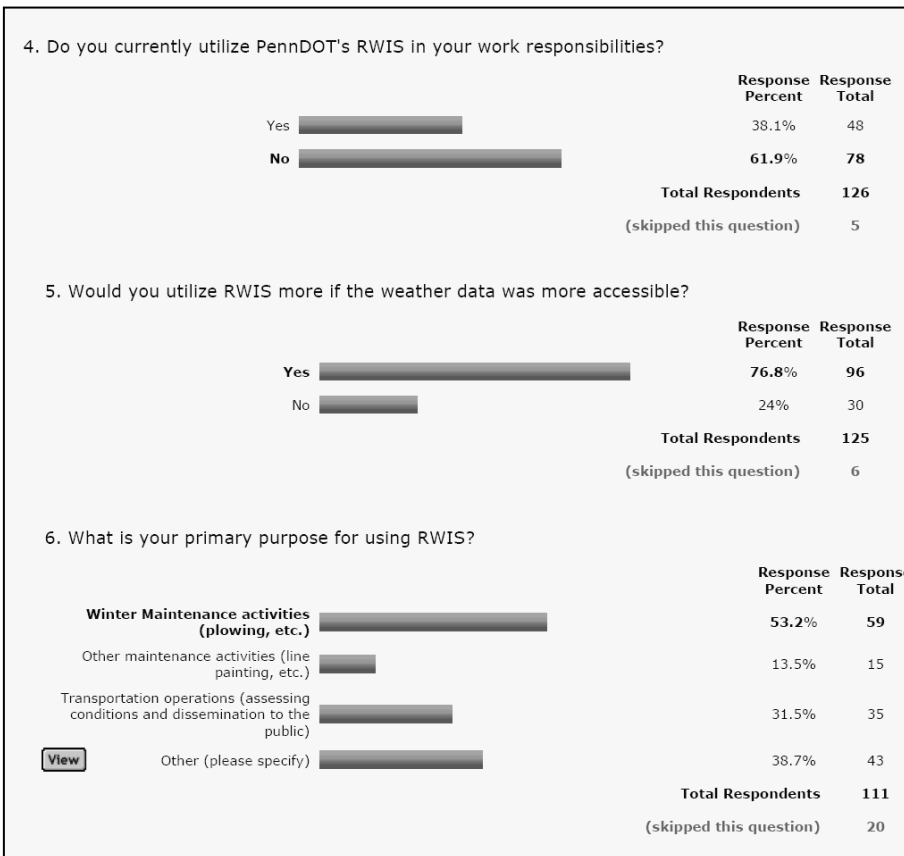
1. What is your name?	2. What is your job title?	3. What PennDOT Bureau, PennDOT District, or other agency do you work for?
john townsend	tcs	District 5-0
Dave Bachman	Bike/Ped Program Manager	Hwy Safety and Traffic Eng
Charles P Enoch	Senior Maintenance manager	Lancaster Maintenance
Chariti McGarvey	Clerk Typist 3	Planning and Research
Sara Kowal	DSS2	BIS
George Kirlin	Telecom Specialist	Information Systems
Todd Kravits	District Traffic Engineer	District 11
	Site Administrator	Equipment Division, District 2
Kamie Downen	Project Coordinator	Business Information Systems
Michael Taylor	Database Administrator for GIS	Bureau of Planning and Research
Colin McClenahan	Roadway Program Tech 2	BOMO
Donald H. Kirschman	Manager, Data Administration	BIS
		PennDOT
Frank Cippel	Civil Engineer Manager	District 11
Thomas TenEyck	Director, Bureau of Planning and Research	Bureau of Planning and Research
Rod Irvin	RoadWay Programs Manager	BOMO
Patricia Shinaberger	County Maintenance Manager	McKean/Elk County
Michael H Stamm	Sign Shop Supervisor	BHSTE
		Bureau of Maintenance & Operations
Doreen Wallen	Applications Developer	BIS
Mike Hammond	Assistant County Maintenance Manager	PennDOT District 1-5
John W. Smith	County Maintenance Manager	District 8-0
John Seiders	Clerk Typist 2	Equipment Division
Guy F. Mahosky	Maint. Mgr	Penn Dot 0370
Jon Fleming		BOMO
Larry Allen	Highway Equipment Manager	BOMO
Kristen Rodkey	Roadway Program Technician 2	BOMO
Stephen J. Shimko	District Executive	District 4-0
Gaye Liddick	Trans. Planning Manager	Planning and Research
		Maintenance & Operations
Jim Scalise	Application Developer 2	BIS
Ron Hoover	IT Technician	BIS
		BOMO

1. What is your name?	2. What is your job title?	3. What PennDOT Bureau, PennDOT District, or other agency do you work for?
jason spangler	Western Regional Fleet Advisor	4610 Eq, Division
John Stencovage	Computer Operator Supervisor	BIS
Bill Monstrola	District Manager	District 12
		MAINTENANCE DIST 8
Phillip Yannotti	SHMM	Transportation 1120 and 1140
Bob Skrak	Butler County Manager	District 10
Ted Deptula	County Manager	0340 Northumberland County
Karen Dussinger	CRC	District 4-0
Tom	Application Developer Supervisor	BIS
Frank Barone	Senior County Maintenance Manager	560
Larry Lentz	Sr. Traffic Control Specialist	Highway Safety and Traffic Eng.
Greg Penny	Community Relations Coordinator	PennDOT Engineering District 8
William J. Laubach	Traffic Control Specialist Manager	Bureau of Highway Safety and Traffic Engineering
Neil Cheers	TCSS	District 1-0
Larry Bilotto	Maint Prog Engr / RWIS Coord	District 9-0
Steve Stevenson	ACMM	DISTRICT 2 - MAINTENANCE
Martin J. Ferguson	County Maintenance Manager	Maintenance District 1030
Ted Zurla	Wayne Co Mgr	460
Tom Hofer	County Maint. Mgr.	District 9
Robert B. Kennedy Jr.	Regional Maintenance Advisor	Transportation Central Office BOMO
Kim Reese	CMM	Clearfield County PennDOT
Scott Majot	County Maintenance Manger	Maintenance
Andrea Bahoric	Transportation Planning Manager	Bureau of Planning and Research
michael rebert	sr. highway maint. mgr.--chester county manager	district 6
William Hook	IT Manager	District 11-0
Marie Stump	Roadway Program Coordinator	Transportation
James Griffin	Rdwy. Pgms. Mgr. 1	BOMO
glenn rowe	traffic engr. and operation	BHSTE
Marc Schmiedel	Traffic Control Tech	District 8-0 ITS unit
Developer	Developer	BIS
Keith D. Williams	Assistant Traffic Engineer/ITS Coordinator	District 4, Maint. Division, Traffic Unit
Jeff Breen	CMM	District 12-4
Mike Budzanoski	RPT	District 12-4



1. What is your name?	2. What is your job title?	3. What PennDOT Bureau, PennDOT District, or other agency do you work for?
GWHESS	Emergency Management Specialist	BHSTE
Douglas Yacoboski	Assistant County Maintenance Manager	Maintenance/District 4/Luzerne County/0430
Frank DeSendi	Planning Division Manager	Planning and Research
bob crawford	County manager	District 11-1
Dennis Toomey	District Traffic Engineer	District 5-0
Sue Klouser	Clerical Supervisor	Bureau of Highway Safety
Joe Dubovi, III	District Executive	District 10-0
John Breon	Applications Developer Administrator	Bureau of Information Systems
John Lizza	Radio Operator	Maintenance Dist. 1210
Floyd Keefer	Roadway Program Coordinator	District 2/0
Dave Matheson	ACMM	District 2-8
Terry Snyder	Roadway Program Specialist	BHSTE
Greg Sayers	Assistant County Maint. Mgr.	Clearfield County
Barry Bentz	Equipment Operator Instructor	Bomo, Equipment Division
Dave Adams	HEM II	4610 Eq div
Robert Conrad	Traffic Control Specialist	District 8-0
Scott Chronister	RPC	Trans/0800/0840
Rick Mason	community relations coordinator II	District 3-0
Brent Piccola	Roadway Programs Coordinator	Armstrong County
Chris	Senior Civil Engineer	BOMO
ron bonacci	Dist Traffic Engr	District 4-0
A.J. Stambaugh	Acting County Manager	Cumberland County Maintenance
Laine Heltebridle	Transportation Planning Division Manager	Bureau of Planning and Research
Ryan Succheralli	District Roadside Specialist	District 10
George Reiegl	Roadway Programs Technician II	Cumberland Maintenance
Brian Leighow	County Manager	District 3-0
ROBERT NOLL	ASSISTANT COUNTY MANAGER	9-4 FULTON COUNTY
Karen Saul	Applications Developer 3	Bureau of Information Systems
Ken Swezey	Assistant Maintenance Manager	District 8, Lancaster County
jack hocker	rpc	penndot lancaster county
George J. Cole	Sr. Hwy. Maint. manager	Dist. 6--Montgomery County
Lisa Marsh	RPS	District 9-3

1. What is your name?	2. What is your job title?	3. What PennDOT Bureau, PennDOT District, or other agency do you work for?
Donna Sylvain	Computer Operator 2	PennDOT BIS
Richard Albert	District Maintenance Manager	PennDOT District 10-0
steven sansoni	senior highway maintenance mngr	maintenance, 0630
Joseph Demko	Roadside Manager	BOMO
Jimmy Adams	machinist	BOMO
Elwood Litvin	ACMM	District 4-0 Susquehanna County
Andrew Markunas	Civil Engineer Manager	BHSTE
Dan Storm	County Maintenance Manager	Maintenance District 8-0
DAVID R. WIMER	ASST. HIGHWAY MAINT. MGR.	DISTRICT 8
Nicole Ryan	Internet Unit Manger, Dept Webmaster	BIS
michael schoss	Safety Manager	Dist.11-0
William Shaw	RPC	Dist 3-7
Beth Bonini	Transportation Planning Manager	Rail Freight, Ports and Waterways
Dan Cessna	District Executive	District 11
Robert Joe	Traffic Control Specialist Supv.	District 12-0
Bob Schell	HMM	Maintenance District Mifflin and Juniata County
Wes Hess	Maintenance Operations Manager	District 1-0
Jerry Hartman	RPC	Dist 8-1
Charle Goodhart	ADE-M District 8-0	District 8-0
David R. Jones	roadway Program tec II	District 2-6
charlie webb	assistant hwy maintenance manager	Lancaster Co. Maint
Scott K. Young	Acting Maintenance Services Manager District 1-0	District 1-0 Transportation
Dave Maciak	County Manager	PENNDOT Lackawanna Cty 4-2
Rhonda R. Stankavich	TCT	District 2-0
Ronald Gresko Jr.	ACMM	Maintenance 10-4 Indiana County
Alan Keller	District Traffic Engineer	District 3-0
Kevin Kline	District Executive	District 2-0
Tom Opalka	Assistant Maintenance Coordinator	District 4-0



Other Responses to Question 6:

1. Emergency planning for State Police operations.
2. Use cameras to view traffic.
3. Share with Media
4. personal travel
5. To assist customers find road condition information via our website
6. Would use for work zone performance measurements - and the weather related info can also influence that
7. Information on road conditions for travel to and from work.
8. TCC operations
9. Travelling to and from Harrisburg and home when there's inclement weather.
10. Because of all the major news media and a broad array of roadway cameras the District has not employed RWIS to date. Therefore, my exposure has been limited.
11. Don't use.
12. Winter Services
13. We would like to use traffic data that is collected at RWIS sites.
14. Do not use due to the lack of confidence in the information gathered.
15. communications with our external customers, primarily the media
16. on one in county located at Reeser Summit; WTS usage when it functions
17. Training for equipment operators, Snow academy, and also on the state Emergency team
18. Traveling to work
19. I have used the RWIS system since its inception here in Potter as well as neighboring counties and find it to be a valuable tool for winter storm events. I have placed a monitor in the radio room and have explained the scene data benefits to them. They were disappointed that the RWIS was not functional during the 2006-07 winter. Floyd Keefer
20. None
21. Road Closures - for notification of fatal accidents
22. My PennDOT customers may want to use it
23. Emergency, crisis, and incident management
24. To see road conditions for daily travel to and from work and weekends.
25. To monitor field conditions and to assist in relaying information to my superiors.
26. I don't use RWIS, I am responsible for overseeing the maintenance of it in my District
27. Currently I do not use RWIS but would if traffic data was available
28. I would use the info when coordinating winter activities.
29. Maintaining the system integrity and part of District EOC team
30. To determine weather and road conditions at site of RWIS
31. Also summer weather and traffic.
32. curiosity
33. Check the road conditions in the direction of the storm. Rarely assess the conditions in my own county.
34. NONE LOCATED IN COUNTY
35. NONE
36. Have not used RWIS because so few sites are operational, but RWIS sites in the area of BPR TMS sites could be used to determine traffic flow when remotely diagnosing faulty TMS sites.
37. I used to use it to let vendors know what the conditions are in the winter if they were delivering equipment to PA.
38. Review road conditions during state wide travel due to work assignments.
39. We do not use RWIS in McKean/Elk. System never worked in McKean, In Elk, the equipment was destroyed in a severe storm and we could not replace due to costs
40. We do statewide pavement testing year round and I really need to know the road and subsurface conditions.
41. check of roadway conditions for field survey operations.
42. We use the highways to train equipment operators
43. Support role in making the service available and to work with the service provider and PennDOT

7. What weather data provided by the existing RWIS program do you utilize (check all that apply)?

	Response Percent	Response Total
Air Temp	85.2%	69
Surface Temp	86.4%	70
Surface Condition	86.4%	70
Sub Grade Temp	42%	34
Precipitation	86.4%	70
Dew Point	27.2%	22
ADI Agent Index	22.2%	18
Freeze point	45.7%	37
Wind Speed	55.6%	45
Total Respondents		81
(skipped this question)		50

8. Are there other forms of weather or traffic data that you would like to see collected (please describe)?

	Response Percent	Response Total
Subsurface Temperature	20.2%	21
Precipitation Type	55.8%	58
Precipitation Rate or Intensity	55.8%	58
Precipitation Accumulation	62.5%	65
Visibility	55.8%	58
Ice Percentage	36.5%	38
Depth of Water Layer	17.3%	18
Relative Humidity	26.9%	28
Barometric Pressure	13.5%	14
Wind Direction	35.6%	37
Wind Gusts	34.6%	36
Traffic Volume	66.3%	69
Traffic Speed	68.3%	71
Video Imaging	73.1%	76
Other (please specify)	19.2%	20
Total Respondents		104
(skipped this question)		27

Other Responses to Question 8:

1. Some we already have.
2. We are very fortunate to have nearly 100 cameras throughout the Pittsburgh Metro. I do believe that additional RWIS sites with cameras or even just additional cameras will continue to improve our ability to manage or major transportation network.
3. Delay times (or travel times over base conditions)
4. Highway closures and congestions.
5. None.
6. Pan and zoom on cameras would provide verification of traffic, road conditions first hand and be accurate.
7. All of the above would be nice once they function
8. Yes...Split scenes, adjacent counties(directional)...Please contact me.
9. all video would be helpful the more camera's the better-camera's must work video not snap shots
10. Weather modelling across the state
11. WEBCAM! I have been trying to use the webcam but they seem to be down 95% of the time for maintenance.
12. Traffic Classification Data, all 13 FHWA Vehicle Classifications. All traffic information archived.

13. Multiple sites linked together so we can determine the size and movement of a storm, among other reasons.
14. It already handles some of these
15. NONE
16. Streaming Video, traffic sensors in all lanes and archiving of data. These sites could be used as continuous traffic monitoring sites for planning and reporting purposes if sensors and data archiving were added. Additionally there are relatively inexpensive portable systems available for real time traffic monitoring and queue detection that could be used by the Districts on projects during the construction season and then strategically deployed throughout the district during winter maintenance.
17. All of #7
18. I would like to see the history tables saved again. It was a very useful tool in After Actions Reviews. Currently we have no data being saved.
19. WE WOULD USE EVERYTHING YOU PROVIDE THAT IS IN WORKING CONDITION
20. Also vehicle classification, and perhaps truck weights. Traffic data would need to be archived for long term use.

9. How could the information collected be better disseminated (please describe)?

1. The internet/intranet is probably the best way. Internet site with specific information for the public, and intranet site with specific information for PennDOT users.
2. we need quicker and better links on or website to this info. Easy access would help everyone.
3. Access from various location, internet for foreman at stockpiles, other ACMM from home, etc.
4. Emailed updates for changing conditions for example when the pavement temp drops below freezing, or traffic slows to 15 mph.
5. Ability to get the information to the satellites and outlying stockpiles via computer stations/kiosks. It loses quality via fax and inhibits any type of trend analysis or timelines associated with time, duration, etc.
6. Should be web based and real time. Should be accessible via blackberry's or other mobile devices. Should provide to private sector for their use. Should be put on an internet site along with road condition data so customers can access.
7. Real time information on the desktop PC. Make use of cable or satellite for communications. Dial up modems? Phone lines in remote locations? This is the main reason why the sites are down.
8. I have had experience over 10 years with RWIS and rarely found the data provided from the sensors to be accurate enough to use for effective winter storm management. Possibly, we reduce the number of outputs and concentrate on making a smaller system more accurate and effective.
9. Temperature and freeze point displayed directly on a large information board as you enter the county on the major highways.
10. WEB based is ok but finding it wasn't easy. The system was mostly down, hardly any of the sites were working.
11. Website needs to be up to date and easily navigated to find information
12. ALL SITES SHOULD WORK!
13. right now we do not have any of these devices in Adams county. If some were strategically placed at the state line and also to my west, it would allow us to see what is coming to us and give us a way to more efficiently have our people out before it hits us.
14. Internet (web-based app) would work well for all users if the system is designed well and maintained
15. Location on the PennDOT Website is fine.
16. Info should be promptly distributed to local radio and tv stations when problems exist to alert motorists. Automated e-mails or cell text messages when data indicates a possible problem.
17. Real-time website; send alerts when certain conditions are met: freezing precipitation, freezing pavement, major changes in traffic speed, etc.
18. Field access by Foremen and AMM via air card when in the field.
19. 1-800 number with up-to-the-minute information.
20. the system needs to work
21. Change to format to give the proper information.
22. Use the system in place but have it up and functioning.
23. High speed internet connection. The current dial-up is antiquated and faulty. Monitors with some information at District level as well as County level. Command center style.
24. It would be nice if the data collected would be real time information. The department website displays data that is one hour old.
25. Improve the accuracy first then worry about how to better disseminate.
26. Text messages, HAR's, media, kiosks and internet/intranet RWIS message board displaying for example air and surface temp when "ice is possible", fog ahead, queued traffic etc
27. Accessing the info from the PennDOT website is fine as long as it is accurate information.
28. By making the RWIS stations more reliable.
29. e-mail or intranet
30. More real-time data.

31. Real time data to the counties not through District or Central offices the counties need the info before anyone else when you call up the sites the data is not always current.
32. Agency wide email with alerts
33. Additional monitors as in # 6 above.
34. I think it's fine the way it is.
35. On Road Closures knowing exactly what county the accident occurred in when the road closure spans over 2 counties.
36. Intranet
37. First thing we always have a problem with RWIS. Every time we go to use it, it is down. But if it would work it would be a good tool for all of our needs, weather, precip, etc
38. Make available as real time as possible to maintenance, emergency response, and others via web interface.
39. There needs to be more real-time data. There is no way for a department employee to poll the site for instant data without having direct access to the polling computer. There are plans to monitor these sites in a 24 hour traffic operation center.
40. Real-time web based application. Traffic volume and speed may indicate an incident. All weather data is invaluable for HAZMAT plume plotting as well as serious weather response.
41. IF THE THING WORKED MORE OFTEN
42. all camera's on the internet
43. More sites combine with existing weather gathering sites (intellicast, NOAA, etc)
44. REAL TIME info to be accessed from any computer with a web connection.
45. Insure the system is reliable, always seemed to be down, rendering it unreliable. Equip field personnel with wireless technologies (wireless laptops with hi-speed/DSL capability) for instant access to RWIS info.
46. Be able to access from my desk.
47. Making it known what data is available and how it can be used, marketing, websites.
48. Enable the foreman to access all pertinent information from their laptops at the stockpiles. This will enable them to better fight the storm.
49. I have no idea how to access the present info.
50. Periodic e-mails to county radio operators would bring information to someone who could monitor changes and be alerted to condition changes.
51. Keep the sites functioning
52. The information collected is not hard to access but we have found that much of this information is not valid or is not updated frequently enough.
53. The information is disseminated ok now with computers in the county offices. The public has a link to the site also. If someone wants the info they will go to a single collection point.
54. website is sufficient as long as the data collected is more closer to real time!
55. The existing web site works well.
56. A good website.
57. RWIS could be programmed automatically to send information by email when certain thresholds are reached (such as air pavement temperature) so as to alert recipients of the emails of new conditions reached.
58. through the web
59. Camera and video are very important. The ability to visualize what the weather or traffic look like is important.
60. A regular report PUSHED from a central location. We could subscribe to geographical areas or District-related locations, then receive by email a PUSHED form with pertinent info.
61. Web page is fine as long as it is accessible.
62. We need RWIS sites that give good data. The current ones we have in 1020 are not functioning and are constantly broken.
63. NOT SURE, NONE CURRENTLY IN COUNTY
64. up grade technology
65. N/A
66. advertise. I currently don't know how to access RWIS.

67. Automatic email message to those wanting the information.(They must provide you with their email address)
68. Add a Traveler Information icon/link to the PAPowerPort for accessing RWIS, ITS and TCC info, construction maps, rest area locations, the road closure application, state police locations, information phone numbers, and PTC traveler info which are scattered about the web at this time. This link could also be added to PennDOT's Internet and Intranet home pages.
69. The county supervisory staff and radio operators should be required to check data on own if we could trust the information.
70. easily accessible website
71. ?
72. We have three different systems in the county and have to look at three different computer screens. Let's put everything in a common format or GUI, update it in a timely manner, and train people how to use it. The web page is alright if it is realtime data, unfortunately it is not.
73. RWIS information could be gathered and then made available in a data warehouse structure for trending analysis.
74. Internet
- 10. How could RWIS be better integrated into your key decision making processes (please describe)?**
1. It would be useful for assistant managers and foremen to have access to the trends in the subgrade, pavement and air temps and not just the current conditions. This option is available at the coordinator level, but I don't believe it is available to all RWIS users.
2. Keep the system up and running by having all sites operational and maintained.
3. It could be dependable. As a rule I believe our district does not utilize this information very much due to the RWIS sites are non-functional.
4. Ability to watch / read the information on weather changes, temp.,precip.,subgrade temp.,etc.
5. During winter maintenance, use RWIS to verify and monitor actual conditions instead of relying on differing opinions. This could be used to help make the decision to divert resources to the interstate before conditions deteriorate and tie ups occur.
6. It already is.Another tool to validate what we receive locally from our area Doppler Services. The truth is always somewhere in between. When you can overlay enough sources it does become somewhat clear.
7. We should be able to key on certain sites for advance warning of certain predetermined conditions. similar to a weather bug. If condition is met would flash on screen for attention.
8. It hasn't worked reliably for years. This should be combined with a maintenance decision support system like FHWA is developing. Must include weather forecasting and nowcast also. RWIS assists managers with making key decisions during winter storm events. It will only be used if data is real time, accurate and system is reliable.
9. The system needs to be functioning and accurate most of the time before managers and supervisors will take the time to look at the info. When the systems are down more than up you tend to make use of other tools.
10. RWIS needs to operate in a more efficient manner instead of being down numerous times in the past
11. I rarely get involved in operational decision making for winter storms in my current capacity, as the appropriate staff are empowered to make these decisions. We do review exception based reporting to determine opportunities for improvement.
12. Make it easier to access directly instead of having to make a call to the district office and connect to another computer to access the information.
13. n/A
14. ALL SITES SHOULD WORK!
15. See previous box
16. If expanded to include traffic volume and travel time (vehicle speed data) the potential exists that this system can be part of daily operations for all work zone and traffic managers
17. Send alerts when precipitation occurs during herbicide spray operations, winter weather events, flooding.

75. HAVE ALL EQUIPMENT IN PLACE AND WORKING
 76. Model our RWIS site to be like Ohio's RWIS Site. Ohio has an excellent RWIS site that gives you a large amount of information that could be very usefull internally as well as externally to the public.
 77. A web site.....but not just real time information. A data base with archived information and location referencing to be able to tie to GIS applications and other mapping initiatives. Also a data manager would seem to be a necessity.
 78. Data can be collected from multiple PennDOT and even other state or federal data sources into an integrated data warehouse.
 79. Have it up and running. Include a link on PennDOT's main website, not just district sites.
 80. Sharing how/where to get the information.
 81. N/A
 82. Insure the current units are up and running I dont think I need anything other than access.
 83. real time
18. relaying real time weather, traffic and video info to county office which in turn would assist management staff in making better decisions to changing weather, traffic conditions, etc.
 19. If the AMM and Foremen had air cards for their lap tops they could access the sites in the field and use the information in a more timely manner. Also, they would be able to validate what the site is telling us compared to what is actually there.
 20. TV and radio station notifications should work day be cancelled or delayed for inclement weather BEFORE 04:00 AM. Some workers are already travelling to job sites by 05:00 AM and it would be nice to know if work will be closed before setting out.
 21. you could monitor conditions in adjacent counties
 22. Get the information directly to each assistant.
 23. WE USE IT PRIMARY FOR CHECKING THE GROUND TEMPERATYRE AND THE SUB-GROUND TEMP FOR FREEZING RAIN
 24. 1. Call out decisions (winter services) 2. Being aware of temperature changes to our west. 3. Knowing what is really happening on the ground. The radar image often shows weather but it is not always hitting the ground.
 25. More sites
 26. County management does not rely on the RWIS sites due to lack of accuracy and reliability. I think with improved accuracy and liability it would be sold to the county management team.
 27. If traffic data was archived, it would be useful and could be stored with other traffic data collected by our Bureau.
 28. See #9.
 29. By providing accurate and reliable info. and being operational. As an ITS componant bring it into TMC's
 30. Make sure sites are working properly and producing real time information.
 31. N/A
 32. more locations through out county; basicly the interstates and interstate look-a-likes
 33. With real-time data we could activate message boards for changing roadway conditions,
 34. e-mail alerts to our phones as needed.
 35. We need to have the pre-winter and after action reviews like we did at the onset of RWIS before I could answer this question.
 36. I could like to see how many trucks we need out in the county for patrol during the winter. We could also see if the road way is good to chip or mech patch, example when the rain is coming into the county. Is the roadway dry yet from the last storm.
 37. I use it to evaluate ground conditions beneath the radar images readily available over the internet, for verification of conditions in a call out situation, to assess traffic backlog distances, and overall weather conditions.
 38. Available as a webb application accessible from the State Emergency Operations Center as well as from home before a response gets out of hand. The National Weather Service would also be very interested in the data, especially real-time.

39. They need to work
40. Auto start of ITS deployments...ie RWIS senses fog which triggers VMS message. Future potential to marry with variable speed limits.
41. Again REAL TIME info to be accessed from any computer with a web connection.
42. make it more dependable
43. If available it would be useful for winter operations and certain summer operations.
44. If traffic data was available (archived capabilities), it would help to enhance the Traffic Division with more data and also update RMS. If the data is archived in a useable format, it would be included in our reporting to FHWA, used in determining our growth factors, etc.
45. One site per-county is not enough. If we could group sites together and get a clearer picture of the storm would be an excellent way to move the crews where they are needed.
46. Advance warning of changing conditions, water to ice condition.
47. Information from RWIS and other sources is used to determine when to call crews out or to send them home.
48. Keep the nsites functioning
49. Again, the system has provided us with false readings which hamper us in our decision making process. If we are not provided accurate / correct / up to date information our faith in the system is corrupted. Sensors have provided us with false readings.
50. we use the information to make real time decisions. That's why we need real time input.
51. Real Time DATA!
52. Provide accurate information and reliable equipment, will greatly increase its use and usefulness.
53. RWIS would first need to prove itself reliable. That hasn't happened over the past 10 years. Secondly, it will only be a factor in the decision making – and perhaps a small one at that since there are only a few installations to take into consideration in the counties where they are located. Also, not all RWIS stations are strategically located – which undermines their value.
54. Will there be an integration with RCRS or any other CENTRAL info center? I would not want to receive disjointed info that would not be connected to other info-sharing sources. It MUST be integrated!!
55. Chart the time precipitation starts and stops. If RWIS was up and running properly, it would be used more often.
56. the data would be helpful if you could trust it.
57. When to Anti-ice. When to have winter patrols out.
58. IT WOULD ALLOW US TO MAKE REAL TIME DECISIONS
59. If used appropriately you can view counties which would get storm in advance of your location .use their info as a time line as to when storm should hit your area the intensity and ending time I've done this and it works

11. How could the information collected be better disseminated to the public (please describe)?

1. The website could use a facelift, but the way it is already set up on the internet is probably the best way to disseminate the information.
2. Easy access on PennDOT's website.
3. The equipment needs to work, and be dependable.
4. Access on internet, video imaging, Weather Band, etc.
5. I'm not an expert in this subject area but do see an application with tying it into Variable Message Boards, Highway Advisory Radios, etc. I do know with working with the County Emergency Management group that they have the ability to place a ribbon on the bottom of TV telecasts and Radio advisements so quite possibly the information could be shared with them as well in a more proactive role.
6. See answer to 9 above.
7. Real time information on the desktop PC.
8. Better access through the website and media. We currently have agreements with media for use of our video feeds for traffic related cameras. Perhaps we could do the same for these cameras.
9. Same as 9 above.
10. Easier access through the web. A more common link (name) that the general public would recognize.
11. see #9

60. N/A
61. A link could be added to our Divisions business application but it has not been done due to the condition of the RWIS system.
62. If data is reliable, the information provided would be of great benefit in winter decision making process.
63. Reliability and through better visual output through the camera system. All cameras to be color, better resolution, visual images depicting a broader section of the highway to help assess type of traffic and visual volumes
64. The more accurate data; the more informed the decision. Real Time Data would be ideal for deciding how much, when and where is greatest need.
65. Most RWIS sites are placed in a sunny area. You have to keep that in mind when you are using the data. I have used this data, when I trusted it, to determine if I should call crews out. The RWIS is only one tool to use in making decisions. We also look at the radar, forecast, and call other counties. RWIS does let you know the surface temp and if there is precipitation. I would consider these factors as well as the rest of the ambient conditions at the site. We also look at Ohio RWIS data to help make decisions.
66. Allow to receive advance weather conditions when planning travel activities.
67. HAVE ALL EQUIPMENT IN PLACE AND WORKING
68. Yes, we have a need to do certain types of pavement testing at very precise temperatures. We have a great need for surface and subgrade temperatures to plan our testing requirements and scheduling.
69. RWIS would need to be integrated into a comprehensive data collection initiative that looked at weather, traffic, trucks, and the ITS sites and data. I don't believe looking at RWIS alone is a solid strategy.
70. Often, the system is down... so it is not a reliable source of input.
71. It has been in the past and would still be in the future, if it is working and updated regularly.
72. By integrating into some sort of website or on desktop. I don't even know what RWIS is, honestly. Never heard of it but it seems to be interesting and something I would use.
73. the information should be reliable and easily accessible to the folks in the Regional Traffic Management Centers or somehow be integrated into the ATMS platform being rolled out statewide
74. N/A
75. RWIS would only make up a small part of our decision making process. With the limited number of units and the vast areas and miles of roadway we are responsible for we utilize the internet and local forecasting far more than anything RWIS provides.
76. reliable up to date info

12. Give the public an easy route to access this info on our website, then make sure the navigation areas to access the particular area are easy to get to also.
13. Again, the internet would be fine (as described above), but there needs to be a better link from the PennDOT home page (which is horribly designed)
14. Automated e-mails or cell text messages to local radio and tv stations when data indicated problems on roadways.
15. Provide video, precipitation, freezing conditions, visibility, traffic speed on a public web site.
16. by relaying this info to district press office
17. Someone that thoroughly understands the data should disseminate what the data is telling us and put that out to the public.
18. Please see my answer to No. 10. above.
19. it should work
20. unknown
21. 1. Using the system in place. 2. The information is more helpful to internal customers than external.
22. Real time information on the department website. If you are traveling and rely on these sites for weather and road conditions an hour is a world of difference.
23. Have links on the PennDOT website in addition to the links on the State website.

24. Refer to item 9
25. The PennDOT website is fine.
26. Only by making it more reliable, would I then promote its availability through the media.
27. internet and news media
28. See # 10
29. do not worry about this the current way of the public access to the info is fine.
30. Media communication. There was not enough publicity of internet access to RWIS so that the public knew it was out there for their use.
31. Knowing the condition of the roadway during ice and snow storms. In some areas where there could be flooding they will know that and then could bypass that area.
32. Make available as real time as possible via weather interface.
33. There needs to be more realtime data.
34. Maybe all doesn't need to be available to the public
35. In general I say yes.
36. Again, I stress, REAL TIME info to be accessed from any computer with a web connection.
37. easy web access
38. Install safeguards and hold your contractors responsible for system performance.
39. Access to a website with up to date information. Making the public aware that this information is available. Keeping the sites up and running.
40. Via the internet.
41. From the PennDOT Website, let them know of the conditions on a section of roadway, as other DOT's do.
42. unsure
43. Internet if the site were up and running but they are usually down
44. It is accessible over the internet. Communication of this to the public would benefit. Again, it needs to be providing correct information.
45. I think the links from all the state agencies and the media are enough.
46. website, to tv / radio would be fine
47. I do not know.
48. A good wesite and 511.
49. Make available by website to the media and the general public. Provide the capability for automatic updates for those who elect to subscribe to the service.
50. make sure they info is correct
51. 4-0 Has an opt-in email and text messaging service, but that only covers a fraction of the public. Could it be a subscription to public

12. Is there a need to combine RWIS data with other information sources to create enterprise solutions (software solutions that combine multiple data sources and allow multiple uses) (please describe)?

1. It would be ideal to integrate the RWIS system with the message boards in some way. The RWIS system could pick up information and "talk" to the message boards. I think the Turnpike has done this in one area where there are problems with fog. Fog is picked up by the sensors and a message is automatically displayed on a message board to warn motorists. This could be useful for pavement conditions as well as traffic speeds. This would speed up the process of providing timely information to the public.
2. Not sure.
3. Use as data collection for various comparisons among storm events, with material used (Winter Material Database) to treat roadway to maintain passable roads.
4. Absolutely as pointed out in question in #10.
5. See answer to 10 above.
6. RWIS sites should have the ability to integrate with software that changes VMS and HAR's.
7. Yes, we are severely hampered in the District with lack of access to server capacity to operate and manage some systems. Progress is being made on this front, but not fast enough. We have to be careful not to create too many District standalone systems, but we need to balance that with allowing innovation at local levels which can be

- and/or media as other weather forecasting services are? The thing is, info would need to be "translated" into layman's terms, not necessarily in transportation jargon if it would be opened up that way.
52. Public should have access to web site. Web site should be promoted if it works properly.
 53. The web sites are fine.
 54. Public web sites.
 55. combine it with the RCRS that way they have one location to view all conditions
 56. N/A
 57. Same as number 9 above. Also by using radio and TV stations in a timely manner.
 58. See response to Question 9 then provide marketing to the media and post on VMSS.
 59. Make information available via internet.
 60. easily accessible website
 61. Website
 62. generic web information to the public, more indepth information pertaining to the ADI, and precip info, etc. only accessible to PennDOT
 63. ?
 64. The web page is only useful if it is reasonably up-to-date data and they can access the internet. Message boards that are triggered off the data to display certain meesages could be useful.
 65. A simple map on a website with RWIS stations on it that could be clicked for information would be helpful. Also, the ability to select a specific road and see all RWIS stations on that road would be helpful.
 66. Local news and internet access.
 67. HAVE ALL EQUIPMENT IN PLACE AND WORKING
 68. Once again, model our RWIS site to be like Ohio's.
 69. The information could become part of our District 11 website that shows the traffic cameras.
 70. Make sure the website is available to the customers, media, employees, etc. Make it user friendly... and easy to access.
 71. *Give access to the link on local news media websites. *Post web link on PennDOT's traffic advisory information boards (DMS) when no major events are ocuring.
 72. Internet and Intelligent Transportation Systems.
 73. Website, email ... on the news, in the newspaper ... basic media marketing.
 74. via the Department's website
 75. As it is today on the internet.
 76. real time info with internet access

- further rolled into statewide solutions. Rarely do the best innovations in operations come from the top down, they come from our line staff involved in operations and this needs to be encouraged and facilitated.
8. An automatic recording device connected to the rwis system that can have the current information available and accessed by a phone call at any time. This would be handy for our foremen in the stocking areas to get current weather conditions.
 9. a one stop shop would be nice for the public - combined with RCRS, for example..instead of have multiple links for me to post during the seasons.
 10. NO
 11. When a TCC is operational in district 8 they could be monitoring the RWIS for impending storms and email to the county contacts.
 12. Yes, integrate with traffic data (speed, volume, to calculate travel times and to estimate delay)
 13. RWIS data should be able to layer over the Peirs mapping and/or DOT systems like RMS, RCRS, etc.
 14. NO
 15. Combine it with TRAFFAX.
 16. There is a need for this but I would not know how to go about doing it.
 17. SHOULD HAVE SOME KIND OF ALERT SYSTEM THAT SENDS MESSAGES TO OFFICE WHAN TEMPS ARE AROUND FREEZING



18. I am not real computer fan. Too much information together is not always better for field use. We need the basic information. Is it snowing and how cold is it.
19. Since we are installing the message boards along the interstates it would be nice if the RWIS systems could "talk" to the VMI's and display a message that contained weather and road conditions. Also traffic speed and volume would be a great tool for winter operations.
20. Archiving the traffic data that is collected would be beneficial for our use.
21. All data should be seamless and be available for our internal and external customers
22. I think if you just have links to the other sites it would aid in decision making.
23. Don't know.
24. yes; if intrgrated with local weather sources and news; would provide a more comprehensive coverage system
25. we need to focus on good data before we worry about the need to combine the data
26. Not at this time.
27. User friendly display for Operations Center
28. I would prefer to see the raw data.
29. Maybe RCRS.
30. In general I say yes.
31. Absolutely. The ideal system would integrate RWIS with other data&information sources (i.e. NWS radar, satellite imagery, local roadway reports) into a user-friendly system. This will enable all levels, from county radio operators to District/Central Office management, to analyze and communicate conditions based on common data sources. Integration of the status and forecasting of traffic flow should somehow be developed. For example, if there is a problem at an RWIS site where traffic is backing up due to an accident a warning should be posted for all RWIS sites that can be affected by that backup. Also, warnings posted on VMS systems should be able to be viewed as well for all affected areas. Keep up with the mobile technology.
32. Yes. Some people will just be interested with current congestion for travel purposes, others may want to know weather information for the area, and others want to know peak travel/congestion times, etc.
33. You could gather information from multiple site throughout a county and a program develope a view of what the storm is doing in a specific location and also help determin what the storm is going to do. It could also flash a warning on our computers when the weather is changing in a certin area.
34. Winter Activities, Traffic Volume, Back ups.
35. Radar images of rain/snow events are useful to determine tracks and speed of storms. This coupled with RWIS information supply the information we need for decisions related to snow removal.
36. No.
37. no
38. I do not know.
39. Yes.
40. ABSOLUTELY! See above reference to RCRS, etc. or future-planned traffic/incident management centers. Other ITS sources should be located within proximity to ensure that info is coordinated (video matches weather matches road surface readings in a geo location,

- etc.) There must be a way to provide a uniform and true profile of representative areas.
41. Not that I'm aware of. RWIS will give real time weather information. Internet weather sites give past data (radar) and forecasts (educated guesses). The use of RWIS in conjunction with internet weather sites can help make good decisions.
42. I don't think so.
43. N/A
44. Of course. The District, BHSTE and BPR share similar needs for traffic information and collect information from similar but seperately managed roadside facilities. The consolidation of the RWIS, ITS and continuous traffic monitoring sites would create one program where shared expertise in operation and maintenance could be utilized to enhance all the systems.
45. no
46. yes
47. Yes. The more accurate data; the more informed the decision.
48. If you are talking about a site that combines RWIS data with the local weather radar and forecast, that might be a useful tool. If you are talking about some kind of a payroll data/RWIS data combination, it is food for thought.
49. Absolutely! RWIS data combined with crash information, roadway maintenance information, bridge information, APRAS routing information, state police citation information, river stage information (to predict bridge and roadway flooding and deterioration), etc. Then all these should be available to GIS to provide a map to show this data visually - a picture is worth a thousand words.
50. HAVE ALL EQUIPMENT IN PLACE AND WORKING
51. RWIS should be totally integrated with GIS to let the user choose different map layers and features along with RWIS sensors. The GIS maps should be the major navigation tool for RWIS.
52. Of course. RWIS sites(BOMO managed)can be combined with the ATR (automatic traffic recorder) sites (63 of them statewide)(BPR managed) and the ITS sites (BHSTE managed), to form a comprehensive data collection system.....tied to GIS...with single management and with a single maintenance contract. Software solutions can then look at many crosscutting data sources as the needs arise.
53. Weather data can be combined with other data from key PennDOT and other systems, including accident, materials, maintenance, state police reports, traffic and others. Some vital research and planning could be conducted.
54. Could be combined with GIS and Vedio Log internet applications.
55. If I knew exactly what RWIS did and how to use it I could definitely come up with some suggestions to this question. But in general, creating enterprise solutions should be a goal. Stovepipe systems do not stick around. People dont know about it, funding dries up and even if it was useful, it goes.
56. the information should be reliable and easily accessible to the folks in the Regional Traffic Management Centers or somehow be integrated into the ATMS platform being rooled out statewide
57. Not sure.
58. I dont think so the majority of the information I need I can obtain from the INTERNET FOR FREE.
59. in traffic operation center

13. Please Rank where RWIS sites should be deployed?				
	First	Second	Third	Response Average
Regular intervals on major freeways and arterials	57% (67)	29% (34)	14% (17)	1.58
Areas with higher than normal weather related crashes	45% (52)	37% (43)	17% (20)	1.72
Co-located sites with other intelligent transportation systems (ITS) such as Dynamic Messages Signs (DMS) and CCTV	24% (27)	29% (32)	47% (52)	2.23
			Total Respondents	119
			(skipped this question)	12



14. Please provide any additional feedback regarding the future direction of the RWIS program at PennDOT.

1. RWIS sites should be located at "hot spot" problem areas as determined by our maintenance crews. Hills, shady areas, areas with high winds, or anywhere there has been a history of winter maintenance problems.
2. I would suggest a representative from each District to guide this along as we know from history one size doesn't fit all. The geographical considerations from each District could be considered this way. Please feel free to contact me at (814) 678-7149 should any further clarification be necessary. Thank you.....Scott
3. System needs have automatic notification process incorporated so preselected conditions would trigger a warning or notification to computer asking for notification.
4. We need to first develop a winter services strategic plan and see how RWIS fits into this plan. RWIS should be combined with ITS and our traffic data recoding network.
5. Weather related crashes would be best controlled by other maintenance options. More than knowing about conditions...treating conditions that historically happen in the same areas.
6. Would be more of a benefit if it would be able to provide accurate information.
7. Again, we need to be careful not to over react and create a system that is so sophisticated that our folks just don't bother using it. Focus on a core feature system and make it work. Look at what is working in other states with similar conditions. Establish an effective measurement system for operations and provide statewide oversight for the maintenance of the system. Something this unique cannot be solely managed locally. We all need to not forget that winter operations are as much an art as a science. Our desire to over technify our winter maintenance will not take away from the fact that our success is the result of good information in the hands of key decision makers at the right time and those decision makers making effective decisions and mobilizing resources effectively for the situation. Additionally, folks must be empowered to make changes in operations when the protocol is not working. We cannot, as a state, manage winter as we have since February 14th or we will spend many times the amount necessary and likely drive our folks crazy resulting in loss of key staff, which in this urban District I simply cannot afford.
8. Automatic reporting to the traveling public by way of information signs along the road.
9. I was disappointed that the system was mostly non-operational and it seems to be in disarray. I logged on to Maryland's system and was immediately connected and the sites were working fine.
10. These could be useful but I think there is a lot of maintenance issues that will be very costly. This expense can't be dealt into the already woeful county budgets!
11. it should be maintained and integrated with other systems
12. Problem with the camera is that when most needed (blizzard conditions) you won't be able to see anything.
13. The taxpayer money used to pay for these systems should not be wasted by letting the maintenance and updates to these systems fall behind. If they are broke get them fixed.
14. The RWIS information gathered would be used by more department personnel at co-located sites to set DMS and utilize TV.
15. The maintenance cost associated with these sites should reside in BOMO.
16. Pursue this area seriously and keep the hardware and software working no matter the weather.
17. none
18. Get it to be up and running and ready for use. It needs to be functional and not in a repair mode when a storm is predicted.
19. Better connectivity. Too much lag time with dial-up phone line.
20. We really need to upgrade all of our equipment. We are working with mid to late 90's software and technology.
21. I think RWIS needs funded out of Central Office instead of county budgets because of shrinking buying power in the counties.
22. Over the years I noticed a significant lack of reliability regarding the RWIS sites in my district. There needs to be a greater commitment

from central office regarding maintenance to ensure the reliability and dependability of these sites, if we are to incorporate them into our toolbox of useful hardware.

23. additional sites and a formal maintenance schedule
24. CCTV's should be PTZ camera's. Not fixed looking at roadway surface.
25. fix what we have before we try to add anything else.
26. A wind storm (downed tree) destroyed Elk Counties only RWIS site three years ago. Funding to replace this site would be needed.
27. As in # 10, we need to get back on track with the pre-winter and after winter action reviews for the county RWIS coordinators.
28. We need the system to be user friendly and be up and running at all times
29. It seems the county never had a lot of input on where the sites were located. The counties should be polled to see where they would locate additional sites if available. I believe an automatic contract for down sites monitored by the vendor to be repaired can be a benefit.
30. We really need to have this info back on line...
31. Maintenance of equipment is VITAL.
32. WEBCAM! I have been trying to use the webcam but they seem to be down 95% of the time for maintenance. Keep the webcam up.
33. The current system needs help. I think that we have learned the maintenance is a long term problem. The Districts need to play more of a role in placement of these devices.
34. I was a county RWIS coordinator in my past position. The system was, and is, totally useless because it is totally unreliable. Good concept, but needs much improvement. I know I would never make a critical decision based on data from an RWIS site. Either hold the vendors and consultants accountable for system performance or junk the system and cut your losses and start over. Hope my honest feedback doesn't get me in trouble, just trying to help after the black eye we ALL took after Feb. 14th.
35. The involvement of other bureaus with the RWIS program could prove beneficial. The Transportation Planning Division has knowledge of traffic data both permanent site and portable sites. We have approx. 80 permanent sites we are responsible for the data and maintenance. We also have experience with maintenance contracts for WIM sites.
36. If you were to group RWIS sites together you could give the public warnings via message boards. This could slow people down and save lives.
37. RWIS sites need to be strategically located and not necessarily always on the interstate. This will allow the tracking of the storms and improve the response times on the interstates. An example is when a storm hits the southern part of my county first, we can deploy equipment to the northern interstate.
38. If maintained could be an additional tool for Winter Activities, the liquid dispensing RWIS systems for problem icy areas would be a large assistance in Winter Activities.
39. Keep the sites functioning. They are down most of the time so we stop using them.
40. Just reiterating what was stated before about the information that is gathered and output information needs to be accurate and up to date. One question that was not asked is in reference to the initial cost and the upkeep of this type of system. County budgets cannot support the high cost associated with the RWIS system.
41. I would like to see them up and running.
42. REAL TIME DATA & VIDEO
43. Either need to fix the sites and properly maintain them, or completely abandon them and craft a different solution.
44. The lack of RWIS availability did not lead to the shut down of I-78, I-81 and I-84 on February 14th. RWIS was irrelevant to what happened. To be more valuable to Department personnel, a more extensive network is needed. Does the Department really want to spend the funds necessary to do this? Wouldn't the funds be better spent elsewhere? Would it not be better to choose locations strategically where needed by county personnel to monitor trouble spots? Please note that the Department was warned repeatedly for years about promoting RWIS to the public before working out all the bugs. Over the past 10 years, RWIS was never reliable over a sustained

period of time; and consequently, RWIS was never promoted to the public by District 8 because it was prone to breakdowns and faulty information. It never became an integral tool in winter services due to its unreliability.

45. I believe more sites are needed, cameras are more important than all the road temperature sensors. Temperature sensors are not needed as often as the camera.

46. I can't tell you how many inquiries I've had to respond to regarding this non-working system. That maintenance was delayed going INTO a winter season is unforgivable. A reliable, predictable and FUNDED schedule of maintenance, replacement and repair needs to be a part of future planning.

47. Interstate and major arterials with existing sites should be maintained. Sites on secondary roads should be removed. This would provide more resources where they are needed and less headaches where they are not. The information on RWIS is more "up-to-date" than information on the internet weather sites such as Accu-Weather, NOAA, etc. However, we don't have to pay anything for the internet. If the internet is used wisely, the same results at PennDOT can be attained. Instead of putting more money into RWIS, train the decision-makers how to use information attained on the internet. This information can be used to determine when to call out crews, how many crew members are needed, when to send the crews home, what strategies to be used for fighting a winter storm (material type and rate). Experience and education can't be bought with RWIS.

48. Get better groundhogs that work.

49. Have them working. I currently do not use them due to them usually being broke in this area of the state.

50. I THINK HAVING THE ABILITY TO VIEW VIDEO IMAGING IN SURROUNDING COUNTIES WOULD BE A BIG HELP IN CALLING OUT OUR CREWS.

51. The reliability of the system has had a negative affect on the people who are suppose to use it...Wwe need to upgrade the system, train those who would use it and show the value it would have to them

52. Get it working!

53. In some areas, we only need cameras not total RWIS information. Need means of maintaining existing sites so data is reliable.

54. Reliability is the key. It would also help to have access internally to a reporting frequency greater than every 2 hours during the winter

months. PennDOT TCC could use updates (easily to access) on the half hour at the minimum for winter emergency operations/PEMA reporting.

55. REAL TIME DATA IS CRITICAL. I do not need to know what it was like a half an hour ago. I need to know NOW.

56. I believe that different areas of the state have different needs or no need for RWIS sites. We have lake effect snows and place the sites where squalls generally come through but spaced out so that you can get the overall picture of the county from the office. We have found the original SSI sites to be the most reliable and easiest to use. I don't feel that video is needed at all the sites and creates a bandwidth problem. We should utilize either a cellular approach, such as Ohio currently has at most of their sites. Or we could use locally available high speed cable or DSL to get real time data to users. I believe there is a need to maintain and upgrade these sites with monies from Central Office.

57. RWIS data has great potential. However if it exists all by itself and isn't combined with data from other systems, it will be just another silo. It's value is multiplied exponentially by combining it with other data sources.

58. HAVE ALL EQUIPMENT IN PLACE AND WORKING

59. I believe RWIS could be a great tool if it had a lot of major improvements. I also believe that RWIS should include sites that just live traffic cams placed at all major highway junctions throughout the state.

60. In my opinion, a comprehensive look at highway data collection (weather, traffic, trucks, congestion etc.), software options, data archiving and management, and site maintenance options is needed...not just a study of RWIS alone. It appears to me some efficiencies would be identified with sites collecting multiple data items.

61. Needs to be reliable and monitored for problems.

62. Please market the system.

63. Before investing more funding we need to determine what we need not what we want. We also need to determine what we will provide to the public. In 2003 based on snow removal needs the MECE group recommended maintaining the system until obsolete and not expanding it.

64. Need to get sites up and running with no lag time for information hour old info is no good to anyone

Appendix G TSOP-06 Roadway Weather Management



Pennsylvania Department of Transportation
Transportation Systems Operations Plan (TSOP)

TSOP-06: Roadway Weather Management

Scope

This project augments PennDOT's existing roadway weather management activities. PennDOT has undertaken several efforts in roadway weather management which include:

- Deploying road weather information systems (RWIS) to monitor road weather conditions throughout the Commonwealth of Pennsylvania.
- Establishing a 'Winter Road Condition Hotline' for interstate highways. This phone service disseminates seasonal statewide road conditions including road closures, detours, alternative routes, work zone/construction events, and road surface conditions.

The purpose of this project is to monitor existing road weather management activities in Pennsylvania and broaden those activities, as it becomes necessary.

Project Needs

- Monitor existing efforts and developing recommendations and conclusions for identifying and implementing appropriate strategies for the future.
- Improve safety and provide motorists will accurate weather information.

Long-Term Goals

- Deploy ITS devices to improve safety along the Pennsylvania highways and arterial roadways.
- Provide motorists with accurate, real-time road weather information.

Near-Term Objectives

- Review best practices and identify any issues or needs relating to roadway weather management strategies and deployments.
- Develop a plan that provides direction for roadway weather management applications across the Commonwealth of Pennsylvania.

Performance Metrics



- Fatality and accident rates due to weather conditions.
- Customer satisfaction surveys of roadway weather traveler information.

Project Oversight

A Project Advisory Panel (PAP) shall oversee this project. Bob Pento will be the Project Manager.

Project Owners

- PennDOT/Bureau of Highway Safety and Traffic Engineering (BHSTE)

Key Stakeholders

- PennDOT/Bureau of Maintenance and Operations (BOMO)

Activities and Milestones

1. Review road weather activities in Pennsylvania and across the United States.
2. Identify the issues/barriers, lessons learned, opportunities for success of other similar applications through case studies, best practices guides, and other similar documents.
3. Develop a roadway weather management plan, including recommendations for identifying and implementing appropriate strategies.

Key Outputs

- A document discussing current best practices of implementing roadway weather management, including roadblocks experienced in developing similar strategies
- A roadway weather management plan including recommendations to implementing strategies
- Recommendations and next steps for the roadway weather management program

Future Direction of the
Roadway Weather Information System (RWIS) at PennDOT
Project Number 06-02 (C01)



COUNTY	DISTRICT	ESTIMATED TOTAL RWIS DEMAND								ADDITIONAL RWIS REQUIRED								TOTAL
		FEDERAL AID LINEAR MILES				NON FEDERAL AID				FEDERAL AID LINEAR MILES				NON FEDERAL AID				
		INTER-STATE	OTHER FRWV/ EXPWY	OTHER PRINC ART	MINOR ART	MAJOR COLLEC	MINOR COLLEC	LOCAL	TOTAL	INTER-STATE	OTHER FRWV/ EXPWY	OTHER PRINC ART	MINOR ART	MAJOR COLLEC	MINOR COLLEC	LOCAL	TOTAL	
1 CRAWFORD	1-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
2 ERIE	1-0	2	0	0	0	0	0	0	2.0	0	0	0	0	0	0	0	0	
3 FOREST	1-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
4 MERCER	1-0	2	0	0	0	0	0	0	2.0	0	0	0	0	0	0	0	0	
5 VENANGO	1-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
6 WARREN	1-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
TOTAL		5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1	
AVERAGE																		
7 CAMERON	2-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
8 CENTRE	2-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
9 CLEARFIELD	2-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
10 CLINTON	2-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
11 ELK	2-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
12 JUNIATA	2-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
13 MCKEAN	2-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
14 MIFFLIN	2-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
15 POTTER	2-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
TOTAL		3	0	0	0	0	0	0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	
AVERAGE																		
16 BRADFORD	3-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
17 COLUMBIA	3-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
18 LYCOMING	3-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
19 MONTGOMERY	3-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
20 NORTHUMBERLAND	3-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
21 SNYDER	3-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
22 SULLIVAN	3-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
23 TOGA	3-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
24 UNION	3-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
TOTAL		3	0	0	0	0	0	0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2	
AVERAGE																		
25 LACKAWANNA	4-0	2	1	0	0	0	0	0	3.0	1	1	0	0	0	0	0	2	
26 LUZERNE	4-0	3	0	0	0	0	0	0	3.0	0	0	0	0	0	0	0	0	
27 PIKE	4-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
28 SUSQUEHANNA	4-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
29 WAYNE	4-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
30 WYOMING	4-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
TOTAL		7	1	0	0	0	0	0	8.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	3	
AVERAGE																		
31 BERKS	5-0	2	1	0	0	0	0	0	3.0	1	1	0	0	0	0	0	2	
32 CARBON	5-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
33 LEHIGH	5-0	1	1	0	0	0	0	0	2.0	1	1	0	0	0	0	0	2	
34 MONROE	5-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
35 NORTHAMPTON	5-0	0	1	0	0	0	0	0	1.0	0	1	0	0	0	0	0	1	
36 SCHUYLKILL	5-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
TOTAL		6	3	0	0	0	0	0	9.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	6	
AVERAGE																		
37 BUCKS	6-0	1	1	1	0	0	0	0	3.0	1	1	1	0	0	0	0	3	
38 CHESTER	6-0	1	2	0	0	0	0	0	3.0	1	2	0	0	0	0	0	3	
39 DELAWARE	6-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
40 MONTGOMERY	6-0	2	1	1	0	0	0	0	4.0	2	1	1	0	0	0	0	4	
41 PHILADELPHIA	6-0	1	0	1	0	0	0	0	2.0	1	0	1	0	0	0	0	2	
TOTAL		6	4	3	0	0	0	0	13.0	6.0	4.0	3.0	0.0	0.0	0.0	0.0	13	
AVERAGE																		
42 ADAMS	8-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
43 CUMBERLAND	8-0	3	1	0	0	0	0	0	4.0	1	1	0	0	0	0	0	2	
44 DALPHIN	8-0	1	1	0	0	0	0	0	2.0	0	1	0	0	0	0	0	1	
45 FRANKLIN	8-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
46 LANCASTER	8-0	1	1	0	0	0	0	0	2.0	1	1	0	0	0	0	0	2	
47 LEBANON	8-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
48 PERRY	8-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
49 YORK	8-0	2	0	0	0	0	0	0	2.0	1	0	0	0	0	0	0	1	
TOTAL		9.0	3.0	0.0	0.0	0.0	0.0	0.0	12.0	4.0	3.0	0.0	0.0	0.0	0.0	0.0	7	
AVERAGE																		
50 BEDFORD	9-0	2	0	0	0	0	0	0	2.0	2	0	0	0	0	0	0	2	
51 BLAIR	9-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
52 CAMBRIA	9-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
53 FULTON	9-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
54 HUNTINGDON	9-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
55 SOMERSET	9-0	1	0	0	0	0	0	0	1.0	1	0	0	0	0	0	0	1	
TOTAL		5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	3	
AVERAGE																		
56 ARMSTRONG	10-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
57 BUTLER	10-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
58 CLARION	10-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
59 INDIANA	10-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
60 JEFFERSON	10-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
TOTAL		3.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	
AVERAGE																		
61 ALLEGHENY	11-0	3	2	1	1	0	0	0	7.0	1	2	0	1	0	0	0	4	
62 BEAVER	11-0	1	1	0	0	0	0	0	2.0	1	0	0	0	0	0	0	1	
63 LAWRENCE	11-0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	
TOTAL		4.0	3.0	1.0	1.0	0.0	0.0	0.0	9.0	2.0	2.0	0.0	1.0	0.0	0.0	0.0	5	
AVERAGE																		
64 FAYETTE	12-0	0	1	0	0	0	0	0	1.0	0	1	0	0	0	0	0	1	
65 GREENE	12-0	1	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	
66 WASHINGTON	12-0	2	1	0	0	0	0	0	3.0	1	0	0	0	0	0	0	1	
67 WESTMORELAND	12-0	2	1	0	0	0	0	0	3.0	2	1	0	0	0	0	0	3	
TOTAL		5	3	0	0	0	0	0	8.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	5	
AVERAGE																		
STATE TOTAL		56.0	17.0	4.0	1.0	0.0	0.0	0.0	78.0	26.0	15.0	3.0	1.0	0.0	0.0	0.0	45	
STATE AVERAGE																		

As warranted based on local conditions and funded by others

As warranted based on local conditions and funded by others

As warranted based on local conditions and funded by others

30 mile RMS site Spacing (Snowfall <30 inches)
25 mile RMS site Spacing (Snowfall 30-60 inches)
20 mile RMS site Spacing (Snowfall >60 inches)



ROUTE	TOTAL LINEAR MILES	MEAN AADT	CURRENT RWIS DEPLOYMENTS	CURRENT AVG SPACING	ESTIMATED SPACING CRITERIA	TOTAL RWIS DEMAND	ADDITIONAL RWIS REQUIRED
I 70	80.69	32,386	2	40.3	30	3	1
I 76	349.62	37,691	3**	-	28	12	9
I 78	75.49	43,349	1	75.5	29	3	2
I 79	182.91	31,027	4	45.7	25	7	3
I 80	311.07	29,947	13	23.9	25	12	0
I 81	232.60	45,797	9	25.8	25	9	0
I 83	50.52	63,629	1	50.5	30	2	1
I 84	54.89	22,468	1	54.9	23	2	1
I 86	7.00	8,813	0	-	20	0	0
I 90	46.39	28,981	2	23.2	20	2	0
I 95	51.08	117,247	0	-	30	2	2
I 99	51.12	16,716	1	-	25	2	1
I 176	11.32	19,580	0	-	30	0	0
I 180	28.84	27,908	0	-	27	1	1
I 276	32.65	81,845	0	-	30	1	1
I 279	19.52	75,849	0	-	30	1	1
I 283	2.91	61,435	0	-	30	0	0
I 376	14.70	76,616	1	14.7	30	0	0
I 380	24.44	22,663	1	24.4	22	1	0
I 476	129.61	43,428	0	-	27	5	5
I 579	1.57	64,432	0	-	30	0	0
I 676	2.55	112,230	0	-	30	0	0
INTERSTATE SUBTOTAL	1,761.49		36.00	37.89	27.09	65.00	28.00
US 1	92.37	39,536	0	-	252	0	1
US 6	404.58	6,445	4	101.1	374	1	0
US 6N	27.93	3,761	0	-	400	0	1
US 11	246.98	12,644	0	-	288	1	1
US 13	43.55	18,061	0	-	308	0	1
US 15	192.19	13,177	2	96.1	124	2	0
US 19	186.75	9,071	0	-	358	1	1
US 20	45.38	11,436	0	-	324	0	1
US 22	321.81	18,655	4	80.5	190	2	0
US 30	328.39	18,500	1	328.4	263	1	0
US 40	82.69	7,866	1	82.7	400	0	0
US 62	118.53	5,237	1	118.5	343	0	0
US 119	125.52	10,577	1	125.5	250	1	0
US 202	61.25	37,312	0	-	289	0	1
US 206	0.40	8,200	0	-	30	0	0
US 209	140.73	8,542	0	-	370	0	1
US 219	208.05	7,107	3	69.4	297	1	0
US 220	226.09	5,678	0	-	212	1	1
US 222	93.49	24,390	0	-	241	0	1
US 224	8.06	9,250	0	-	400	0	0
US 322	363.38	8,394	4	90.8	325	1	1
US 422	203.29	19,966	1	203.3	251	1	0
US 522	126.98	3,934	0	-	398	0	1
US ROUTE SUBTOTAL	3,648.39		22.00	129.63	290.74	13.00	12.00
TOTAL INTERSTATES AND US ROUTE	5,409.88		58.00	167.52	317.83	78.00	40.00

** 7 RWIS sites are within 7 miles of one another for the fog detection system, recorded as 1 RWIS site
Each US Route of at least 25 miles should have a minimum of 1 RWIS site