Technical Report Documentation Page

1. Report No. FHWA/TX-98/1380-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle IMPLEMENTATION GUIDELINES FOR ROAD WEATHER INFORMATION SYSTEMS		5. Report Date November 1997 6. Performing Organization Code
7. Author(s) Carl Haas, José Weissmann, Benjamin McKeever, and Richard Greer		8. Performing Organization Report No. 1380-2
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Section/Construction Division P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Research Report (9/96 — 8/97) 14. Sponsoring Agency Code
15. Supplementary Notes Project conducted in cooperation with the Federal Highway Administration.		

16. Abstract

This report presents guidelines for implementing road weather information systems (RWIS). These guidelines will assist highway agency personnel with the planning, installation, and maintenance of road weather information systems for either ice or high-water detection. This tool provides maintenance engineers and supervisors with a step-by-step methodology through which various RWIS applications can be used to decide whether it is economically beneficial to implement an RWIS. Once the decision has been made to implement an RWIS, these guidelines can be used to assist in the implementation process.

17. Key Words		18. Distribution Statement	
Remote automatic monitoring and public information systems, hazardous road conditions, road weather information systems, RWIS		No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.	
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 40	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

IMPLEMENTATION GUIDELINES FOR ROAD WEATHER INFORMATION SYSTEMS

by

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Research Report Number 1380-2

Study No. 0-1380

Develop a Remote Automatic Monitoring and Public Information System for Hazardous Conditions

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH

Bureau of Engineering Research

THE UNIVERSITY OF TEXAS AT AUSTIN

November 1997

IMPLEMENTATION STATEMENT

This report presents guidelines for implementing road weather information systems (RWIS's). These guidelines will assist highway agency personnel with the planning, installation, and maintenance of RWIS's for either ice or high-water detection. This tool provides maintenance engineers and supervisors with a step-by-step methodology through which various RWIS applications can be implemented. This report complements the RWIS Decision Support Tool, which can be used to decide whether or not it is economically beneficial to implement an RWIS. Once the decision has been made to implement an RWIS, these guidelines can be used to assist in the implementation process.

ABSTRACT

In order to ensure safer driving conditions on highways, state highway agencies are exploring the use of new technologies that will improve the flow of information about hazardous road conditions. These technologies are called road weather information systems (RWIS's). The objective of this report is to provide a systematic methodology that assists highway agency personnel with each step of the RWIS implementation process. The report first presents background information for RWIS's and then provides step-by-step guidelines for implementing an RWIS. These steps include: selecting an RWIS vendor, choosing meteorological services, analyzing communications alternatives, installing RWIS hardware and software, training agency staff, and maintaining the system.

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ACKNOWLEDGEMENTS

The researchers acknowledge the invaluable assistance provided by Mr. Don Baker, TxDOT project director for this study.

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF REPORT

This report provides guidelines for implementing road weather information systems (RWIS's). In this report, the term *road weather information system* encompasses both low-water crossing monitoring systems and bridge ice detection systems. These guidelines are to be used in conjunction with the RWIS Decision Support Tool. The RWIS Decision Support Tool is used to decide whether it is economically beneficial to implement a bridge ice detection system or low-water crossing monitoring system (LWCMS). Once the decision has been made to implement one of these systems, these guidelines can be used to assist in the implementation process.

This report will primarily be used by the maintenance supervisors within a state's department of transportation (DOT). It is the job of the maintenance supervisors to ensure safe driving conditions on all roads within their area of responsibility. In some cases it may be economically and socially beneficial to implement a bridge ice detection system or LWCMS at a particular site or group of sites where freezing or flooding frequently occurs. Under such circumstances, this report should be used as a guide for implementing these systems.

1.2 ORGANIZATION OF REPORT

Chapter 2 provides background information about the various components of bridge ice detection systems and LWCMS's, including how these components work together. It also inventories available turnkey systems and provides performance evaluations for some of these systems. Chapter 3 describes in detail all steps that need to be completed in order to ensure successful implementation of these systems. These steps include selecting an RWIS vendor, choosing meteorological services, analyzing communications alternatives, installing RWIS hardware and software, training agency staff, and maintaining the system.

CHAPTER 2. BACKGROUND

2.1 ROAD WEATHER INFORMATION SYSTEM COMPONENTS

Road weather information systems (RWIS's) sense and collect on-site weather and road condition information, process and disseminate the information, and create forecasts of road and weather conditions (Boselly 1993). There are several components of an RWIS. These include:

- Sensors
- Remote Processing Units (RPUs)
- Central Processing Units (CPUs)
- Telecommunications equipment to transmit data
- Computer workstations equipped with software
- Forecasts from the National Weather Service (NWS) or other meteorological services

2.1.1 Sensors

The sensors include ice-detection sensors, which are typically embedded in the pavement, and water-level sensors, which tend to be installed in or around a creek bed. Most RWIS's also include a number of atmospheric sensors that provide additional information about current weather conditions, including air temperature, relative humidity, wind direction and speed, visibility, and presence of precipitation.

2.1.2 Remote Processing Units

Located at the site, RPUs are responsible for processing raw data from the sensors. These data, whether they are in digital or analog format, are converted to a usable form and then transmitted either to roadside message signs, flashing lights, or to a CPU. The RPUs are usually either battery or solar powered.

2.1.3 Central Processing Units

CPUs are located at a central control office. The CPU analyzes, stores, and arranges the data obtained from the RPUs. Data are received from the RPUs usually via radio or telephone and are converted by the CPU into usable information and graphic displays for decision makers or meteorologists. In some cases, data are formatted for use in forecasting models.

2.1.4 Communications Equipment

Communications equipment used to transmit RWIS information comes in a variety of forms. Communications can be transmitted via direct-wire connection, telephone, cellular link, radio, microwave, satellite, forecasts, or local area network (LAN). Direct connection requires only cable. For telephone communications, telephone lines and modems are needed. For radio links, transmitters/receivers, antennas, and sometimes repeaters are necessary. Microwave and satellite communications are slightly more expensive and require special types of transmitters/receivers and antennas. LAN connections require an Ethernet card, Token Ring, or some other type of networking device.

2.1.5 Computer Workstations

Computer workstations equipped with special software can be used to access the RWIS data stored on the CPU and present the data to users in a variety of usable forms. These forms include tabulated text formats, geographic information systems (GIS's), map locators, voice messages, and graphical outputs. The displays can be tailored to the customer's needs.

2.1.6 Forecasts

The final components of an RWIS are weather and pavement forecasts. Forecasts are often considered an entity separate from the other RWIS components because they require information from other sources. Typical sources of weather forecasts include the public media, the NWS, and Value-Added Meteorological Services (VAMS's). Most public forecasts are issued by the NWS and retransmitted by broadcast media. According to many maintenance engineers, public forecasts are often too conservative and rarely provide adequate detail to relate to specific sites. Highway decision makers must have accurate weather forecasts for specific sites in order to optimize their maintenance procedures. VAMS's use NWS data and forecasts, specialized observations, and meteorological models to provide state agencies with specific weather packages tailored to meet an agency's needs. These packages usually include live radar observations and satellite images.

VAMS's can also provide 24-hour pavement forecasts for each RWIS site being monitored. Pavement forecasts, used with bridge ice detection systems, graphically depict current and future pavement temperatures and conditions. These pavement forecasts can warn decision makers of potential problems before they occur so that they can act proactively rather than reactively. This advance warning has been proven to save state agencies money through reduced labor, materials, and equipment costs.

Another source of weather forecasts that has been growing in recent years is the World Wide Web. Many NWS and public media weather forecasts are now available on the Web. Also, a number of news and weather centers are now adding live Doppler radar and satellite images to their Web sites. Figures 2.1 and 2.2 present the major components of a bridge ice detection system and a low-water crossing monitoring system (LWCMS), respectively.

2.2 INVENTORY OF TURNKEY SYSTEMS

A number of vendors provide turnkey RWIS's for both bridge ice detection and low-water crossing monitoring applications. The two main providers of bridge ice detection systems are Surface Systems, Inc. (SSI) and Vaisala, Inc. The SSI system (SCAN) has been widely used throughout the U.S. for the past 10 years. Vaisala's system (ICECAST) has been used mostly in Europe, although there are a few ICECAST installations in Texas and Minnesota. In recent years, a number of smaller vendors have also begun to provide bridge ice detection systems. These vendors include Climatronics, Aanderraa, Coastal Environmental, and Reed Systems, Ltd. The cost of a typical RWIS for ice detection ranges from about \$10,000–\$40,000 per site, depending on the complexity of the system and the mode of communication.

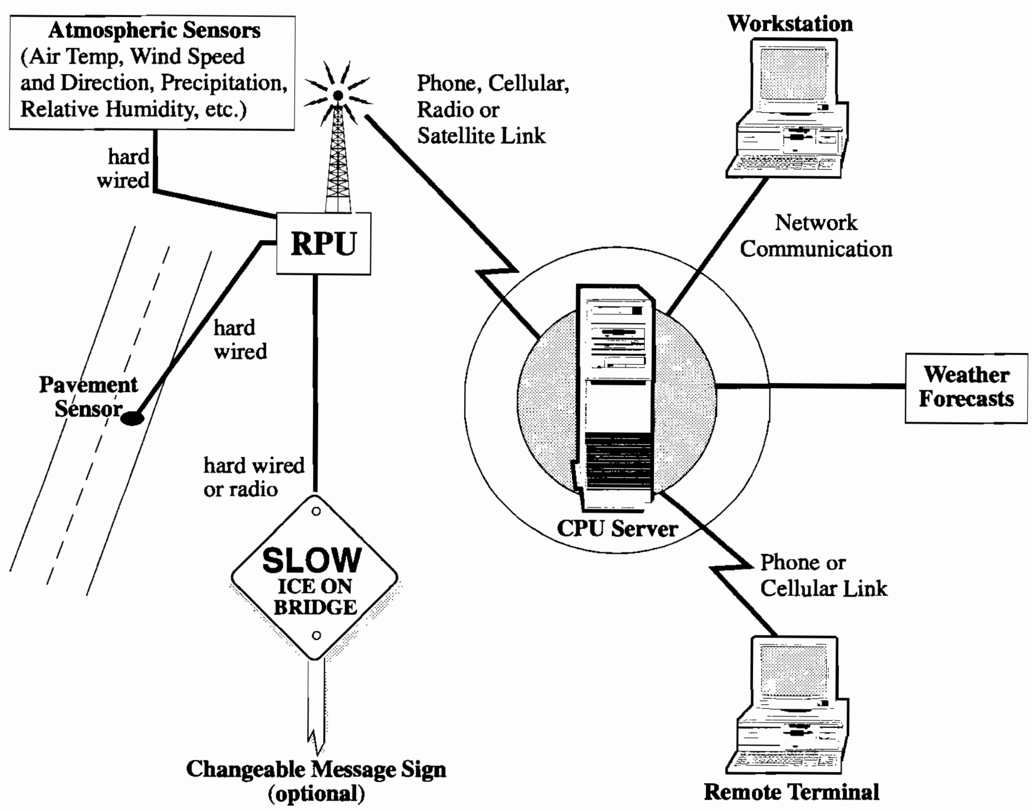

Figure 2.1 Major components of a bridge ice detection system

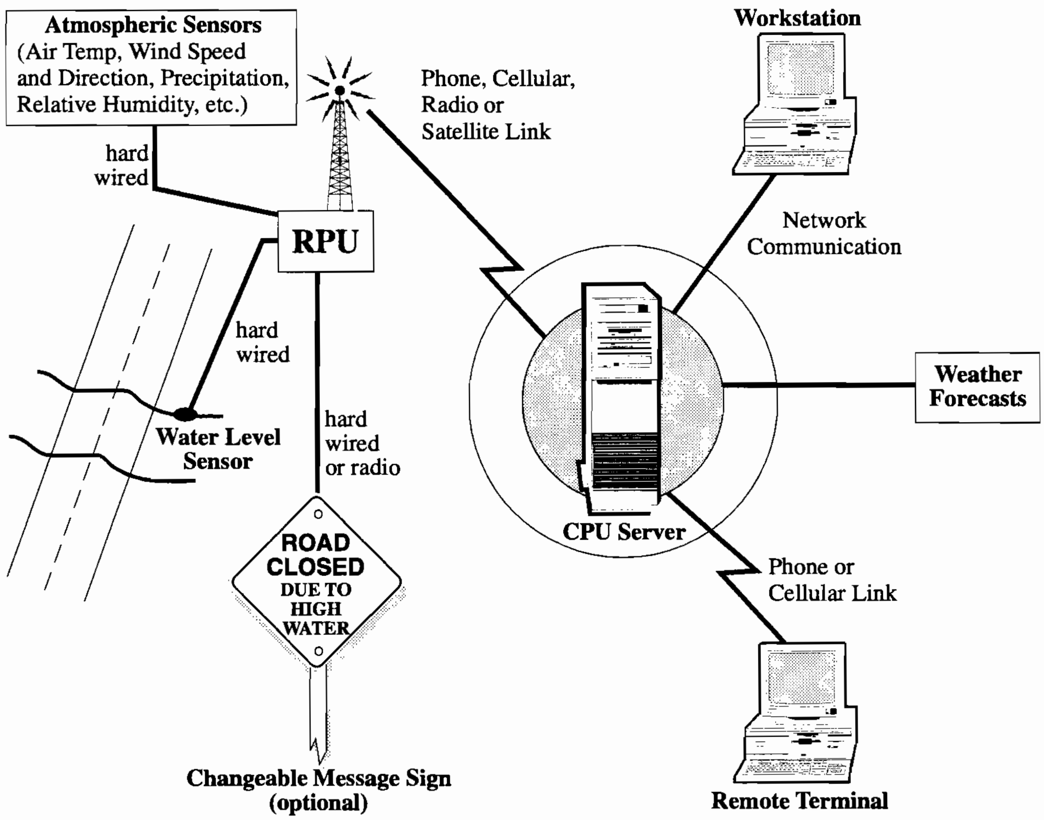

Figure 2.2 Major components of an LWCMS

There are also a number of vendors that provide LWCMS's. Remote Operating Systems (ROS), which operates out of San Antonio, has installations in San Antonio, Kerr County, Lubbock, and in other Texas cities and counties. ATEK, another vendor of LWCMS equipment, has a system installed at a site just outside of Austin that so far seems to be working well. There is also a system called the Automatic Inundation Monitor (AIM) provided by Applied Sciences, Ltd., out of Des Moines, Iowa. AIM is a microprocessor-based flash flood alarm system, which may be used to actuate gates, lights, or telemetry. The cost of a typical LWCMS ranges from $5,000 –$20,000 per site, depending on complexity and mode of communication.

For more detailed information about each of these products, consult Center for Transportation (CTR) Report 1380-1, "Remote Automatic Monitoring and Public Information System for Hazardous Conditions" (Haas, Weissmann, McKeever, and Greer). Report 1380-1 provides a comprehensive survey of RWIS's and their components, along with a technical description of how each system component works. The report also includes a summary of various states' experiences with RWIS's based on the results of numerous site visits and phone interviews.

2.3 PERFORMANCE EVALUATION OF SYSTEMS

As part of the research performed for the writing of this report, several of the systems mentioned above were monitored and evaluated for their performance, reliability, and value. For bridge ice detection, the two sites being evaluated included a Vaisala system in Amarillo and an SSI system in Abilene. For low-water crossing monitoring, three sites were evaluated. Two of these sites were ROS systems, one in San Antonio and one in Kerrville. The other site was an ATEK system located in Austin. The results of these performance evaluations can be found in Appendix C.

2.4 STANDARDIZATION ISSUES

For RWIS's to be fully realized there must exist a standard communication protocol so that systems from different vendors can share information with one another. For instance, an SSI system in Abilene should be able to retrieve RWIS information from a Vaisala in Amarillo in order to gain advanced warning of storms approaching from the northwest. This is extremely important for anti-icing operations, where the roads must be treated before the pavement freezes; for low-water crossings, it would allow the maintenance supervisor to better predict if and when a flood event will occur. The standard communication protocol should operate on the RPU-to-CPU and CPU-to-CPU level. An RPU-to-CPU communication standard allows for a sensor site from any vendor to be directly monitored by a CPU from any other vendor. Thus, each district would have to purchase only one CPU to cover all of the sites in the area. A CPU-to-CPU communication standard would ensure that each of the different districts could monitor the sites from other districts remotely, which would give them the aforementioned advance warning they were seeking.

Currently, no standard communication protocol exists for RWIS's. Thus, vendors set up their own protocols for transmitting data from the sensor to the RPU, from RPU to CPU, and from CPU to CPU. Consequently, if a customer wishes to use the sensors from a certain vendor, he/she must purchase the RPU, CPU, and software from the same vendor. Also, if the customer wants to add additional RPU sites to his system, he/she must purchase equipment from the same vendor from which the original system was purchased.

Although there is currently not a standard specifically for RWIS protocols, there has been a standard under development for transportation control equipment, such as traffic signal controllers, variable message signs, and cameras. This protocol, called the National Transportation Control/ITS Communications Protocol (NTCIP), has been developed by the National Electrical Manufacturers Association (NEMA) to allow for the implementation of a national intelligent transportation systems program. In recent months, a standard RWIS communication protocol has been added to a list of NTCIP development efforts and should become available in the next few years. Purchasers of RWIS's should obtain a guarantee from the vendor that their system will adopt the NTCIP protocol when it becomes available.

CHAPTER 3. ROAD WEATHER INFORMATION SYSTEM IMPLEMENTATION

This chapter describes a process that will lead to successful implementation of a road weather implementation system (RWIS). The process described is sufficiently generic and flexible so that it can be used by any highway agency. The RWIS implementation process includes the following steps: selecting RWIS vendors, choosing meteorological services, analyzing communications alternatives, installing RWIS hardware and software, training, and maintaining the system. Each of these steps is explained in detail below.

3.1 SELECTING ROAD WEATHER INFORMATION SYSTEM VENDORS

Once an agency has made the decision to purchase an RWIS and has determined where the RWIS sites will be located, it should begin the RWIS acquisition process. This involves selecting an RWIS vendor or group of vendors. Most RWIS's are available only as turnkey systems, so in most cases there will be a single vendor of RWIS hardware and software. As mentioned in Chapter 2, SSI, Vaisala, Climatronics, Aanderraa, Coastal Environmental, and Reed Systems, Ltd., all provide turnkey RWIS'S for ice detection. ROS, ATEK, and Applied Sciences, Ltd., provide turnkey low-water crossing monitoring systems. The highway agency that is purchasing the RWIS should examine each of these products carefully and know exactly what it is willing to pay before beginning the process of requesting bids.

When selecting potential vendors for an RWIS, the purchaser should know what data are truly needed from the system to allow maintenance personnel to perform their duties. This will help them select vendors that have the proper equipment, as well as aid the potential vendor in providing the correct components.

The vendor should already have a good idea as to what is needed to perform the water-level or bridge ice detection tasks. However, they may try to provide additional components that are not necessary for maintenance purposes. For example, at a minimum, in order to detect and predict bridge icing one needs a pavement temperature sensor that hopefully gives the chemical content and freezing point of the solution on the road. This is probably not a very good predictor of when the road will freeze, but it is the cheapest option and provides the pavement temperature for the maintenance personnel. The purchaser may or may not be interested in visibility sensors, atmospheric data, or live video from the site. The vendor may try to sell these components, perhaps saying that they are necessary, but the purchaser may or may not need them depending on how the site device is going to be used.

For both low-water crossing and bridge ice detection systems, one needs to know how the vendors handle lightning suppression. This could be a fairly significant problem, because the state has many thunderstorms every year. If a unit is struck by lightning, it is important to know what components will have to be replaced and at what cost.

In order to acquire an RWIS, almost all agencies will be required to prepare a request for proposal (RFP). The RFP should include a clearly defined scope of work in order to establish a mutual understanding of what is required of the vendor. The scope should be very specific and should cover all aspects of RWIS implementation, including installation, maintenance, calibration and training. The RFP should also request that the responders demonstrate or include each of the following in their proposals: an understanding of the project, qualifications, scope of work, and costs.

According to the Strategic Highway Research Program (SHRP), the agency's selection committee should review each of the proposals carefully and then interview the top two or three respondents based on technical merit (SHRP 1993). In many cases, the highway agency will be required to select the RWIS vendor submitting the lowest bid, but whenever possible, the selection committee should not base their decision solely on cost. They should also take into account the vendor's qualifications, understanding of the project, and the scope of work. If the agency is not bound to a low-bid selection process, then it should first determine the top-ranked respondent based on qualifications, and then negotiate a price (SHRP 1993).

3.2 CHOOSING METEOROLOGICAL SERVICES

As with the selection of an RWIS vendor, a highway agency should issue an RFP when evaluating value-added meteorological services (VAMS's). The RFP should require each responding VAMS to state its understanding of the nature of advice needed, the qualifications of its staff, the numbers and types of customers who use its services, and references. VAMS selection should be similar to RWIS vendor selection. The selection should be made by a consultant selection committee and, whenever possible, the selection should be based primarily on technical merit.

Ideally, the information provided by the VAMS will be resident on the statewide network so that it can be shared by all state agencies that rely on weather information and forecasts. This could significantly reduce the cost of the service. Typical vendors of meteorological services include Weather Services, Inc. (WSI), Weather Data, Inc. (WDI), Kavouras, Marta, Alden, and many others. SSI provides weather packages to complement its SCAN system.

Another vendor, Data Transmission Network Corporation (DTN), supplies unlimited access to comprehensive, time-sensitive, weather information via satellite. DTN provides all necessary equipment, including a satellite receiver, a compact satellite dish, a high-resolution VGA color monitor, and data storage capability. The satellite technology of the DTN weather center allows the user instant access to in-motion radar maps, current temperature, humidity and sky conditions, severe weather maps and forecasts, regionalized wind speed maps updated hourly, in-motion satellite cloud photos, and over 250 major city forecasts. All this information is provided for a set monthly fee of $64 (with a required start-up charge of $318). There are no "on-line" fees or phone access charges associated with this system. DTN currently serves over 94,000 subscribers throughout the U.S.

3.3 COMMUNICATIONS ALTERNATIVES FOR ROAD WEATHER INFORMATION SYSTEMS

Before installing an RWIS, agency personnel must first decide how they wish to have their communications network set up. Each part of an RWIS must be able to communicate with at least one other RWIS component. This includes the following communication links: the sensor to the remote processing unit (RPU), the RPU to the central processing unit (CPU), the CPU to the CPU, and, finally, the RPU to the traveling public. This section discusses the various modes of communication that are available for each RWIS communication link.

3.3.1 Sensors to Remote Processing Units

In most cases, RWIS sensors are hard-wired with the RPU. The cable is either buried in the ground or run through conduit along bridge supports to the RPU. The sensors transmit either an analog or a digital signal over these wires, with the signal then interpreted by the RPU for possible transmission to the CPU or warnings signs. Only in extreme cases in which the sensors are located more than 304 m (1,000 ft) from the RPU should any other mode of communication be considered.

3.3.2 Remote Processing Unit to Central Processing Unit

There are several methods of communicating from the RPU to the CPU. Standard phone lines represent a common mode of communication between RPUs and CPUs. The RPU sends data via modem to the CPU either automatically when an event occurs or when requested by the CPU. This is done by a standard RS-232 modem connection. If the cost of installing or maintaining a phone line is impractical owing to the site not being near a phone line or owing to excessively high long-distance charges, cellular phones could be an alternative. In any event, there are a couple of problems with phone communication. First, there is the cost. Phone lines have associated with them a monthly cost and, possibly, long-distance charges or airtime charges if cellular phones are deployed. Also, there is the problem of phones being rendered inoperable during a storm — with the serious consequence of no data being transmitted when these data are most needed.

Another common method used to establish communication between RPU and CPU is UHF/VHF line-of-sight radio transmission. This method requires a radio transmitter in the RPU, a receiver in the CPU, and a Federal Communications Commission (FCC) license to transmit signals at a certain frequency. It also requires line-of-sight communication. If line of sight is unavailable, a repeater tower or a daisy-chaining configuration would need to be deployed: In such a system, a series of repeaters are arranged to transmit the signal from the RPU to the CPU. Radio systems have an advantage over phone systems in that they require only the up-front cost of the transmitter and receiver (i.e., there are no additional monthly costs). However, if line of sight cannot be obtained, radios are not a feasible option.

Microwave technology is a reliable way of transmitting the data from the RPU to the CPU, especially over long distances. For this method to be feasible, the microwave towers would have to be already in place and available for use by the RWIS. The most common method of using microwaves for communication includes transmitting by line-of-sight radio to the tower and converting the signal to microwaves for further transmission to the CPU. It would be necessary to install a radio receiver/microwave converter on the microwave tower, and a microwave receiver would then decode the information and send it to the CPU. As mentioned above, this is viable only if the microwave towers are already available, given that microwave technologies are considerably more expensive than radio technology.

Satellites represent an emerging communication option. Once overly excessive, the price for sending data via satellite is now dropping to a level that appears economical for many applications. These satellite-based systems include a satellite transmitter and a telemetry antenna at the RPU for sending data, and a satellite receiving unit and antenna at the CPU for receiving the data. An advantage of using satellite communication is that it is reliable — insofar as line of sight is not an issue. A disadvantage to using satellites is that there is usually a time lag of 4 to 10 minutes, the time required for the signal to transmit from the RPU to the CPU.

3.3.3 Central Processing Unit to Central Processing Unit

There are basically three networking options for CPU-to-CPU communications. The first is to have the RWIS CPU operate as a stand-alone system, where it is not linked to any other CPUs, terminals, or workstations. While this option is probably the cheapest and easiest, it limits the number of RWIS users (since the CPU is the only location where RWIS data can be viewed).

The second option is to allow the RWIS CPU to communicate to other CPUs and workstations via modem. In this form of communication, a user on a remote CPU will dial up the RWIS CPU. The user of the remote CPU would then log in and start a session that would involve the uploading and downloading of data to and from the RWIS CPU; the user could also simply view the RWIS data remotely without downloading the information. When finished, the user would log off and break the connection. This is a well-known and reliable form of data transfer that is currently available with all RWIS's.

The modem option will be slightly more expensive than the stand-alone option, since there will be some telecommunications costs involved; however, this option will allow for a greater number of RWIS users, since any computer equipped with a modem will be able to access the RWIS data. The only problem with this option is that it requires a standard communication protocol and a standard data format if different RWIS devices are being used. Also, there may be a significant time delay in retrieving RWIS data from remote workstations, especially during weather emergencies, because that is the most likely time that the data will need to be accessed.

The last option is to connect the RWIS CPU to a statewide network and allow the CPU to share RWIS information with other RWIS CPUs and with other agencies that are connected to the statewide network. For data sharing, users should consider exchange arrangements among states, counties, municipalities, and the private sector. This option also allows the data from the weather forecasting service to be put onto the network, thus making such information available to the entire state. Figure 3.1 presents the schematics for a statewide RWIS network.

Of the three options mentioned, the statewide network option is the most desirable, since it allows for the largest number of RWIS users and because connection to the statewide network is free (i.e., there are no telecommunications costs involved in CPU-to-CPU communication). Of course, this option also requires the existence of a standard communication protocol and standard data format if different devices are being used.

3.3.4 Remote Processing Unit to the Traveling Public

Deploying the RPU to alert the traveling public about possible dangerous road conditions can involve the use of flashing lights, variable message signs, or a combination of both. Generally, when an RPU receives a signal from the sensor that is interpreted as an alarm, it sends a signal to the warning sign either via radio or via a hard-wired link. The signal turns on the sign's lights, changes the sign's message, or performs both actions. When the RPU receives a message from the sensor that the hazard is over, it sends a signal to the sign to return to its default state. Other methods of alerting the public about hazardous road conditions include television and radio advisories and through kiosks located at public rest stops. Figures 3.2 and 3.3 illustrate a sign complemented with flashing lights and a changeable message sign, respectively.

When variable message signs or flashing lights are used, it is generally recommended that the signs be able to report their status back to the master RPU or the CPU. This option would allow the maintenance supervisor back at the office to monitor whether the sign was functioning properly, which is very important when dealing with storm events. If the sign is not functioning properly, a road crew would need to be sent to the site to close the road manually. If variable message signs, flashing warning lights, automatic road blocks, etc., are going to be used, the user in the office needs feedback in order to verify that they are operating properly. Other data pertaining to the sign that should be monitored include battery voltage level, battery charge, and burned-out flash bulbs. The use of only a receiver at the signs, flashers, or other user-alerting device is not a recommended option owing to the lack of feedback provided in such arrangements.

3.4 INSTALLING ROAD WEATHER INFORMATION SYSTEM HARDWARE

For low-water crossing monitoring and bridge ice detection systems, there are several hardware issues that must be resolved. First, there is the question of who will install the RWIS hardware. Next, the agency needs to determine what type of power will be used for the RPUs and for message signs (solar or AC). Finally, the physical location of the various pieces of the RWIS, such as the sensors, RPUs, and message signs, must be determined. The rest of this section provides detailed guidance for resolving the hardware concerns involved with RWIS installation.

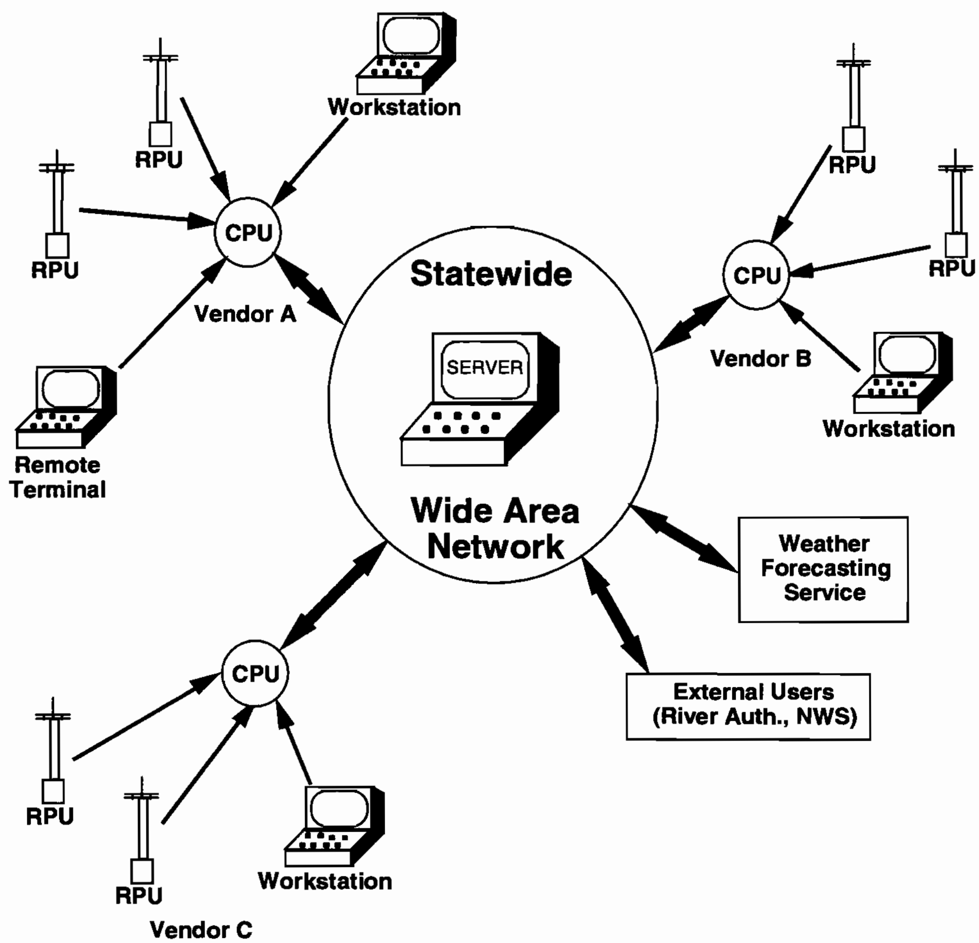

Figure 3.1 Statewide RWIS network

Figure 3.2 Sign complemented with flashing lights

3.4.1 Assigning Installation Duties

Before installing the RWIS hardware, an agency must determine who will physically install the RWIS equipment. Either the highway agency staff or a contractor can install the RWIS equipment. Most vendors offer turnkey installations of their systems at a substantial cost. If an agency plans to perform the installation, it must determine if there are technicians in house or in other agencies that are qualified to do the work. If only a few RWIS sites will be installed, it may be cost effective to have the sensors and RPUs installed by a contractor. If more than a few will be installed, or if additional systems will be acquired over a period of time, it may be more cost effective to train a group of technicians to perform these installations.

3.4.2 Location of Road Weather Information System Hardware

The RWIS hardware to be installed in the field includes the sensors, RPUs, and, possibly, message signs. The main objective in the placement of RWIS hardware is to get data that are truly representative of the site. Also, the RPU must be able to retrieve the data and transmit them to the CPU or other slave RPUs that are controlling variable message signs, flashing warning lights, or other road user alerting devices. To aid with the proper siting, guidelines will now be presented for both low-water crossing and bridge ice detection systems. If one is unsure of the site placement of the equipment, the selected vendor should be able to provide a site survey (though usually at an additional charge).

Figure 3.3 Changeable message sign

3.4.2.1 Location of Hardware for Low-Water Crossing Monitoring Systems: The placement of the water-level sensor at a low-water crossing requires only a few rules to be followed. First, one needs to make sure that the level sensor is placed in an area that will be representative of the actual stream level at all times. This involves placing the water-level sensor in an area that will not send false readings from runoff water during a storm. For instance, if the level sensor is placed in an area that is right below the runoff area, then it may actually be measuring the runoff water level rather than the true stream level. This could result in the system reporting a false flooding condition.

Another constraint on the placement of the level sensor is to ensure that it is protected from traffic. If the level sensor must be placed near the roadway, it should be mounted in such a way as to minimize potential damage to itself and to vehicles and passengers. This can be done by using a fold-down mounting in place of a rigid design. A fold-down design for the sensor mounting will collapse when struck by a vehicle, thus reducing damage to the sensor, the vehicle, and, most importantly, to motorists. Water-level sensors would be placed upstream of the crossing to allow them to be knocked over only when struck by a vehicle and not by flood debris. Figure 3.4 shows a water-level sensor equipped with a fold-down design that is installed upstream from the crossing and at a safe distance from traffic.

The RPU placement for a low-water crossing monitoring system generally has fewer constraints placed on it than one for a bridge ice detection system. This is largely due to the fact that the atmospheric weather sensors that are usually present for ice-detection systems are not generally needed at low-water crossing monitoring sites. Thus, the main considerations for a low-water crossing RPU siting are based on (1) the communication methods used, (2) the availability of power (if it is required), and (3) the need to reduce the risk of it being struck by a vehicle. If atmospheric sensors are to be added, then follow the directions for RPU placement for ice-detection systems presented in Section 3.4.1.2.

The sensor and RPU are usually hard-wired together, which requires trenching from the sensor to the RPU. There will be a limit on the maximum length of cable that is allowed, depending on the protocol used between the sensor and RPU, but this should be 61 m (200 ft) and should not usually be a problem.

If the communication between the signs and main RPU is all via hard wire or modem and external power is required, then the RPU should be placed at a point where the amount of trenching is minimized and where the RPU's exposure to possible vehicular damage is minimized. By using radio communications between the RPU and signs and CPU, the RPU can potentially be placed in a safer location with minimal trenching, but it must be in an area that can maintain line-of-sight radio communication.

If variable message signs or flashing warning lights are to be installed, they must be placed according to the required signing standards, taking into account the minimum safe stopping distance needed to avoid the hazard. The standards for visibility, sign height, etc., must be maintained.

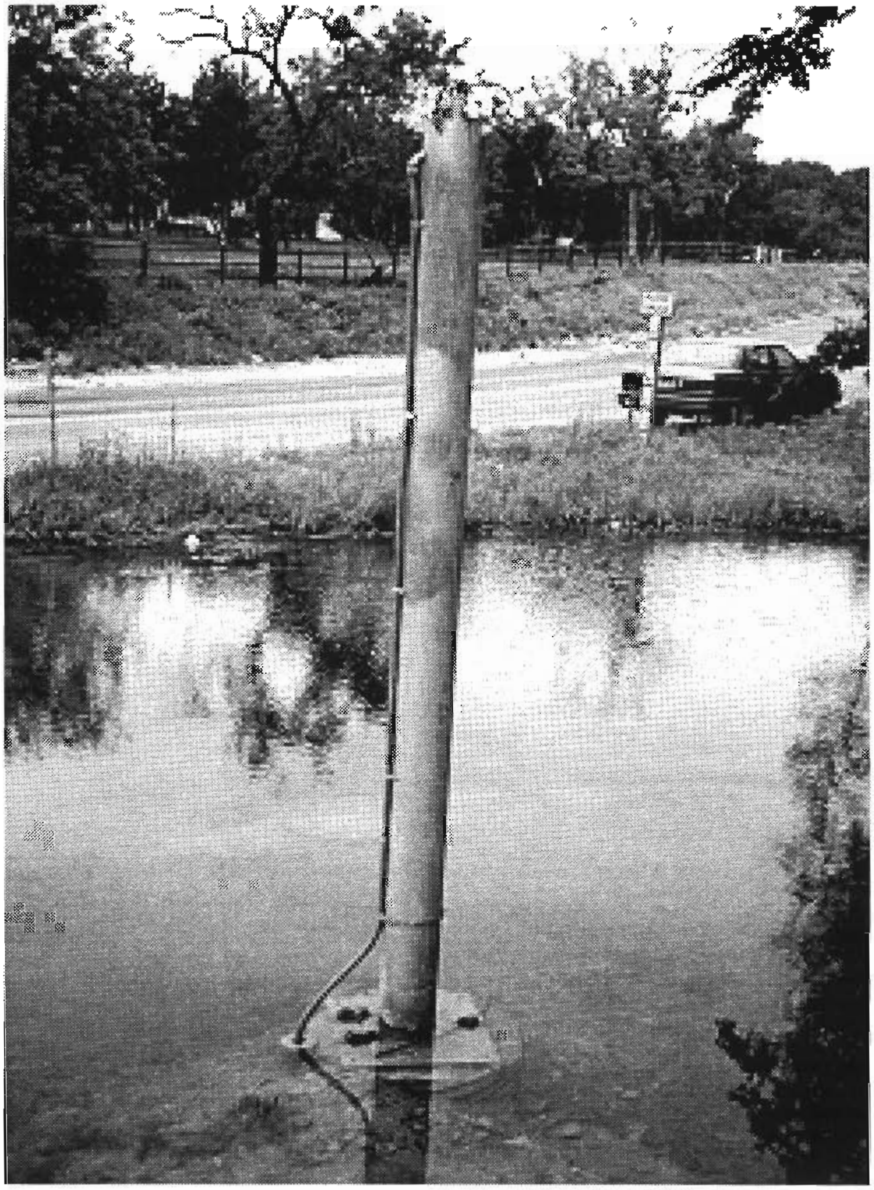

Figure 3.4 Water-level sensor

If radio communication is used between the master RPU and the message signs, then each sign will need a slave RPU to activate it. The slave RPU and its power source should be erected away from the sign in a place that minimizes the possibility of it being hit by a vehicle, as shown in Figure 3.3. Thus, if a vehicle strikes the sign, only the sign will need to be replaced. The slave RPU must be placed in an area that (1) allows it to have power, either solar or standard AC, and that (2) will allow for communication with the main RPU by radio, phone, etc. The need for a slave RPU to control a message sign or flashing lights can be avoided by hard-wiring the sign with the master RPU, though this usually requires a large amount of trenching.

3.4.2.2 Location of Hardware for Bridge Ice Detection Systems: Several factors also determine the placement of the hardware for bridge ice detection systems. These factors include what types of weather sensors will be used at the site, where the weather sensors and RPU will be located, how many pavement sensors are going to be installed at the site, and where the pavement sensors should be placed. Fortunately, there are published research reports that can aid in the proper placement of RWIS equipment for ice-detection applications. The most thorough of these reports is *Road Weather Information Systems — Volume 2: Implementation Guide*, published by the Strategic Highway Research Program (SHRP 1993). The remainder of this section will briefly summarize the main points of the SHRP report. For more detailed guidance on RWIS sensors and RPU sitings, please consult the SHRP report.

The RPU is usually mounted on an instrument tower having atmospheric sensors. The tower may be located at the side of the road or at a distance from the road, if such would provide more typical weather data. The RPU tower may include an antenna if radio communication is used; otherwise, a modem is needed in the RPU for telephone communication. Pavement sensors are embedded in the pavement and subsurface sensors are placed under the pavement near the RRU; both are connected to the RPU via buried cable. Figure 3.5 shows an RPU tower installed just outside of Abilene.

The most important consideration for RPU placement is to ensure that the data are representative of local weather conditions. Other considerations, such as availability of power and proximity to communications, are only secondary considerations. An RPU should be installed as close to the road as possible — but not so close as to be influenced by passing vehicles. If installed too close to the road, vehicles can splash slush and deicing chemicals onto the electronics enclosures, atmospheric sensors, and tower. Also, an RPU site should be as protected as possible to prevent vehicles from striking the assembly.

In order for meteorological information to be representative, standard meteorological instrument siting criteria should be followed to the greatest extent practicable. Anemometers, which detect wind speed and direction, should be installed at least 10 m (32.8 ft) above the ground in as open an area as possible and not downwind from a highway obstruction in the prevailing flow. Temperature and relative humidity sensors should be located at least 1.83 m (6 ft) above the surface; they should be placed over grassy areas, with a second choice being bare ground (rather than pavement). Precipitation sensors should also be placed in as open an area as possible and on the upwind side of the RPU tower. Figure 3.6 shows an anemometer and precipitation sensor installed on top of an RPU tower.

Figure 3.5 RPU tower installed near Abilene

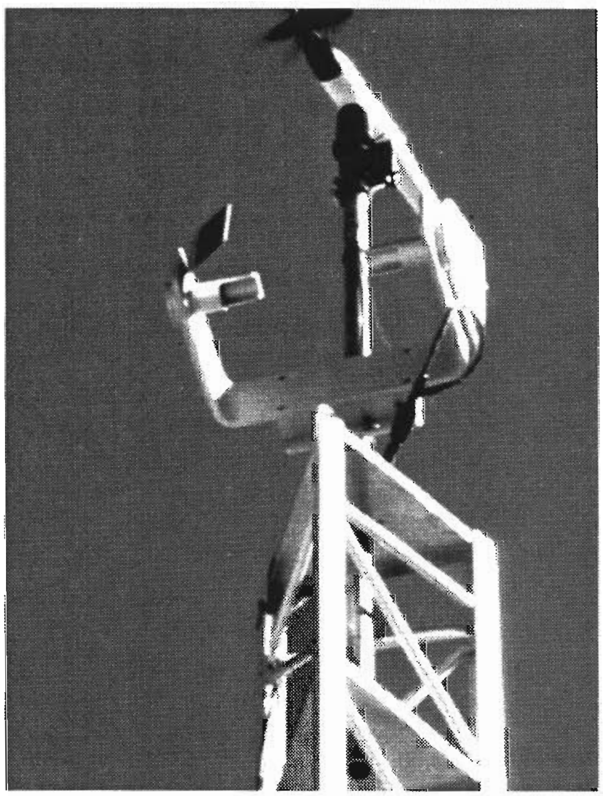

Figure 3.6 Anemometer and precipitation sensor

Pavement sensors should be implanted in the pavement flush with the surface to ensure that liquid does not pond on the sensors. Figure 3.7 shows a picture of a pavement sensor embedded in a bridge deck. Care should be taken to ensure that the slope of a road is such that there is no drainage onto the sensors from the shoulder or the median. Sensors should not be placed in the roadways on curves.

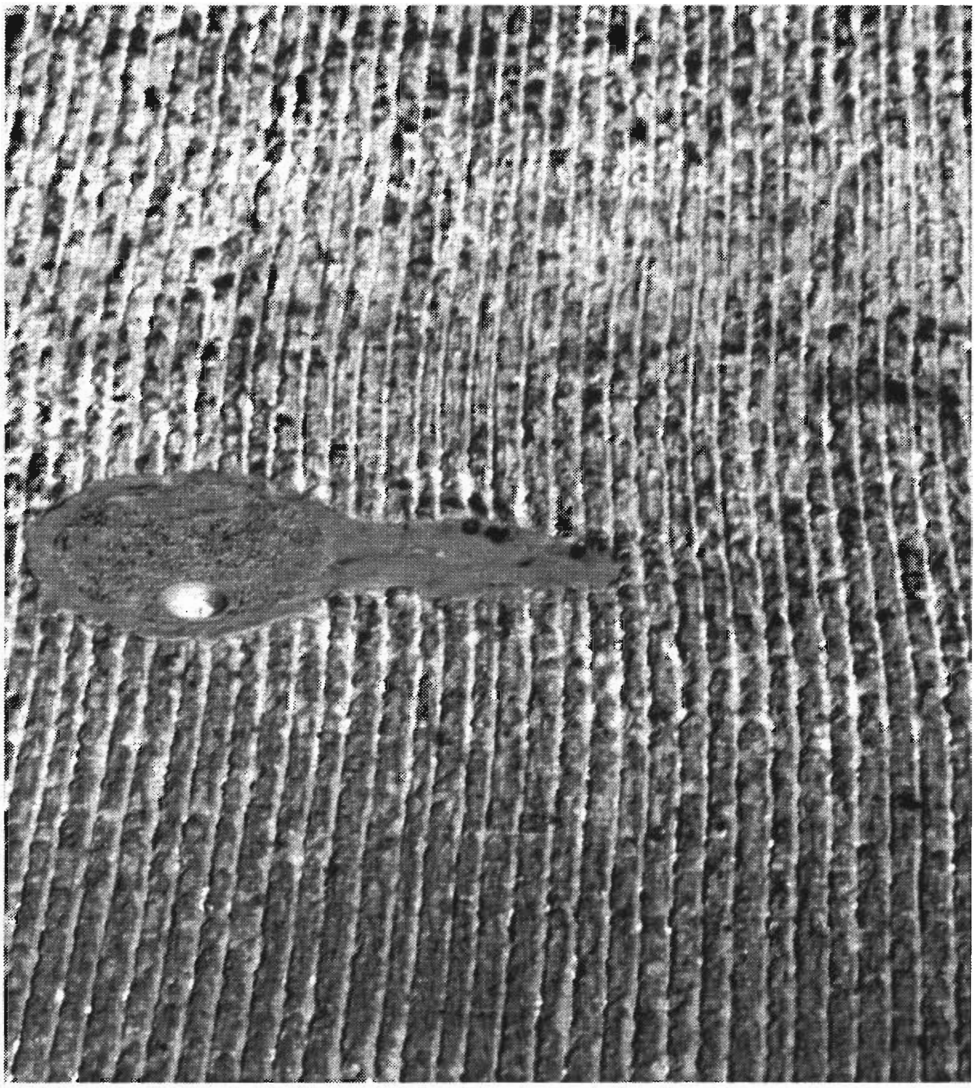

Figure 3.7 Pavement sensor embedded in bridge deck

Maintenance engineers frequently disagree on where pavement sensors should be located within the lanes of a roadway. Some engineers prefer to place the sensors in the wheel tracks; however, these areas tend to get cleaned out by tire friction and may not be representative of the rest of the roadway. Since vehicle heat influences pavement temperatures, placing sensors in the center of the lanes is not recommended. A third possible location is between the lanes. While this area is probably the least disturbed, it is also subject to increased concentrations of deicing chemicals and debris. The SHRP report generally recommends placing pavement sensors approximately 20.3 to 30.4 cm (8 to 12 in.) from the center of the outside wheel track (SHRP 1993).

3.4.3 Power Source

RWIS's can be powered by either AC or solar power. Solar power is the generally recommended option for the RPUs. Solar power offers the flexibility of placing the RPUs where no power lines are readily available. Having solar power also allows the site to stay up and running even if the normal AC power lines should fail. Normal AC has the greatest chance of failing during heavy thunderstorms, which is, again, the time when it is most important for the site to be operating normally. However, when using solar power the RPU must be placed in an area that will receive adequate sunlight; this requirement may represent a problem in heavily forested areas.

3.5 INSTALLING ROAD WEATHER INFORMATION SYSTEM SOFTWARE

RWIS software is necessary to access the RWIS data stored on the CPU and present the data to users in a readable format. RWIS vendors usually provide their own software as part of a turnkey package. Most RWIS software runs on basic IBM-compatible PCs, though many RWIS vendors attempt to sell their own CPU servers to the user at an additional cost. The servers will require modems or radio receivers, depending on how the data are being transmitted from the field to the maintenance office.

Before purchasing the RWIS software, an agency should determine what level of sophistication is needed and how many software licenses will be required. The level of software sophistication can range from simple tabulated text to complex graphical output. Most RWIS vendors can tailor the software to the agency's needs. The number of software licenses required will depend on how many people in the agency will use the RWIS and how the RWIS data will be shared (see Section 3.3.3). The number of agency personnel using the RWIS also becomes an issue with regard to training.

3.6 TRAINING

Training is critical for successful RWIS implementation. An agency needs to determine who will be trained (e.g., shift supervisors, foremen, superintendents, or maintenance engineers) and what level training will be required. Anyone involved in using RWIS information for decision purposes should probably be trained, though the level of training detail required will probably be greatest for those who will be using terminals to acquire RWIS data.

3.7 SYSTEM MAINTENANCE

Either agency personnel or a contractor can assume responsibility for maintaining the RWIS. Many state agencies choose to purchase a maintenance contract from the vendor. Under the terms of these contracts, the vendor receives an annual fee in exchange for repairing, replacing, or calibrating RWIS components when necessary. Based on the experiences of other state DOTs, the cost of these maintenance contracts ranges from about $1,900 to $4,100 per RPU site per year.

If the agency plans to maintain the RWIS, it must determine if there are technicians on staff or in other agencies that are qualified to do the work. If only a few RWIS sites will be installed, it may be cost effective to have the sensors and RPUs maintained by a contractor. If more than a few will be installed, or if additional systems will be acquired over time, it may be more cost effective to train a group of technicians to perform RWIS maintenance. At a minimum, electronics technicians and signal technicians will be required.

It is estimated that the complete life cycle of an RWIS is 25 years, after which time the entire system will need to be replaced. Also, RPUs and CPUs will need to be upgraded or replaced every 5 years or so in order to keep up with technological advances.

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APPENDIX A: ROAD WEATHER INFORMATION SYSTEM CONTACT INFORMATION

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