# WEATHER INFORMATION FOR SURFACE TRANSPORTATION

## NATIONAL NEEDS ASSESSMENT REPORT


OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

FCM-R18-2002

U.S. DEPARTMENT OF COMMERCE/National Oceanic and Atmospheric Administration

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OFFICE OF THE FEDERAL COORDINATOR
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# Foreword

Surface transportation in the United States faces significant weather threats on a nearly continuous basis. This report provides a compilation of weather information needs across the six surface transportation sectors--roadway, railway, transit, marine transportation, pipeline systems, and airport ground operations--and an analysis of these needs. The findings in the report provide a framework for actions to substantially improve surface transportation operations in the future.

In September 1998, the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) was briefed on the Office of Federal Coordinator for Meteorology (OFCM) "Look to the Future." The briefing identified priority areas, issues, problems, and ideas to improve the effectiveness of interagency coordination and cooperation. Surface transportation needs (including ground and marine transportation modes) were emphasized. Weather support for surface transportation was described as minimal and safety and economic productivity were at stake. Coordination among the Federal Highway Administration (FHWA), other partners from the Departments of Transportation and Commerce, state and local entities, and others in the public and private sectors would be essential for defining requirements and developing tailored decision aids. The FCMSSR agreed on the importance of addressing users' needs for weather information for surface transportation (WIST) through a coordinated effort.

Subsequently, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) directed that a Joint Action Group be formed to address mission needs and meteorological requirements for surface transportation. Two WIST symposia followed; the first (November - December 1999) helped to identify WIST user needs, and the second (December 2000) reviewed the progress of compiling and analyzing the data collected over the previous year. FCMSSR endorsed the continuation of this process in November 2000.

As I review this report in its final form, I want to emphasize four significant points:

- **Environmental Support to Homeland Security.** Most of the effort to identify, compile, and analyze WIST needs occurred prior to the tragic events of September 11, 2001. Nonetheless, there were WIST needs identified in each of the transportation sectors that are directly relevant to our national resolve to be better prepared for any future acts of terrorism. For example, airport ground operations will continue to be an important nexus of weather-related and security concerns. As a second example, a nationwide network (or "infostructure") to collect key transportation performance information, including road weather data, will support the needs of emergency services personnel for more timely information. Public and private entities would also be able to use this information to create more accurate models of atmospheric dispersion, in the event of an atmospheric release of hazardous materials. WIST will play a critical role in emergency preparedness at all levels of federal, state, and local planning and response. We have known this for a long time with respect to preparedness for natural disasters. ***Now we also need better weather information to support the emergency response to disasters inflicted on our communities by those who would do us harm.***

- **The Twin Values of Safety and Economic Productivity.** The report demonstrates how the sometimes competing values of safety and economic benefits are closely intertwined when we consider the potential for improving the information available to all those who make decisions concerning surface transportation systems and activities. From the templates in this report, we find that many of the impacts that increase costs, slow down a transportation activity, or divert resources from other tasks result from actions necessary to mitigate risks to the safety of personnel across the spectrum of transportation sector activities. ***By meeting the requirements for provision of WIST to users, as outlined in this report, we can often increase safety and realize economic benefits at the same time.***

- **Primary Use for Decision Support.** In a sense we have always used weather information as one input into life's daily decisions: what to wear, when to plant or harvest, whether to move up or delay a shipment or a ship. This study corroborates and expands on a key point made in numerous other technical and program documents on transportation weather. The weather information provider community must better understand how users can incorporate more detailed weather information (which is also more accurate and at finer spatial and temporal scales) in operational decision-making processes. These can be as simple as the new "511" telephone advisory services for travelers, or any of the prototype demonstration projects underway today. The ultimate test of these systems will be their acceptance by the users.

- **Essential Cooperation among Weather Information Providers.** The report stresses that the broad requirements for provision of weather information to meet surface transportation needs fall on the weather information provider community as a whole. The specificity and detail of information needed for individual users speak to important and expanding roles for private sector providers. The federal agency partners can provide basic weather and environmental observations and forecasts, encourage the transfer of research results into operations, and support the fundamental research and technology innovation needed to advance the state of the art. The report's use of the term "information provider community" is not a euphemism. ***Success in meeting these requirements will entail cooperative efforts and working partnerships among federal agencies; among federal, state, and "private-public" entities; and between the governmental and commercial sectors.***

I wish to thank all those who participated and contributed to this report, particularly the many nonfederal participants, from whom we learned a great deal. The WIST Needs Templates, which constitute Appendix B of this report, derive much of their value from validation by representatives of the six surface transportation sectors. I am indebted to the members of the FCMSSR and ICMSSR for their support and guidance and to the members of the Joint Action Group for Weather Information for Surface Transportation for their perseverance. Without this support, our ability to identify and resolve specific, time-critical issues and projects would not have been possible.

The WIST project does not end with this report. The process is dynamic; support capabilities mature; and future needs evolve. Even the most successful weather information system requires nurturing and maintenance to remain healthy and relevant. It remains for us, the readers, and particularly the weather service providers, to make maximum use of this information on WIST needs and requirements. We must re-invigorate existing support capabilities, initiate creative new solutions, and exercise judicious use of assets to maximize the cooperative interests of government and private sector participants for the benefit of the surface transportation public we serve.

Samuel P. Williamson
Federal Coordinator for Meteorological Services
and Supporting Research

# Weather Information For Surface Transportation

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# Executive Summary

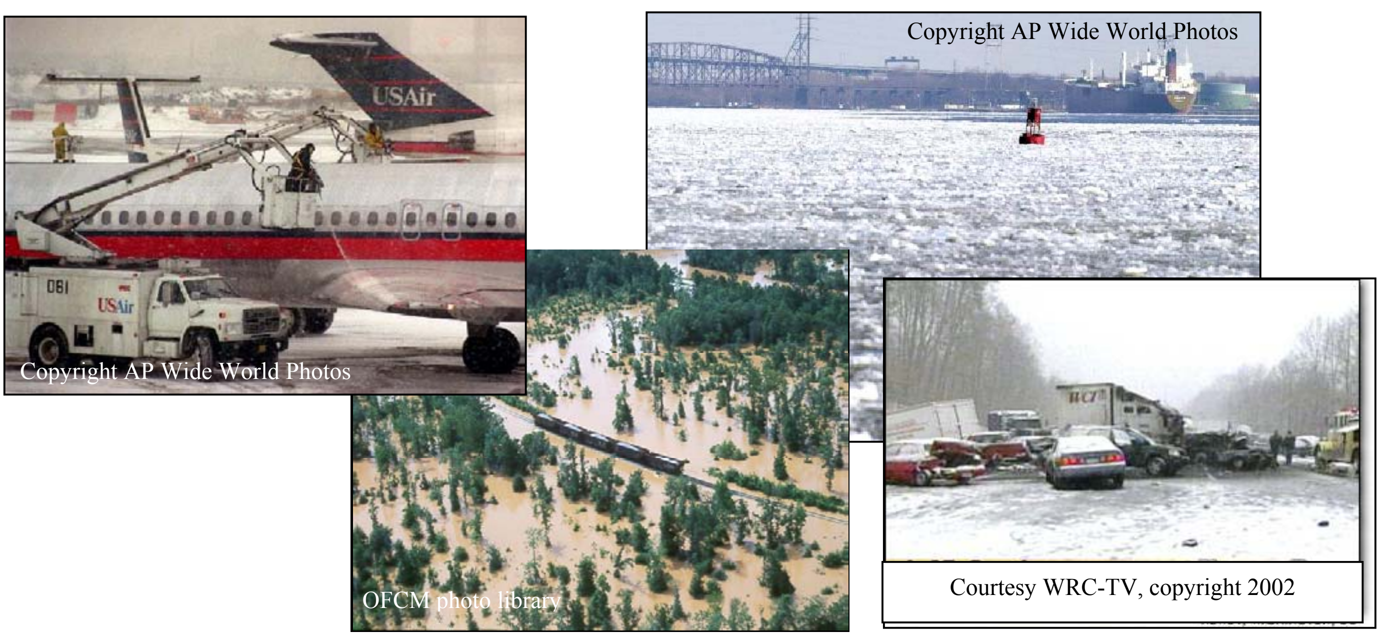
In 1998, a federal interagency committee identified the weather information needs of surface transportation sectors (including ground and marine transportation systems) as a priority for coordinated action. In response, the Office of the Federal Coordinator for Meteorological Services and Supporting Research undertook a study of existing and potential needs for weather information for surface transportation (WIST).

This report presents a compilation of these needs and analyzes them in the context of interests and concerns expressed in two symposia on WIST, plus many smaller meetings and interviews. Its purposes are first, to make the compiled needs accessible to the many audiences with an interest in WIST, and second, to suggest next steps in a coordinated WIST initiative. To achieve the second purpose, the report draws some general conclusions about WIST needs that cut across the six transportation sectors included in the study. It relates these conclusions to overarching themes present in the current transportation environment (Chapter 1) and confirmed by the compiled WIST user needs. These conclusions

**Surface Transportation Sectors**

This report covers six transportation sectors:

**Roadway—**state and federal highways, roads, and streets
**Long-Haul Railway**—rail lines providing intercity freight and passenger service, with their yards, stations, and depots
**Marine Transportation System**—coastal and inland waterways, ports and harbors, and the intermodal terminals serving them
**Rural and Urban Transit**—bus and van service on streets and roadways, rail lines for metropolitan subway and surface "light rail" systems
**Pipeline Systems**—Above and below ground pipelines for commodities such as crude oil, refined petroleum products, and natural gas, plus the storage, transfer, and pumping facilities for pipelines
**Airport Ground Operations**—All ground movement of vehicles, work crews, and passengers.

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Weather can increase safety risks and economic costs, while disrupting the efficiency of systems in every surface transportation sector. Among the threats are (left to right) wing icing on planes before takeoff, hurricane flood damage to railbeds, ice on waterways, and winter weather on highways.

provide the basis for suggesting next steps in each of six strategic thrust areas for continuing the WIST initiative.

## Why We Should Be Concerned About Transportation Weather

The effects of weather on the nation's surface transportation systems touch our lives every day. Weather affects the safety, efficiency, and economic productivity of our transportation systems and facilities. According to a National Highway Traffic Safety Administration estimate, 7,000 fatalities and 800,000 injuries each year involve weather-related adverse road conditions as a factor. The Coast Guard attributes 7 percent of recreational boating accidents to weather. Weather has daily impacts on the goods carried by the nation's Marine Transportation System and its intermodal connections to rail, motor carrier, pipeline, and air cargo transportation systems. These impacts affect the transit time, delivery reliability, efficiency, and cost of all goods transported by these systems.

## Meeting WIST Needs—The Time Is Right!

We cannot control the weather or its effects on vital transportation systems. What we can do is ***use information about the weather more effectively in managing the operation of transportation systems***. We can mitigate or avoid the negative consequences of adverse weather for users of those systems, while getting the most value from benign weather conditions. Fortunately, the immense advances made in meteorological and environmental sciences, coupled with the twin technological revolutions in computing and digital-based communications, provide us with powerful new tools for delivering weather information to potential users across the surface transportation sectors.

**Costs of Roadway Weather**

Adverse weather is estimated to play a role, directly or indirectly, in 800,000 injuries and 7,000 fatalities annually resulting from vehicle crashes. This represents about 28 percent of all highway crashes and 19 percent of all fatalities. The estimated annual economic cost, just from weather-related crashes (deaths, injuries and property), amounts to nearly $42 billion. A study of the effects of snow, ice, and fog estimated that these weather conditions caused 544 million vehicle-hours of delay on highways in 1999.

As an example, forecast-activated anti-icing pretreatment has been tested on a 29-mile length of Idaho highway that is frequently icy in winter. The test resulted in a 62 percent reduction in road maintenance labor hours, an 83 percent reduction in abrasives used to improve traction, ***and an 83 percent decrease in crashes***. A road weather service system in Finland for both road maintenance personnel and road users has an estimated cost–benefit ratio of approximately 1 to 5 for snow and ice control.

As these examples show, the answer lies not simply in providing more and more data; the information conveyed by the data must be useful. It must be timely and accurate enough for decision makers to rely on it when each decision can be costly in terms of both safety and economic consequences. These requirements merge in two ***key challenges*** to be met by current and emerging capabilities for delivering WIST to users:

- **WIST is for decision support**. Transportation system managers, infrastructure operators and maintenance personnel, vehicle operators, shippers, and travelers—the entire gamut of potential WIST users—need WIST as one factor in often complex decisions about their actions.

- **WIST users have diverse needs.** Because the kinds of transportation-related decisions made by WIST users differ, as do the circumstances in which decisions must be made, the information content and its attributes vary from user to user.

## Identifying and Validating WIST Users' Needs

This report presents a compilation of needs for weather information that have been expressed by, and validated by, existing and potential users of that information from the affected surface transportation communities. Representatives from those communities were asked:

- Which specific weather elements (a weather event or a condition affected by the weather or related environmental factors) can affect their activities?
- What information about those weather elements (spatial scale, thresholds of severity or proximity important to decisions, timing of onset and duration) would help the operators and users of those transportation systems to ameliorate negative consequences and exploit positive consequences?
- When is the information needed (the lead time of forecasts or the currency of observations) to be most effective in supporting the decision processes of transportation system managers, travelers, and others who decide on transportation activities?

> This report presents weather information needs expressed and validated by existing and potential information users from surface transportation communities. These user-derived information needs are compiled in the WIST Needs Templates in Appendix B.

Appendix A identifies the entities from the public and private sectors that participated by providing answers to the above questions through an initial questionnaire and a more detailed follow-up survey. The data provided by these information users on their existing and potential needs for WIST were compiled as a set of WIST Needs Templates, which constitute Appendix B. The draft template for each transportation sector was validated with many of these same information users. Their comments were used to produce the final set of templates included with this report and incorporated in the report's analyses and conclusions.

## Cross-Sector Conclusions from Analysis of WIST User Needs

The analyses of the compiled WIST needs (discussed in Chapter 4), together with the detailed discussions with WIST users during the WIST symposia and the template validation process, support five conclusions that apply to all six of the transportation sectors for which user needs were identified.

### Conclusion 1. Users recognize the value of weather information.

> In a 2002 survey of potential users of "511" traveler advisory services, road weather and road surface conditions were most frequently identified as the most critical component for this service.

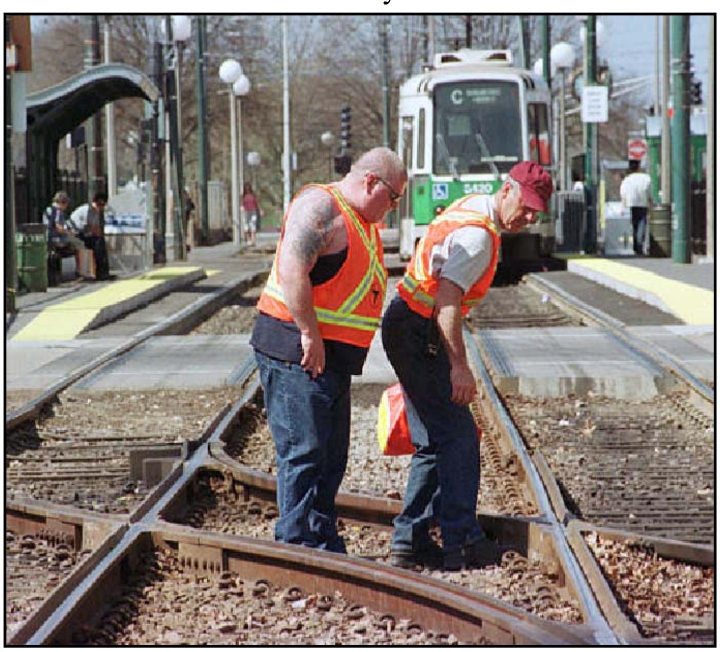
During the WIST needs study, decision makers, regulators, and operators across the spectrum of transportation activities confirmed the value of ***appropriate*** weather information for improving safety and enhancing the efficiency and effectiveness of their activities. Highway maintenance managers concerned about freezing precipitation, pipeline operators worried about hurricane-induced tidal surge, and vessel captains concerned about keel clearance in shallow water must take actions whose consequences depend critically on ***accurate and timely*** knowledge of weather and related conditions. The value of accurate and timely weather information is well recognized throughout the surface transportation user community.

**Conclusion 2. Users want information tailored to their activities.**

In every transportation sector, users stressed the importance of getting weather information tailored for the activity or decision-making process for which they are responsible. They want detailed, location-specific forecasts and situation reports. They also need multiple ways of getting the information—from radio and television, the Internet and other electronic data links, and other communications media. Repeatedly, users stated needs for information that is much more precise, focused, and relevant to their operations. They want higher resolutions, both spatial and temporal. At the same time, they demand better accuracy in the forecasts.

**Conclusion 3. WIST needs cover a variety of weather elements, user activities, thresholds, and lead times.**

The WIST needs validated by the surface transportation user communities encompass many diverse weather elements, including a range of important environmental conditions that depend on "the weather" as commonly understood but that are not viewed as meteorological parameters. Examples include ground surface and rail temperatures, wave height and tidal predictions, and air quality. The WIST needs also cover a broad range of desired lead times and action thresholds for various user activities within each transportation sector.



Trackwalkers inspect a transit line track switch for warped rails on a hot day in Massachusetts. Copyright AP Wide World Photos.

**Conclusion 4. Users differ in their knowledge of weather impacts and awareness of WIST sources.**

Within each transportation sector, there were users with a clear understanding of how information on weather and weather-related conditions could make a difference in the efficiency and effectiveness of their operations, as well as users with lesser degrees of awareness. The latter category of users knew how ***the weather*** affected their operations; they just had not considered how ***better information about the weather*** would be useful. In many instances, once users had an opportunity to discuss the subject, they quickly saw how timely and more accurate weather information could be of benefit.

Users also varied widely in their knowledge of what weather information was available and where they could get it (information sources). Education of potential WIST users, including interactions between the users and providers of weather information, must be part of the WIST service delivery process. Providers must also understand users' decision contexts and provide information that supports the real-life decisions to be made.

### Conclusion 5. Significant differences exist between and within transportation sectors.

The user groups that participated in the WIST needs study come from across the nation; they represent the full geographic and climatic spectrum of the United States. Consequently, there is significant variation in specification of WIST needs, both between the transportation sectors and within a sector. These variations affect which weather elements are important and the thresholds at which the user needs information to make key decisions. Chapter 4 includes a sector-by-sector analysis of what users reported about the impacts of weather elements on their activities and the mitigating actions they could take.

## Goals and Next Steps for WIST Strategic Thrust Areas

Chapter 5 defines one or more goals in each of six strategic thrust areas for continuing a coordinated WIST initiative. Next steps are suggested to move toward these goals.

### Strategic Thrust Area 1: Identifying and Specifying the Gaps in Coverage of WIST User Needs

The first strategic thrust area for continuing the WIST effort is to determine where there are gaps in coverage of WIST user needs and how a diverse provider community—comprising both public and private sector providers—can address them. A joint effort is needed to determine which needs are not fully met and how the resulting gaps should be addressed.

**Goal for Identifying Gaps in Coverage of WIST Needs.** Identify validated user needs for surface transportation weather information that cannot be met with existing information resources of the public–private provider community. Determine whether technology development in progress will meet the need or if additional technical development and/or research is needed.

**Next Step 1A.** Establish a task force to:

- Ascertain (1) which WIST user needs in the initial baseline compilation are fully met now, (2) which could be met more fully through improved presentation and interpretation of current observational and forecast data, and (3) which require data that are not yet available or that have attributes (e.g., accuracy, spatial and temporal scale, timeliness) beyond what is now available
- Review and sustain or adjust priorities for research programs and for transitioning promising tools and other technologies into operations

- Support agency processes to validate and update user needs and provider community programs and approaches for addressing them.

**Next Step 1B.** Sustain and expand the dialogue between the meteorological community as information providers and surface transportation communities as information users.

**Next Step 1C.** Use the baseline of WIST needs represented by the templates developed during this study as a work in progress, to be refined, extended, updated, and validated by the participants in a continuing assessment of where capabilities can be delivered that fill an identified gap or enhance value.

### Strategic Thrust Area 2: Expanding Coordination Among WIST R&D Programs and WIST Providers

To accelerate the application and use of new or emerging technologies and capabilities for WIST support, technology transfer processes (concepts, capabilities, practices, and tools) linking the government and private sectors need to be enhanced. Work to be done in this area includes more, and better, coordination and agreement among federal, state, and local governments and the private sector on the provision of data and services. The guiding principle for expanded coordination and partnering must be to transfer the results of research and development (R&D) programs, typically funded with federal support, to whichever entities are most capable of implementing effective and efficient delivery of WIST services and products to the users.

**Goal for Coordinating R&D and Technology Transfer.** Expand and improve the coordination and communication among both WIST-relevant R&D programs and field implementation programs and projects aimed at incorporating WIST elements in the decision processes and decision support systems used by transportation activities in all sectors. New and expanded partnerships among government entities, the private sector, the academic R&D community, and public-private entities for provision of WIST services and products should aim at increasing the efficiency and effectiveness of translating R&D results into operational value for WIST users.

Traffic advisory signs, like this one in Atlanta, represent an initial step toward intelligent transportation systems with route weather information. Copyright AP Wide World Photos.

**Next Step 2A.** Coordinate the WIST-related R&D research efforts and technology transfer programs of federal agencies, including but not limited to the U.S. Weather Research Program, the national Intelligent Transportation Systems research efforts, and a WIST R&D Program as proposed in this report. Transfer of research results and technology demonstrations to operational capabilities, services, and products available to WIST users should be a major component of this expanded coordination effort.

**Next Step 2B.** Prepare for and form strategic partnerships and alliances among government entities (federal, state, and regional/local), the private sector, the academic R&D community, and public-private entities.

**Next Step 2C.** To provide the legislative basis and funding support for expanded coordination, the provider communities, with the support of the WIST user communities, should give immediate attention to:

- Reauthorization of the U.S. Department of Transportation surface transportation program under the Transportation Equity Act for the 21st Century (TEA-21).
- Full support for the Marine Transportation System as proposed by the Marine Transportation System National Advisory Council and the Interagency Committee for the Marine Transportation System.

### Strategic Thrust Area 3: Clarifying and Defining Provider Roles and Responsibilities

The primary roles in providing weather information for surface transportation are shared among a diverse array of partners in the public and private sectors. In the public sector are federal entities and a large number of state and local government activities. In the private sector, commercial entities sell value-added meteorological services and products. An even larger set of commercial entities provides general information and communication products or services, in which WIST is now or could be incorporated. Partnerships and alliances are critical in this environment, where thousands of entities have roles in developing, maintaining, and operating the nation’s transportation system.

A significant barrier to improving the products and services available to WIST users is that the roles of federal entities versus those of state and local governments or the private sector are neither clear nor consistent. Continued cooperative efforts by all parties in the WIST provider community will be necessary to resolve these conflicts and fill gaps in the service, guidance, and regulatory structures that influence delivery of weather information to WIST user communities. Explicit policy guidance on the roles and responsibilities of public and private sector participants in providing and tailoring weather information would provide a solid basis for expediting provision of new and improved products and services to WIST user communities.

**Data Standards and a National Data Collection System.** The means of generating, obtaining, transferring, and applying weather information are not standardized at present. This lack of standards significantly hinders dissemination and application. Nonstandard or erratic updates to observations and forecasts undermine the value of weather information for transportation-related decision processes and systems.

A nationwide collection of local weather data does not exist and has not been mandated. These data are usually of greatest value locally, but ideally they should then be passed to a national collection location, where the data can be subjected to quality controls, aggregated, synthesized, and archived. The Cooperative Observer Network, operated by the National Oceanic and Atmospheric Administration's National Weather Service (NWS), is a nationwide weather and climate observing network that, when modernized, will provide a useful framework for more extensive national collection and integration of weather and environmental data from regional mesonets.

**Goal for Data Standards.** Provide guidance on the roles and responsibilities of the public and private sectors for various types of observations and networks, particularly in light of better understanding of the accuracy needed to support the nontraditional weather/environmental elements and the new higher-resolution observation and modeling products required by WIST users.

**Goal for Nationwide Data Collection.** Integrate proliferating surface weather observations and networks and incorporate their data into a nationwide data system. This data system should provide access to related geophysical data of value to surface transportation operations. This effort should address:

- Equipment (measurement/sensor adequacy and accuracy, siting criteria, calibration, metadata, and legacy systems)
- Communications protocols and standards
- Data standards for quality control, accessibility, compatibility, interoperability, and archiving.

The National Weather Service maintains automated surface observation systems, like this one, at airports and other locations across the nation. Local and regional mesonets provide more detailed coverage over limited areas. Courtesy NWS, Medford, Oregon.

**Next Step 3A.** Determine the roles of NWS and/or other public and private sector partners in pursuing the above goal for nationwide data collection.

**Next Step 3B.** Address issues of observation standards and protocols, equipment siting, data collection, processing, archiving, access, and proprietary data through the use of a task force or similar action group.

**Next Step 3C.** Examine, test, and implement operationally current and emerging technologies for system definition and transition, system optimization, modal optimization, and environmental considerations.

**Value of an Open Systems Approach for WIST.** A WIST information network will have many providers of services and products and will serve a diverse community of consumers. For this network, there are technical advantages to open systems architectures for communications and interfaces. Decision support tools can be implemented as an application layer on top of this open-systems foundation. The national Intelligent Transportation System (ITS) architecture can provide a starting point for discussing technical issues of data management and accessibility (e.g. format standards) for WIST communications. There must also be attention to security issues, including protecting the integrity of shared data resources and managing the risk that open information will be used in hostile actions.

**Goal for Open Systems in WIST Communications.** Resolve the technical aspects of providing open access to weather information in a manner that benefits diverse WIST users fairly, while providing commercial or mixed public-private value-added suppliers with a level playing field and reasonable incentives for participating. Address issues of data system security.

**Next Step 3D.** Work toward full compatibility of transportation-related communications and information systems with the national Intelligent Transportation Systems architecture.

**Next Step 3E.** Establish a task force to develop a security strategy for national weather information networks, addressing issues of data integrity and the balance between open access to data and restrictions to avoid hostile use of data systems and resources.

### Strategic Thrust Area 4: Translating Research Results and New Technologies into WIST Applications

A number of currently unmet WIST user needs can be met in the near term (within 5 years) through applied research or development of technology applications. Some of these technologies incorporate advances in observing or forecasting meteorological parameters, others involve weather-affected conditions, such as black ice on highways or railbed ground heave. Still others involve information technology and software to make WIST data easier to incorporate and apply in users' decision processes. For these areas, translating research results and science into practical information for users is the primary objective.

Icy conditions after a March 9, 2002 storm in Nebraska caused this trailer truck to jackknife on Interstate 80. Technology is now available to detect black ice that drivers cannot see. Copyright AP Wide World Photos.

Decision support systems will need to incorporate techniques for working with the predictive uncertainty inherent in high-resolution forecasting at longer lead times. For a number of activities in the surface transportation sectors, an accurate forecast of favorable weather is often just as important as a forecast of adverse or mission-limiting weather.

There are significant near-term opportunities to translate technology advances into operations supporting the Marine Transportation System. One key to reducing risks while increasing efficiency in this vital transportation system is to invest in the information infrastructure that supports it. This infrastructure includes weather predictions and forecast models that use both meteorological and oceanographic data to forecast conditions for navigation.

The U.S. Weather Research Program, a partnership of federal entities with the academic and commercial communities, plays a key role in providing the fundamental knowledge and application development that feed the ongoing stream of new meteorological technology from the modernization of the National Weather Service. This research program has substantial value as an umbrella program through which all federal entities with weather-relevant program objectives contribute resources to a coordinated R&D effort. However, the limited portfolio of the U.S. Weather Research Program, together with its emphasis on research rather than operational implementation, constrains its capability to serve all the WIST R&D needs of federal agencies. The range of R&D required, and particularly the specificity of applications tailored to the needs of the surface transportation communities, argues for a separate ***WIST R&D program***. This program would address issues relevant to weather impacts on surface transportation (all sectors) and to improving the capability to move meteorological and other weather-related information into users' decision processes.

R&D programs under a number of federal departments and agencies also provide technology for various surface transportation communities. Greater coordination of the R&D effort across these intramural programs, in conjunction with an interagency WIST R&D Program, would leverage the federal investment in improving and expanding WIST. Cooperative planning and participation by all levels of government, the university research community, and the private sector can leverage the investments made in research to obtain the greatest benefit for and from the transportation systems of the future. The WIST R&D Program should include mechanisms for transitioning research results and new technology into WIST applications. Special attention should be given to leveraging research that has linkages, synergy, or applications in other high priority programs such as homeland security.

**Goal for Translating R&D into WIST Applications.** Establish a WIST R&D Program. This program should be coordinated with and complement the U.S. Weather Research Program, as well as other R&D programs in transportation weather, including work in progress, planned, or funded by federal entities, state and local public sector entities, universities, or private sector organizations.

**Next Step 4A.** Users and providers need access to information about the technology developments and research initiatives relevant to their WIST needs.

- This information must be structured and presented in ways that allow users to understand how they can best exploit available and emerging technology and information resources.

- Access to the information can be facilitated through interdepartmental cooperation at the federal level, coupled with strategic partnerships and alliances within and among the weather information provider communities of the public and private sectors.

**Next Step 4B.** The federal partners in the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) should propose a significant, cohesive research and development program that will provide the basis for improved, integrated weather information, tailored to supporting users' decision processes across all surface transportation sectors and activities.

### Strategic Thrust Area 5: Providing the Fundamental Knowledge to Support Future Technology Development and Application

There are areas in which our fundamental knowledge of weather phenomena is too limited to provide all the information WIST users need, when they need it. If these needs are to be met, fundamental research is needed that is oriented toward filling in the gaps in what we know. Over the next decade, additional and substantial benefits to the nation, in terms of safety, reduced economic losses, and increased productivity, are possible with (1) better spatial and temporal resolution in both forecasts and observations and (2) better forecast accuracy.

The spatial and temporal resolution of weather information needed for surface transportation applications in general and for decision support systems in particular is typically in the misoscale horizontally (grid spacing of 40 meters to 4 km) and in a very shallow layer vertically (from ground level to about 2 meters above it). To meet operational time lines, updates must be rapid—on a scale of minutes to hours—and coupled with lead times of 48 hours. These spatial and temporal requirements present formidable scientific challenges. Meeting them will require improved understanding in areas such as boundary layer meteorology, misoscale thermodynamics, the effects of small local variations, probability and statistics, high-resolution numerical modeling that includes land-air-water interactions, the verification and quality control of nonstandard data, and the preparation and communication of probabilistic forecasts. Processing data at these finer scales will require expanded computational capabilities.

**Goal for Providing the Fundamental Knowledge Base.** Identify and support fundamental research representing a longer-term investment in acquiring the knowledge base needed to meet important WIST user needs that cannot be fully satisfied on the basis of current knowledge.

**Next Step 5a.** Include in the coordinated R&D programs for WIST a substantial level of fundamental research with ***strategic potential for expanding the fundamental knowledge*** needed to meet WIST users' needs.

**Next Step 5b.** The federal agency partners in the FCMSSR should present a unified rationale to Congress and the Administration for the strategic potential of the fundamental research topics included in the WIST R&D Program and other coordinated R&D programs, similar to what has been done in the past for the U.S. Global Change Program.

### Strategic Thrust Area 6. Expanding Outreach and Education

There are major cultural differences between the meteorology and transportation disciplines. Users need assistance and training to achieve maximum benefit from applications of weather information. To help with educating WIST users, universities can offer surface transportation weather courses in programs for transportation management degrees. Training programs for users and managers of transportation systems that provide emphasis on weather factors and the use of weather information will benefit the transportation industry and its consumers.

At the same time, those with training in the meteorological and environmental sciences, as well as expertise in the technologies and techniques of observing and forecasting weather and related phenomena of concern to WIST users, must do better at communicating the significance of their knowledge and technology to the users. Courses in both degree programs and continuing education programs will help meteorologists and other scientific specialists understand surface transportation systems and management processes. This formal training in the conceptual frameworks, operational environments, and technical systems within which transportation decision makers work can be coupled with direct experience working with the user communities.

As traveler-oriented weather information services evolve, the general public needs to be informed about them. Broad support for WIST initiatives can be fostered by communicating the values of WIST, in improving both transportation safety and economic efficiency, beyond just transportation system managers and operators.

**Goals for WIST Outreach and Education.** (1) Incorporate mechanisms for education of potential WIST users, including interactions between the users and providers of weather information, in WIST service delivery processes. Include current information on WIST applications and the value of WIST in transportation systems operations in the training for surface transportation professionals. (2) Provide and promote educational opportunities for meteorologists and related professionals to learn about surface transportation systems where weather and related environmental information can improve system performance. (3) Include information about WIST applications and ways that the public can access and use WIST in their

Hands-on training with state-of-the-art meteorological information systems is part of this course conducted by the Cooperative Program for Operational Meteorology, Education, and Training (COMET), funded by the NOAA National Weather Service. Photo courtesy COMET and NOAA.

own transportation activities in "weather education" outreach to the general public and in school weather education programs.

**Next Step 6.** Conduct a WIST Education Forum on the status of, and directions for expanded efforts in, education, training, and outreach for delivery of services and products to meet WIST user needs. There should be broad participation from the provider and user communities, as well as from the FCMSSR partners. Include topics on:

- Mechanisms for education of WIST users
- Opportunities for meteorologists and related professionals to learn about surface transportation systems
- Outreach to the general public through the media and school programs.

# Chapter 1
# Introduction and Background

## 1.0 Introduction

This report provides a compilation of users' needs for weather information—needs that have been validated with user communities in six surface transportation sectors. Based on an analysis of these needs, the report identifies strategic thrust areas for improving and expanding the weather information currently available. It suggests next steps in these areas that will enhance the value of weather information to the safety, efficiency, and effectiveness of the nation's surface transportation systems.

For this report, ***needs*** are defined as weather data that provide important elements of information for the decision-making processes used by travelers, operators, or managers involved in any surface transportation activity (the ***users***). A weather information need is characterized by a ***weather element***, the transportation ***activity*** that requires the information, the ***threshold*** at which the activity needs information about that element, and the ***lead time*** required for effective planning or action.

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Courtesy Office of Pipeline Safety, Department of Transportation

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The nation's surface transportation sectors include (from upper left) rural and urban transit systems, long-haul railroads, the Marine Transportation System, pipeline systems, and airport ground operations.

This chapter highlights some of the important impacts of weather on the nation's surface transportation systems and summarizes some of the existing and emerging capabilities for providing ***weather information for surface transportation*** (WIST) to users. Chapter 2 describes the process by which users' needs for WIST were identified and validated by developing a set of WIST Needs Templates. The final version of these templates is included as Appendix B. Chapter 3 summarizes the interests in WIST of the federal, state, and local organizations that participated in developing and validating the templates. Each template covers one of the six transportation sectors: roadways, long-haul railways, the Marine Transportation System (MTS), pipeline systems, rural and urban transit, and airport ground operations (see textbox below).

Chapter 4 provides a high-level view of the data in the WIST Needs Templates, along with background information—gathered from the user communities during development of the templates—that helps in interpreting the template data. Users throughout the surface transportation communities surveyed for this study need accurate weather information beyond what is currently available. From highway maintenance managers concerned about freezing precipitation to pipeline operators worried about hurricane-induced tidal surge to river barge captains concerned about reduced visibility in fog, users, decision makers, and regulators across the spectrum of transportation activities ***confirmed the value of weather information in improving safety and enhancing the efficiency and effectiveness of their activities.***

**Transportation Sectors Versus Modes**

For this report, the term ***mode*** best describes a narrower, more specific form of transportation, such as automobile, bus, truck, ferry or subway train. The term ***sector*** is broader in scope and encompasses multiple modes that share a major characteristic, such as the medium in which they operate (on water, on roads, on railways, in the air, etc.) or operation under one management (e.g., transit authorities). This report covers six transportation sectors:

**Roadway—**state and federal highways, roads, and streets

**Long-Haul Railway**—rail lines providing intercity freight and passenger service, with their yards, stations, and depots

**Marine Transportation System (MTS)**—coastal and inland waterways, ports and harbors, and the intermodal terminals serving them

**Rural and Urban Transit**—bus and van service on streets and roadways, rail lines for metropolitan subway and surface "light rail" systems

**Pipeline Systems**—Above and below ground pipelines for commodities such as crude oil, refined petroleum products, and natural gas, plus the storage, transfer, and pumping facilities for pipelines

**Airport Ground Operations**—All ground movement of vehicles, work crews, and passengers.

The economic impact of weather on transportation systems, its toll on the safety and health of the public using these systems, and the increasing demands that will stress system capacity, environmental quality, and social equity dictate that actions be taken to resolve the myriad weather-related transportation issues facing our nation. These factors are reflected in the conclusions from the WIST needs analysis, presented in Chapter 4. Chapter 5 suggests the next steps to be taken in six strategic thrust areas for continuing the coordination of research and development (R&D) programs and for translating research results and new technology into products and services to meet WIST users' needs. Chapter 5 also presents a summary vision of future weather information systems for surface transportation, if users' WIST needs are recognized and met.

## 1.1 Why Should We Be Concerned?

The nation's surface transportation systems touch our lives many times each day. They connect consumers with resources and enable us to travel where we need or desire to go. Nearly every citizen uses or relies on these systems daily—including the 3.9 million miles of public roads, 2 million miles of oil and natural gas pipelines, 120,000 miles of major railroads, and over 25,000 miles of commercially navigable waterways. Transportation services are provided at 5,400 airports, throughout the 6,200 miles of urban rail transit, and at 3,750 waterport terminals (FHWA 1998, p. 17; DOT 1999; TRB 2001). The total value of the national transportation infrastructure is $1.5 trillion, and 11 percent of the national gross domestic product (GDP), or about $8 trillion, is related to transportation (TRB 2001, FHWA 2002a). Weather influences virtually every type of operation or activity involved in these transportation systems and facilities.

The scale of use of surface transportation systems in the United States is impressive. More than 200 million cars and light trucks use our highways. Commuters number about 115 million, and 34 million of them travel more than 45 minutes each way. Of the more than 9 million recreation vehicles, 1.1 million are on the road at any given time. Of the more than 3 million truckers, about 1.1 million are long-distance haulers. Rental cars number about 1.6 million (TRB 2001, FHWA 2002a). On the nation's waterways, ferryboats carry about 134 million passengers each year, while about 78 million people annually engage in recreational boating. In addition, cruise ships provide service to 5 million passengers every year (DOT 1999).

Parts of our surface transportation system function at or near their maximum capacity much of the time, and capacity utilization is increasing. All surface transportation modes have congestion at critical bottlenecks. Weather reduces the capacity throughout the system, creating new bottlenecks and exacerbating existing ones. Actions that mitigate these weather effects improve transportation system safety and efficiency.

### 1.1.1 Adverse Weather and the Nation's Streets and Highways

In the United States about 41,000 people die on highway systems each year. These deaths result from six million crashes that also cause more than 3 million injuries annually. According to the National Highway Traffic Safety Administration (NHTSA), each year, on average, about 1.7 million of these vehicle crashes occur in adverse weather or weather-related adverse road conditions.[1]

> **Road Weather Bottom Line:**
> **7,000** fatalities
> **800,000** injured
> **$42 billion** in economic costs
> ***—each year***
>
> Source: NHTSA estimate (Lombardo 2000).

One estimate from NHTSA is that adverse weather and adverse road conditions related to weather are directly or indirectly a factor in approximately ***800,000 injuries*** **and** ***7,000 fatalities*** resulting from vehicular crashes. That represents about 28 percent of the total crashes and 19

[1] Uniform statistics on weather conditions as a *factor* in accidents are difficult to collect. NHTSA is working on gathering reliable data on this important factor from state and local public safety authorities, but results were not available for this report. The numbers cited here for weather-related injuries, fatalities, and costs are estimates presented by a NHTSA official at the WIST II symposium.

percent of the total fatalities. The estimated annual economic cost from these weather-related crashes (deaths, injuries, and property) amounts to nearly ***$42 billion*** (Lombardo 2000)**.**

Table 1-1 shows the weather condition present when vehicle crashes caused injuries or death. Table 1-2 compares, by vehicle type, the deaths during adverse weather with total roadway deaths. Note that neither of these tables includes weather-related adverse road conditions, which may persist after the weather clears. Nor does the presence of adverse weather at the time of a crash imply that weather was a causal factor.


Winter weather causes a pile-up on Interstate 95 in Virginia. Image Courtesy of WRC-TV, copyright 2002.

Safety and the economic consequences of accidents are certainly critical reasons for being concerned about ***road weather***—the impact on road and highway conditions of weather and related phenomena. But they are not the only reasons. Rain, ice, snow, fog, and other adverse weather conditions can directly reduce the effective capacity of roads and highways (Chin et al. 2002). Because of safety concerns and the consequences when an accident occurs, state and local authorities may impose lower speed limits and partial or complete closures of streets, roads, and highways. Or they may restrict the vehicles allowed to travel on them. Many effects of weather on road conditions—for example, standing water after heavy downpours, roadbed weakening from prolonged excessive soil moisture, potholes after the winter freeze-thaw season, fallen trees and debris after strong storm winds—can continue to slow or halt normal traffic for hours, days, and even weeks after the weather itself has turned fair.

**Table 1-1 Weather Condition at Time of Vehicle Crashes (1999 Data)**

| Number of Crashes (percent total) | | Weather | Injuries | Deaths |
|---|---|---|---|---|
| 5,281,000 | 84% | Normal | 2,757,000 (85%) | 37,107 (89%) |
| 679,000 | 11% | Rain | 364,000 (11%) | 3,086 (7%) |
| 199,000 | 3% | Snow/Sleet | 63,000 (2%) | 680 (2%) |
| 47,000 | <1% | Fog | 18,000 (0.5%) | 569 (1%) |
| 72,000 | 1% | Other | 34,000 (1%) | 275 (<1%) |
| 6,279,000 | 100% | All conditions | 3,236,000 (100%) | 41,717 (100%) |

Source: Lombardo 2001.

**Table 1-2 Adverse Weather and Deaths by Vehicle Type (1989–1999 Totals)**

| Vehicle | Total Deaths | Adverse Weather Present | Percent of Total |
|---|---|---|---|
| Passenger Cars | 312,620 | 42,585 | 13.6 |
| Light Trucks | 190,271 | 26,221 | 13.8 |
| Large Trucks | 56,278 | 9,346 | 16.6 |
| Motorcycles | 28,537 | 969 | 3.4 |
| Buses | 3,617 | 622 | 17.2 |

Source: Lombardo 2001.

In one year (1999), an estimated 544 million vehicle hours of delay occurred on freeways and principal arterial roads, just from fog, snow, and icy conditions (Chin et al. 2002). State, city, and county highway maintenance agencies spend $2.1 billion per year to treat snow and ice on roadways—a third of which is spent just for treatment chemicals (FHWA 1998, p. 16; Davies et al. 2001). The information gathered from transportation system decision makers for this study suggests that these measurable costs represent merely the tip of an iceberg of total direct and indirect economic costs incurred each year because of road weather.

### 1.1.2 Adverse Weather and Other Surface Transportation Sectors

Other surface transportation sectors are also affected by the weather, although the significant weather conditions and consequences may differ from the more familiar effects on roads and highways. For most of us, the MTS and the nation's pipeline systems operate behind the scenes of our everyday lives. Our road and rail systems are familiar sights, but most of us are unaware of the extent to which daily commerce depends on waterways and pipelines, as well as on trucks and trains. Figure 1-1 shows major ports and waterways of the MTS; Figure 1-2 shows just one of the nationwide pipeline systems in the pipelines sector.

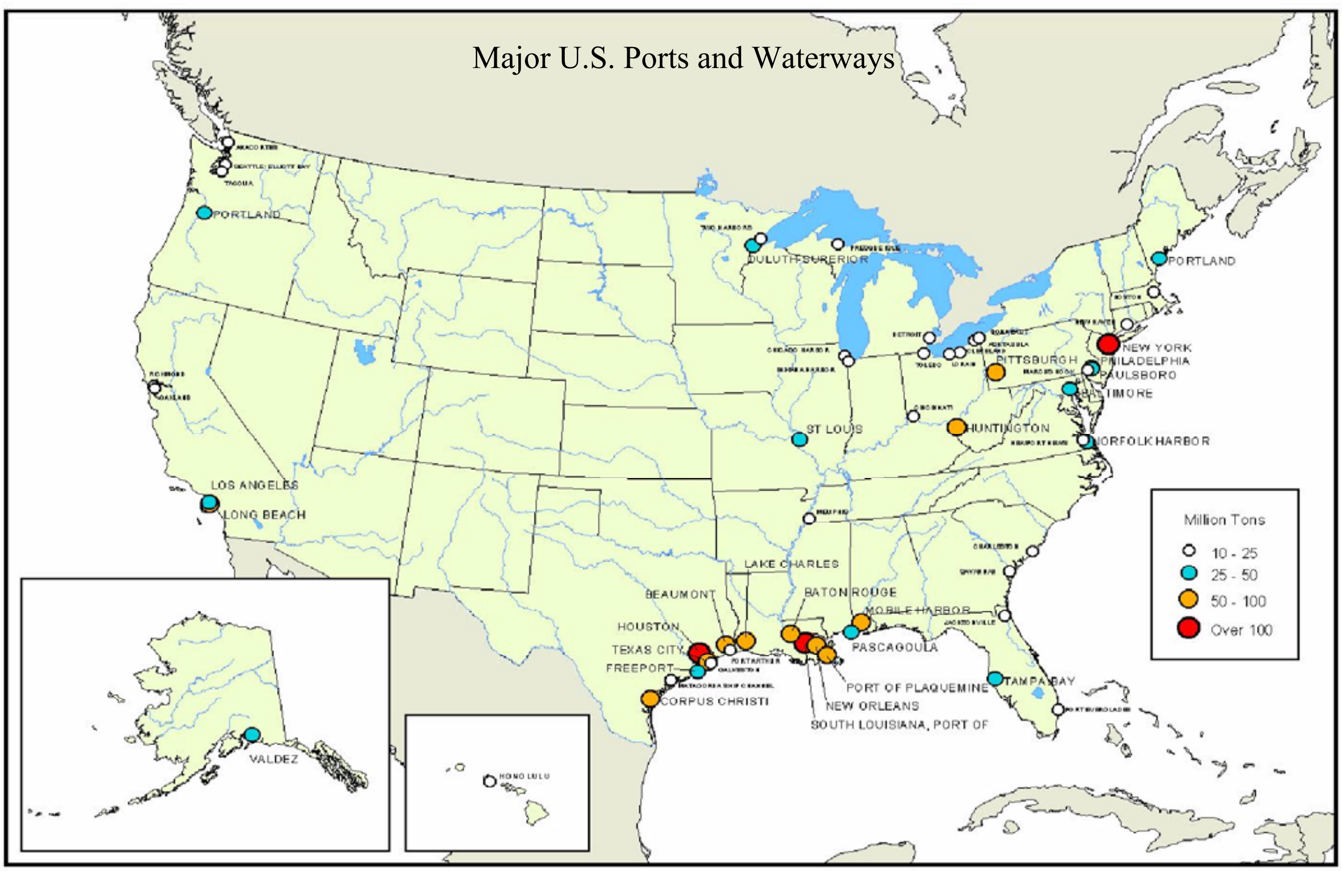



**Figure 1-1** Major U.S. ports and waterways. Source: U.S. Army Corps of Engineers

We are even less aware of the diverse ways that weather affects these essential transportation sectors. Although these sectors—railroads, waterways and ports, airport ground operations, and pipelines systems—have far fewer injuries and deaths than occur on roads and highways, weather still affects safety and economic efficiency. The U.S. Coast Guard lists weather as the cause of 7 percent of recreational boating accidents (DOT 1999, p. 41). Weather impacts in one region have consequences that ripple through interconnected transportation networks, causing bottlenecks, delays in delivery, and imbalances in supply and demand that lead to higher costs for consumers.

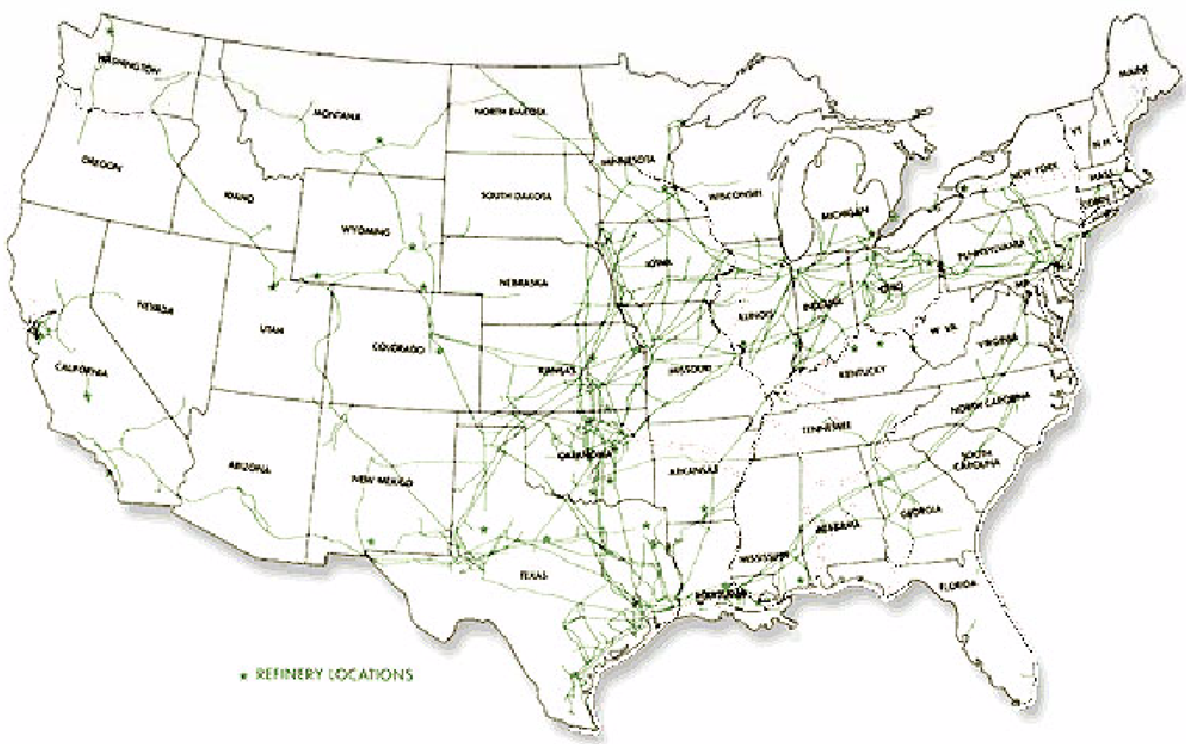



**Figure 1-2** Major refined petroleum product pipelines of the United States. See Section 4.6 for additional maps of U.S. pipelines. Source: AOPL 2002.

The freight community views these transportation assets and infrastructure as an end-to-end system. This systems viewpoint begins with the goods as they arrive at a port in the United States aboard a ship; are transferred to truck, rail, or plane assets; and move to distribution centers or retail centers. To be efficient, this intermodal system requires significant coordination among many producers and shippers. As the practice of just-in-time delivery (the dependable delivery of raw materials or goods so that a factory or retailer does not have to maintain a large inventory) spreads through U.S. industry, shippers must plan for and cope with weather of all types and severity.

Reduced visibility from fog slows traffic on the MTS.
Photo courtesy NOAA Photo Library.

The MTS offers a telling illustration of how these essential transportation systems can be affected by weather. This system comprises the nation's navigable waterways, ports, and harbors, as well as the connections to railroad, roadway, and pipeline systems. It enabled the United States to become the world's leading maritime trading nation; over 95 percent of U.S. foreign trade tonnage is shipped by sea (DOT 1999), and more than 38 percent of intercity freight is carried on inland waterways and pipelines (Coyle et al. 2000). On February 27, 2001, fog closed the Houston ship channel to inbound traffic, causing long delays for vessels using this waterway. Similar conditions caused a backlog of almost 80 ships earlier in the month. Houston and neighboring ports are home to the nation's largest oil and petrochemical plants. Fog along the Gulf Coast was cited as the main reason for a huge, 12 billion barrel decline in the output of U.S. refineries that week. (Reuters 2001).

In October 1994, a major flood on the San Jacinto River near Houston undermined numerous pipelines. Eight pipelines ruptured, igniting petroleum spills into the river. More than 500 people suffered burn injuries. Effects of weather phenomena are the second-most frequent contributor to pipeline damage or failure.

Source: NTSB 1996

Another incident, this one involving an Amtrak passenger train derailment, illustrates how weather conditions can cause problems specific to a transportation system's infrastructure and operations. July 29, 2002, was an excessively hot day in the Mid-Atlantic region. As the Capitol Limited sped through Kensington, Maryland, the engineer applied the train's emergency brakes after spotting an area of misshapen track ahead. The multiple car derailment 45 seconds later left bleeding passengers crawling out the windows of overturned cars. A total of 101 passengers were injured, with one still in serious condition the next day. Experts considered the most likely cause of the 30-inch misalignment of the welded track to be buckling due to the hot weather. A heat order issued that day had reduced the posted speed for freight trains from 55 to 45 miles per hour (mph), but not the 70 mph speed limit for passenger trains. The line remained closed to all traffic until the derailed cars could be removed and the damaged track replaced. Although the number of derailments due to heat buckling of rails has declined, there were 44 accidents attributed to this weather-related condition in 2001 (Manning 2002).

## 1.2 Exposures, Threats, and Risks are Increasing

The economic and safety impacts of adverse weather and weather-related road conditions on highway carrying capacity will multiply as traffic approaches the effective carrying capacity of the system (Figure 1-3). Since 1982, while the U.S. population grew just 20 percent, the time Americans spend in traffic jumped an amazing 236 percent (U.S. News and World Report 2001).

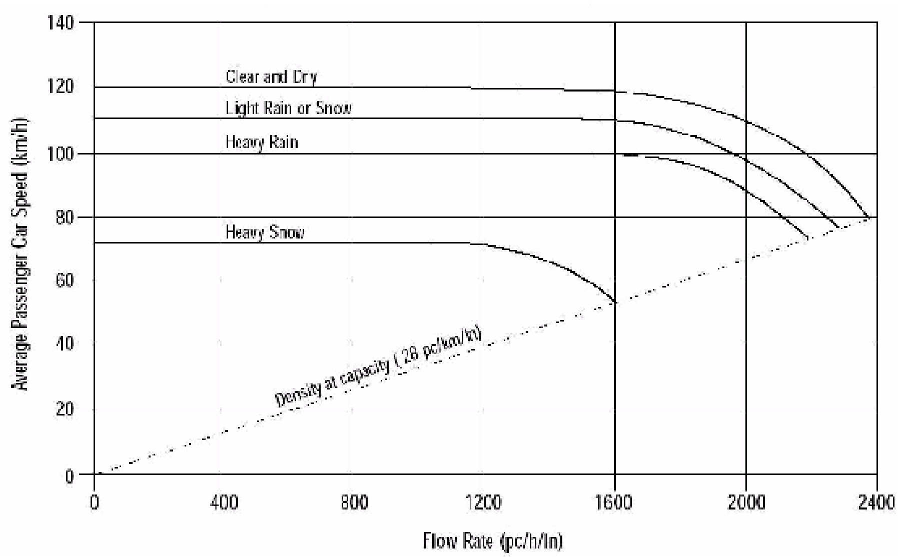



**FIGURE 1-3** Speed-flow curves for different weather conditions, assuming a free-flow speed of 120 km/h. As traffic density (flow rate) increases, adverse weather has a greater impact on average vehicle speed. Pc = passenger car, ln = lane.

In major American cities, the length of the combined morning–evening rush hours doubled, from under three hours in 1982 to almost six hours today. The average driver now spends the equivalent of nearly a full workweek each year stuck in traffic. Congestion costs Americans $78 billion a year in wasted fuel and lost time—up 39 percent since 1990. In Houston, traffic jams cost commuters on the Southwest Freeway and West Loop 610 an average of $954 a year in wasted fuel and time. In New Jersey's Somerset County, congestion costs the average licensed driver $2,110 a year (U.S News and World Report 2001).

The Federal Highway Administration projects that, over the next 10 years, the number of vehicle-miles traveled is estimated to increase by 24 percent. In 20 years, it is expected to increase by 53 percent (FHWA 2002a). As more people and more freight travel more miles on the same streets and highways, adverse weather and weather-related road conditions will increase the strain on the roadway system.

Travelers are certainly aware of the risks associated with road weather. In March 2002, the Gallup Organization reported the results of a public opinion survey on the information most important to potential users of "511" traveler advisory services. Reports on weather-related and road surface conditions were most frequently identified as the most critical component for a 511 service, ahead of accident and road incident reports, construction updates, and even congestion levels on freeways. Forty percent of the respondents identified weather and road conditions as most critical (ITSA, 2002b).

**Call "511" for Road Weather!**

**40%** of potential users of 511 travel advisory services identify road weather and surface conditions as the "most critical" component of this growing transportation information service.

To the extent that capacity-reducing weather variations can be anticipated and communicated, and more precise mitigation measures can be implemented, system efficiency can be improved while operating costs and the number of crashes can be reduced. A recent literature review found no comprehensive studies of costs and benefits for an implemented road weather information system (RWIS) in North America (Boon and Cluett 2002, p. 39). However, there are numerous case studies of how limited RWIS deployments, combined with an anti-icing program, have decreased costs and improved efficiencies for both road maintenance management and travelers.

The costs and benefits of forecast-activated anti-icing pretreatment have been studied on a 29-mile stretch of U.S. Highway 12 in Idaho. This study showed a 62 percent reduction in road maintenance labor hours, an 83 percent reduction in use of abrasives to improve traction, and an 83 percent decrease in accidents (Breene 2001). Case studies prepared for the FHWA's RoadSavers program include the following results reported by state and local highway agencies using an RWIS (FHWA 2002c):

- In the first winter of using an RWIS in decisions on deploying crews for de-icing, the Massachusetts Highway Department saved over $53,000, one-fourth from lower labor costs and the rest from reduced use of equipment, salt, and sand.
- The West Virginia Parkways Authority installed four RWIS units along a 153-km stretch of the West Virginia Parkway in 1989. The savings in salt use were estimated at $6,500 per storm, with labor savings of an additional $2,300 per storm.
- The Dallas, Lubbock, and Amarillo districts of the Texas Department of Transportation installed RWIS stations beginning in 1990. Maintenance managers reported cost savings in materials, equipment, and labor that paid for the installations after the first two or three storms. The RWIS stations have also proved useful in scheduling construction work in fair weather. The RWIS sensors are being evaluated for use in flash-flood warnings during the summer thunderstorm season.
- The New Jersey Department of Transportation began installing RWIS stations in the 1980s and plans to build up to a system of 50 to 60 stations providing statewide coverage. Savings in chemicals, labor, and equipment costs are estimated to reduce expenses for snow and ice control by 10 to 20 percent or more, statewide.

A road weather service system in Finland for both road maintenance personnel and road users has an estimated cost–benefit ratio of approximately 1 to 5 for snow and ice control (DOT 2002).

Richard Raczynski, Chief Engineer for the New Jersey Turnpike, with one of the RWIS stations installed along that state's highways. Copyright AP Wide World Photos.

A 1 to 5 ratio of costs to benefits has also been estimated for full implementation of RWIS and related operational efficiencies in Washington State (Boon and Cluett 2002, p. 39). Thus, a well-informed "weather response" has a high economic payoff, as well as decreasing the risks to persons, goods in transit, and transportation assets.

Risks from exposure to adverse weather conditions are increasing in other ways as well. Certain elements of the population, such as those who are elderly, disabled, or have a low income, are more severely affected by weather impacts on their modes of transportation than the average citizen may be. In the 2000 census, persons 65 and older were 12.6 percent of the population. The Census Bureau expects this fraction to rise to 20 percent by 2030 (Kinsella and Velkoff 2001, pp. 133-134). Many of the elderly rely on rural and urban transit systems, which are subject to delays and cancellations in adverse weather. As a second example, the Census Bureau reports that one fifth of all Americans and nearly half of all senior citizens over age 65 have some level of disability (McNeil 1997). The routine of scheduled, accessible transit operations is a key factor in enabling people with disabilities to find and accept employment and to participate in other daily life activities. Because the number of people with disabilities is likely to increase as the population ages, the total risk from adverse weather impacts on their modes of transportation will increase.

A third example of increasing risks is the shipment of hazardous materials. Hazardous materials are shipped via many modes of transportation in the roadway, rail, MTS, and airport ground operations sectors covered in this study. If a release of hazardous materials occurs, atmospheric transport and diffusion of hazardous substances becomes an immediate concern of the public safety and emergency response teams involved. Major arteries may be closed, and populated areas at risk of exposure may need to be evacuated quickly. The weather may or may not play a role in causing a hazardous release. However, emergency response managers always need to know how the weather will affect the dispersion of materials and their plans for containing the damage and recovering.

## 1.3 MEETING WIST Needs—The Time is Right!

We cannot control the weather or its effects on vital transportation systems. What we can do is *use information about the weather and weather-related conditions* to manage the operations of our transportation systems more effectively, in preparing for and responding to whatever the weather may bring. Fortunately, the immense advances made in meteorological and environmental sciences, coupled with the twin technological revolutions in computing and digital-based communications, provide us with powerful new tools for delivering weather information to potential users across the surface transportation sectors.

However, the answer lies not simply in providing more and more data. The information conveyed by the data must be useful. It must be timely and accurate enough for decision makers to rely on it when their decisions can be costly in terms of both safety and economic consequences. Just as important, the information must be readily assimilated into the decision processes and procedures that potential WIST users already rely upon—or will use in the future—to make their decisions, implement them operationally, and reassess those operations for continuing correction and improvement. Two *key challenges* should be kept in mind when assessing current and emerging capabilities for delivering WIST to users:

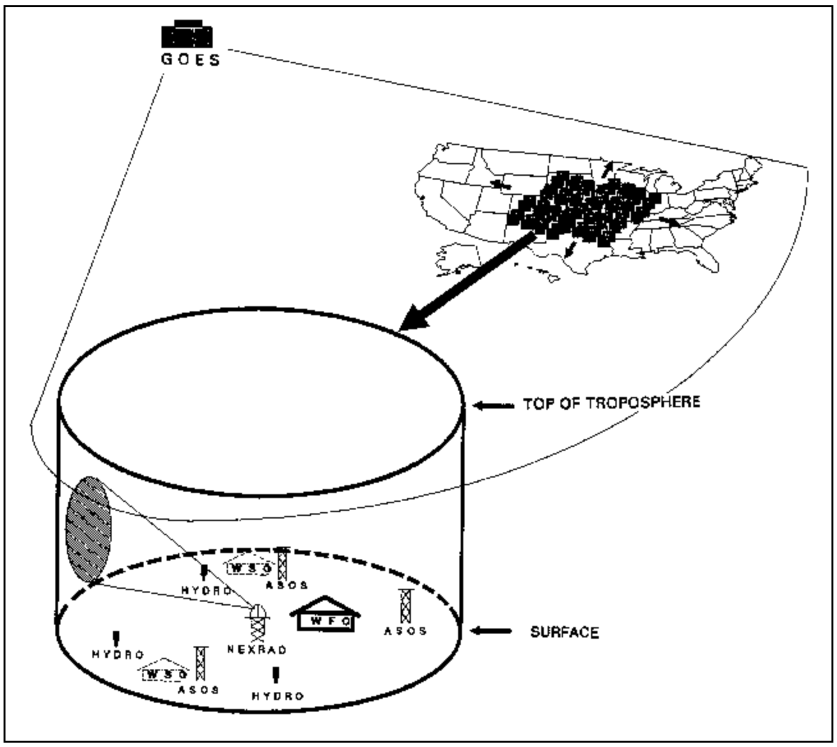
- **WIST is for Decision Support**. Transportation system managers, infrastructure operators and maintenance personnel, vehicle operators, shippers, and travelers—the entire gamut of potential WIST users—need WIST as one factor in often complex decisions about their actions. Meeting those needs requires understanding how the information could affect the user's decision process: What information does the user need? When is it needed? How accurate does it need to be to make a difference?
- **WIST Users have Diverse Needs.** Because the kinds of transportation-related decisions made by WIST users differ, as do the circumstances in which decisions must be made, the information content and its attributes vary from user to user. This report recognizes the diversity of information needs by referring to multiple "user communities" even within a transportation sector. At a general level, a weather map in the newspaper or the weather report on the evening television news provide some useful information to many of these communities. But the *potential benefits* of our scientific knowledge and technological capabilities can only be realized by tailoring WIST at a much more detailed level, across a broader spectrum of diverse user communities, than has ever before been done.

Section 1.3.1 highlights some of the most promising tools to meet this challenge. Section 1.3.2 describes future opportunities that further research and development can provide. In Section 1.3.3, the current situation in coordinating technology implementation for WIST—with the R&D to support it—is compared with the progress made in aviation weather during the past decade.

### 1.3.1 The Potential for Existing and Emerging Technology to Meet WIST Needs

#### Collecting Observations and Preparing Forecasts

Many of our existing national science and technology assets can be applied to the challenges of meeting WIST user needs. The National Weather Service (NWS) within the National Oceanic and Atmospheric Administration (NOAA) is the main federal provider of weather information. The recently completed NWS modernization of observing and information systems has already greatly improved high-resolution weather information through more and better weather observations, improved weather analysis and forecast models, a wider range of forecast information, and broader dissemination of products and services. In addition to providing weather data and services to the nation around the clock, every day of the year, the NWS also partners with other federal programs, academia, and the private sector in research and operational areas.




The suite of observing systems used by the modernized NWS includes weather satellites in geostationary orbit (GOES), Doppler weather radars (NEXRAD), automated surface observing systems (ASOS), and automated rain gauge and stream gauge networks (HYDRO). Courtesy NWS.

A recent initiative growing out of the NWS modernization is the National Digital Forecast Database (NDFD). The mission of NDFD is to increase the benefits of government weather forecasts, primarily through providing digital weather information to "drive" custom applications developed by partners in the weather information provider community. The database is intended to be a "seamless mosaic of NWS digital forecasts" including weather, water, and climate forecasts from Weather Forecast Offices, River Forecast Centers, and the National Centers for Environmental Prediction. It will begin with 5-km spatial grids prior to 2003, with the aim of improving resolution to 2.5 km nationally after that. Temporal resolution will be 6 hours for days 1 to 3 prior to 2003, migrating to 3 hours for days 1 to 3. Temporal resolution for days 4 through

7 will be 12 hours. NDFD will be available to all users and partners in the public and private sectors (Ruth 2002).

Supplementing the suite of NWS data and services, the private sector provides specialized or value-added weather information to a wide range of WIST users. Commercial providers already provide specialized processing of observational data from the NWS systems, mesonets, and specialized observing systems, as well as preparing special-purpose analyses and forecasts (many of which are developed for surface transportation or aviation users). A key role for the private sector in the WIST delivery systems of the future will be information technology applications for specialized weather services, including value-added graphics and data dissemination formats suitable as input for specific users' display or decision support systems (Smith 2001).

> "The provision of weather information in the United States is essentially a partnership between the public sector and the private sector."
>
> Jimmie Smith
> Chair, AMS Board of
> Private Sector Meteorology
>
> Source: Smith 2001, p. 76.

## Intelligent Transportation Systems (ITS) and WIST

The ITS concept has been defined as "the application of computers, communications, and sensor technology to surface transportation." An intelligent transportation system can be viewed as a physical transportation infrastructure supported by a communication and information network. An objective of ITS is to provide highway and transit systems with communication capabilities that are already part of air and maritime transportation. These capabilities include controlling elements of the physical infrastructure, dispatching resources, and informing users (ITSA 2002).

ITS as a guiding concept for surface transportation traces back to research authorized under the 1991 Intermodal Surface Transportation and Efficiency Act (ISTEA). The Department of Transportation administers the resulting research and subsequent deployment programs through the ITS Joint Program Office, but ITS programs are overseen by various agencies with responsibilities for surface transportation. Academic and private-sector organizations are involved in much of the work. In practice, ITS programs have to date primarily covered the highway and transit transportation sectors, with little application yet to other sectors of surface transportation.

The connection between ITS and WIST, in essence, is that ITS provides a means to communicate WIST to anyone connected to an intelligent transportation system's communications network. The National ITS Program has established a functional standard for ITS communication networks called the national ITS architecture.[2] This architecture, based on the concept of open systems, currently defines 32 user services and the interfaces between them. WIST information would be one of the information types flowing into some of these user services, for example the Maintenance and Construction Operations service. User-oriented information tools—such as graphical display systems or decision support systems—that are connected to an ITS-compliant system can be designed to make use of WIST data available on

[2] The national ITS architecture can be accessed in full at <http://itsarch.iteris.com/itsarch/>.

that system. Thus, the ITS architecture provides a technical foundation for delivering WIST in a form relevant to the diverse needs of users.

**Smart Road Research**

*The control room overlooking the Smart Road where Virginia Tech researchers analyze data – near Blacksburg, VA*

Courtesy Intelligent Transportation Society of America.

An ITS communications architecture can also aid in gathering WIST observation data. For instance, the Environmental Sensor Station interface standard in the national ITS architecture can be used to pick up observations from environmental sensor stations along roadsides or railbeds.

### WIST and Surface Transportation Decision Support Systems

A ***decision support system***, as this term is typically used, means a computer-based information processing and display system (hardware and software) that incorporates a variety of data inputs and processes them into an information product (e.g., a graphical display, an audio message, or a printed report) useful to a subsequent decision process. This decision process may occur in the thinking of a system manager or operator, or it could be automated as another computer-based application. Typically, though, current decision support systems are designed to aid human decision makers by giving them highly pertinent information in a form the user can understand quickly.

Decision support systems that incorporate WIST input data can be as simple as roadside traffic advisory signs or a 511 telephone number service for recorded traffic advisory information. Advanced traveler information systems (ATISs) have proven successful in giving travelers alternative routes to avoid congestion and incidents. Studies of recent ATIS deployments have found that they: (1) help drivers make better-informed choices; (2) assist drivers in avoiding congestion and unexpected delays; and (3) reduce the time spent driving (Lappin 2000). These systems show that reliable and timely information about current and future weather conditions enables people to make better decisions about their particular activities and contributes to their safety, as well as increasing the efficiency of those activities. Three examples of current decision support systems that incorporate WIST are described below.

**ATWIS.** One example of current technology for providing in-vehicle information on road conditions and weather forecasts is the Advanced Transportation Weather Information System (ATWIS). ATWIS began as a means of providing route-specific road condition reports and nowcasts (forecasts from the current time through the next six hours) by cellular telephone to rural travelers in the northern Great Plains. The weather forecasts, which are updated hourly, provide information from a traveler's present location (specified by saying the interstate highway mile marker and direction of travel) to approximately 60 miles down the traveler's route. Road weather observations, including road surface conditions, are acquired through coordination with the state departments of transportation (Owens 2000).

By 2000, ATWIS had expanded to three states (North and South Dakota and Minnesota), covering 96,000 miles of highway. Surveys conducted by an independent evaluator found that 94.3 percent of travelers who knew of the service believed it would benefit their safety in the future. The system also provides departments of transportation in the three states with a simple text message and 48-hour forecast tailored to each transportation district. The surveys found that nearly all maintenance crew supervisors read the reports daily. Ninety-five percent said that the daily forecasts were helpful in their planning, and 75 percent altered plans or assignments as a result of the forecasts. A commercial partner has now joined the project (Owens 2000). During 2002, the commercial deployment of this system was enhanced and expanded to include 511 service available to both land lines and cellular telephones in South Dakota and Montana. Extension of the 511 service is planned for additional states. Additional service options are being added on a state by state basis (Osborne 2002b).

**FORETELL.** FORETELL is a multi-state initiative covering the Upper Mississippi Valley region and funded in part by the Federal Highway Administration (FHWA). The goal of the FORETELL program is a RWIS integrated with a wider set of ITS services to enhance safety and facilitate travel. FORETELL provides detailed weather forecasts, generated four times per day for the next 24 hours, with hourly updates, available to users via the public Internet. Spatial resolution is on a 10-km grid, and the forecasts are mapped to interstates and highways to predict pavement conditions. It also collects atmospheric and road condition observations from roadside sensors and mobile platforms, processing them into "plain English" descriptions for users. A field operational test of the RWIS has been completed in Missouri, Iowa, and Wisconsin (FHWA 2002b). A final report is forthcoming.

FORETELL forecasts include precipitation, temperature, cloud cover, wind direction and speed, weather radar imagery, atmospheric pressure, pavement temperatures, and 24-hour precipitation accumulation. They also predict ice conditions and provide information on drifting snow and roadway temperature. The FORETELL display can provide users with route-by-route information about the specific weather parameters required to conduct their operations. For example, it can be configured to flag sections of roads that are affected by frost, drifting snow, ice, or snow accumulation (Sheffield 2000).

**MDSS and the STWDSR Initiative.** The FHWA's Office of Transportation Operations is sponsoring a multi-year, multiphase initiative to develop Surface Transportation Weather Decision Support Requirements (STWDSR) as part of the Road Weather Management Program. Early documents produced under STWDSR developed a needs analysis for decision support to winter road maintenance managers, as a first step toward a conceptual WIST Decision Support System (WIST-DSS). A prototype system aimed at winter road maintenance, called the Maintenance Decision Support System (MDSS), has been developed for the FHWA by a team of national research centers (NCAR 2002):

- Massachusetts Institute of Technology–Lincoln Laboratory and the National Center for Atmospheric Research, representing the university research community
- The Forecast Systems Laboratory, and National Severe Storms Laboratory of NOAA (Department of Commerce)
- The Cold Regions Research and Engineering Laboratory of the U.S. Army Corps of Engineers

In the future, snow removal operations will be guided by road weather data from maintenance decision support systems. Photo courtesy Ohio Department of Transportation.

The MDSS work is guided by an Operational Concept Description, which is the high-level specification for the WIST-DSS (Nelson 2001, p. 7). The MDSS project goal is to develop a prototype capability that:

1. Capitalizes on existing road and weather data sources,
2. Augments data sources where they are weak or where improved accuracy could significantly improve the decision-making task,
3. Fuses data to make an open, integrated and understandable presentation of current environmental and road conditions,
4. Processes data to generate diagnostic and prognostic maps of road conditions along road corridors, with emphasis on the 1- to 48-hour horizon,
5. Provides a display capability on the state of the roadway,
6. Provides a decision support tool, which provides recommendations on road maintenance courses of action, and
7. Provides all of the above on a single platform, and does so in a readily comprehensible display of results and recommended courses of action, together with anticipated consequences of action or inaction.

(Mahoney 2001).

The priorities of the MDSS include developing capabilities for improving diagnostic and prognostic weather information, supporting operational-scale road treatment decisions, and tailoring the interface for use by winter road maintenance managers (NCAR 2002). Release 1 of an MDSS functional prototype was made available to the public in September 2002. This functional prototype is designed to be a template for future operational capabilities in winter road maintenance decision support. The design is modular, so that components can be modified and improved by organizations responsible for winter maintenance operations. The developers anticipate that the private sector and transportation departments at the state and local level will jointly develop operational versions of the system (Mahoney 2002).

### 1.3.2 Expanding the Fundamental Knowledge Base for New Capabilities

As the preceding section illustrates, a great deal is being done with the current state of knowledge in atmospheric and environmental sciences, as well as the state of the art in technologies for observing systems, information analysis, modeling and forecasting, and information visualization and communication. However, there are areas in which our fundamental knowledge of weather phenomena is too limited to provide all the information WIST users need, when they need it. If these needs are to be met, fundamental research must be done to fill the gaps in what we know. The goal of such research should be to expand the understanding of the causal factors responsible for weather elements that affect surface transportation systems.

Weather and related information of interest to surface transportation includes conditions throughout the boundary layer (to about 1 km altitude, higher for some weather radar applications). But the consequences that affect the first 2 meters vertically are particularly relevant to surface transportation. These effects include the interaction of weather with structures above ground level and ground-surface-subsurface geophysical conditions related to weather. In each of these domains, there are issues of the temporal and spatial resolution required to reflect climatic and physiographic variations at the scales relevant to different transportation activities.

To provide this information, atmospheric science must be extended through better physiographic characterization, more complete observation of the weather and weather-related elements of interest at relevant spatial and temporal scales, and improved modeling to predict future states of these elements. Appendix E contains a detailed list of the needed research, gathered during the WIST needs identification process described in Chapter 2.

The observational issue is partly a matter of integrating diffuse capabilities (e.g., the variety of nontraditional surface/subsurface observing systems) and extending other environmental observing capabilities (e.g., higher resolution remote sensing at ground level) and new space-based remote sensing techniques. Heat balance modeling for road temperature is a good example of how weather modeling concepts can be applied, but further extension of current geophysical modeling capabilities is needed before the potential benefits of this and other modeling concepts can be reaped through technological applications.

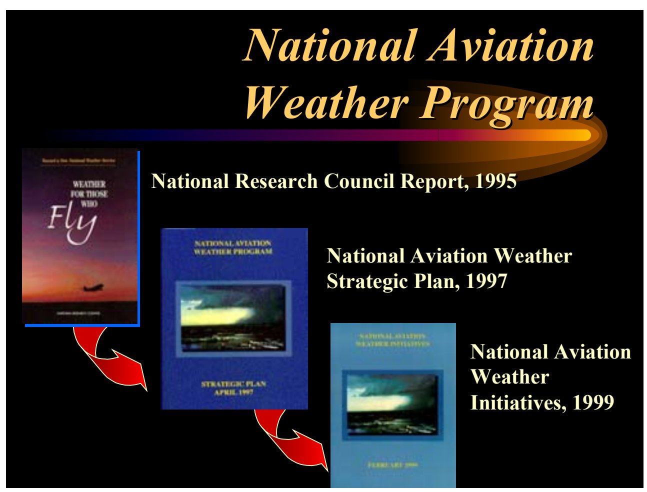
Many environmental prediction techniques are related in their common use of observations, the sequential processing of environmental information, or the fusion of parallel kinds of information. Integrating these techniques to meet WIST user needs will require an open system of environmental information (incorporating observational data and short-term extrapolations from observations, as well as forecasts based on model outputs) that can also disseminate information products to end users in user-friendly formats.

WIST-related research must include more than environmental sensing stations and meteorological modeling. There must also be investigations into new remote-sensing technologies, such as using differential Global Positioning System data to provide water vapor information. Also needed is work in cognitive structures and knowledge representation, to guide development of information structures that communicate *useful* information more effectively and quickly to transportation system managers and crews, vehicle/vessel operators, and other transportation decision makers. Finally, research is needed on what motivates users to pay attention to weather information and incorporate it in the decisions that guide their daily actions.

### 1.3.3 Aviation Weather and Surface Transportation Weather

The situation for WIST now is reminiscent of the situation for aviation weather a decade ago. A 1994 report from a National Research Council study committee, *Weather For Those Who Fly,* described the significant impacts that weather has on safety and efficiency in different aviation sectors (air carriers, commuters and air taxis, general aviation). It presented a vision of how technology could marry recent advances in weather observation and prediction with information communication and visualization to provide diverse communities of aviation weather users with information that would be far more useful and relevant to their operational decisions (NRC 1994).

A year later, a second study committee of the National Research Council shook up the status quo. It called on the Federal Aviation Administration (FAA) to "provide leadership, establish priorities, and ensure the funding needed to improve weather services for aviation weather users and to strengthen related research" (NRC 1995, pg. 1). This report, *Aviation Weather Services: A Call For Federal Leadership and Action,* decried the fragmentation of federal R&D programs for aviation weather and recommended a coordinated federal effort to seize the opportunities that science and technology were offering.




Reports from the National Research Council spurred a federal interagency strategic plan for aviation weather, leading to initiatives that are now producing operational results.

In the years after these reports were published, the FAA, NOAA/NWS, the aviation weather services in the Department of Defense, and other agencies did embark on a much more vigorous initiative to improve aviation weather. They clarified roles and responsibilities of key players, including the private sector, in providing aviation weather services. The information providers worked with the academic research community and user communities in the aviation sectors to find a pragmatic balance between technology push and (user) requirements pull. User needs were validated, and the federal partners defined and adopted a coordinated set of requirements, to be addressed by programs within and among the partners. These efforts not only coordinated R&D programs but also implemented projects to transfer research results and innovative technology into aviation operations. The fruits of this initiative are now improving the safety and cost-effectiveness of day-to-day operations. Thus, the series of steps taken to improve aviation weather provides a useful case study for the effort required to address WIST needs.

In some respects, however, the situation for WIST is even more challenging than it was for aviation weather a decade ago. By 1994, the importance of aviation weather to the aviation industry and the nation had already been recognized for fifty years, dating back to the importance of weather services during World War II and every military action since. The vulnerability of the first commercial services to adverse weather made aviation weather a priority for both the air carriers (cargo and passenger) and the National Weather Service. Many Weather Service Forecast Offices were co-located with an airport. By contrast, at a June 2001 meeting on the future of intelligent transportation systems, surface transportation weather was described as "a niche industry for the past thirty years that has received little attention from the meteorological community" (Osborne 2001).

Compared with the more mature status of aviation weather, WIST-related R&D is still in its early, tentative phase, as is federal agency support for implementing WIST in operational systems. This difference is reflected in federal budget outlays (Table 1-3). Within the Department of Transportation, weather-related operations in fiscal year 2003 totals $456 million and is supported by $30.8 million in R&D programs. However, nearly all (97 percent) of the operations are in aviation weather, as is 94 percent of the supporting research. The $2 million R&D budget in the FHWA represents just 6.5 percent of the total DOT budget for weather research.

**Table 1-3** Federal Budget for Meteorology, Fiscal Year 2003

| Annual Budget | Weather Operations | Supporting Research |
|---|---|---|
| Total DOT: $59.3 billion | $456 million | $30.8 million |
| Aviation | $443 million | $28.8 million |
| FHWA | $0 | $2 million |
| All Federal Entities:<br>$2.84 billion for meteorology | $2.46 billion | $384 million |

Source: OFCM 2003

Of course, much of the federal presence in weather-related operations and in R&D for atmospheric sciences is in other departments and agencies, particularly in NOAA/NWS, as indicated by the bottom line in Table 1-3. A coordinated effort to develop WIST-related applications of existing and emerging science and technology can be leveraged from this large investment in general meteorological services and the R&D to support it. Given the significant role that surface transportation plays in the nation's economy and public safety, a similar table for the federal budget in 2012 could show significant growth not just in WIST-related R&D but also in WIST operations—but only if a coordinated WIST effort can follow the trail blazed by aviation weather.

## 1.4 Roles and Responsibilities of Information Users and Providers

The primary roles in providing weather information for surface transportation are shared among a diverse array of partners in the public and private sectors. In the public sector are federal entities and a large number of state and local government activities. In the private sector, commercial entities sell value-added meteorological services and products (often referred to as VAMS). There is an even larger (in numbers and in market presence) set of commercial entities that provide general information and communication products or services, in which WIST is now or could be incorporated. (Broadcast and cable television news, commercial radio, newspapers, and Internet service providers are just a few examples in this second category.) Participating in both the public and private sector provider activities are the academic research community and a growing number of "public-private" entities, often established with public support at the state level.

Federal entities generate most of the general weather information and services for public use, as well as providing regulatory guidance for both providers and users of WIST. Federal entities are also major WIST users in their roles as regulators of, or service providers to, the surface transportation communities. State and local entities augment federal WIST services with local or specific types of observations and transportation-oriented weather decision aids. These entities also constitute major WIST user communities, particularly those with direct responsibility for maintaining infrastructure or operating transportation systems (state departments of transportation, city and county street/highway departments, regional transit and airport authorities, school districts, and more). The private sector includes substantial WIST user communities, including any commercial entity involved with transporting goods or people in any of the surface transportation sectors, as well as the VAMS and general information disseminators on the provider side.

Partnerships and alliances are critical in this environment where thousands of entities have roles in developing, maintaining, and operating the nation's transportation system. The framework for successful partnering, particularly where the federal agencies are involved, is shifting toward more inclusive participation. There is greater consideration of multiple goals, as well as recognition of the diverse priorities present in local, regional, national and international activities, plans, and markets. Leadership will be essential to facilitate the changes required, but the leaders must be willing and able to listen to and work with their partners. Building constructive relationships will go a long way toward overcoming the obstacles to introducing innovative ideas and technologies and proliferating their beneficial use throughout the nation.

## 1.5 The Path Forward

The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) has collaborated with representatives of its 15 federal partners (Figure 1-4) to sponsor meetings and symposia to identify the weather support needs of national transportation systems. These gatherings highlighted the need for, and merits of, coordinating the federal R&D effort to provide a programmatic focus dedicated to weather information for surface transportation. This effort would address the needs of users in all surface transportation sectors. An initial task defined in the meetings was to identify, compile, and validate existing and potential needs for WIST of the transportation communities among the constituencies of the OFCM federal partners.

**OFCM PARTNERS**

| **Departments of:** | **Independent Agencies:** |
|---|---|
| Agriculture | Environmental Protection Agency |
| Commerce | Federal Emergency Management Agency |
| Defense | National Aeronautics and Space Administration |
| Energy | National Science Foundation |
| Interior | National Transportation Safety Board |
| State | Nuclear Regulatory Commission |
| Transportation | |

**Executive Office of the President**

Office of Management and Budget
Office of Science and Technology Policy

**Figure 1-4** OFCM federal partners in defining weather information needs.

### 1.5.1 Initial Endorsement for a Coordinated WIST Effort

Federal programs that include assessment of WIST user needs trace back at least as far as the formation of a Weather Team by the FHWA, under the Intelligent Transportation System program within the DOT (DOT 1998, p. 1). The effort to coordinate the federal effort on WIST began the following year. On September 22, 1998, the Federal Coordinator for Meteorology and Supporting Research presented a “Look to the Future” to the Federal Committee for Meteorological Services and Supporting Research (FCMSSR). The FCMSSR, which is a multi-agency committee of senior-level representatives from seven cabinet-level departments, six independent agencies, and two offices within the Executive Office of the President (Figure 1-4), was established to provide policy guidance to OFCM (Figure 1-5).

The “Look to the Future” report identified priority areas, issues, problems, and ideas to help improve the effectiveness of interagency coordination and cooperation. Surface transportation needs (including ground and marine transportation modes) were highlighted for attention. Support for WIST was described as minimal, relative to the unmet needs of travelers, transportation maintenance and traffic management operations, and transportation industries. Both safety and economic productivity were emphasized as benefits to be gained. Coordination among the FHWA, other partners from the Departments of Transportation and Commerce, state and local entities, and others in the public and private sectors would be essential for defining requirements and developing tailored decision aids. The FCMSSR agreed on the importance of addressing WIST user needs through a coordinated effort.

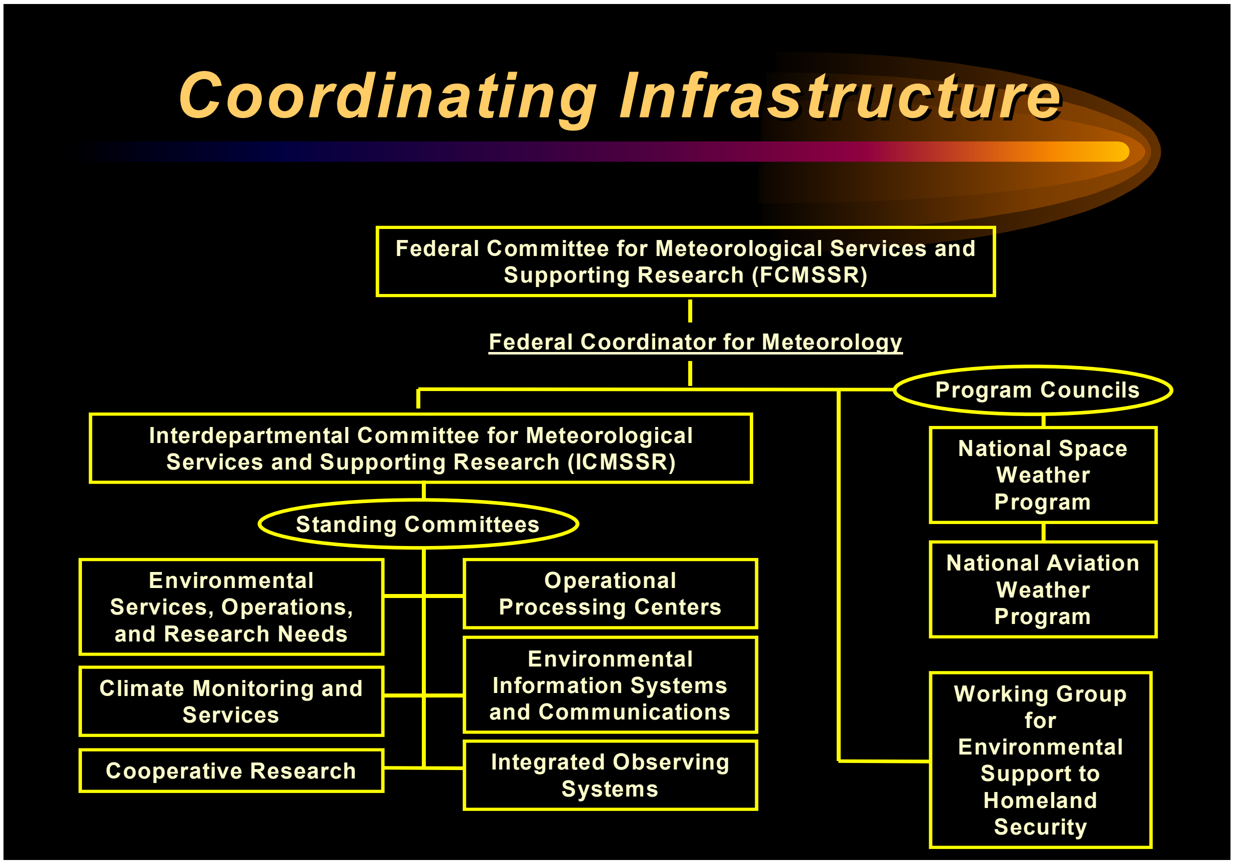



**Figure 1-5** OFCM infrastructure.

Subsequently, in December 1998, the director of DOT's ITS Joint Program Office spoke before the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) on the connection between ITS and WIST. This presentation concluded with a recommendation that a relationship be established between the FHWA and NOAA for surface transportation weather, similar to that between the Federal Aviation Administration and NOAA for aviation weather. In response, the ICMSSR tasked the OFCM to establish a Joint Action Group to address mission needs and meteorological requirements for surface transportation weather.

In June 1999, the OFCM sponsored an interagency meeting with 35 participants representing key federal entities. The meeting, which focused on the federal entities' views on WIST needs and potential requirements, featured presentations by users, providers, and research organizations. The participants supported an effort to identify and publish WIST needs that could be identified by the federal entities, state and local governments, trade associations, and commercial and private enterprises. In addition, the group endorsed the ICMSSR direction to establish a Joint Action Group.

Also in June 1999, the OFCM formed an interagency Joint Action Group for Weather Information for Surface Transportation (JAG/WIST). The JAG/WIST consisted of representatives from 15 federal entities whose mission areas give them regulatory or operational responsibility in four surface transportation sectors. The JAG/WIST met in July 1999 and began planning for a symposium on WIST (the First WIST Symposium), which was held in December 1999 under the joint sponsorship of the OFCM and the FHWA.

To cover the spectrum of current and potential WIST users, the needs identification effort gathered perspectives from intermodal, interstate, national, and international transportation entities; the public and private sectors; and local and regional organizations. Organizing and validating the needs submitted from these sources required extensive coordination with federal, state, and local transportation agencies; metropolitan planning organizations; the transportation industry; the transportation research community; resource agencies; law enforcement and emergency response agencies; educational institutions; public interest groups; and others committed to quality transportation. This process is discussed in detail in Chapter 2.

A second symposium (WIST II) was held in December 2000 to report on progress in identifying and validating WIST user needs and plan next steps. (See Chapter 2 for the role of both WIST symposia in the needs identification and validation process.)

### 1.5.2 FCMSSR Endorsement for Continuing the WIST Effort

The FCMSSR met on November 14, 2000, to focus on issues relevant to the transition team for the newly elected administration. To improve road weather information, the committee recommended investments in expanding observing networks and developing decision support systems. The FCMSSR thus endorsed continuation of the objectives of the WIST effort it had initiated in September 1998.

### 1.5.3 Strategic Thrust Areas and Next Steps in the Coordinated WIST Effort

Because of the great diversity of roles and responsibilities in the WIST provider community, a validated set of WIST user needs does not automatically generate a corresponding set of requirements. Understanding the needs of users is an initial step in an ongoing process. The analysis of WIST needs in Chapter 4 supports both cross-sector and sector-specific conclusions. In Chapter 5, these conclusions, informed by all the information gathered during this study, provide the basis for defining the next stage of a coordinated WIST effort. Next steps are recommended for each of six strategic thrust areas.

The opportunities for improving safety and economic efficiency across all surface transportation sectors are burgeoning. We also have good reason to invest resources, time, and talent to pursue those opportunities. But we must find the will and the way—politically, fiscally, and programmatically—to seize them.

# Chapter 2
# Needs Identification and Validation Process

## 2.0 Strategy

Early in the WIST needs assessment, a decision was made to include a broad spectrum of surface transportation sectors. Each sector was to be treated equally with respect to its information needs. The initial sectors selected for assessment were roadways, railways, the Marine Transportation System (MTS), and pipeline systems. Sectors for transit (metropolitan/regional transit systems) and airport ground operations were added as the sampling process evolved.

The process began by creating a model for identifying weather information that might be needed or useful in operating surface transportation systems in these sectors. The model included identification of mission statements, weather factors, time scales, weather information providers, and information delivery methods. The Joint Action Group for Weather Information for Surface Transportation (JAG/WIST) coordinated the federal initiative. Individual members of the JAG/WIST coordinated their agencies' responses and provided guidance for subsequent steps in the needs assessment.

Identification of WIST needs began with broad characterizations of transportation sectors, without attempting to capture the nuances and variations within these sectors. The starting objective was to identify as many weather characteristics as possible that affect surface transportation. Then, as the needs identification process passed through successive iterations, subsectors were identified and refined with respect to substantive differences in their weather-related impacts or potential actions in response to weather information. These subsectors were eventually termed "activities" within a sector, and the term "activity" is used in Chapter 4 and in the WIST needs templates. The rationale for delineating an activity within a sector was either the uniqueness of the activity's needs and requirements or differences in institutional operations among activities within a sector.

## 2.1 First WIST Symposium

The goal of the first WIST Symposium, held in December 1999, was to establish national needs and requirements for weather information associated with decision-making actions involving surface transportation (OFCM 2000). This goal was consistent with a major theme of the historic *Transportation Equity Act for the Twenty-First Century*. Former Secretary of Transportation Rodney E. Slater, in his summary message describing this important legislation, stated that

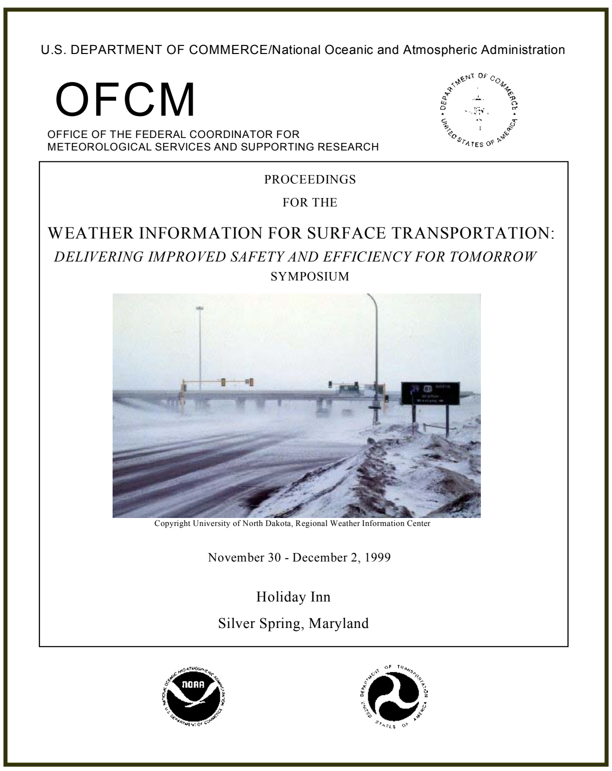
> *… transportation is about more than concrete, asphalt, and steel: it is about people, and providing them with the opportunity to lead safer, healthier, and more fulfilling lives.*

Implicit in Secretary Slater's statement was recognition of the effects weather has on the safety, health, and productivity of the nation's citizens. Actions to be taken in response to this legislation included expanding the coordinated response to identified national needs. More than 120 transportation and weather professionals attended the plenary sessions and three workshops.

They represented federal entities, state and city governments, urban and rural transportation agencies, professional and trade organizations (with member corporations), and weather service providers (government and commercial). The sessions focused on:

- Department of Commerce and Department of Defense services and capabilities for surface transportation decision support
- Commercial weather information production capabilities and services
- Federal entity weather information needs
- State and local weather information needs
- Weather information needs of professional and trade organizations
- Research and technology innovation for decision support.

Not surprisingly, the symposium produced some shared themes. The participants emphasized weather events that trigger decisions, spatial and temporal dependencies, standards and formats, decision-making authorities, user and provider capabilities and responsibilities, new initiatives, and implementation. They emphasized both the importance of weather observations relevant to surface transportation and the current lack of observations suited to the needs of transportation decision makers. *The attendees also overwhelmingly supported a proposal to establish a nationwide baseline of weather information needs for surface transportation and endorsed the pursuit of solutions that would meet their specific mission needs.*


U.S. DEPARTMENT OF COMMERCE/National Oceanic and Atmospheric Administration

OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

PROCEEDINGS
FOR THE
WEATHER INFORMATION FOR SURFACE TRANSPORTATION:
*DELIVERING IMPROVED SAFETY AND EFFICIENCY FOR TOMORROW*
SYMPOSIUM

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November 30 - December 2, 1999

Holiday Inn
Silver Spring, Maryland

Cover from WIST I proceedings.

## 2.2 Initial Information Gathering

The process of identifying and building a nationwide baseline of weather information needs began in earnest shortly after the WIST I symposium. The first stage was to identify the agencies and activities that had a stake in this information resource. The next stage was to implement a process to collect and validate data on WIST user needs.

To identify existing and potential WIST users, the study staff sent a letter to request participation, with a questionnaire, to surface transportation professionals from federal, state, and local governments and from the commercial sector. The questionnaire solicited comments on agency missions, identification of operations impacted by weather elements, actions and decisions taken in response to weather elements, and general information on availability of weather information to meet user needs. This last category included sources and communications media such as newspaper, radio, and television. The distribution list for this initial contact letter was compiled with the help of the JAG/WIST members and other staff from the WIST-relevant programs of the FCMSSR federal partners.

The request letter and questionnaire were sent to more than 700 persons, of which about 500 were transit managers across the United States. The 108 responses provided the basis for expanded sampling of weather information needs from entities of transportation modes that represented a cross-section of geographical areas and regional concerns. In addition to the data from the replies, the staff, with assistance from members of the JAG/WIST, conducted one-on-one interviews with representatives of the FCMSSR federal partners and with operations and management officials of metropolitan transit authorities in the local area. The responses to the initial request for participation provided two kinds of information for continuing the WIST needs identification process. First, interested individuals from across the target transportation sectors were identified for participation in subsequent steps of identifying and validating WIST needs. For sectors in which there were few responses or in which major activities within the sector had few responses, additional names were sought for and request letters were sent out.

Second, the responses to the initial questionnaire and the staff interviews were used to refine and expand the data gathering model. Overall, the responses confirmed that weather is indeed a factor in many phases of transportation operations. The responses also reinforced the view that more accurate, timely, and mission-specific information about current and forecast weather will conserve resources and enhance operational effectiveness, efficiency, and safety. Two shortcomings of currently available weather information also emerged from these responses:

1. A lack of definitive information at the spatial and temporal scales required for many users' decision processes
2. A lack of specific thresholds at which information on identified weather elements was needed.

## 2.3 Follow-up Survey

To address the limitations in the first questionnaire and to build upon the information obtained from the First WIST Symposium, the questionnaire responses, and the agency interviews, OFCM staff, with the assistance of the JAG/WIST, prepared a follow-up survey. The survey was sent to recipients of the original WIST questionnaire, plus others identified over the course of the first year of information gathering. More than 750 surveys were distributed.

The extended survey sought details on the time and distance scales, thresholds, and operational decisions and actions important for each weather element of potential interest to the respondent. The survey form was formatted as a table shell, or ***template***, with weather elements as the rows of the table and columns for thresholds, lead times, impacts, and mitigating actions for each weather element.

## 2.4 Data Extraction and Analysis for Summary WIST Needs Templates

Data extracted from the initial questionnaires and the follow-up survey were used to identify transportation activities (subsectors) within the six major sectors, weather elements and thresholds, mitigating actions and key decisions, and time and spatial scale sensitivities. These data were incorporated into summary tables of draft WIST needs, with one table for each transportation sector. The summary tables, called WIST Needs Templates, were used in the validation phase. The final seven templates for the six major sectors, representing all the needs identified and validated during the study, are reproduced in Appendix B. In addition to a general Roadways template, a template specifically for federal highways was prepared to capture the scope and interests of programs within the Federal Highway Administration. Tracking information for participants' organizations and administrative data, along with general comments, was also collected and maintained, although these data are not included in the WIST Needs Templates.

### Weather Elements

A ***weather element*** is a particular weather condition or a consequence of weather conditions that WIST participants identified as affecting (1) transportation system operations (e.g., road or railway maintenance; traffic management on rail, road, or marine transportation systems) or (2) the safety, economic value, or efficiency (time as well as cost) of transportation activities using those systems (e.g., ship or barge movement on the MTS, truck and car movement on roadways). The categories of weather elements that emerged from the initial data gathering and the first WIST Symposium are precipitation elements; temperature-related elements; thunderstorm-related elements; winds; visibility; tropical cyclone, sea state, and ice (on waterways); and miscellaneous elements. Table 2-1 lists the individual weather elements, as identified by the respondents, in each of these categories.

This list of WIST weather elements contains many traditional meteorological parameters. But it also contains some unique and nontraditional elements for which the weather information provider community has not routinely provided information to their customers in the past. For example, freezing precipitation is a standard element, but "ice accumulation on structures, in inches" is not. Likewise, air temperature is a standard element, but air temperature change rate, rail temperature, and subsurface temperature are not. Some of the elements desired by WIST users are clearly not meteorological in nature and would be characterized by environmental scientists as hydrologic, geophysical, or oceanographic data. However, the users view all these elements as ***conditions about which they need information*** and which, to them, are intrinsically linked to the impact of weather on their operations.

**Table 2-1** Weather Elements Identified by WIST Users, Grouped by General Category

**Precipitation Elements**
- Freezing precipitation (ice)
- Structure ice accumulation (inches)
- Pavement ice accumulation (inches)
- Frozen precipitation (snow, inches)
- Snow accumulation observation (inches)
- Roadway snow depth observation (inches)
- Roadway snow pack depth observation (inches)
- Adjacent snow depth observation (inches)
- Snow/ice bonding observation (inches)
- Drifting snow (inches)
- Snow drift levels observation (inches)
- Blizzard
- Liquid precipitation
- Precipitable water vapor observation (inches)
- Soil moisture
- Flooding
- Water course flow volume (cubic meters per second)
- Water body depths (feet)

**Thunderstorm Related**
- Thunderstorms with lightning (includes microburst event; proximity to route or operations, in miles)
- Thunderstorm with hail (proximity to route or operations, in miles)
- Thunderstorms with tornado (proximity to route or operations, in miles)
- Severe storm cell track (location, direction, speed, severity, proximity to route or operation area)

**Temperature Related**
- Air temperature (°F)
- Air temperature including maximum and minimum (°F)
- Air temperature (°F) first occurrence of season
- Air temperature change rate (°F per 24 hours)
- Air temperature (°F relative to freezing) to include trend (rising or falling)
- Dew point temperature (°F)
- Wet bulb temperature (°F)
- Relative humidity (percent)
- Rail temperature (°F)
- Pavement temperature
- Pavement freeze point temperature with dew point temperature
- Pavement condition
- Chemical concentration (in-road sensor or mobile infrared)
- Water temperature
- Soil temperature
- Wind chill
- Heat index
- Cooling or heating degree days
- Air stability

**Winds**
- Wind (speed and direction), includes microburst event
- Wind—head, tail, cross (speed)
- Upper air winds

**Visibility**
- Visibility (statute miles) to include restriction (e.g., fog, haze, dust, smog)
- Sun glare

**Tropical Cyclone, Sea State, Ice**
- Tropical cyclone or hurricane (winds, sea state, storm surge, flooding)
- Seas (wave height in feet)
- Wind wave height (feet)
- High surf
- Freezing spray (seas and low temperature)
- Storm surge/abnormal high or low tides
- Tsunami, tidal surge
- Inland ice coverage
- River ice/ice gouging
- Open water sea ice

**Miscellaneous**
- Seismic activity, earthquakes (any land motion, land slides, avalanches, etc.)
- Nuclear, biological, or chemical hazard dispersion
- Atmospheric transport and diffusion
- Air quality (characterization/code)
- Fire and fire weather
- Total sun (insolation hours per day)
- Cloud cover forecast
- Fair weather
- Avalanche danger
- Volcanism
- Volcanic ash
- Space weather (e.g., solar flares)

Several respondents and symposium participants commented that meteorological information available today is heavily biased toward (1) the protection of life and property (e.g., severe convective, winter, and tropical storms) and (2) aviation forecasts and observations. Several expressed the belief that surface transportation weather products and services will one day be on a par with aviation weather products. The "nonstandard" elements in Table 2-1 provide insight into the information content that will be needed in WIST products and services to meet these expectations in the user communities.

A plume of nitric acid fumes rises from an industrial accident site. Atmospheric transport and diffusion is among the nontraditional weather elements important to WIST users. Copyright AP Wide World Photos.

### Thresholds

As noted, the responses to the initial WIST questionnaire emphasized the importance of specific ***thresholds*** at which a weather element affects a transportation activity or (in the case of multiple thresholds) affects it differently. In some cases, any occurrence of a weather element has impacts and requires action. For other elements, thresholds are critical to defining the users' information need.

### Scale Factors

The data requested on scale factors included topography, time (forecast lead time required to affect decisions or and actions), and spatial resolution.

**Topography.** The questionnaire and survey allowed users to comment on an agency's area of responsibility and the regional topography. Responses on regional topography ranged from coastal marine environments and waterway marshlands to deserts and mountain forests.

**Forecast Lead Time Required for Action-Decision.** One of the most critical factors in supporting surface transportation with weather information is, "How much lead time does the user need?" For the WIST needs identification, lead time was defined as the advance warning prior to an event. This advance warning gives the decision maker the time needed to make the necessary preparations to minimize the effects of the weather on the specified event or activity. The survey used a decision time line to solicit users' responses on the lead times they require.

The query was designed to focus on three conventional support cycles for weather information: planning (climatology, historical probabilities), preparation (forecasts in near-term), and action (nowcasting in near real-time).

When the data for the three support cycles were consolidated, four specific time segment maxima were evident (Figure 2-1). For the planning cycle, a major response spike occurs at 3–6 months and a smaller spike occurs at 7–10 days. For the preparation cycle, a major maximum occurs at 1–3 days. For the action cycle, a peak occurs at 1–3 hours, but the response distribution is fairly evenly dispersed from the 6–12 hour threshold to the actual event. The distribution of user responses along this timeline suggests that, to provide the greatest benefits, planning information should be available up to 6 months before the weather event is likely to occur. Near-term forecast information is needed for preparation actions three days in advance of a weather event. Near-real-time nowcast information is needed for final implementation decisions throughout the 12-hour period just prior to an event.

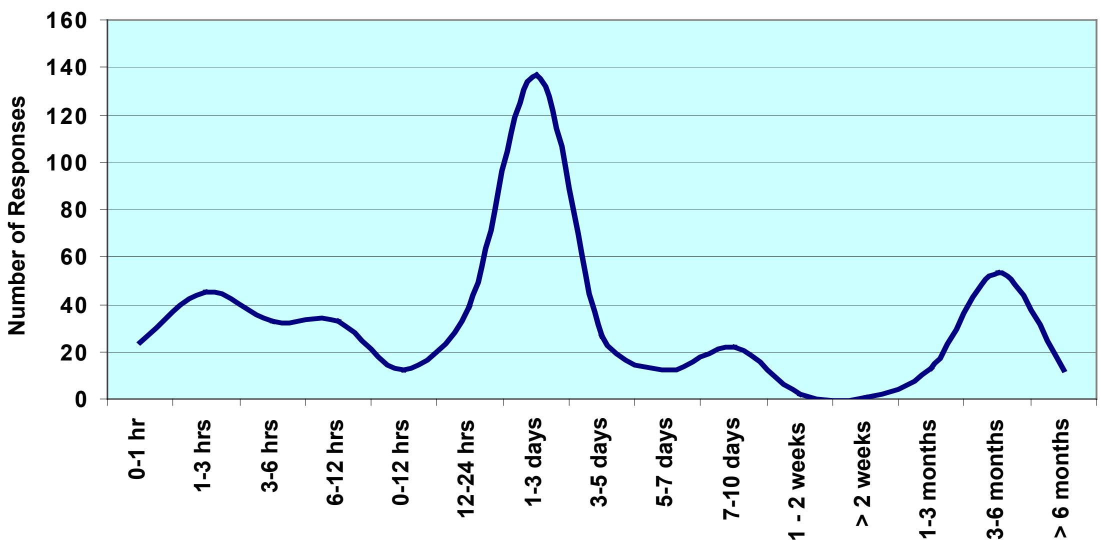



**Figure 2-1** Distribution of desired lead times, all sectors.

**Spatial Resolution.** Spatial scale refers to the spatial distribution or density of information that users need—or would prefer to have—to support decisions in response to weather events. The weather forecast community typically uses three broad categories to describe spatial scale:

- ***Synoptic scale*** is the scale of a typical continent-wide weather map showing features that cover hundreds of kilometers horizontally, such as high-pressure and low-pressure systems and their associated fronts.
- ***Mesoscale*** is the scale of meteorological phenomena that range in size from a few kilometers (horizontal scale) to about a hundred kilometers. Typical mesoscale phenomena include local winds, thunderstorms, and tornadoes. Meteorologists sometimes differentiate between the meso-β-scale and meso-γ-scale, where the

former discriminates phenomena ranging from 20 to 100 kilometers in the horizontal and the latter discriminates phenomena ranging from 2 to 20 km. (Kluzek 1999).

- ***Misoscale*** phenomena range in size from a few meters (horizontal scale) to about 4 kilometers. Typical misoscale phenomena include whirlwinds, dust devils, small waterspouts, and channeling or funneling of winds around buildings and overpasses or through tunnels.

Of the 262 responses received from participants in the needs identification survey, 100 included information on spatial scale. The extracted data on spatial scale are represented by Figure 2-2. The pattern of responses suggests two required levels of resolution; a synoptic scale and a very strongly supported mesoscale. Not surprisingly, users want refined levels of analyses and predictions beyond what is now available. Of the 100 responses that included scale information, 57 desired data resolution at 5 km or less.

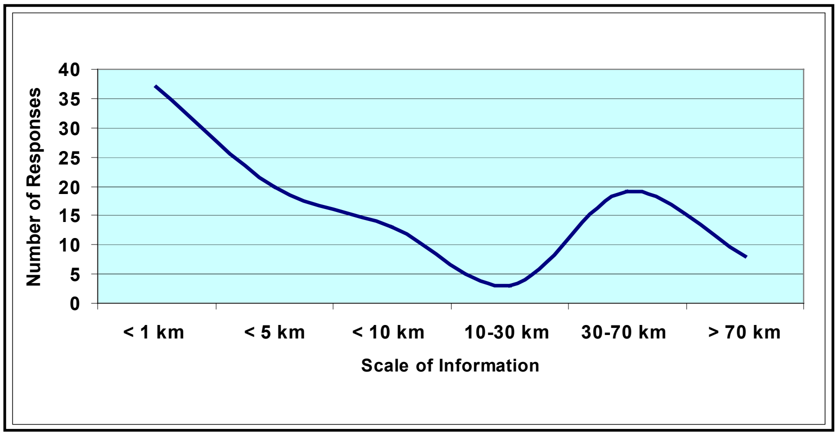



**Figure 2-2** Spatial grid spacing desired by weather information users. A 30–70-km grid represents the state of current global atmospheric model technology. A grid with less than 10 km spacing represents the state of the art for modeling mesoscale phenomena.

## Administrative Information

The administrative data on survey respondents includes the following information:

- Agency name — Office title, e.g., Federal Highway Administration
- Organization — Type of agency, e.g., federal, state, commercial, university
- Transportation mode — Mode and sector distinction, e.g., Roadway, Railway
- Agency mission — Narrative description of the agency's mission
- Action-decision — Narrative of the action or decision to be made that is affected by weather
- Address(es) — Mailing, office codes, email, phone numbers, etc.

Chapter 4 discusses and analyzes the responses from the questionnaire and the survey in detail, as the basis for drawing conclusions about WIST needs.

## 2.5 Validation and Verification of Sector-Specific WIST Needs Templates

The first drafts of the summary WIST Needs Templates were distributed to surface transportation professionals in each sector for verification and validation. Over 165 agencies and user groups provided inputs to the templates, answered supplemental questions during the study, and coordinated on validating the templates for one or more modes of transportation within the sectors (Table 2-2). Appendix A lists all the participants and the transportation sectors of interest to them. Their responses were consolidated into the appropriate template, and a final agency validation or concurrence was obtained for each summary template. The final versions from this validation process are the templates in Appendix B.

**Table 2-2** Participating Users and Entities

| | |
|---|---|
| 24 | federal agencies |
| | 15 FCMSSR partners |
| | 9 other federal agencies |
| 26 | state departments of transportation |
| 40 | rural/urban transit authorities |
| 13 | public school districts |
| 20 | regional airports |
| 26 | trade associations |
| 4 | airline companies |
| 8 | railroad companies |
| 7 | petroleum/natural gas companies |
| 2 | government corporations |

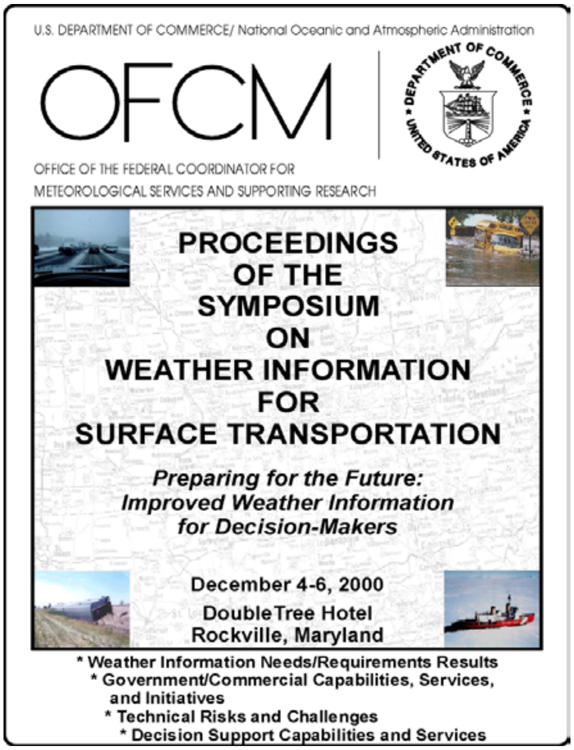
## 2.6 Second WIST Symposium

While the First WIST Symposium focused on identifying the wide range of weather information needs for the nation's surface transportation activities, the goal of the second symposium (WIST II) was to provide ***a framework for improving weather information for those who make operational decisions about surface transportation systems***. The symposium's theme reflected this goal: *"Preparing for the Future: Improved Weather Information for Decision-Makers*" (OFCM 2001a).

The objectives of WIST II were to:

- Summarize activities and progress over the 12 months since the first WIST symposium
- Present and discuss the status of the needs and analysis represented by the WIST Needs Templates
- Solicit feedback on the WIST needs identification and validation process
- Identify initiatives and programs that were relevant to identifying or meeting WIST needs and either underway at the time of WIST II or planned
- Illuminate strategic thrust areas where additional effort was required
- Identify next actions or other steps toward improving weather information for decision makers.

WIST II brought together key stakeholders from federal entities, private industry, and the academic research community. Reports and briefings showed significant progress in improving weather information for surface transportation decision makers. Nevertheless, by the conclusion of WIST II, it was clear that certain areas still require concerted attention and action. Further actions are needed to ensure advances in technical knowledge, implementation of new technologies, and validation of the weather information needs of surface transportation activities in the various transportation sectors. The participants agreed on a list of actions, to be taken by the OFCM and other participants, which would foster further improvements. Chapter 5 uses the




WIST II showed that significant progress had been made to improve weather information for surface transportation decision makers but, also identified strategic areas that require concerted attention and action.

results of the WIST needs validation process to provide a foundation for the strategic thrust areas and next steps that emerged from WIST II.

## 2.7 Special-Case Needs Validation Processes

This section describes how the WIST needs data were collected and compiled for two sectors that differed to some extent from the general process described in Sections 2.2 and 2.3.

### 2.7.1 Long-Haul Railways Sector

For rail transportation, the information obtained from the questionnaire and survey showed that there are two distinct operational entities: long-haul railways versus rail as a component of local or regional transit operations. Transit operations include bus and van service on streets and roadways, as well as railways, such as surface "light rail" and metropolitan subway lines, which are principally oriented toward moving people. The long-haul railways, which operate on more than 144,000 miles of track (see Figure 2.3), provide primarily cargo services, moving over 1.8 billion tons of freight annually.[1] These long-haul railways also provide intercity passenger service through Amtrak. The differences in operational settings, impacts, and actions of the two types of rail transport were distinct enough to define them as separate transportation sectors for the purposes of WIST needs identification.

[1] Rail mileage and freight statistics for long-haul railways are from the "Railroads and States—1999" web page of the Association of American Railroads, available at <http://www.aar.org/rrstates1999.nsf>.

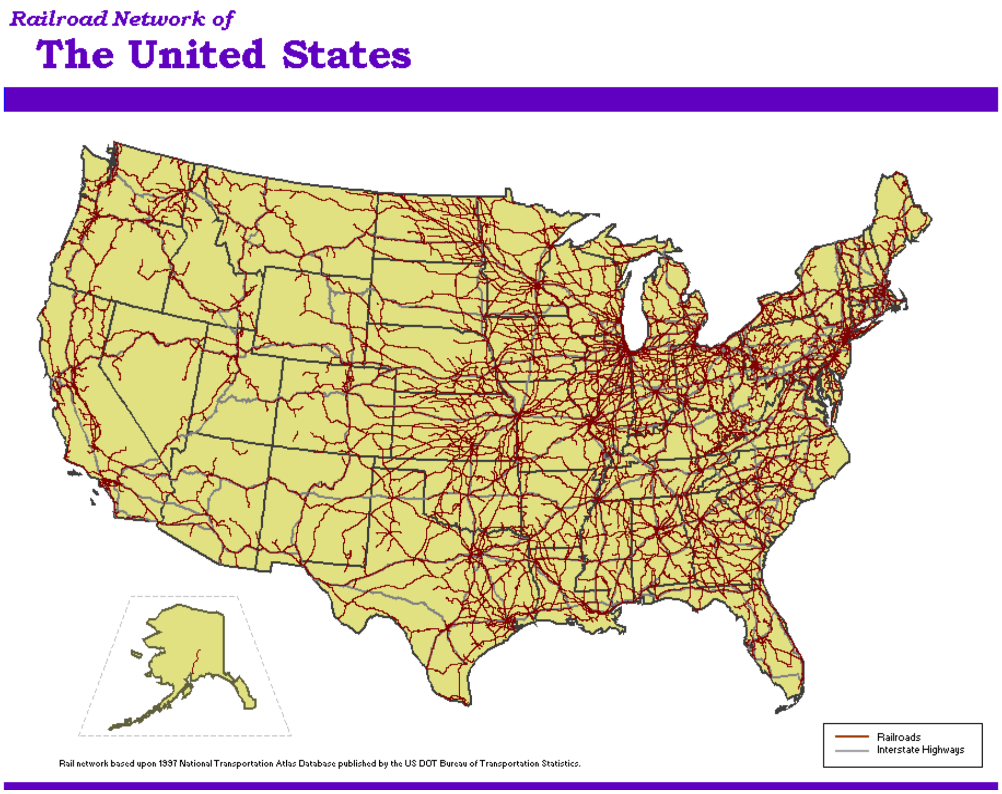



**Figure 2-3** Railroad network of the United States. Source: AAR 2002.

The original questionnaire and survey included 47 responses that addressed rail operations in both categories. However, the absence of information from long-haul carriers was a concern, so a special effort was made to seek participation from several of the major long-haul rail companies. After the WIST II conference in December 2000, OFCM staff set up a draft WIST Needs Template for long-haul railways and met with the Association of American Railroads (AAR), a railway trade association, to review the weather-related information needs of the long-haul railway sector. The AAR reviewed the draft template with its members, and their suggestions were incorporated in a revised version. This revised template was distributed to the AAR members, and their comments were incorporated to complete the validation step of the process. The final WIST Needs Template for long-haul railways is in Appendix B-2.

### 2.7.2 Pipeline System Sector

The design of the WIST project included pipeline systems as a surface transportation sector. Surface transportation sectors were defined as activities supporting the safe, efficient and economical transport of people, goods, and services, so pipelines fall under the definition.

#### Direct and Indirect Effects of Weather Elements on Pipeline Systems

Even though pipelines are a controlled, closed system, weather elements do affect their safe, economical, and efficient operation. The weather elements that factor into impacts and actions for this sector are rarely the primary meteorological parameters such as precipitation air temperature. For example, in October 1994, a major flood on the San Jacinto River near Houston undermined numerous pipelines. Consequently, eight pipelines ruptured, igniting petroleum spills into the river. More than 500 people suffered burn injuries. (The most frequent factor in pipeline damage or failure is third-party excavations, e.g., utility trenching and digging by private homeowners.)

### The WIST Identification and Validation Process for the Pipeline System Sector

The pipeline system sector was by far the most difficult of the surface transportation sectors about which to acquire WIST user information. Of the questionnaires and surveys distributed, only four responses were received for pipeline systems.[2] Only one of the responses addressed weather issues for pipeline systems and the impacts and actions related to weather elements. The response received from the Department of Transportation's Office of Pipeline Safety (OPS) and information gleaned from the Code of Federal Regulations (CFR 193–195) were used to create a follow-on survey for this sector. Few recipients of the second survey form responded until a baseline WIST Needs Template was drafted, which incorporated the concerns of other surface transportation sectors and the input from OPS.

The OFCM staff identified commercial pipeline companies and contacted them individually to foster interest in participating in the WIST needs process. In addition to pipeline companies, several pipeline trade associations were contacted. The trade associations proved an invaluable aid in reaching the industry. The American Petroleum Institute (API) distributed the draft WIST Needs Template for pipeline systems to its client members. API also invited OFCM staff to the 52nd Annual API Pipeline Conference, held on April 17–18, 2001, in San Antonio, to discuss the WIST project during ad hoc meetings. This effort allowed the data gathering phase to be completed and initiated a successful validation phase.

After the API conference, an updated pipeline template was distributed to pipeline companies and trade association clients. This template was overwhelmingly approved and accepted as the benchmark for weather information needed to support pipeline operations. In particular, key personnel in one operational control center (of the Buckeye Pipe Line Company) graciously reviewed the template and concurred with the contents.

[2] The vast majority of surface transportation responders were associated with the roadway and railway sectors. Only a small segment identified pipelines as a concern.

# Chapter 3
# Organizations Participating in WIST Validation

## 3.0 Overview

This chapter presents an overview of the agencies and organizations that participated in the study process described in Chapter 2. The partners in the Federal Committee for Meteorological Services and Supporting Research (FCMSSR), plus the U.S. Postal Service, are described in Section 3.1. The programs of these agencies have been and will continue to be the focus for federal WIST technology transfer activities, as well as supporting research and development (R&D). Section 3.2 describes state and local agencies that participated with the FCMSSR partners in validating the weather information for surface transportation (WIST) needs compiled in the templates in Appendix B.

## 3.1 Federal Entities

The federal partners in FCMSSR have constituencies that they serve, whether through regulation, oversight, inspection, management, operations, or assistance. For this report, these various constituencies have been grouped according to the transportation sector of predominant interest to them. The assessment of WIST needs for which each agency has mandated responsibility or a mission interest was also segregated by transportation sector. Table 3-1 shows this relationship for all the participating federal entities. As this summary table illustrates, the interests and responsibilities of most of the federal entities cut across multiple transportation sectors.

The major surface transportation and weather-related agencies, offices, and programs of the federal entities shown in Table 3-1 are introduced briefly below. More detailed descriptions, provided by the federal entities for this report, are in Appendix F.

### 3.1.1 Department of Transportation

As the federal entity with primary responsibility for shaping and administering policies and programs to protect and enhance the safety, adequacy, and efficiency of transportation systems and services, the Department of Transportation (DOT) has broad and deep involvement with WIST user communities in all six of the surface transportation sectors covered by this study. As Table 3-1 indicates, operating administrations within DOT that have constituencies in these sectors are the Federal Highway Administration (FHWA), National Highway Traffic Safety Administration (NHTSA), Federal Transit Administration, Federal Railroad Administration, Federal Aviation Administration (FAA), Maritime Administration, Saint Lawrence Seaway Development Corporation, Research and Special Programs Administration (RSPA), the U.S. Coast Guard, and the Transportation Security Administration (TSA).

**Federal Highway Administration.** The roads and highways of the United States are planned, built, and operated through a division of responsibilities between the federal government, represented by the FHWA, and the states. The FHWA performs its mission through two main programs. The Federal-Aid Highway Program provides federal financial assistance to the states to construct and improve the National Highway System, urban and rural roads, and bridges. The Federal Lands Highway Program provides access to and within national forests, national parks, the Tribal nations, and other public lands.

**Table 3-1** Federal Agency Responsibilities and Interests by Transportation Sector[a]

| **Federal Entities** | **Transportation Sectors** | | | | | |
|---|---|---|---|---|---|---|
| **Department-Agency** | **Road** | **Rail** | **MTS** | **Pipeline** | **Transit** | **Airport Ground Ops** |
| Department of Transportation | | | | | | |
| Center for Climate Change | X | | X | | X | |
| Federal Aviation Administration | | | | | | X |
| Federal Highway Administration | X | | | | | |
| Federal Railroad Administration | | X | | | | |
| Federal Transit Administration | X | X | X | | X | |
| Maritime Administration | | | X | | | |
| National Highway Traffic Safety Admin. | X | X | | | | |
| Research & Special Programs Administration | X | X | X | X | X | X |
| Office of Emergency Transportation | X | X | X | X | X | X |
| Office of Hazardous Materials Safety | X | X | X | X | | X |
| Office of Pipeline Safety | | | | X | | |
| St. Lawrence Seaway Corporation | | | X | | | |
| Transportation Security Administration [b] | X | X | X | X | X | X |
| U.S. Coast Guard [b] | | | X | | | |
| Department of Energy | | | | | | |
| National Transportation Program | X | X | X | | | X |
| Power Marketing Administrations | X | | | | | |
| Department of Defense | | | | | | |
| Defense Logistics Agency | | | | X | | |
| U.S. Air Force | X | | | | | X |
| U.S. Navy | X | | X | | | X |
| U.S. Transportation Command | X | X | X | | X | X |
| Military Traffic Mgmt Command | X | X | X | | X | X |
| Department of Commerce (NOAA) | | | | | | |
| National Ocean Service | | | X | | | |
| NOAA Corps | | | X | | | |
| National Weather Service | X | X | X | X | X | X |
| Department of the Interior | | | | | | |
| Bureau of Indian Affairs | X | X | X | X | X | X |
| Bureau of Land Management | X | X | X | X | X | X |
| Bureau of Reclamation | X | | X | | | |
| Fish and Wildlife Service | X | | X | | X | |
| National Park Service | X | | X | | | |
| U.S. Geological Survey | | | X | | | |
| Department of Agriculture | | | | | | |
| Agricultural Marketing Service | X | X | X | X | X | X |
| Farm Service Agency | X | X | X | X | X | X |
| Forest Service | X | X | X | X | X | X |
| Office of the Chief Economist | X | X | X | X | X | X |
| Environmental Protection Agency | X | | | | | |
| Federal Emergency Management Agency [b] | X | X | X | | | |
| National Aeronautics and Space Administration | X | X | X | | | |
| Nuclear Regulatory Commission | X | X | X | | | |
| U.S. Postal Service | X | X | X | | | |

[a] An"X" in the matrix indicates an agency responsibility or interest in that sector.
[b] Entities designated for transfer to the new Department of Homeland Security.

The FHWA develops regulations, policies, and guidelines for federal-aid funding, with the aim of achieving FHWA goals for mobility, safety, productivity, the human and natural environment, and national security. It also manages a national research, development, and technology program that includes the Intelligent Transportation System (ITS), through the ITS Joint Program Office. In 1997 the Rural ITS program began a focus on road-weather information. This effort has

A winter storm in the nation’s capital. Snowplows work to clear Roosevelt Bridge while passenger cars struggle to cross on the inbound lanes. Copyright AP Wide World Photos.

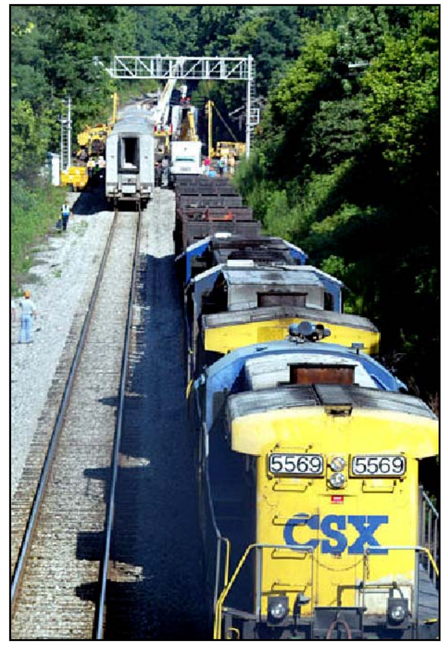

evolved into the Road Weather Management Program (RWMP) within the FHWA 0ffice of Operations. The RWMP includes work on road-weather sensing related to prediction techniques, dissemination of road-weather information through ITS, the development of decision support applications that use information on weather threats, and the improvement of transportation operations to respond to threats. It has been the FHWA lead office for interagency coordination concerning road-weather information.

**Federal Transit Administration.** Through its funding program, the Federal Transit Administration assists in developing improved mass transportation systems for cities and communities across the country. Beyond typical bus and rail systems, it supports other forms of public transportation, including commuter ferryboat, trolleys, and people movers. Through its technology programs, it supports research on intelligent transportation systems, alternative fuels, and new communication technologies. Programs and technologies such as the Bus Rapid Transit Initiative and communication-based train control help transit services meet the current and future needs of the traveling public.

**National Highway Traffic Safety Administration.** NHTSA sets and enforces safety performance standards for motor vehicles and equipment. Through grants to state and local governments, it enables them to conduct effective local highway safety programs. The statistics on highway accidents, including injuries and economic consequences of accidents, cited in this and most other WIST-related reports originate from NHTSA databases.

**Federal Railroad Administration.** The Federal Railroad Administration promotes safe and environmentally sound rail transportation. It employs safety inspectors to monitor railroad compliance with federally mandated safety standards, including track maintenance, inspection standards, and operating practices. It conducts tests to evaluate research and development projects that support its safety mission and enhance the railroad system as a national transportation resource.

**Maritime Administration.** The Maritime Administration promotes development and maintenance of an adequate, well-balanced, U.S. merchant marine, sufficient to carry the nation's domestic waterborne commerce and a substantial portion of its waterborne foreign commerce. It also seeks to ensure that the United States enjoys adequate shipbuilding and repair service, Freight trains travel at reduced speed during a high-heat day, when rail buckling is a potential threat. Copyright AP Wide World Photos.




efficient ports, effective intermodal water and land transportation systems, and reserve shipping capacity in time of national emergency.

**Saint Lawrence Seaway Development Corporation.** In tandem with the Saint Lawrence Seaway Authority of Canada, the Saint Lawrence Seaway Development Corporation oversees operations safety, vessel inspections, traffic control, and navigation aids on the Great Lakes and the Saint Lawrence Seaway.

**U.S. Coast Guard.** The Coast Guard ensures safe and secure transportation on America's waterways and protection of the marine environment. Its mission includes seasonal ice observation and Ice Patrol service whenever icebergs threaten primary shipping routes between Europe, the United States, and Canada.

**Research and Special Programs Administration.** The RSPA oversees rules governing the safe transportation and packaging of hazardous materials by all modes of transportation, excluding bulk transportation by water. It also assists local and state authorities with training for hazardous materials emergencies. It operates the Volpe National Transportation Systems Center in Cambridge, Massachusetts, which is dedicated to enhancing the effectiveness, efficiency, and responsiveness of other federal organizations with critical transportation-related functions.

Within the RSPA are three offices with special relevance to WIST needs and applications. The **Office of Emergency Transportation** performs coordinated crisis management functions for multimodal transportation emergencies, including natural disasters. Natural disasters include severe weather events such as hurricanes, tornadoes, major flooding, and similar events that cause disruptions in transportation systems. This office also works with other federal and state agencies to ensure relationships are in place before the stress of disaster response begins. The functions of the **Office of Hazardous Materials Safety** include regulatory development, enforcement, training and information dissemination, domestic and international standards, and interagency cooperative activities. The **Office of Pipeline Safety** develops regulations and other approaches to risk management, to assure safety in design, construction, testing, operation, maintenance, and emergency response of pipeline facilities.

**Federal Aviation Administration.** The FAA oversees the safety of civil aviation by certifying airports that serve air carriers and enforcing regulations under the Hazardous Materials Transportation Act for shipments by air. It operates a network of airport towers, air route traffic control centers, and flight service stations; develops air traffic rules; allocates the use of airspace; and provides security control of air traffic. At air terminals, the FAA is responsible for coordinating or controlling operational movements on the ground. It supports the collection of weather information for aviation and other uses through automated observing systems and human weather observers at critical locations. It also supports R&D on aviation weather.

**Center for Climate Change and Environmental Forecasting.** This DOT-wide virtual organization coordinates Departmental strategies and policies for mitigating transportation's contribution to greenhouse gas emissions and assessing the effects of climate change on the transportation system. Projects sponsored by the Center include impacts of climate change on transportation, fuel options, and data analysis and modeling for transportation greenhouse gases.

**Transportation Security Administration.** The primary objective of the TSA is to stop terrorist incidents before they can be implemented. Although protecting the traveling public in airports and on airplanes may be the most visible responsibility of the TSA, it also has lead responsibility for security of the nation's highways, waterways, seaports, railways, public transit, and pipelines (DOT 2002b).

### 3.1.2 Department of Energy

The roles of the Department of Energy (DOE) in surface transportation include the transportation of nuclear materials, through the National Transportation Program, and access by repair crews of the Power Marketing Administrations to electric transmission lines. The National Transportation Program supports infrastructure and coordinates transportation activities for all nonclassified shipments of hazardous materials, including radioactive materials, mixed wastes, and commodities such as coal, other fuels, maintenance materials, and supplies. Within the scope of the WIST study, the information needed by the Power Marketing Administrations is mostly limited to weather elements that affect the ability of repair crews to service power transmission lines.

### 3.1.3 Department of Defense

In addition to being a consumer of transportation weather information, the Department of Defense (DoD) is also one of the nation's principal producers of weather information. The Air Force and Navy have responsibilities for weather and climate observation and forecasting support, including severe weather warnings, for military installations and military airports, training and maneuver areas, and wherever military operations are underway worldwide. (Civilian/military joint use airports have different arrangements for weather support.)

- The **U.S. Transportation Command** is designated the single manager of the Defense Transportation System. Strategic mobility allows the United States to act upon the world stage at whatever level is chosen by the national leadership. The **Military Traffic Management Command,** which is the overland lift component and primary traffic manager for the U.S. Transportation Command, provides global surface transportation to meet national security objectives in peace and war.
- Within the **U.S. Air Force,** Air Force Weather has the mission of providing timely, accurate, and relevant mission weather and space environmental information to meet

Air Force, Army, Joint, and other defense and intelligence community needs worldwide.

- The **U.S. Navy** has the military requirement to provide meteorological products and services to support Navy, Marine, and Joint forces. It also provides oceanographic support to all elements of the DoD. Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command.

Air Force Weather, the Naval Meteorology and Oceanography Command, and the National Oceanic and Atmospheric Administration (NOAA) have long cooperated in providing weather services and continue to identify new areas of cooperation.

### 3.1.4 Department of Commerce and the National Oceanic and Atmospheric Administration

NOAA, the nation's primary civilian agency for weather data, is dedicated to predicting environmental change and protecting the environment. NOAA provides services to the nation through five major divisions and numerous special program units. The major divisions are NOAA's National Ocean Service, National Marine Fisheries Service, National Weather Service, Office of Oceanic and Atmospheric Research, and National Environmental Satellite Data and Information Service. NOAA also includes the nation's seventh, and smallest, commissioned service, the NOAA Corps.

As the nation's principal advocate for coastal and ocean stewardship, **NOAA's National Ocean Service** develops the national foundation for coastal and ocean science, management, response, restoration, and navigation. It provides nautical charting products for safe navigation to the marine community and conducts research on the health of the coastal environment. Activities authorized by the Coast and Geodetic Survey Act of 1947 and the 1998 Hydrographic Services Improvement Act include programs for Mapping and Charting, Hydrographic Surveys, Geodesy, and Tide and Current Data. These programs, along with critical weather services described in the next paragraph, are the backbone of the information infrastructure for the U.S. Marine Transportation System (MTS).

**NOAA's National Weather Service (NWS)** provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, and adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. The NWS maintains a constant vigil to provide warnings and forecasts of hazardous weather, including thunderstorms, floods, hurricanes, tornadoes, winter weather, tsunamis, and climate events. It is the sole official federal voice for issuing warnings during life-threatening weather situations. The NWS broadcasts life-saving information to the public during severe weather events and other hazardous situations through the NOAA Weather Radio network. Section 1.3.1 opens with a discussion of the technological advances made through the NWS Modernization and the importance of NWS products and services as the foundation for meeting WIST user needs.

### 3.1.5 Department of the Interior

Within the Department of the Interior are a number of bureaus and offices with interests related to WIST. These include the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, Fish and Wildlife Service, U.S. Geological Survey, and the National Park Service.

- The **Bureau of Indian Affairs** is responsible for 50,000 miles of road on Tribal lands. An additional 25,000 miles of Indian Reservation Roads, which are public roads that provide access to and within Tribal reservations, trust land, restricted Tribal land, and Alaskan native villages, are under the jurisdiction of the Bureau of Indian Affairs and the Tribal nations.
- The **Bureau of Land Management** manages 266 million acres of federal land and 570 million acres of subsurface federal mineral resources. On these public lands, it administers about 85,000 right-of-way authorizations, including a variety of transportation-related systems for roads, railroads, and pipelines. It maintains and manages an additional 81,000 miles of roads for public use on the public lands. and 180,000 miles of rivers and streams running through them.
- The **Bureau of Reclamation** has constructed more than 350 large dams and reservoirs in the 17 western states, including Hoover Dam on the Colorado River and Grand Coulee Dam on the Columbia River. These dams affect major inland waterways and lakes, particularly for recreational boating.
- The **Fish and Wildlife Service** operates the National Wildlife Refuge System, which comprises 10,000 miles of roadway, about half of which is open to the public. It maintains 10,000 miles of dikes and 23,000 water control structures to maintain habitat.
- The **National Park Service** is responsible for roadways and navigable waterways within the National Park System, which comprises 384 areas covering more than 83 million acres in 49 states, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the Virgin Islands.
- The **U.S. Geological Survey** (USGS) serves the nation as an independent fact-finding agency that collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. The USGS collects surface-water data, such as gauge height (stage) and streamflow (discharge), which, along with data collected by the U.S. Army Corps of Engineers, are used by the NWS River Forecasting Centers to make critical flood forecasts throughout the nation.

### 3.1.6 Department of Agriculture

The U.S. agricultural sector is the largest user of freight transportation, accounting for nearly one-third of all freight transportation services in the Unites States. Trucks are the primary movers of agricultural products, accounting for 45 percent of all commodity transport, mainly for short hauls. Rail is the predominant transportation mode for long hauls in regions far from barge-loading locations. Railways transport 32 percent of agricultural products. Barges, which account for 12 percent of agricultural transport, handle large volumes of field crops, fertilizer, and pesticides. The remaining 11 percent of agricultural commodities are transported by pipelines, air freight, and other modes.

- The purpose of the **Agricultural Marketing Service** is to ensure an efficient transportation system for rural America, beginning at the farm gate. This system moves agricultural and other rural products on the nation's highways, railroads, airports, and waterways and into the domestic and international marketplace. The program supplies research and technical information to producers, producer groups, shippers, exporters, rural communities, carriers, government agencies, and universities.
- The **Farm Service Agency** arranges for commercial ocean, ground (motor carrier and rail), and air transportation to deliver agricultural commodities domestically and worldwide.
- The **Forest Service** manages public lands in National Forests and National Grasslands. Forest roads and recreational boating within these public lands are under its jurisdiction.
- The **Office of the Chief Economist** advises the Secretary of Agriculture on the economic implications of policies and programs affecting the U.S. food and fiber system and rural areas, including issues related to transport of agricultural products.

### 3.1.7 Other Federal Entities

Five additional federal entities have WIST-related interests and participated in the WIST needs identification and validation process:

The **U.S. Environmental Protection Agency** (EPA) ensures that environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade. The EPA also ensures that human health and safeguarding the environment are considered in establishing environmental policy. Because air quality and water quality are major EPA responsibilities, the effects of surface transportation systems on air and water pollution come under the EPA's regulatory authority.

Two primary areas of **Federal Emergency Management Agency** (FEMA) responsibility with implications for WIST are evacuation management and response to nuclear, biological or chemical (including hazardous materials, or HAZMAT) incidents. Evacuation management includes the movement of people and resources such as emergency equipment and relief supplies in response to major catastrophic events such as earthquakes, flooding, fires, and hurricanes. Response to nuclear, biological, or chemical events includes evacuation of people and care for victims. To respond effectively to these events, FEMA incorporates atmospheric transport and diffusion information into emergency decision-making processes.

The principal WIST-related interests of the **National Aeronautics and Space Administration** (NASA) involve the ground transport of spacecraft, vehicles, and equipment from one facility to another, particularly to launch facilities. The most prevalent mode of transportation is by truck.

In addition, NASA research and development facilities provide substantial support for remote sensing technologies, including applications for remote observation of weather and related conditions relevant to WIST user needs.

In addition to regulating nuclear energy facilities and radioactive materials in the United States, the **Nuclear Regulatory Commission** regulates the transport, storage, and disposal of nuclear materials and nuclear wastes. From a transportation perspective, the Commission is important in approving the packaging designs and quality assurance programs for transport of high activity radioactive materials and spent nuclear fuel. It coordinates and develops guidance with other U.S. government and international agencies on storage and transportation policy and safety issues.

Transportation responsibilities of the **U.S. Postal Service** range from long-haul interstate movements to local delivery. The delivery of postal services has supported development of national transportation and communication infrastructures. It has linked urban and rural economies and has led to the creation of the country's physical address system.

At the command center for the U.S. Postal Service, electronic weather displays help to keep the mail moving during the December pre-holiday surge. Copyright AP Wide World Photos.

## 3.2 State and Local Agencies

The next tier of organizations that validated the WIST Needs Templates, after the federal entities described above, consists of state and local government agencies. Unlike the federal agencies, whose roles are primarily regulation, policy making, and oversight, the state and local agencies are largely WIST users; they make operational decisions that are affected by weather. The chief examples are the state departments of transportation, with their road and highway operation and maintenance responsibilities. Among the WIST transportation sectors, the one with the most types of weather-impacted activities is the roadway sector. A large percentage of the specific weather information needs in the WIST template for the roadways sector were put forward by the state transportation departments.

The interests of state departments of transportation in WIST applications have been a major driver for university research and private-sector application development. One WIST II participant estimated that the total funding support from the states specifically for WIST R&D probably exceeds that of all federal programs combined (Osborne 2002).

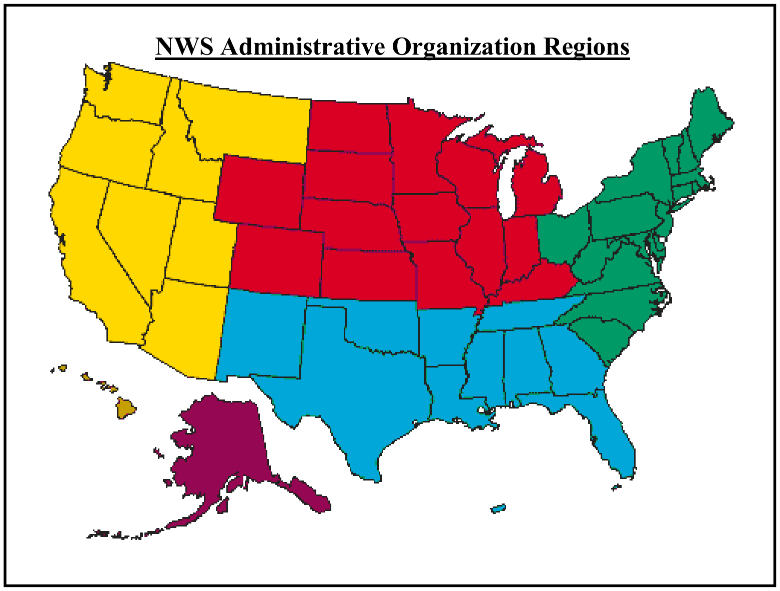



**Figure 3-1** NWS regions.

For the validation of WIST user needs, the continental United States was divided into four regions, coinciding with the four geographic regions used by the NWS (see Figure 3-1). This division aligns the state and local participants in the validation process with the NWS organizations that provide them with regional weather information products and services. Within each NWS region, a geographic distribution of participants was sought to represent major climatic variations (Figure 3-2).

In addition to the state transportation departments, this section addresses rural and urban transit authorities, public school districts, and regional airports. Figure 3-2 includes the distribution of

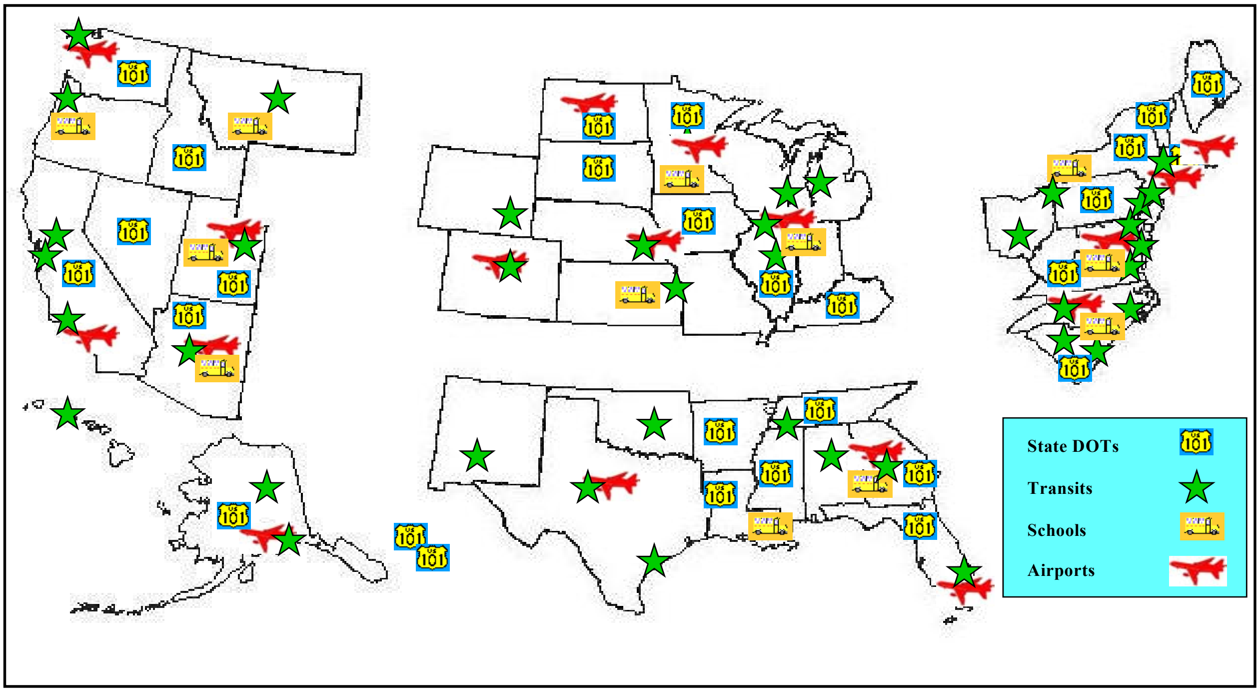



**Figure 3-2** State and local entities participating in WIST needs validation.

these state and local entities that participated in validating the WIST templates. The distribution was designed to include locales that experience almost every kind of weather that occurs in the United States, as well as covering the full range of transportation environments, from the vast open spaces of the West to the densely packed urban corridor of the East Coast. (Note that the map is only a rough representation; icon placement is only approximate. Where there are multiple entities of the same type within the same geographic area, a single icon for that type of entity is shown, to reduce clutter.)

### 3.2.1 State Departments of Transportation

Although there are some differences among the various states, in general the core functions of the state departments of transportation are similar and can be expressed as a generic mission statement. Their mission is to provide, operate, and maintain safe, environmentally sound, and reliable transportation systems and public facilities cost-effectively. These state agencies design, construct, operate, and maintain state transportation systems, buildings, and other facilities. Their responsibilities include maintaining and operating thousands of miles of roads and thousands of bridges. They test and license millions of drivers and register thousands of motor vehicles, boats, and aircraft. They assist in developing, preserving, and improving hundreds of public airports and thousands of miles of railroads and multi-use trails. The state departments of transportation also promote river navigation, provide financial and management assistance to public transit systems, support safe transport of commodities through thousands of miles of pipeline, maintain harbor facilities and ferry systems, and regulate intrastate commercial carriers.

**Participating State Departments of Transportation**

**Western Region**
Alaska, Arizona, California, Idaho, Nevada, Utah, Washington

**Central Region**
Iowa, Illinois, Kentucky, Minnesota, North Dakota, South Dakota

**Southern Region**
Arkansas, Louisiana, Mississippi, Tennessee

**Eastern Region**
Connecticut, Maryland, Maine, New Hampshire, New York, Pennsylvania, South Carolina, Virginia, Vermont

The primary interest in weather information of the state transportation departments is road and highway maintenance to ensure safe movement of traffic and roadway integrity.

#### Winter Road Maintenance

A brief look at several areas important to state departments of transportation underscores the imperative to move forward in meeting WIST needs. The first area is winter road maintenance; state and local agencies spend more than $2 billion on snow and ice control operations each year (FHWA 1998, p. 16). Timely decisions on snow and ice control can prevent roads from being closed and reduce the number of accidents. Accurate decisions prevent unnecessary deployment of vehicles and material—a crucial advantage in areas where each deployment represents a sizeable portion of the local road maintenance budget.

In addition to resource costs, there is also a productivity cost to bear. In any given year, half of the U.S. population has a 5 percent or greater chance of being affected by a hurricane; 69 percent of the of the population lives in areas that normally have more than 5 inches of snowfall each year. Seventy-four percent of the National Highway System is in the nation's snow belt. A one-day highway shutdown due to snow costs a metropolitan area between \$15 million and \$93 million in lost time wages, retail sales, and taxes (Johnson 2001).

Snow removal is a major road maintenance cost for many states. Better WIST implementation can help reduce these costs, while improving service and safety for highway users. Copyright AP Wide World Photos.

### Tropical Cyclone Evacuation


Hurricane evacuation proceeds more quickly by using both sides and all lanes of a coastal highway. Copyright AP World Wide Photos.

A second area of great concern to the state departments of transportation, as well as to FHWA and FEMA, is hurricane evacuation of coastal areas. In 1993, 35 million people lived in 22 coastal counties. By 2010, this number will increase to 76 million, and no new roads are planned. Nearly 60 percent of the deaths attributed to Hurricane Floyd were drownings involving vehicles. During this one hurricane, approximately 3 million people were evacuated from Florida, Georgia, and North and South Carolina, resulting in record congestion problems. Because emergency center managers with the South Carolina Department of Transportation and the State Highway Emergency Patrol had not agreed on a lane reversal plan prior to the hurricane, lane reversal was not employed during the evacuation. Travel times from the coastal area to inland safe havens increased by factors of two to seven times longer than normal. The average travel time of 30 minutes from Savannah to I-95 became 3 hours, and the two-to-three hour trip from Charleston to Columbia, South Carolina, grew to between 14 and 18 hours (FHWA 2002d). These consequences, in terms of both safety and economic costs, highlight the critical importance of accurate forecasts with lead times long enough to make decisions to evacuate and then carry out the evacuation efficiently.

### 3.2.2 Rural and Urban Transit Authorities

Transit authorities, both urban and rural, provide a basic transportation network and commuter resource that is an alternative to the private automobile. Transit authorities build, operate, and maintain these transit systems. While buses and rail vehicles are the most common types of public transportation, other types are commuter ferryboats, trolleys, inclined railways, subways, and people movers.

In many areas, rural transit operators provide services to a diverse clientele that often is spatially dispersed and includes the elderly and the medically or physically challenged. In inclement weather, safe and reliable operation becomes even more important to these travelers. Unfavorable road conditions, vehicle delays, or failure to make pick-ups as scheduled can mean that medical appointments and other essential routines of daily life are missed. These consequences add complexity to rural operations. Timely and accurate weather data complements real-time decision-making and allows for more comprehensive transit planning, adding significant value in ensuring clients are picked-up promptly and arrive safely at their destinations.

Forty transit authorities (see text box) participated in WIST project and specified weather information needs for systems ranging from ferryboats serving Bremerton, Washington, to traditional buses in Omaha, Nebraska.

**Participating Rural and Urban Transit Authorities**

**Western Region (including Alaska and Hawaii)**

- People Mover Anchorage Public Trans., AK
- Fairbanks, AK
- City of Phoenix, AZ
- METROLINK South. Calif. Regional Rail Authority, Los Angeles, CA
- Bay Area Rapid Transit, Oakland, CA
- Sacramento Regional Trans Authority, CA
- Honolulu Transit, HI
- Great Falls Transit District, MT
- Cherriots Salem Area Mass Trans, OR
- Salt Lake City Transit Authority, UT
- Kitsap Transit, Bremerton, WA

**Central Region**

- Denver Regional Transportation District, CO
- Rockford Mass Transit District, IL
- South Central Illinois Mass Transit District, Centralia, IL
- Grand Rapids Area Transit Authority, MI
- Metro Transit (Minneapolis/St. Paul), MN
- Kansas City Area Transportation Authority, MO
- Omaha, NE
- Milwaukee County Transit System, WI
- Cheyenne Public City Bus, WY

**Southern Region**

- Birmingham-Jefferson County Transit Authority, AL
- Palm Beach County Transit (PalmTrans), FL
- Metro Atlanta Rapid Transit Authority, GA
- Oklahoma City Metro Transit, OK
- Memphis Area Transit Authority, TN
- Corpus Christi Regional Transportation Authority, TX
- Fort Worth Transportation Authority, TX

**Eastern Region**

- Greater Hartford Transit District, CT
- Massachusetts Bay Transportation Authority, Boston, MA
- Montgomery County Dept. of Public Works and Transportation, MD
- City of Charlotte, Dept. of Transportation, NC
- Research Triangle, NC
- New Jersey Transit, Newark, NJ
- New York City Dept. of Buses and Rails, Brooklyn, NY
- The Greater Cleveland Rapid Transit Authority, OH
- Miami Valley Regional Transportation, Dayton, OH
- Southeastern Pennsylvania Transportation Authority, Philadelphia
- Charleston Area Regional Transportation Authority, SC
- Hampton Roads Transit, VA
- Potomac & Rappahannock Transportation Community, VA

### 3.2.3 Public School Districts

The WIST interests of school districts are similar to transit authorities, with an added concern for young, inexperienced drivers commuting to schools as students.

**Participating Public School Districts**

**Western Region**
- Bozeman, MT
- Phoenix, AZ
- Salem, OR
- Salt Lake City, UT

**Central Region**
- Chicago, IL
- Kansas City, MO
- Minneapolis, MN

**Southern Region**
- Atlanta, GA
- Jackson, MS
- New Orleans, LA

**Eastern Region**
- Charlotte, NC
- Cleveland, OH
- Fairfax County, VA

Whether large or small, whether rural, suburban, or urban, the transportation interests of public school districts are generally the same: the safe and efficient transportation of their students to and from school. Most districts operate fleets of buses, similar in many respects to transit authorities. Fairfax County, Virginia, for example, currently transports more than 104,000 students every day, covering more than 5,000 routes with 1,428 school buses.

In addition, many rural and suburban school systems have another dimension to their transportation problem, which they take seriously. This aspect is the large number of inexperienced, young drivers who drive privately owned vehicles to school. As expected, school systems place the safety of their students first when considering inclement weather decisions. That policy often is reflected in decisions that serve to keep students off the roads during peak traffic periods if road conditions are unfavorable. Prime examples include delaying the opening of schools or dismissing students early, both of which limit students' exposure on the roads during the peak commuter travel times, whether the students are in buses or private autos.

"Safety is primary in all decisions."

Greg Clemmer, Charlotte-Mecklenburg Schools, NC

### 3.2.4 Regional Airports—Airport Ground Operations

Discussions with airport operations personnel for the WIST study covered a wide range of weather support issues, driven largely by variations in climate associated with the geographic location of the airport. However, even with the diversity in the details received, it was possible to find ranges of values for thresholds and lead times that could be applied to the meteorological events of concern. Further, operational users of weather information were able to concur in the way their individual concerns were treated in the groupings presented in the WIST template for airport ground operations.

Early in the discussions between the OFCM staff and the airport operational personnel, agreement was reached on how to use the terms "advisory" and "warning." An ***advisory*** is an alert to the possibility of a particular weather event, including its expected magnitude and duration. In general, advisories have their greatest utility when issued 12 to 24 hours before the weather event occurs. They provide time for planning and marshaling resources to deal with an impending weather event. A ***warning*** is issued closer to the start of an event, when the meteorological data support a more accurate analysis and forecast with regard to start time, type of event, magnitude, and duration. Warnings generally have their greatest utility when issued 3 to 6 hours in advance of an event's occurrence. Warnings typically trigger specific actions to ensure that all the right preparations have been taken by the time the weather event is likely to occur, so that the event is dealt with efficiently and effectively.

The FAA issues ***advisory circulars*** to provide guidance to airport owners and operators in developing procedures to deal effectively and efficiently with different situations. A number of the existing advisory circulars treat a variety of situations affected by weather elements. The FAA office responsible for issuing these circulars is FAA/AAS-100. Within the framework of guidance provided by the advisory circulars, each airport establishes policies and procedures for dealing with weather-related events. While a great deal of commonality exists, allowances are made for geographic location, climate, volume of traffic, number of runways, and other characteristics specific to a given airport. In all cases, close coordination must exist between airport operations and air traffic control, as well as between airport operations and all airport tenants.

**List of Participating Regional Airports**

**Western (including Alaska and Hawaii)**
- Seattle-Tacoma, WA
- Los Angeles, CA
- Salt Lake City, UT
- Phoenix, AZ
- Anchorage, AK

**Central**
- Minneapolis-St. Paul, MN
- Chicago-O'Hare, IL
- Denver, CO
- Grand Forks, ND
- Omaha, NE
- Offutt AFB, NE

**Southern**
- Dallas-Ft. Worth, TX
- Atlanta, GA
- Miami, FL

**Eastern**
- John F. Kennedy, NY
- Charlotte, NC
- Washington-Reagan, VA
- Washington-Dulles, VA
- Andrews AFB, MD
- Boston, MA

In the area of current weather support, the WIST study found that virtually every airport operations center contacted derives its weather information from the following sources: the local weather observation taken at the airfield, a service provided by a commercial vendor, the Weather Channel, the local TV station, and to some degree, sources on the Internet. Some airport operations centers continue to work closely with the nearest NWS Weather Forecast Office, even though some of these offices have recently moved away from the airport in order to be collocated with a NEXRAD weather radar site. New technology will contribute to improved weather data displays and to increased accuracy of forecasts, nowcasts, and observations. These improvements are eagerly anticipated by airport operations personnel. They recognize that they can help their situation by a more rigorous and articulate expression of their WIST needs.

Additional opportunities to address WIST needs for airport ground operations include extending the application of existing DOT/FAA investments in weather information technologies and services. Examples include the Integrated Terminal Weather Systems and Weather Support to De-icing Decision Making, both of which are operational technologies.

# Chapter 4
# WIST User Needs—Analysis and Conclusions

## 4.0 Overview

> The conclusion that emerged most clearly and prominently from the WIST study is that weather information that better meets the sector and activity-specific needs of users will reap benefits in improved safety and increased cost-effectiveness of surface transportation activities.

This chapter summarizes the results of, and draws general conclusions from, the analysis of the user-validated WIST needs compiled in the templates in Appendix B. General conclusions, which cut across the sectors, are discussed first, followed by sector-specific results. The chapter ends with four overarching themes about the potential benefits from meeting users' needs for improved weather information and the utility of the WIST templates for guiding this significant national effort. Chapter 5 uses these conclusions and themes as the basis for suggested next steps in six strategic thrust areas for continuing a coordinated interagency initiative on WIST implementation and supporting research.

## 4.1 User Needs: General Conclusions from the WIST Study

The general analysis of the WIST data across all transportation sectors supports some general conclusions and underscores a set of basic information needs. The four conclusions, which are discussed in the remainder of this section, can be summarized as follows:

- Users recognize the value of weather information.
- Users want weather information tailored to their activities.
- Users' WIST needs cover a broad range of weather elements, thresholds, and lead times.
- Within transportation sectors and subsectors, users differ in their knowledge of how improved weather information could affect their activities and their awareness of WIST sources.

Beyond these general conclusions, the analysis found significant differences in specific user needs among and within the transportation sectors. (As noted in Chapter 1, for this report a user need is defined as a specific combination of weather element, user activity, threshold, and lead time.) These differences provide the basis for the sector-specific analyses in Sections 4.3 through 4.8.

### 4.1.1 Users Recognize the Value of Weather Information

The value of accurate weather information is well recognized throughout the surface transportation user community. Highway maintenance managers concerned about freezing precipitation, pipeline operators worried about hurricane-induced tidal surge, and vessel captains concerned about keel clearance in shallow water must take actions whose consequences depend critically on accurate and timely knowledge of weather and related conditions. Decision makers, regulators, and operators across the spectrum of transportation activities confirmed the value of

***appropriate*** weather information for improving safety and enhancing the efficiency and effectiveness of their activities. New technologies can improve information systems, maintenance tools, and road weather management practices. This will help transportation officials reduce weather-related costs, provide more accurate and up-to-date information to the public, and decrease the number of weather-related traffic injuries and fatalities.

### 4.1.2 Users Want Information Tailored to Their Activities

> Repeatedly, users stated needs for information that is much more precise, focused, and relevant to their operations.

Transportation decision makers want detailed, location-specific forecasts and situation reports. They also need multiple ways of getting the information—from radio and television, the Internet and other electronic data links, and other communications media. ***In every transportation sector, users stressed the importance of getting weather information tailored for the activity or decision-making process for which they are responsible.*** This manifested itself in several ways. Users said that large-scale, general-area weather information was inadequate for their needs. Repeatedly they stated the need for information that is much more precise, focused, and relevant to their decision thresholds. The general analysis of user needs shows that they want higher resolutions, both spatial and temporal. At the same time, they demand better accuracy in the forecasts, especially for the longer ranges (from 12 hours out to many days).

An important point made by a number of users is worth emphasizing: ***a forecast of favorable weather is often just as valuable as a forecast of adverse or mission-limiting weather***. This point is sometimes lost on the weather information supplier community, where the focus has been on correctly forecasting the onset, duration, and intensity of "bad" weather. The road maintenance community provides a salient example. In most states, road maintenance is performed by the same crews and trucks that clear, plow, and sand roads in the winter. To perform maintenance work, the trucks must be physically reconfigured from their wintertime duties. Operations managers in these states must be assured of a stretch of "good" weather—at least 5 to 7 days—before they can risk starting a maintenance project.

Another important point about user-specific needs is that observations of current weather (the current values of certain key parameters) are as important to some users as the forecasts for those same parameters. For example, current observations of ice and snow accumulations, temperatures, and severe convective weather are particularly important for road maintenance, school and commercial bus operators, and transit authorities.

These needs for current observations are relevant to two other topics. First is the broad issue of coordinating regional weather/environmental observing networks, sometimes called mesonets, which are proliferating around the country. Although each network may be effective and useful for its original purposes, there is no common standard for the attributes and formats of the data collected from them. This lack of coordination on data compatibility undermines the potential value of "mesonet" data as a finer-scale complement to the national observing systems. For WIST needs in particular, where finer spatial and temporal scales are often critical to meeting users' decision support requirements, these regional observing systems represent a potential wealth of high-resolution weather data. The potential economic value to tailored WIST applications (i.e., applications developed and distributed primarily through commercial providers) could provide an incentive for agreement on voluntary standards, with appropriate leadership on this issue. This topic will be addressed further in Chapter 5.

The second issue related to weather observations is more conceptual for the near term, but it could have important consequences in the longer term. In many cases where users want to know current conditions, they do not actually require ***observations*.** Rather, they only require weather information that is accurate, valid for the current time, and at the scale and resolution that matches their activity. At some point in the future (although not yet), high-resolution, very fine scale forecasts and nowcasts prepared for these users will meet at least some of these needs.

For example, a state or county highway department that needs to know the current depth of snow accumulation along rural highways could use a model-based interpolation of the snow depth along the roadway, based on "anchoring" observations taken at key locations along the road. To the extent that such a model also supports prediction of conditions, even for one to several hours after the latest observations, such nowcasts provide a substitute for strictly observational data. The Advanced Transportation Weather Information System (ATWIS) is providing short-range nowcasting of this kind already (Owens 2000, pp. 11-13). In essence, the users' requirement is for weather information that accurately describes current conditions. Provided that short-range nowcast information is *reliably accurate for the time that a user's decision must be made*, it should not matter to the user whether the information comes directly from an observation or a forecast (based on observational inputs).

### 4.1.3 WIST Needs Cover a Variety of Weather Elements, User Activities, Thresholds, and Lead Times

Taken as a whole, the WIST needs elucidated by the surface transportation community encompassed many different weather elements, including a range of important environmental conditions that depend on "the weather" as commonly understood but are not always viewed as a part of the weather. Examples include ground surface and rail temperatures, wave height and tidal predictions, and air quality. The WIST needs also cover a broad range of desired lead times and thresholds, as defined in Chapter 1, for various user activities within each transportation sector.

#### The Weather Elements

Table 2-1 groups the weather elements identified by WIST users during the identification and validation process into seven categories. As noted in Section 2.4, this list contains many traditional meteorological parameters, but it also contains "weather elements" that have not been included in conventional weather reporting and forecasting. "Ice accumulation on structures, in inches" and "rail temperature" are just two examples of these nontraditional elements. Although environmental scientists might categorize these elements as hydrologic, geophysical, or oceanographic data, the users view all of them as need-to-know information intrinsically linked to the impact of "weather" on their operations.

## Analysis of Activity–Element Combinations

An "activity" is a grouping of functionally similar or identical WIST users within a transportation sector. For example, WIST user activities within the roadways sector include road maintenance operations, bus operations, state police, and others. The long-haul railways sector has activities for railroad stations and depot operations. Among the activities in the U.S. Marine Transportation System (MTS) are inland waterway recreational boating and open water cargo/freight operations.

The combination of a weather element and a sector activity is a useful level of aggregation for discussing WIST user needs. For example, freezing precipitation (ice) is a weather element that affects 11 roadway sector activities, including road maintenance, truck operations, fleet utility and transport vehicle operations, bus operations, and private vehicles. In the remainder of the report, these combinations of the sector activities impacted by a weather element, as defined in the WIST needs templates in Appendix B, will be called "activity–elements." Each activity–element thus includes all the WIST needs (i.e., combinations of element, sector activity, threshold, and lead time) for one sector activity and weather element. Figure 4-1 shows the count of activity–elements for each of the transportation sectors represented in the WIST needs study.

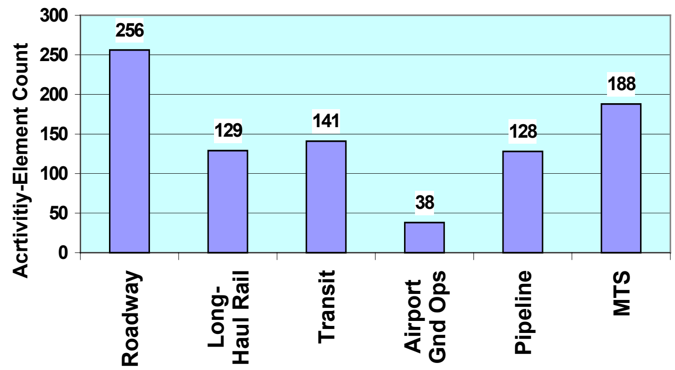



**Figure 4-1** Activity-element combinations by sector.

Figure 4-2 shows the distribution of activity–elements among the element groups defined in Table 2-1, for each of the six transportation sectors. Although all the transportation sectors are subject to the same weather conditions, the sectors vary with respect to which groups of weather elements comprise larger or smaller shares of the sector's total weather information needs. The distribution of activity–elements among the weather groups for each transportation sector will be discussed in detail in Sections 4.3 through 4.8. A few general observations about the distribution, as shown in Figure 4-2, are made here.

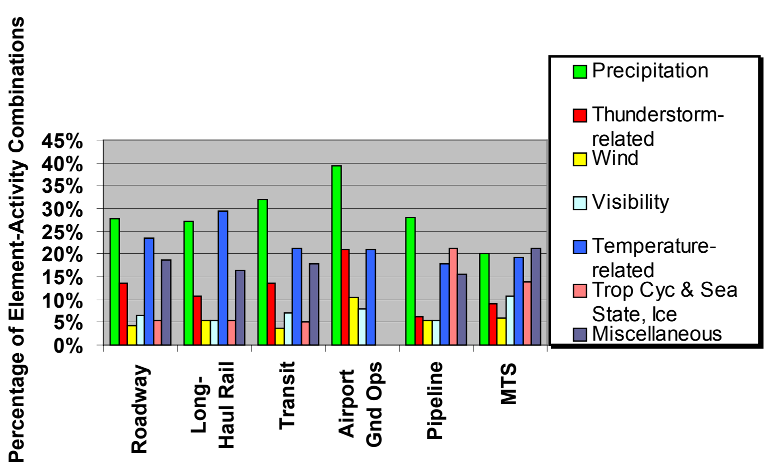



**Figure 4-2** Distribution of activity-elements by sector.

A surprising result is the relatively high proportion that tropical cyclone and sea state conditions represent among the activity–elements for the pipeline systems sector. The importance of this group reflects the crucial nature of physical components of the pipeline transportation system that are vulnerable to tropical cyclone–induced weather, including pipeline segments that are buried underwater or in vulnerable flood plains, pumping stations and storage facilities in coastal areas, and similar factors. The small proportion of thunderstorm-related activity–elements for pipelines reflects the fact that most of a pipeline system is below ground and therefore relatively impervious to thunderstorm activity.

The high proportion of long-haul railway activity–elements that are temperature-related illustrates the temperature sensitivity of steel rail—a critical and ubiquitous structural component of the rail transportation system. Finally, conspicuously absent from airport ground operations is the tropical cyclone category. The explanation is that none of the airports that participated in validating the needs templates happened to be in coastal locations where the storm surge or flooding associated with tropical cyclone conditions would be expected. The airports accounted for the impacts of weather elements associated with inland tropical cyclones, such as high winds, heavy precipitation, and low visibility, under the other weather element groups.

**Table 4-1** Lead Time Categories

| | |
|---|---|
| 1 = | Current to less than 3 hours (includes observations) |
| 3 = | 3 to less than 6 hours |
| 6 = | 6 to less than 12 hours |
| 12 = | 12 to less than 24 hours |
| 24 = | 24 to less than 48 hours |
| 48 = | 48 hours or more |

## Lead Time Analysis

Another way to examine the similarities and differences among the WIST needs of the transportation sectors is to look at the ***lead times*** required by the activities in each sector. The lead time is the amount of advance notice of a weather-related event or condition that a user needs to plan or respond effectively. For this analysis, the lead times specified by each sector activity for each weather element were grouped into the six categories shown in Table 4-1. Note that the first category includes data or information required from “now” up to three hours in advance, which means this category includes current weather observations, as well as forecasts with lead times up to three hours. The last category includes all WIST needs for which the requested lead time was 48 hours or more.

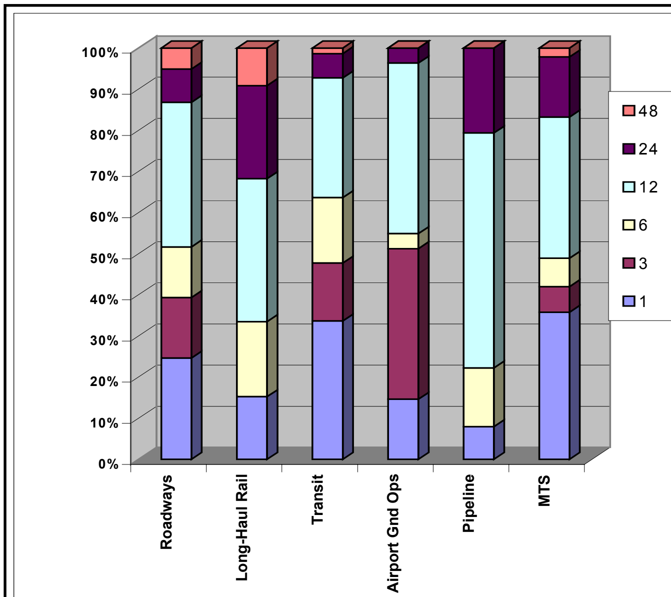



**Figure 4-3** Distribution of lead time categories (Table 4-1) by transportation sector.

Figure 4-3 shows the distribution of lead times among the six categories, by transportation sector. Each bar is normalized to 100 percent of the element–activity–lead-time combinations requested by users within that sector. (The actual counts of these combinations vary widely from sector to sector, ranging from 333 for roadways to 82 for airport ground operations.) One important pattern that can be seen in the graph is the dominance of the block with lead times of 12 to less than 24 hours. For three sectors (roadways, transit, and MTS), the second largest lead-time category is the first, from current observations to less than 3 hours. The lead-time requirements for these sectors have a bimodal character, reflecting a pattern in which users need WIST data with 12 to 24 hours lead time to prepare for an event. They can follow up with execution decisions and operations for which more immediate information (0 to 6 hours) is useful.

Another interesting aspect of Figure 4-3 is the small proportion of WIST needs, in every sector, for lead times of 48 hours or more. This suggests that the decision processes now prevailing in surface transportation communities could be better served by highly accurate and timely forecasts out to 2 days (48 hours) than by longer-term forecast services and products with lower forecast skill.

The bimodal character of the lead time distribution becomes more apparent when the counts of element–activity–lead-time combinations by transportation sector are plotted against the lead time categories, as in Figure 4-4. All sectors except pipeline system operations show a bimodal pattern, although the trough between the preparation peak at 12-24 hours and the shorter-term operational decision peak is shifted in some sectors. For airport ground operations, the lead-time for influencing operational decisions appears to be somewhat longer, peaking at 3 to 6 hours, although the preparation peak at 12-24 hours still holds.

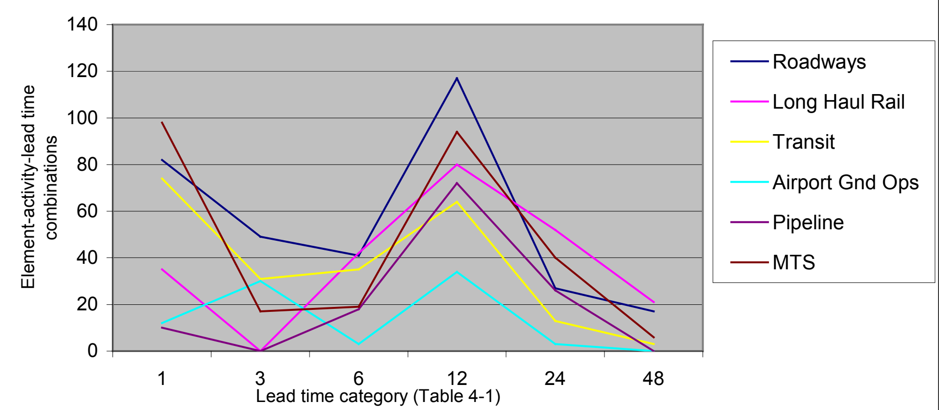



**Figure 4-4** Bimodal Lead Time Distribution

## 4.1.4 Users Differ in Their Knowledge of Weather Impacts and Awareness of WIST Sources

> Users vary in their understanding of how weather information could affect their operations, and thus in their ability to articulate that understanding in specific WIST needs.

Several significant observations on users' knowledge about weather impacts and sources of WIST emerged from the needs identification and validation effort. First, even within a sector activity, users varied in their understanding of how weather information could affect their operations and thus in their ability to articulate that understanding in specific WIST needs. With the exception of highway maintenance operations (in which users from many states had a good-to-excellent grasp of their weather information needs), this variability occurred across all the transportation sectors. Within any given sector, there were users with a clear understanding of how information on weather and weather-related conditions could make a difference in the efficiency and effectiveness of their operations, as well as users with lesser degrees of awareness. The latter category of users knew how the weather affected their operations; they just had not considered how better information about the weather would be useful. In many instances, once users had an opportunity to discuss the subject, they quickly saw how timely and more accurate weather information could be of benefit.

A second observation is that users varied widely in their knowledge of what weather information was available and where they could get it (information sources). Many users were fully attuned to the wealth of information sources, ranging from dedicated Internet suppliers (including commercial providers) to National Weather Service sources, to simply watching the weather on television. However, other users were unaware that weather information useful for their transportation activities was available from sources other than the commercial radio and television reports.

Closely related to this second observation is a third: There is a tremendous range in users' sophistication in exploiting weather information and products. Examples at one end include users (e.g., airline companies) that have meteorologists on-staff who are an integral part of the organization's planning and daily operations. Others purchase sophisticated decision-assistance products from commercial weather service providers. At the other end of the spectrum are users who rely on the information in the weather report during the evening news on television.

An important general conclusion from these observations is that understanding how weather affects an activity does not automatically give users an understanding of how better weather information can benefit that activity. Education of potential WIST users, including interactions between the users and providers of weather information, must be part of the WIST service delivery process. A second conclusion is that, the more sophisticated the decision process is for responding to weather information, the more beneficial periodic interaction between information provider and consumer becomes. These interactions promote understanding of both the users' needs and the capabilities that the provider can offer, as well as increasing awareness, by both sides, of the value of weather information that is accurate, timely, and tailored to users' specific needs.

### Weather Information Sources and Communications—Today and Tomorrow

During the collection of WIST needs data and the subsequent template validation with various federal, state, and local agencies, a sample of the participants were asked a series of questions about their weather data and products. These questions requested information about their data sources, how they received and displayed the data, what changes they envisioned for the future, and related issues. The answers bring to light some interesting similarities, as well as differences, between and within the transportation sectors.

## Sources of Weather Information

| |
|---|
| What is the current source(s) for the weather information used in your operations (e.g., NOAA's National Weather Service, Weather Channel, private provider, other)? Do you envision this changing in the future? |

Twenty of the state transportation departments responded to the above questions on their sources of weather information; the results are shown in Figure 4-5. Nearly every respondent listed at least one commercial weather service provider, and some listed multiple providers, making commercial providers by far the most common source of their information. This category was followed closely by the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS), which was listed by about 70 percent of the state transportation departments. After the NWS were Internet access to web-based resources and The Weather Channel, both at 35 percent. Almost 70 percent of these transportation departments said they did not envision changing their sources in the future. By contrast, in a (much smaller) sample of trucking companies the primary sources of weather information were The Weather Channel and NWS maps delivered as an adjunct to another (non-weather) information management system.

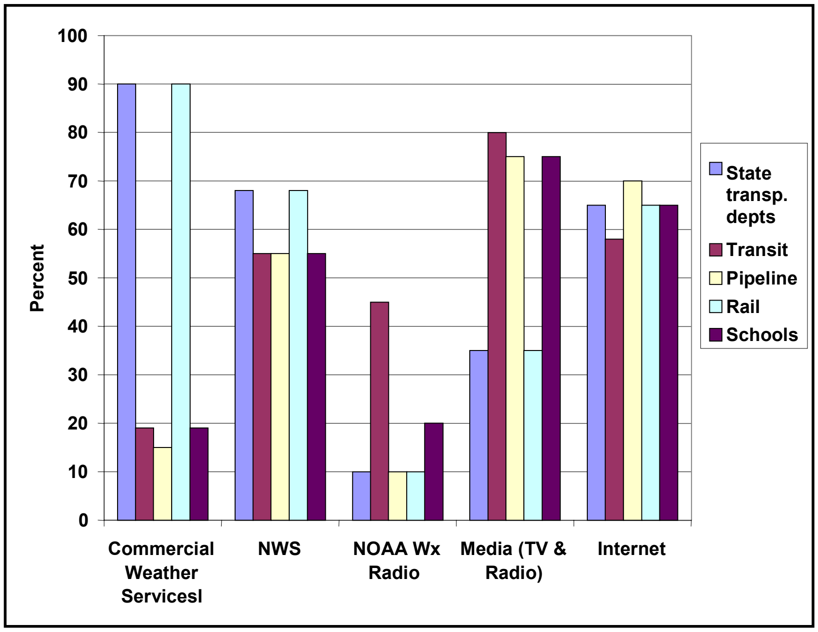



**Figure 4-5** Sources of weather information reported by respondents.

Thirty-one rural and urban transit authorities responded to the questions on information sources. Their responses highlight interesting differences between these two major user groups. In contrast to the transportation departments, only 19 percent of the transit agencies rely on commercial weather service providers; 80 percent listed radio and television (including The Weather Channel) as a primary source of information. Next in frequency of response were access to Internet-based sources at 58 percent and NWS products and services at 55 percent. These transit agencies listed communication with drivers in the field as a primary information source 26 percent of the time, whereas only one state transportation department did so. However, as the transportation departments install state-of-the-art air and pavement sensing systems on their vehicles, this source will probably be used more frequently. Among the transit authorities, NOAA Weather Radio was used as a source by 45 percent, compared with only 10 percent of the state transportation departments.

The public school systems that were sampled gave responses similar to the pattern from the transit authorities. The school systems rely chiefly on commercial radio and television for weather information but also make some use of Internet-based sources. At least one school system, the Charlotte–Mecklenburg schools in North Carolina, added local utility companies and the local airport weather information to their list of sources.

The pipeline companies generally relied on television and Internet-based sources, while the sources for long-haul railroads more closely resembled the state transportation departments in using commercial weather service providers extensively, in addition to television and The Weather Channel as sources. State police organizations reported using a variety of sources, including the NWS, Internet-based sources, radio and television, and commercial providers. The Bonneville Power Administration has a resident meteorologist, who uses a full suite of NWS products received through a NOAAPort terminal connection.

Of the 22 percent of the state transportation departments and 56 percent of the transit authorities who envisioned changes in their sources of weather information, the most frequent theme was anticipation of increased use of robust Internet applications providing real-time information. Second in frequency were changes from infusion of new technologies.

### Means of Communication

> By what communication means is weather information received now for your operations? By what means do you envision receiving weather information in the future (e.g., National Weather Service Family of Services, television, radio, the Internet, facsimile, or others)?

The second set of questions asked about the means of communication by which respondents receive their weather information now, and how they planned to receive it in the future. Again there are noteworthy similarities and differences between the state transportation departments and the transit authorities. For both groups, the most prevalent means for receiving weather information is radio and television (including The Weather Channel), used by 75 percent of the responding transportation departments and 84 percent of the transit authorities. Next are Internet-based applications, at 65 and 55 percent, respectively. The response patterns diverge after this point. Transportation departments are more likely to receive information by email (40 percent versus 6 percent) and by telephone (52 percent versus 16 percent). However, 39 percent of the transit authorities receive data by facsimile, as opposed to only 15 percent of the state transportation departments. While 26 percent of the transit authorities use NOAA Weather Radio, only 5 percent of the transportation departments do. Participants in the template review noted that some highway departments are now using custom satellite delivery of weather information.

School-system decision makers seem to receive their weather information by much the same means as do the transit authorities. They rely for the most part on radio and television, followed by Internet-based sources and NOAA weather radio. Secondary means include cell phones and pagers, as well as two-way radio networks connected to local emergency management centers. One school system, Fairfax County Public Schools in Virginia, placed particular importance on talking directly with the NWS meteorologists at their local Weather Forecast Office. For the future, school-system managers envision more reliance on the Internet and regional intranets, as well as increased contact with emergency management agencies and local transit agencies.

The responses of pipeline operators to these questions again resemble those of the transit authorities, with primary dependence on radio, television and Internet-based sources. The long-haul railroads employ a more robust suite of communication tools, including television, radio, the Internet, facsimile machines, and dedicated direct-line communications.

Of the 40 percent of respondents who envision future changes in their means of communication, more than half expect to rely on the Internet or Internet-based solutions as the next evolutionary step. The remaining responses were distributed among a variety of technologies and practices, ranging from direct satellite read-out to pagers and cell phones.

#### The Recipients of Weather Information Within a WIST User Entity

> Where is weather information currently being received in your operations (e.g. dispatch/operations center or other)? Do you envision this changing in the future?

The third set of questions asked to whom in the organization weather information and products are routed for display, analysis, and decision-making. The response from the transit authorities was almost univocal; 94 percent of those that responded indicated that the weather information was routed to an operations center or a dispatchers' office. The state transportation departments were almost evenly split between routing the weather information to a central location, such as an operations center, and sending it directly to shop and garage foremen and supervisors in the field.

Here again, the school system responses parallel those from transit authorities. Although school systems do not customarily have operations centers, many do have transportation dispatch offices for the school buses. The key similarity is that the decision-making occurs at a central point and the weather information is routed to that person or activity for use in informing decisions.

Similarly, pipeline operators route weather information to their control/operations centers. The railroads do this as well but also provide the information directly to locomotive cabs.

### 4.1.5 Significant Differences Exist Between and Within Transportation Sectors

The user groups that participated in this study come from nearly all 50 states, and they thus represent the full geographic and climatic spectrum of the United States. Consequently, there is significant variation in specification of WIST needs, both between the transportation sectors and within a sector. Often these differences exist even within a specific activity for the same weather criteria. An example is drifting snow. Some state highway maintenance agencies require notification for drifting snow of any amount; others (primarily in the snow belt) are only interested when it is 8 inches or deeper. Likewise, extreme high temperatures in the desert Southwest do not create the same magnitude of difficulties that those same temperatures do in regions with more moderate climates. Thus, the thresholds at which a weather element is seen as having substantial impact on a transportation activity, possibly requiring response preparation and implementation, vary with geography, as well as varying by sector and (sometimes) activity within a sector.

Other factors that produce differences in WIST thresholds include the scale of an agency's "mission," the scale of the decisions being made at a particular time, and the uniqueness of the mission or transportation activity. For example, movement of spacecraft and critical components by the National Aeronautics and Space Administration (NASA) to the launch facilities occurs on intermittent schedules, which may be greatly affected by a weather element. Differences in regulatory or policy guidance, such as local policy that is more restrictive than federal guidance, can also produce varying needs with respect to thresholds and lead times. Finally, related to the observations in section 4.1.4, users with greater sophistication about the utility of weather information, the sources of information, and the means of acquiring it often specify needs that may be more stringent and precise, with a sequence of thresholds to trigger a sequence of actions on their part.

## 4.2 Introduction to Sector-Specific Analyses of Weather Impacts, Mitigation Actions, and Information Needs

The remainder of Chapter 4 consists of a sector-by sector analysis of the WIST needs compiled in the templates in Appendix B. Each major section starts by listing the set of transportation activities, defined by the users from that transportation sector, for which the survey sought WIST needs. Next is a brief analysis of the distribution of activity–element combinations for the sector among the major element groups defined in Table 2-1. The third subsection is a detailed discussion, by weather element group, of the impacts of specific weather elements on the sector and the mitigation actions that users identified as potentially useful, *if they have accurate information at the thresholds and lead times specified.* These discussions highlight just some of the key impacts and actions for important activity–element combinations. More comprehensive details for all weather elements, sector activities, thresholds, and lead times are contained in the templates.

Users and operators of transportation systems (everyone from individual motorists to transit authority managers) make daily decisions that are designed to mitigate the effects of weather on their activities. Mitigation can range from simply increasing awareness of the conditions or forewarning operators and travelers of impending events to taking specific ameliorative actions, up to and including curtailing or suspending normal operations. All of these mitigation actions are intended to avoid unnecessary cost, damage to property, or health and safety risks. Some of the effects of weather simply cannot be overcome. In these cases, the most appropriate action may be to avoid exposure to the weather event or to conditions affected by it. In other cases, specific actions can lessen or overcome the effects of adverse weather conditions.

> The objective is to provide accurate information about current or future weather conditions to those making transportation system decisions, to aid them in mitigating the adverse impacts of weather as much as possible

A WIST need is defined by (1) the weather element involved, (2) the transportation activity affected, (3) the threshold(s) at which information is useful, and (4) the lead time(s) needed to take effective mitigation action. The objective in defining user needs in these terms is to give those who must make decisions about these actions the information they need, in time to inform and guide their decisions. Users' decision processes include many variables other than just weather information. Therefore, the weather may not be the sole factor in a mitigation decision. Moreover, decisions not within the control of a transportation agency can undo what would otherwise have been a sound transportation decision to mitigate weather impacts. For example, the insurance and banking industries of Hartford, Connecticut are mindful of how difficult travel becomes for their employees when it snows. In the past, once snow began to fall, regardless of the predicted duration, coverage, or accumulation, Hartford companies in these industries would often release their employees at 11:00 a.m., without regard to the regularly scheduled public transportation slow-down between the morning and afternoon rush hours. The result was a tremendous demand for transit service at the very time that capacity was at a minimum, with consequent delays and overcrowding. The discussions of WIST user needs in the remainder of this chapter will illustrate some of the decisions that can be made, and actions that can be taken, to mitigate or obviate the effects of adverse weather conditions on various transportation systems.

## 4.3 Roadway Sector

### 4.3.1 Sector Activities

The most developed transportation sector with regard to addressing WIST is certainly the roadway sector, with FHWA as the lead federal entity. The activities that were included in the two Roadways templates (see Appendices B-1 and B-1.1) are listed in Table 4-2.

Traffic moves slowly on a snow and ice covered Interstate 235 in Des Moines, Iowa. The amount of snow was enough to cause school cancellations. Copyright AP Wide World Photos.

**Table 4-2** Roadway Activity Groups

**Road maintenance**. This activity is generally where the requirements of the state transportation departments are compiled. It includes road surface treatment for snow and ice control in the winter, as well as road and infrastructure maintenance year-round to repair damage.

**Truck operations**. The primary example for this activity is commercial trucking operations, both local and long haul.

**Fleet utility and transport vehicle operations**. This activity includes small to medium size fleets of utility vehicles, such as those maintained by telephone or cable television companies, as well as the large, nationwide fleets of mail and parcel delivery vehicles.

**Bus operations**. This activity is intended to cover primarily long-haul bus operations, such as interstate travel, rather than school buses or local transit system buses, both of which are covered by the Rural and Urban Transit Operations sector.

**Private vehicle operations**. Private vehicle operators, daily commuters, long-distance travelers, and local drivers, as well as rental car operators, are included in this activity.

**State/local emergency managers**. This activity encompasses emergency managers at state and local levels.

**State police**. Although state police and highway patrol entities provided the input on WIST needs for this activity, the information is generally valid for law enforcement and public safety officials anywhere with roadway traffic safety responsibilities.

**Forest Service**. The roadway operations of the U.S. Forest Service role are limited to unimproved roads under its jurisdiction within national forests and grasslands. But the ways in which the weather affects these roads has major impact on all the uses of these areas.

**SPECIAL GROUPS**

**NASA spacecraft and equipment transport**. NASA's principal concern with roadways is in transporting spacecraft and components by land routes between its various centers and the launch facilities.

**Power generating operations.** The WIST needs of the power marketing administration (see Section 3.1.2) are limited to road conditions that affect the ability of repair crews in utility vehicles to reach transmission lines and facilities.

**Manufactured home transport**. This specialized activity has WIST needs that represent the general class of high-profile vehicles, which have special sensitivities to wind and other weather elements, such as those that affect tire traction.

Interestingly, state police organizations indicated that knowledge of the local effects and variability of weather conditions gives their troopers an advantage in performing their duties. This knowledge, coupled with accurate and timely weather forecasts, improves the ability of police agencies to refine staffing and enforce traffic control more effectively. Often, the troopers are the first on-scene weather observers, and this information can be relayed to the command center for redistribution. Some states (for example, the Minnesota Department of Transportation) even have mobile observing systems (environmental sensing systems) on board their vehicles. These systems communicate directly to the traffic control center for immediate distribution and input to traffic control decision systems. These organizations believe that monitoring the environment in a proactive manner increases personnel safety and mission accomplishment.

### 4.3.2 Analysis of Activity–Elements

The roadway sector has the greatest number of activity–element combinations among the sectors surveyed. This reflects both the substantial number of sector activities (Table 4-2) and the large number of relevant weather elements identified by the WIST user groups. The 52 distinct weather elements of interest to decision makers in this sector is as large as any of the sectors. (Transit sector WIST users identified needs for an equal number of weather elements. Although the transit sector had the largest representation among study participants, it was less diverse and therefore had fewer activity–element combinations.) The other sectors range from 9 distinct weather elements for airport ground operations to 25 for waterways.

Figure 4-6 shows the percentages of roadway activity–elements in each weather element group. Precipitation in various forms has the most activity–elements, accounting for 28 percent of the total for this sector. Temperature-related activity–elements are next at 23 percent, followed by thunderstorms and related phenomena (including tornadoes, lightning, and hail) at 14 percent. The miscellaneous category, with 19 percent of the total, includes many unrelated phenomena such as atmospheric transport and diffusion, fire weather, total solar insolation, forecasts of fair weather, space weather (the local and high-altitude alterations in the earth's electromagnetic field caused by waves of charged particles spewed from the sun during "solar storms"), and geophysical events such as volcanism and seismic activity.

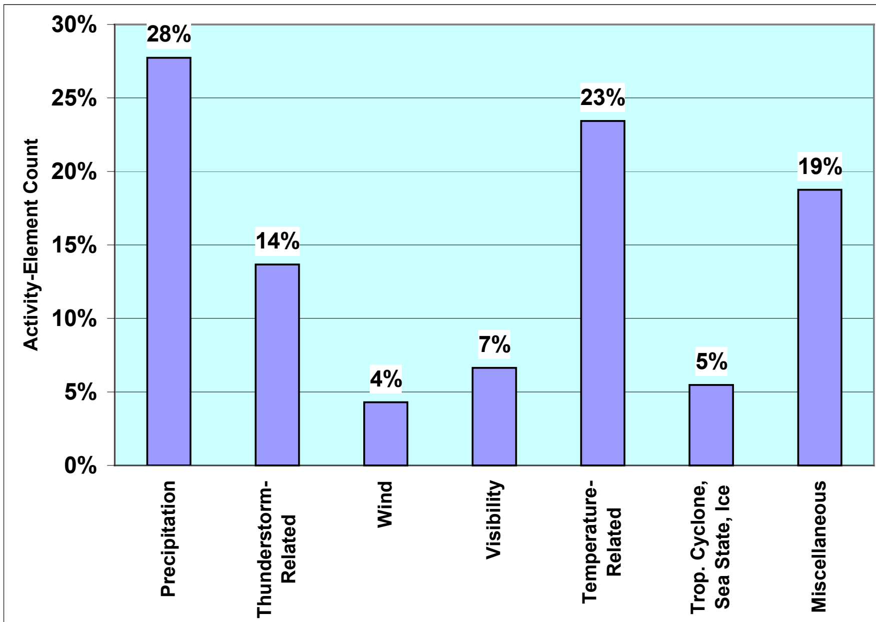



**Figure 4-6** Roadway activity-elements by weather group.

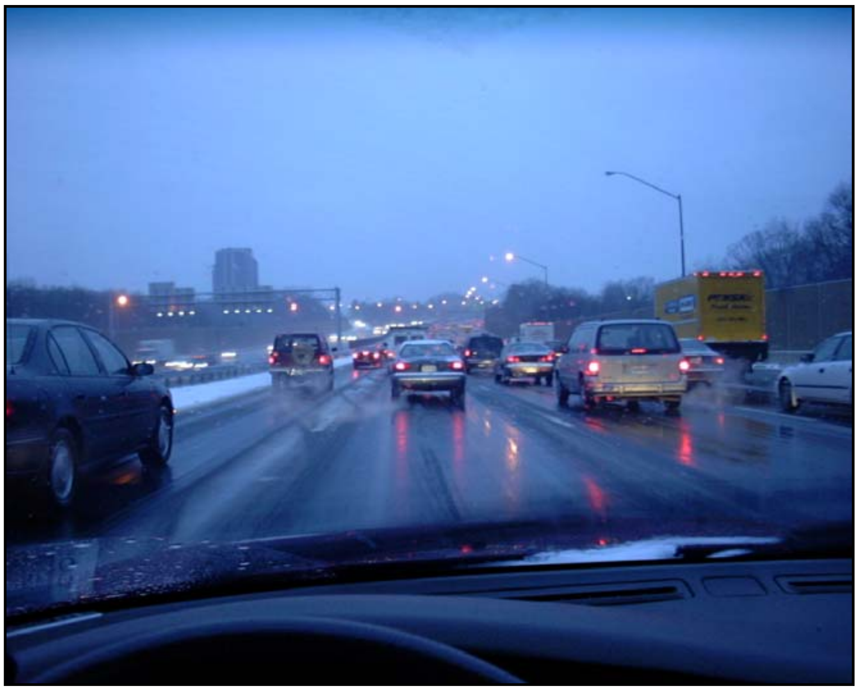
In the initial WIST survey conducted in 2000, which preceded the development of the WIST templates, precipitation was identified by nearly 88 percent of the 157 roadways sector participants as a weather element group that generated information needs. Precipitation was followed by winds, flooding, visibility, temperature-related elements, and thunderstorm-related elements; each of these weather element groups was identified by half or more of the respondents as generating information needs.

### 4.3.3 Impacts and Mitigation Actions, by Weather Element Group

This section discusses the effects that specific weather elements have on roadway sector operations. These effects vary widely by weather element and the affected transportation activity. As discussed in Section 4.2, weather impacts can be mitigated or obviated to varying degrees by timely action, and response decisions are affected by many factors other than weather information.

#### Precipitation Elements

Precipitation, especially freezing or frozen precipitation (ice or snow), causes the greatest impacts for the roadway sector. Most of the activities list safety and health risks to people and property damage risks as potential consequences of any freezing precipitation. Almost all list similar risks for frozen precipitation (snow) as well, with the risks increasing as snow depth increases. Road maintenance activities are most concerned with freezing and frozen precipitation because these conditions typically cause the greatest expenditure of resources in areas where such precipitation occurs. They have the most impact on public safety, other than perhaps a major hurricane. Ice or snow on the roadways mean loss of traction, stability and maneuverability; impaired mobility; roadway obstructions; loss of control; and increased occurrence of vehicle mishaps, with attendant injuries and risks to life and property. For almost all users, it means probable schedule and travel delays.



Precipitation increases the safety risks on crowded urban highways. Photo courtesy Blaine K. Tsugawa, OFCM staff.

State police organizations consistently report that freezing and frozen precipitation dramatically impacts their operation. When the driving public chooses to travel during adverse weather, rather than stay off the roads, the increase in accident rates shifts a larger share of police resources to vehicle accident investigation and traffic control and away from other police functions.

For road maintenance crews, accurate knowledge of the start and ending times of a winter precipitation event is crucial because the effectiveness of road surface treatments is highly dependent on timing. Treating the roadway too early or too late can substantially reduce the effectiveness of the effort to reduce the threat to life and property that freezing or frozen precipitation creates.

A front-end loader clears an avalanche from a Washington state highway. Copyright AP Wide World Photos.

The lead times these users require for information on winter precipitation events vary by activity, but two time frames stand out. The first is a longer range planning time frame, which varies by activity as follows:

- About 12 hours for vehicle drivers (enough time for them to reschedule their activities, reroute, or choose another mode of transportation)
- 12–24 hours for bus and trucking operations (allowing them to reschedule, reroute, postpone, or find safe-haven for vehicles and cargoes)
- 24–48 hours for road maintenance operations (allowing time to begin the preparation process, predict the threatened area, select a treatment strategy, and prepare and deploy treatment assets) and the U.S. Forest Service (enough time to warn campers and hikers to evacuate threatened areas, prepare to repair and reopen roads that will be made impassable, and initiate search and rescue operations if necessary).

A police officer inspects a truck that ran off the road on an icy road in Vermont while attempting to let faster traffic pass. Copyright AP Wide World Photos.

The second lead time window of major value extends roughly from 0 to 6 hours before precipitation begins. This corresponds to the execution phase of mitigation actions planned earlier. For road maintenance crews, this means final decisions and initial operations to treat and clear roads of snow, ice, and debris; deployment of treatment crews and assets; and initiating changes in traffic flow management. This phase makes use of current observations, as well as near-term forecasts and nowcasts.

Unless liquid precipitation is heavy, it affects most roadway activities less than frozen or freezing precipitation does. Two exceptions are road maintenance operations—which have concerns with traction, road submersion, drainage, and reduced visibility—and the transport (towing) of manufactured homes on the highways (many states prohibit such transport if the roadway is wet). In both cases, the critical threshold is any liquid precipitation at all. However, conditions that produce flooding are of concern to all roadway activities. The lead times that activity managers prefer to have prior to a flooding event range from 6–12 hours for local mobilization to 1–2 weeks for road maintenance preparation and detour planning activities. For most roadway activities, the principal action in response to a near-term flood warning is to avoid or escape from the areas of predicted flooding.

### Temperature Related Elements

The second-highest number of activity–element combinations for the roadways sector (23 percent of the total) involve the temperature-related weather elements. Most of these come from the road maintenance community. Of the 60 activity–element combinations, 21 involve just the air temperature (including maximum and minimum; temperature relative to freezing, with rising or falling trend; temperature change rate; and heating/cooling degree days). Another 24 are related to elements combining air temperature and humidity (heat index and wind chill temperature, dew/frost point, wet bulb temperature, and relative humidity). and 12 are related to surface temperatures and moisture conditions (pavement and subsurface temperatures, pavement freeze point temperature with frost point, and pavement condition).

Crews work in the high heat produced by the weather and the asphalt treatment being done along State Route 10 near DeSoto, Kansas. Maintenance managers want advanced notice of high heat days for worker safety. Copyright AP Wide World Photos.

Road maintenance operations are highly dependent upon temperature information, particularly the combination of pavement temperature and air temperature relative to the freezing point, with rising or falling trend. Accurate and timely temperature information, coupled with precipitation information, allows operators to select the correct strategy and treatment material for treating road surfaces to minimize the effects of weather on motor vehicle operations. The Forest Service is concerned about temperatures rising above freezing during the winter months because, as frozen, snow-packed logging roads thaw, heavy logging trucks cause structural damage to the roads. If this condition can be predicted accurately, the roads can be closed to heavy trucks before damage occurs.

Sufficiently high temperatures can be a concern for most roadway activities and users. Not only do high temperatures require caution for work crews and equipment, they pose a risk to vehicles and freight. High pavement temperatures increase the risk of tire blow-outs for heavy loads, such as manufactured homes being towed on the highways. State police also reported that extreme temperatures, both hot and cold, have substantial effects on their duties and workloads with respect to vehicle incidents on the roads and traffic flow management.

### Thunderstorm Related Elements

The next most prevalent group of activity–elements for roadways are the 14 percent associated with thunderstorms and related phenomena. Although the impacts can be very severe and include loss of life and damage to property, thunderstorm phenomena generally affect smaller areas and for shorter durations than some of the other weather elements. When severe thunderstorms do occur, all the roadway activities recognize the potential risks to their people, vehicles, and cargoes. The protective actions are similar: most activities cease outdoor operations in the path of the threatening weather and take evasive actions as necessary.

Road maintenance activities and the Forest Service also must respond to road damage or blockage by debris. In addition to conducting search and rescue for stranded, trapped, or injured recreationists in the wake of a severe storm, the Forest Service must determine where valuable timber has been knocked down and must be salvaged.

Trucking operators and NASA (during the ground transport of spacecraft and equipment) will delay, reschedule, reroute, or seek shelter, as appropriate to protect their people and equipment. State police reported that, although lightning does not routinely affect their mission, serious difficulties do arise when lightning occasionally damages their communications towers and antennae.

### Visibility

Activity–elements related to visibility represented 7 percent of the total combinations for roadways. Generally, visibility does not become a factor for roadway operations until it becomes restricted to a quarter mile or less. At that point, most activities simply slow down and exercise more caution. Some, however, take more specific actions. Manufactured home transporters stop travel; trucking operators, if hauling hazardous materials (HAZMAT), may seek a safe stopping place. NASA will try to reroute, delay movement of, or transport their cargo earlier to avoid encountering conditions of reduced visibility on the road. An element related to visibility that affects most roadway operations is sun glare. For most activities, the principal response action is to reduce speed. State police added that reduced visibility is one of the weather elements that consistently affects their operations dramatically, increasing the rate of vehicle incidents and altering traffic flow.

#### Winds

Although winds account for relatively few of the activity–element combinations (4 percent) for roadways, high winds are a concern to road maintenance activities and transporters of high-profile loads, including trucks, buses, manufactured homes, recreational vehicles, and NASA's road transport activities. The critical threshold for most activities is winds of 50 miles per hour and more. The exception is transporters of manufactured homes, who typically stop travel when winds exceed 25 mph.

#### Miscellaneous Elements

Several of the weather elements and weather-related phenomena in the miscellaneous group are worth noting for their impact on roadway activities. One of these is hurricane (tropical cyclone) storm surge, which affects all road transportation activities in the area where storm surge occurs. The response actions are to suspend travel through and vacate the affected area. Required lead time to respond effectively is 12–24 hours. Another element of interest to important roadway activities is fair weather, or more precisely, accurate forecasts of the duration of fair weather. Many activities rely on "good" weather for success or efficient operations, so an accurate forecast of good weather is just as important as an accurate forecast of adverse weather.

A third element in this category is weather information relevant to incidents of release and atmospheric dispersion of nuclear, biological or chemical hazards. Whether accidental or deliberate, these events are life-threatening, and the responses by roadway activities are either to cease operations and clear the area or participate as part of a previously trained response team. A related element, albeit less critical in potential health effects, is air quality, which typically has the greatest impact in urban areas. Many of the meteorological conditions that influence the movement of a plume from a hazardous-materials release are also of importance in forecasting air quality conditions and the areas affected.

Another element of special interest in the miscellaneous group is space weather. As the nation grows more and more dependent on electronic and wireless systems for communication, navigation, and data transfer, the need increases to monitor and manage the system components that can be temporarily disrupted or permanently damaged by space weather hazards.

## 4.4 Long-Haul Railway Sector

### 4.4.1 Sector Activities

Long-haul railway operations include inter-city freight transportation and a small volume of inter-city passenger traffic. The "light rail" systems used for metropolitan-area passenger transportation are included in the rural and urban transit sector. The long-haul railway activities identified by survey participants from this sector as sensitive to weather or weather-related conditions are described in Table 4-3 and appear in Appendix B-2, the WIST needs template for this sector.

**Table 4-3** Long-Haul Railway Activities

**Railway/control center operations**. The control center monitors the railroad system and advises train and station operators and dispatchers. It controls system integrity.
**Station and depot operations**. Operations at and in the vicinity of stations, involving tracks, rolling stock, and platforms.
**Hump yard operations**. Includes maintenance, inspections, and local operations.
**Construction**. Includes scheduling, maintenance, and repair activities.
**Hazardous material**. Includes monitoring the transport and handling of materials, as well as mitigation, reclamation, and reporting of events or incidents.
**Surveillance.** Includes inspections, monitoring, and maintenance of trackage, supporting structure, and facilities.
**Personnel safety**. Safety of train crews, station and depot personnel, and passengers.

Since 1985, the railroad industry has grown and changed. Boxcars are being replaced by inter-modal containers and trailers. Warehousing is considered inefficient and expensive; the modern business operation plan calls for "on-time delivery" instead. Accounting for the effects of weather conditions on this time-sensitive delivery system is essential for efficient and effective operations. Decisions made with inadequate or erroneous weather information reduce efficiencies, increase operating costs, and decrease customer satisfaction. Each of the four major rail carriers either has its own weather forecast staff or contracts for weather support services.

## 4.4.2 Analysis of Activity–Elements

Because there are so few railroad companies, the railway sector is one of the smaller user populations in the WIST study, in terms of the number of participating entities. But this industry concentration belies the importance of the sector to the transportation industry. Responses to the WIST needs questionnaire were received from 22 separate entities, which identified 18 distinct weather elements that affect them. For the seven sector activities identified by these users, there are 129 activity–element combinations in the WIST needs template. Figure 4-7 shows the distribution of these activity–elements among the weather element groups defined in Table 2-1.

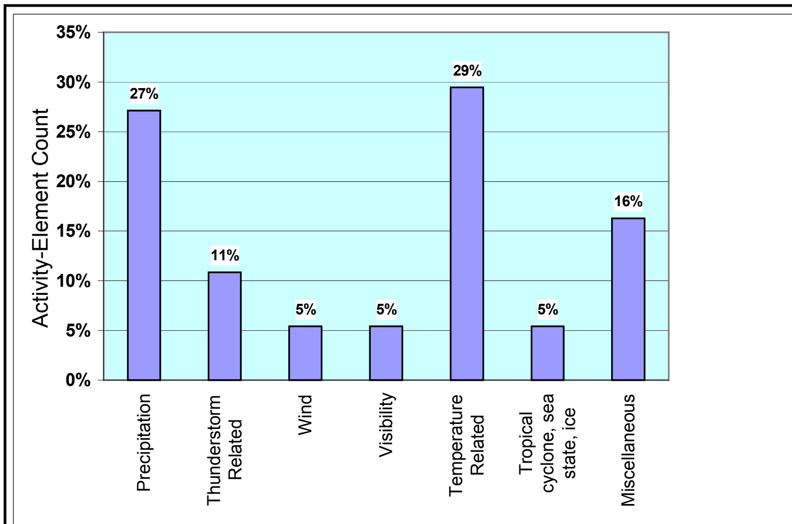



**Figure 4-7** Railway activity-elements by weather group.

The initial WIST survey, which was conducted in 2000 prior to developing the WIST needs templates, showed precipitation as the weather element which drew the greatest amount of interest. Nearly 83 percent of the 47 respondents from this sector indicated a need for precipitation information. The weather elements of visibility, flooding, winds, thunderstorm-related conditions, and temperature-related elements were each identified as WIST needs by half or more of the respondents.

Among the activity–element combinations from the template, temperature-related elements account for the highest number, with 29 percent of the activity–element combinations (Figure 4-8). Activity–element combinations for precipitation elements were next at 27 percent, followed by thunderstorm-related elements at 11 percent. In the miscellaneous group, the activity–elements are split evenly between atmospheric transport and diffusion and space weather.

The emphasis on temperature-related needs reflects the larger number of temperature-related elements identified as important by the railways sector participants. Some of the nuances among the precipitation-related elements that are important for roadways, transit operations, or airport ground operations are less important for long-haul railways. However, temperatures at both the hot and cold extremes—particularly temperature changes—have substantial effects on steel rails.

### 4.4.3 Impacts and Mitigation Actions, by Weather Element Group

This section discusses the effects that specific weather elements have on railway operations and the response actions that the study participants identified as potentially influenced by accurate information on each element. Mitigation actions can range from simply increasing awareness to taking specific corrective actions or curtailing or suspending activities. All these actions are intended to avoid unnecessary cost, damage to property, or safety risk to people. As discussed in Section 4.2, weather impacts can be mitigated or obviated to varying degrees by timely action, and response decisions are affected by many factors other than weather information.

Freight locomotives are trapped and partially derailed in ice pushed up by rising Susquehanna River waters near Cresswell, Pennsylvania. Copyright AP Wide World Photos.

#### Temperature-Related Elements

Of the 38 temperature-related activity–elements identified for the long-haul railway sector, 14 are for air temperature, including daily maximum and minimum and first occurrence of a high or low for the season. Another 7 are for rail temperatures, and 7 are for soil temperature (impacts on the railbed). The remaining 10 are for wind chill temperature and heat index, which affect exposed personnel.

Expansion and contraction of the rails caused by changes in temperature or seasonal extremes are of great concern to this sector. The rail industry routinely inspects all 120,000 miles of track about twice weekly. However, the first occurrence of the fall-winter season when the air temperature drops below freezing produces rail contraction that can cause gaps and misalignment in the track. This greatly increases the number of track warning signals and the potential for derailment, malfunction of track sensors and signal sensors, and signal damage. Rail contraction continues as the temperature drops further. These conditions pose a risk to personnel (crew and passenger) safety and risks to freight and property. Mitigation actions include increased inspections of track and sensors; repair as necessary; slowing, stopping, delaying, or rerouting trains; and preparations for response to HAZMAT incidents. Similarly, increasing air temperatures produce rail expansion, which can cause "kinks" in the track beyond a certain temperature. The seasonal thresholds are the first occurrence of air temperatures in the spring at 70–75 °F, and 90 °F. When air temperatures exceed 90 °F, additional track inspections are prescribed.

More important than any single upper or lower threshold is the diurnal temperature variation. Temperature changes of 30–40 °F over 24 hours can cause inconsistent expansion and contraction, leading to track misalignment and possible rail failure. The actions taken are essentially the same as for crossing the seasonal temperature critical points. The lead time desired by the industry is 3 days for both hot and cold temperatures, followed by another notification 12 hours before the threshold temperature is reached.

Two elements closely related to air temperature are rail temperature and soil temperature. Rail temperature is of interest because of the expansion and contraction issues. The critical thresholds are the freezing point (especially if moisture is present) and 110 °F. Soil temperature is critical at the freezing point, as freezing and thawing of the soil can produce ground heaves, which may result in railbed movement, making track and railbed failures and train derailments possible. Ground heave is most prevalent during the autumn freeze and the spring thaw. Mitigation actions

Hot air rising from a rail bed near Hollywood, Florida, gives track the appearance of being distorted. Rapid temperature changes, particularly the first of a season, can buckle rails and cause accidents. Copyright AP Wide World Photos.

are essentially the same as for rail expansion and contraction. Each of these temperature elements affects all seven of the railway sector activities.

### Precipitation Elements

The second highest count of activity–elements for the long-haul railway sector are those for precipitation events. The sector participants identified five precipitation elements of interest (freezing precipitation, snow, drifting snow, heavy rain, and flooding), each of which affects all seven of the sector activities.

As freezing precipitation (ice) builds up on structures and metal rails, the potential increases for failure of track switches and malfunctions of track sensors, signal sensors, and signals. Monitoring and repair requires dispatching rail and signal maintenance crews. Ice can also require reductions in train speed, causing schedule delays, even while demand for passenger service is surging because other modes of transportation are more affected or unavailable. Ice increases the difficulty for railroad employees in getting to work, impedes mobility of track inspection crews, and increases risks to personnel safety, particularly on passenger platforms at train stations. Mitigation actions include implementing traditional snow and ice control plans, modifying train operations (which may include delaying or rerouting trains), inspecting and repairing tracks as necessary, or recalling additional train and maintenance crews. The lead time desired by decision makers in this sector is 24 hours, with followup notification 6 hours before the freezing precipitation begins. These lead times are generally the same for all ice and snow events.

Frozen precipitation (snow) of less than 6 inches generally does not pose a problem for operation of long-haul trains. Perhaps the best mitigation action is to keep the trains running, which keeps the rails clear and holds accumulations at a manageable level. Snow accumulation greater than 6 inches, however, brings much the same impacts as are associated with ice, with the same range of potential mitigation responses.

Liquid precipitation (rain) is only a problem when it is intense enough to reduce visibility, which may cause a train crew to miss a signal unless train speed is sharply reduced (creating schedule

After the storm surge and heavy rain from a hurricane, obstacles lie across a flooded section of track in Alabama.

delays). However, flooding—a byproduct of rain—can have much more serious impacts. It can wash out portions of the railbed; damage railbed support structures, switches, sensors and signals; or cause mudslides or high water over the tracks, which pose risks to train operations. The rail industry operates under a "fail safe" rule: if there is a reported problem with or on the tracks, a track inspection is required prior to resuming operations. In general, the first reaction to reports of flooding is "when" and "where." This approach isolates the potentially affected region, limits suspension of operations to just the affected areas, and initiates rail inspections.

### Thunderstorm-Related Elements

Tornadoes are of course the most severe threat in the thunderstorm-related group, but they are infrequent and normally confined to a relatively small area. A much more widespread and frequent threat is lightning strikes within 5 miles, which brings many exposed or outdoor operations, such as refueling, to a halt. Lightning can also produce track sensor and signal malfunctions, resulting in train delays and stops. Knowing where lightning has occurred allows the signal repair crews to isolate more quickly the locations of signal and sensor problems. Another problem can be the high winds associated with thunderstorms, which are addressed below in the section on winds.

In 1998, heavy rains from Hurricane Georges washed out 350 feet of track near Crestview, Florida.

### Winds, Visibility, and Tropical Cyclones

Each of these weather elements or weather-related phenomena affects all of the railway activities.

Wind speeds in excess of 50 mph, no matter what the source, are likely to blow some types of rail cars over, which makes it prudent for those trains to be stopped or otherwise protected. Decreased visibility makes it more difficult to see train signals and obstructions on the track, which increases the possibility of collisions and derailments.

Visibility thresholds are based on the stopping distance, which is a factor of speed, topography, and weight. For example, a 10,000-ton train moving at 60 mph on level ground requires 1.25 miles to stop. As a rule, visibility is not a significant factor until it drops below 1 mile. As the visibility drops, the mitigation response is to reduce train speed.

Tropical cyclones combine the effects of storm-force winds, the cumulative effects of tides and storm surge, and inland flooding. These phenomena can scour, bury, damage, or destroy the railbed; damage rail from line stretch and debris impact; damage structures; and cause rail sensor and signal failures. Railbed and track failures are likely, and derailments are possible. Winds, seas, and tides may restrict or suspend coastal rail traffic. Mitigation actions include relocating rail assets before a storm to preclude damage or stranding, suspending rail operations in the affected area, and cleaning up and repairing as necessary afterward. Particular attention must be focused on rail surveillance and inspections of bridges, trestles, and railbed for structural integrity.

## 4.5 The U.S. Marine Transportation System

The MTS is a key component of our national transportation system. In 1998, about 2.4 billion tons of cargo moved on U.S. waterways and through U.S. ports. By 2020, trade is conservatively projected to double, with the largest increase expected in container shipping. The length, width, and draft of commercial vessels have grown dramatically over the last 50 years, pushing the limits of many ports and posing significant safety concerns (NOAA 2001). Environmental risks have also increased with increasing vessel size because nearly half of all goods transported are oil or other hazardous materials. Growth in ferry, cruise line, and recreational boating also contributes to increased congestion on our waterways. Ensuring safe and efficient port operations is vital to maintaining the competitiveness of the U.S. port industry and U.S. exports (DOT 1999). The WIST needs study identified the impacts on this system of weather and related elements. Characteristics of information about these elements that could help in mitigating these consequences were identified and validated by participants from the MTS user communities, as well as the federal agencies with responsibility for the MTS.

In 1998, Congress directed these federal agencies to assess the state of the MTS and develop a vision for modernizing the system. This was a first step toward developing a transportation system for the twenty-first century—a system that addresses the future of marine transportation safety, security, competitiveness, infrastructure shortages, and environmental health. Federal entities—in particular the U.S. Coast Guard, Maritime Administration, and NOAA—and the private sector have partnered to support the MTS initiative by raising awareness of MTS issues.

### 4.5.1 Sector Activities

The sector activities of the MTS include the full spectrum of waterborne transportation on freshwater and estuarine waterways, coastal routes, and the open sea. These activities range from recreational boating and commercial barge traffic on inland waterways to movement of large commercial vessels in harbors and on the open ocean. The first 10 activities in Table 4-4 constitute the waterborne component of the nation’s MTS. A closely allied activity that WIST users in this sector wished to include is marine modeling. All 11 of these activities are covered in the WIST Needs Template in Appendix B-3.

**Table 4-4** MTS Sector Activities

| |
|---|
| **Inland water activities** |
| Ferries. |
| Commerce; includes barge traffic on major rivers. |
| Recreational boating; includes fresh water lakes, rivers and streams. |
| **Open water activities** |
| Cargo/freight; includes large ocean-going vessels, including U.S. Navy ships. |
| Cruise lines. |
| Commercial fishing; primarily includes near-shore and off-shore salt water operations. |
| Recreational boating and salt-water operations. |
| **Port operations.** Operations include keeping port facilities open and safe movement of vessels in and out. |
| **St. Lawrence Seaway operation.** Operation of locks and canals, control of navigation and movement of vessels. |
| **NASA movement of launch vehicle/payload elements via barge.** Primarily external fuel tank and solid rocket boosters moving to and from the launch facility. |

## 4.5.2 Analysis of Activity–Elements

Participants from the MTS sector constituted the third largest population in the WIST needs study, after roadways and transit. Responses were received from 28 separate agencies or entities (Appendix A). These participants identified 25 distinct weather elements that affect them. When these weather elements are combined with the sector activities affected by each element, the total count of activity–element combinations is 188, the second highest count among the six sectors studied.

In the distribution of these activity–elements by weather element group (Figure 4-8), the precipitation group accounts for 20 percent. Temperature-related elements account for 19 percent. Elements in the category of tropical cyclones, sea state, and ice account for another 14 percent of the total.

In the initial WIST survey conducted in 2000, prior to developing the WIST needs templates, “precipitation elements” was the group most frequently cited by the respondents. Of the 32

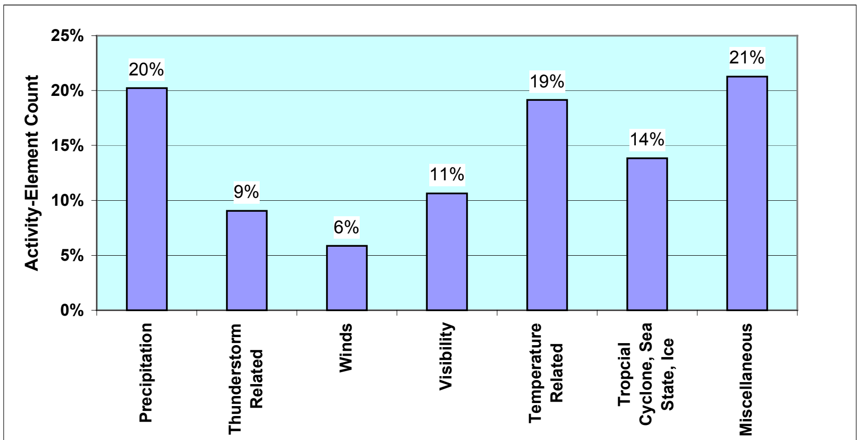



**Figure 4-8** MTS activity-elements by weather group.

respondents for this sector, 75 percent indicated a need for precipitation information. Visibility, winds, and flooding were identified by half or more of the respondents. The groups for thunderstorm-related elements and tropical cyclones were cited by between 30 and 50 percent of this initial set of WIST respondents.

### 4.5.3 Impacts and Mitigation Actions, by Weather Element Group

This section discusses the effects that specific weather elements have on MTS operations and the response actions that the WIST study participants identified as potentially influenced by accurate information on each element. Mitigation actions can range from simply increasing awareness to taking specific corrective actions or curtailing or suspending activities. All these actions are intended to avoid unnecessary cost, damage to property, or safety risk to people. As discussed in Section 4.2, weather impacts can be mitigated or obviated to varying degrees by timely action, and response decisions are affected by many factors other than weather information.

#### Precipitation Elements

Precipitation, especially freezing and frozen (ice and snow) precipitation, causes the greatest impact for this transportation sector. With any amount of freezing precipitation, all the activities show impacts to safety of personnel, impaired operations, and risk to cargo and equipment. Almost all of the sector activities show corresponding risks and impacts with frozen precipitation (snow) as well. Intense rain impairs operations, primarily because it reduces visibility and creates a danger to personnel and equipment due to flooding.

Vessel operators, whether on large commercial or small recreational vessels, mitigate the risk posed by freezing precipitation and the buildup of ice on decks and structures by limiting or terminating on-deck activities, covering equipment, or avoiding operating in areas of, or during periods of, freezing precipitation. When NASA moves spacecraft components by barge, all equipment and cargo are covered, and the operator considers delaying barge movement until the weather event has passed. Snow does not necessarily terminate operations, but it requires operators to clear the snow from decks and consider curtailing on-deck activities. The reduced visibility brought on by heavy rain requires extra vigilance and reduced speeds for vessels.

Representatives from the U.S. Coast Guard, in discussing operation of small and medium size cutters on the Great Lakes, reported that no matter what the form, precipitation reduces visibility and clutters the radar of cutters that are underway. Snowfall accumulating on a cutter affects the cutter’s stability and the crew’s movement onboard. Snowfall on top of ice-covered waters slows a cutter’s movements through the ice. Flooding caused by ice jams may require icebreaking operations to alleviate the flooding.

Port operations are affected somewhat differently than are vessels underway. This sector activity involves not only water-borne operations but also the ground-based operations of the terminal and the surface transportation systems that service the port facilities. Thus, ports have snow and ice removal responsibilities similar to those of other roadway and rail system operations. Heavy rain can hamper port operations by producing local or widespread flooding, which can also endanger inland waterway activities, including lock operations, as well as damaging equipment and cargo.

Inland waterways of the U.S. Marine Transportation System play a critical role in the nation's commerce. Photo courtesy NOAA Photo Library.

Required lead times for information on these weather elements vary by activity, but two time frames are clearly of most value. The first is the medium range planning time frame, which for most water-borne activities is 12 hours for freezing and frozen precipitation and 6 hours for rain. For port operations, 12 hours is the preferred lead time as well, except for heavier snowfall (greater than 4 inches), when 24 hours is desired. The second lead time period of great value is 0–6 hours. Information requested in this time frame includes current observations (or current nowcasts) of weather conditions that are affecting operations, as well as forecasts of weather conditions in the next six hours.

### Temperature-Related Elements

Temperature-related activity–elements account for 19 percent of the total for MTS operations. Of the 36 activity–elements, 11 are for air temperature. Another 20 are for heat index and wind chill temperature, and 8 are for water temperature and freezing spray. (Freezing spray is actually a weather-related consequence of winds, seas, and temperature.)

Air and water temperatures have the greatest effect on water-borne operations as they fall to and below the freezing point. Air temperatures of 32 °F or less cause water that splashes or sprays on a vessel to freeze. The resulting accumulation of ice on decks, superstructure, and rigging of a vessel can make it top-heavy and seriously decrease its stability. This condition occurs with a combination of freezing temperatures, heavy seas (relative to the vessel), and wind, which together produce large amounts of spray inundating the vessel and accumulating as ice. Operators of Coast Guard cutters on the Great Lakes cited this as a particular concern. Mitigating actions include changing direction and speed to reduce the amount of spray, removing ice from the vessel, and seeking shelter until the conditions abate. Cold temperatures are also a health and safety risk for personnel and affect the operation of some equipment, requiring that personnel are properly clothed and equipped and that sensitive equipment is protected.

Decreasing water temperatures and formation of ice, particularly on inland freshwater bodies, affects all vessels from small recreational boats to large ferries and barges. On the Great Lakes, for example, the Coast Guard removes its small boats from the water and Coast Guard cutters become the primary search and rescue resource. Coast Guard icebreaking operations then commence for emergency operations, flood control, and facilitating navigation.

Hot temperatures also affect the safety and effectiveness of personnel. In almost all cases, the lead time desired is 12 hours for the onset of either cold or hot conditions that affect operations or safety, whether it be for a cruise liner or recreational boaters. Port operations are the exception, where the desired lead time is 24 hours to prepare for cold temperatures.

### Tropical Cyclones, Sea State, and Ice

This category includes wave height (which has already been discussed as a factor in freezing spray), storm surge (including abnormally high or low tides), and ice (inland bodies, rivers, and open seas). Other than the U.S. Navy, none of the users specified tropical cyclones, per se, as an item of required information. Instead, they specified elements that can occur with tropical cyclones, such as wave height, high winds, heavy precipitation, thunderstorms, and storm surge.

For the U.S. Navy and operators of other ocean-going vessels, tropical cyclones and even severe winter storms provide planning and operational challenges, as ships cannot generally ride out storms in port without sustaining damage. Once they are underway (or "sortie"), ships must steer well clear of the highest winds and seas to avoid personnel injuries and damage and to ensure their stability limits are not exceeded. Storms that remain well out to sea are of little consequence to the general public but of great concern to the Navy. Because of the need to sortie ahead of tropical cyclones, the Navy must make decisions 3 to 5 days in advance of potentially dangerous weather. Sortie decisions are significant because of their high cost and impact on personnel and operations. In making these decisions, Navy fleet commanders must strike a balance between the risk of staying in port and the cost and potential for damage at sea. Within the continental United States and adjacent ocean areas, tropical cyclone forecasts in particular are closely coordinated between Navy forecasters and the NWS.

Storm surge and abnormally high or low tides are of greatest concern to recreational boaters, ferries, and port operations. The danger is primarily to port and mooring facilities and to vessels that are moored. For ferries, there is an increased risk of grounding and impaired passenger accessibility, especially for those with disabilities. The WIST participants generally requested lead times of 24 hours for response to these weather elements.

Ice poses a threat to all MTS activities due to the risk of hull damage to vessels and damage to port facilities. Mitigation actions include avoiding areas of ice, navigating ice-bound areas at speeds and with equipment that permit safe passage, requesting ice breaking services, or ceasing operations. Lead times requested by participants were generally 12 hours for vessels and 24 hours for port operations. Tailored ice forecasts and analyses are provided by the National Ice Center, located in Suitland, Maryland. The Navy (through the Naval Ice Center), NOAA, and the United States Coast Guard jointly operate the National Ice Center, which provides ice analyses and forecasts to civilian as well as military activities for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes.

Ice on the Delaware River floats in the shipping lanes near Philadelphia, in January 2001. Copyright AP Wide World photos.

## Winds

High wind by itself accounts for only 11 of the activity–element combinations identified for this sector. However, if the wave height element is included with wind (since wave height is a wind-driven phenomenon), the activity count doubles to 21 (11 percent of the total count for this sector). Wind and waves may be the weather elements that most frequently affect a wide range of waterborne and port operations.

High winds are a concern for all sector activities including marine modeling (which seeks to take wind effects into account in the models). Small boat handling becomes difficult at about 20 knots and operators are advised to exercise caution. At about 30 knots and greater, suspension of all small boat operations is strongly recommended. Ferry and barge operations begin experiencing difficulty at 20 knots, and by 30 knots operators may find it appropriate to cease operations until conditions improve. At 45 knots, these operators are likely to experience extreme difficulty with handling and maintaining control of their vessels. Larger ocean-going vessels are not as affected by wind speeds less than 30 knots, but when winds are above that speed they, too, begin to modify their operations to reduce risks to their cargo, passengers, and vessels. Port operations, which are also affected by high winds, begin to implement mitigation actions when wind speeds exceed 25 knots. Wind damage is possible to port facilities at speeds above 25 knots and likely at speeds above 45 knots.

The greatest wind-related effect is increased wave height. Wave heights of 2 to 4 feet affect passenger comfort and pose some risk to small boats, both inland and on open water. At 4 to 6 feet, there are safety risks for passengers and crew, and small boats should curtail or cease operations. Ferries and barges are likewise affected and may need to reduce speed or suspend operations. Waves of this height can also damage port facilities. Coast Guard cutter operations on the Great Lakes are greatly affected by the combination of wind and waves. Indeed, the Coast Guard reports that each class of cutter reacts differently to different wind speeds, and each Coast Guard operation is affected differently by winds at a given speed. When wave height reaches 6 to 12 feet, there is risk to passengers, crew, and cargo for medium to small vessels, which should adjust course and speed to minimize the impact of the seas on the vessel. At this sea state, damage is likely to port facilities, and ports therefore implement procedures to minimize the damage where possible. At heights of 10 or 12 feet and greater, there is safety risk to personnel and risk of structural damage to larger vessels and their cargo. NASA, for example, will consider delaying movement of its cargo until conditions improve.

Although the Great Lakes do not experience gravitational tides, they do have wind-driven tides (referred to as “seiching”) that can affect MTS operations. Under the influence of a steady wind, water is pushed from one end of a lake to the other, leaving behind low water levels that can prevent vessels from transiting shallows that are normally passable. In addition waves on the Great Lakes typically have a shorter period than ocean waves do. They can come from various directions and build rapidly.

For both winds and wave height, the WIST participants reported that they generally require 12 hours lead time for the more moderate conditions that require only increased caution. They require 24 hours lead time for more serious conditions that hinder or preclude safe vessel operations.

### Visibility

Each sector activity except marine modeling has an activity–element for reduced visibility in general and another for sun glare, resulting in a total count of 20. The principal impact is decreased ability to navigate and maintain safe clearance from obstacles and other vessels. Generally, visibility does not become a factor for MTS operations until it decreases to 3 miles or less. At that point, most activities simply slow down and exercise more caution. Some take more specific actions. NASA, for example, does not allow movement of cargo when visibility drops below one-eighth of a mile. Most of the users require only 6 hours lead time for reduced visibility conditions; however, NASA needs 24 hours.

### Thunderstorm-Related Elements

Thunderstorms and related weather phenomena account for 17 of the activity–elements for the MTS sector. Although these phenomena can be very severe and cause loss of life and property, they generally affect smaller areas for shorter periods of time than do some other weather elements. When severe thunderstorms do occur in the vicinity of MTS operations, all the sector activities recognize the potential risks to people, vessels, and cargo. The range of mitigation actions is similar; most activities cease outdoor operations in the vicinity of the threatening weather. Vessels underway take evasive actions as necessary.

Lightning is the most common risk. When lightning is present, small boats will generally cease operations and most users will cease hazardous activities such as refueling. Hail may damage cargo or equipment and injure personnel. Heavy rain and wind reduce visibility, requiring extra caution and reduced vessel speeds. Protective actions include keeping vessels and people out of the severe weather as much as feasible and curtailing outside activities when possible. For example, NASA will delay, reschedule, or reroute water-borne transport of spacecraft, vehicles, and equipment as appropriate to protect people from injury and prevent damage to very sensitive, high-value space program equipment.

The most severe risk is from tornadoes (primarily to inland waterway operations) and some extreme waterspouts. Although this risk is far less frequent than thunderstorms with lightning, tornadoes pose a severe threat to life and property. The preferred mitigation action is to adjust course and speed to avoid the severe storm. In almost all cases for thunderstorm-related weather, the desired lead time is 3 hours, with real-time updates when storms are actually occurring and affecting operations.

### Miscellaneous Elements

The miscellaneous group contains several weather elements of particular interest to WIST users in the MTS sector. One is the element for atmospheric dispersion from release of a nuclear, biological, or chemical hazard. Such events are health and environmental risks, as well as being potentially life threatening. The mitigating action in almost all cases is to cease operations and clear (or avoid) the area. A related element is air quality. Poor air quality can pose a health risk to personnel. Both of these elements were designated as relevant to ten sector activities (all except marine modeling).


Every day, the Port of Baltimore handles tons of coal, hundreds of foreign-built cars, and thousands of boxcar-sized containers. Hazardous material incidents, including deliberate releases of nuclear, biological, or chemical hazards, are among the emergencies for which managers of this complex intermodal transportation node must prepare. Copyright AP Wide World Photos.

Space weather is a third element in this group that was designated as relevant to the ten sector activities except marine modeling. As the MTS becomes increasingly dependent on modern communications, navigation, and data transfer systems, there is a corresponding need to monitor and manage these electronics-dependent systems for any adverse effects of heightened solar weather activity.

The fourth miscellaneous element designated as important to ten of the sector activities is volcanic ash. Volcanic ash can damage equipment, present a health risk, and reduce visibility. Mitigating actions include protecting equipment, clearing the ash, providing breathing equipment for personnel, and curtailing operations in the vicinity of an ash plume.

Finally, although not explicitly designated by the participants from this sector, the element of "correctly forecasting fair weather" is also important to the MTS. Many sector activities rely on good weather for efficiency and, in some cases such as recreational boating, safety and feasibility. Therefore, accurate forecasts of good weather can be as valuable to activities in this transportation sector as a forecast for adverse weather.

## 4.6 Pipeline Systems Sector

Pipelines are essentially product "highways."

Pipeline operations can be divided into two distinct areas of responsibility: the pipeline industry itself and the users of pipeline delivery services. The pipeline industry can be viewed as the "highway system" for commodities transported through long-distance pipelines. These pipelines control the transport of immense quantities of fluids (gases and liquids) across the United States to support our economic system's requirements for on-time delivery of supply to meet demand. This critical function is maintained and managed at control centers operated by the individual pipeline companies. A control center is the focal point for all gathering and distribution of information relevant to a pipeline's operation and status. The control center monitors and controls the complete length of pipeline. It receives measurement data on flows, pressures, and temperatures and remotely controls valves and limited holding tanks. Relative to the volumes being transported in a unit of time, pipeline companies have little or no holding capacity for the transported fluids at either end of the line. Thus the product providers, for example an oil refiner or a natural gas supplier, are responsible for most storage, usually in the form of tank farms. The product providers are also responsible for well-head operations, tank farm pipeline distribution, local pumping stations, and maritime tanker distribution operations.

The Trans Alaska Pipeline carries crude oil from Northern Slope oilfields 800 miles to the ice-free port of Valdez, Alaska. Photo courtesy Office of Pipeline Safety, U.S. Department of Transportation.

### 4.6.1 Sector Activities

Weather-sensitive activities or operations related to pipeline system operations generally fall into one of more of the categories shown in Table 4-5. These nine activities are used in the WIST needs template for this sector (Appendix B-4) to define activity–element combinations.

**Table 4-5** Sector Activities for Pipeline Systems Sector

**Control center operations.** Operations to monitor the pipeline system, advise system operators, and control system integrity.
**Pumping station operations.** Responsible for fuel movement, allocation, storage, and distribution.
**Well head/drill site operations.** Includes operations for fuel pumping, storage, and distribution near source wells.
**Tank farm operations.** Includes fuel storage, distribution, and maintenance at tank farms.
**Construction.** Operations include construction, maintenance, and repair, as well as the scheduling of these operations.
**Hazardous material.** Includes monitoring storage and transport of hazardous materials and any mitigation, reclamation, and reporting operations associated with their accidental release while within the pipeline system.
**Surveillance.** Includes inspections, monitoring, and maintenance.
**Personnel safety.** Any operation where safety and health risks to workers or others may be present.
**Fuel barge operations.** Includes barge docking, fuel movement by barge, and transfer to/from fuel barges.

### 4.6.2 Analysis of Activity–Elements

The pipeline system sector of transportation had the smallest participant population in the WIST needs study, with inputs received from 15 separate agencies or entities. These participants identified 19 distinct weather elements that affect their activities and for which weather information could aid in mitigation actions. Figure 4-9 shows the distribution of the 128 activity–element combinations in the Pipeline Systems template among the weather element groups. Of these groups, precipitation had the highest count of activity–elements, followed by the tropical cyclone–sea state–ice group and the temperature-related group.

Even though a pipeline system, including the well heads, valves, tanks, etc., as well as the pipeline itself, completely encloses the material that is moving (the product flowing through the pipe), weather does affect the system's safe, economical, and efficient operation. Weather affects the complete spectrum of pipeline operations; including all of the sector activities listed above. However, for the weather element groups with the highest counts of activity–elements in the template, it is the secondary phenomena caused by precipitation, temperature extremes, or high winds that are of direct concern. Specific conditions cited by the WIST participants as major threats to sector activities include flooding, seabed scouring, landslides, and frost heave. These and other consequences of weather and environmental phenomena comprise the second largest contributor to pipeline damage or failure.

In the initial WIST survey conducted in 2000, prior to preparation of the WIST needs templates, precipitation elements were of interest to 80 percent of the respondents for this sector. Flooding, visibility, and winds were weather elements of interest to half or more of the respondents.

### 4.6.3 Impacts and Mitigation Actions, by Weather Element Group

This section discusses the effects that specific weather elements have on pipeline system operations and the response actions that the WIST study participants identified as potentially influenced by accurate information on each element. Mitigation actions can range from simply increasing awareness to taking specific corrective actions or curtailing or suspending activities. All these actions are intended to avoid unnecessary cost, damage to property, or safety risk to people. As discussed in Section 4.2, weather impacts can be mitigated or obviated to varying degrees by timely action, and response decisions are affected by many factors other than weather information.

#### Precipitation Elements

Precipitation in its several forms, including freezing or frozen (ice and snow) and liquid precipitation (heavy rain, flooding), is the weather element group with the highest count of activity–elements (36, or 28 percent of the total) in the WIST needs template for pipeline system

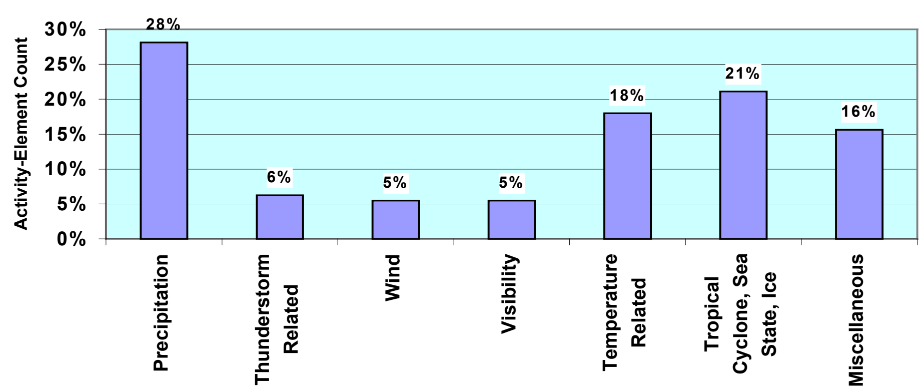



**Figure 4-9** Pipeline systems activity-elements by weather group.

operations. Accumulations of ice and snow can freeze valves, rendering them inoperative. Ice and snow removal may damage valves and gauges, and pipeline sensors are more likely to fail. Consequent disruptions of product delivery may require emergency fuel management procedures; re-allocation, transfer delays, re-routing, or unscheduled storage. Disruption of construction or maintenance cycles may result. Leaks or other pipeline failures are possible, which may require implementing procedures for HAZMAT incident response. Safety of personnel and equipment is critical, requiring proper clothing and increased monitoring of crews and equipment because accidents are more likely in icy conditions. Inspections of buried pipeline by digging an inspection trench or bore hole may be complicated by ice, snow, and frozen soil. Delays in scheduled construction and inspections are likely. During ice and snow storms, telephone communications by satellite, radio, or cellular wireless networks may be disrupted, and data collection from pipeline sensors may fail. Any of these physical consequences may also impact public relations of the pipeline operator, the product provider, and any regulatory or oversight agencies involved with them.

In addition to the impacts listed for freezing or frozen precipitation, heavy rain and flooding may scour pipeline roadbeds and unearth buried pipelines. The pipeline can also be damaged by line stretch and impacts of foreign objects and debris. Direct inspection of buried pipeline sections may be complicated by standing water.

Mitigation actions for precipitation above threshold values for the type of precipitation include increased visual inspections and remote monitoring. Control centers will issue advisories and/or warnings to other pipeline activities (see Table 4-5). Fuel management contingency plans (re-route, store, cancel transfers, etc.) may be initiated. Control centers may issue communication advisories, all operations report communication failures and monitor outages, and alternative modes of communication may be implemented, such as backup plans for collecting and distributing pipeline sensor data.

Crews dig around a buried portion of the Trans Alaska Pipeline in search of an underground leak. Although pipelines are often underground, weather–related conditions are the second-most frequent contributor to pipeline damage or failure. Copyright AP Wide World Photos.

The integrity of pipelines, tanks, and valves is checked, the liquid level in tanks is checked, and tank contents may need to be sampled and analyzed for homogeneity and purity. Inspections of floating tank roofs, sumps, and water impounds may be needed, and these structures may need to be drained or pumped out if heavy rain or snow melt is anticipated. Additional crews or crew assignments may be required. The pipeline scheduler can make arrangements with product providers and terminals or customers to accommodate a schedule disruption. For longer lasting or more severe conditions, any work that can wait until the weather clears is postponed and alternate construction and maintenance schedules are developed. Aerial and vehicle pipeline inspections are rescheduled, restricted, or suspended based on weather safety.

For freezing or frozen precipitation, de-icing, anti-icing, or snow removal programs may be initiated for roads, walkways, valves, gauges, etc. Crews are required to wear proper clothing and footwear for icy or slick conditions. If a pipeline is breached or other leakage occurs, HAZMAT spill reaction and mitigation plans must be implemented and proper authorities notified. If flooding is forecast or observed, additional inspections of bridges, trestles, and pipeline roadbed for structural integrity may be included in the pipeline inspection procedure.

### Tropical Cyclones, Sea State, and Ice

This weather group accounted for 21 percent of the total activity–element count for the pipelines sector. The impacts on pipeline systems are, like those associated with flooding, primarily risks of physical damage to the infrastructure, with potential secondary consequences such as HAZMAT incidents and personnel safety.

Pipeline roadbed may be scoured by flooding, and buried pipeline may be unearthed and damaged or destroyed. Seafloor pipeline may be damaged or destroyed. These conditions increase the risks of pipeline damage from line stretch, foreign debris impact, and corrosion from damaged coating. Pumping may be restricted or suspended. Pipeline sensor failure is more likely. High winds, seas, and tides restrict or suspend movement of barge traffic between offshore drill sites and coastal pumping facilities. Disruption of fuel delivery may require emergency fuel management procedures, including re-allocation, transfer delays, re-routing, or unscheduled storage. Construction and maintenance cycles may be disrupted. Leaks or other containment failures may require HAZMAT procedures.

Mitigation actions begin with increased pipeline and infrastructure surveillance, including visual inspections and remote monitoring. Additional inspections of bridges, trestles, and pipeline roadbed for structural integrity may be included in the pipeline inspection procedure. The integrity of pipelines, tanks, and valves is checked, the liquid level in tanks is checked, and tank contents may need to be sampled and analyzed for homogeneity and purity. Additional crews or crew assignments may be required. Any work that can wait until the weather clears is postponed, and alternate construction and maintenance schedules are developed.

Control centers need hurricane advisories and warnings prior to and during barge operations, tank construction, maintenance, or repair. They will issue advisories or warnings to other pipeline system activities and product providers. If conditions become unsafe at the control center, controllers evacuate the building and go to a strategic backup site. This site is already set up to allow the controllers to monitor and operate the pipelines. The pipeline scheduler will make arrangements with product providers and terminals or customers to accommodate schedule disruptions. Pipelines may be drained or filled, as appropriate to decrease damage susceptibility.

If high winds and heavy precipitation are involved, aerial and vehicle pipeline inspections are rescheduled, restricted, or suspended, based on safety, as are fueling operations. If a pipeline is breached or other leakage occurs, HAZMAT spill reaction/mitigation plans must be implemented and proper authorities notified.

### Temperature-Related Elements

Temperature-related activity–elements constitute 18 percent of the total for the pipeline sector. Soil temperature affects eight of the sector activities. Air temperature (four activity–elements) and heating/cooling degree days are also important for potential impacts on the pipeline infrastructure (five and four activity–elements, respectively). Wind chill and heat index are important primarily for health and safety risks to personnel working outside.

For soil temperature, the principal concern is temperatures below freezing or oscillating around the freezing point. These conditions can produce ground heave, resulting in pipeline motion or movement. Ground heave is most prevalent during the autumn freeze and the spring thaw. Inspections of buried pipelines by digging out an inspection trench or boring may be complicated or delayed by frozen soil. Construction and maintenance delays may also occur.

When the air temperature drops to freezing and below, especially if moisture is present from precipitation, many of the same impacts can occur as are discussed above for freezing precipitation. When the air temperature drops below -20 °F or increases above 100 °F, there are sanctions and prohibitions against the use of plastic pipe.

Mitigation actions for the soil and air temperature elements include most of the non–weather-specific actions listed above for precipitation. Control centers will issue advisories and/or warnings to other sector activities and may schedule additional system inspections and monitoring. Fuel management contingency plans (re-route, store, cancel transfers, etc.) may be initiated. Additional crews or crew assignments may be required. The integrity of pipelines, tanks, and valves may need additional checking, as may the liquid level in tanks. Tank contents may need to be sampled and analyzed for homogeneity and purity. If a pipeline is breached or other leakage occurs, HAZMAT spill reaction/mitigation plans must be implemented and proper authorities notified.

Fuel demand can vary dramatically, depending on the heating or cooling degree days. Thus, this weather element can have major impact on regional and national fuels distribution by pipelines. Accurate forecasts help pipeline operators prepare for changes in demand and help product preparers in readying appropriate quantities of fuels formulated for different regions.

### Wind and Visibility

Taken together, wind and visibility elements make up about 10 percent of the total count of activity–elements for the pipeline sector. Visibility of less than one-fourth of a mile restricts or suspends movement of barges and tankers to and from offshore drilling sites and coastal pumping facilities. Reduced visibility also restricts or suspends the safe surveillance of the pipeline by air or truck, disrupts construction and maintenance operations, may cause pumping to be restricted or suspended, and affects the safety of personnel and equipment.

Wind speeds above 60 mph, particularly in coastal areas, restrict barge and tanker operations, may disrupt fuel deliveries, may cause pumping to be suspended, and may disrupt construction and maintenance schedules. In addition, high winds may cause physical damage to the pipeline system, especially if the wind is associated with heavy seas or inland flooding and severe storms.

Damage can result from debris impact or from scouring or erosion of the pipeline roadbed by water and wave action, particularly for underwater pipelines.

The pipeline system operators generally want 12 hours lead-time for these weather events. Mitigation actions, which are similar to those for flooding or high seas, include increased inspections for integrity of pipelines, tanks, and valves, as well as for bridges, trestles, and pipeline roadbed. Maintenance and construction may be rescheduled, and fueling operations may be suspended. If deliveries are disrupted, fuel management contingency plans may have to be implemented.

### Thunderstorm-Related Elements

This weather element group includes only 6 percent of the activity–elements. The count may be misleading because three separate weather elements—tornadoes, hail, and lightning—were reported together with thunderstorms as a single weather element. Nevertheless, all of the pipeline system activities are impacted by one or more of these severe weather elements, with tornadoes and lightning being the most significant. Both can result in injury to personnel and damage to equipment. In addition, lightning can damage or destroy pipeline sensors and disrupt data flow and communications from both sensors and control facilities. Pipeline operators desire forecasts and warnings of these conditions 6 hours in advance.

Mitigation actions primarily involve delaying or terminating outdoor activities such as fueling and construction. In the vicinity of severe storms, there may be additional inspections of the pipeline system required, after the storm has passed. Contingency plans may need to be implemented for loss of sensor data, physical damage, or disruption of the flow, as well as response to any HAZMAT incident that may occur.

### Miscellaneous Elements

For pipeline systems, the two largest counts of activity–elements from the miscellaneous group are for earthquakes and space weather, with 8 sector activities potentially impacted by each. The importance of these elements reflects the susceptibility of buried pipelines to ground movement and the dependence of pipeline system operations on communications linkages that may be susceptible to the electromagnetic disturbances resulting from solar storms.

The impacts of seismic activity are much the same as those related to flooding or tropical cyclones (hurricanes). Primary impacts include roadbed scouring; buried pipe being unearthed, damaged or destroyed; disruption of fuel delivery; pipeline sensor failure; leaks or other pipeline failures; and, of course, the safety of personnel and equipment. The mitigation actions are similar to those cited above for flooding or tropical cyclone conditions.

Forest fires are a potential threat to above-ground pipelines. Copyright AP Wide World Photos.

Space weather affects all pipeline activities because of the impact it can have on communications (especially satellite, radio and cell phones) and data distribution from pipeline sensors. Remote sensors may detect a leak or pipeline failure, but the communications link to relay the information to the pumping station, tank farm, or control center may be temporarily lost or physically damaged. The control centers monitor communications outages, make use of alternative modes of communication, and execute backup plans for sensor data distribution.

Two other elements, air quality and atmospheric transport and diffusion of hazardous substances, are issues of concern to control centers and personnel at any operation (the "personnel safety" sector activity). In the event of a leak or pipeline failure, vapors and toxins are released to the environment with possible catastrophic results. The control centers ensure the proper authorities are notified and advisories and warnings are issued, work schedules are revised, the HAZMAT spill reaction and mitigation plan is implemented as necessary, and relevant inspections are conducted to ensure the integrity of the pipeline system.

## 4.7 Rural and Urban Transit Sector

Weather impacts on transit operations are often significant. When a weather event is extreme, it can be the most important factor in satisfying or not satisfying the transit mission. Transit systems often experience increased ridership when snowstorms or other severe weather induce mode shift. Thus, even as weather conditions are complicating operations, transit systems must be prepared to meet these surges in demand through increased staffing and deployment of standby equipment (buses, railcars, vans.).

One of the principal goals of transit officials is to provide early and understandable weather information products and services to transit customers, as well as to surface transportation professionals. A key aspect of the WIST problem identified by the transit officials in this study is the current limitations on acquiring reasonable, physically consistent weather data at small scales. This user issue underscores the importance of mesoscale and misoscale variations that

Transit passengers wait for their bus to arrive. The safety of passengers waiting at stops is a major concern of transit system managers. Copyright AP Wide World Photos.


greatly impact the transit sector. Transit authorities need WIST suppliers to provide tailored, detailed, and ***accurate*** forecasts with lead times of 12 to 24 hours.

### 4.7.1 Sector Activities

Table 4-6 defines the operations and transportation activities used in the WIST needs template for rural and urban transit operations (Appendix B-5). The weather sensitivities of transit systems generally parallel those for buses and roadway maintenance operations in the roadway sector and for station and depot operations, railway/control center operations, and personnel safety in the long-haul railway sector. However, in this sector the railway activity is primarily aimed at passenger transport, with commuter schedules (e.g., dealing with morning and evening peak loads) being a major concern. Another sector activity with some unique sensitivities is school transportation.

**Table 4-6** Sector Activities for Rural and Urban Transit Operations

**Roadway maintenance.** This activity includes roadway surface treatment for snow and ice control in the winter, as well as maintenance to repair damage to roads and infrastructure.

**Bus operations**. In addition to bus driving, this activity includes road supervision and maintenance of the bus fleet, terminals and other facilities, and bus stops.

**Trolley bus**. This activity refers primarily to electric trolleys with overhead wires.

**School transportation.** This activity includes transportation of students by bus and commuting to school by young, inexperienced drivers.

**Rail operations.** This activity includes passenger rail operations above and below ground, and station and platform areas. Trains are predominantly electric, using a power rail ("third rail") or overhead wires.

**Traffic management.** Activity consists primarily of managing traffic signals and traffic routing to enhance safety and efficiency.

### 4.7.2 Analysis of Activity–Elements

The transit sector was represented by the largest population of study participants (60). With 141 activity–elements identified by its study participants, the transit sector has the third highest activity–element count of the study. (The roadways sector has the same number of distinct weather elements, 52, and the MTS sector has only 35, but both have a greater number of sector activities affected, resulting in more activity–element combinations.)

Figure 4-10 shows the percentages of Transit activity–elements from the WIST needs template in each weather element group, as defined in Table 2-1. The precipitation group, with 45 activity–elements, has the largest fraction (32 percent). Temperature-related activity–elements constitute the next highest group, with 30 activity–element combinations (21 percent). For comparison, the roadway and long-haul rail sectors had only 28 percent and 27 percent, respectively, of their activity–elements in the precipitation group, but higher percentages than transit in the temperature-related group (23 percent and 29 percent, respectively).

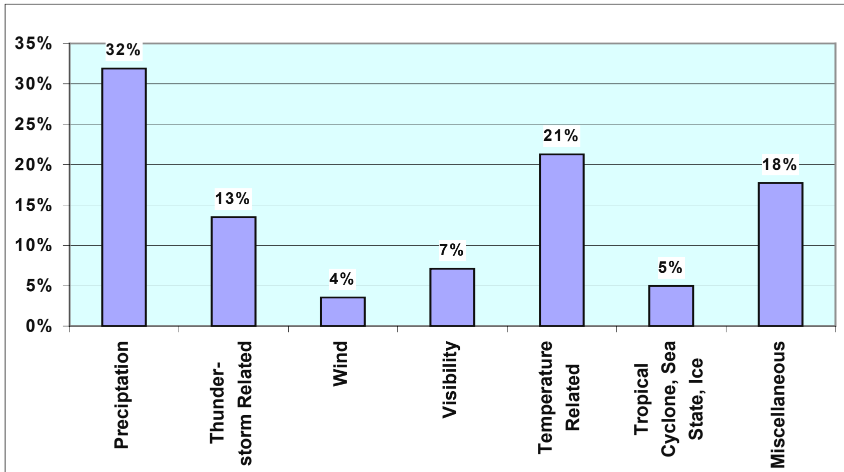



**Figure 4-10** Transit activity-elements by weather group.

In the initial WIST survey in 2000, which preceded the needs templates, precipitation was the general weather condition most frequently cited by transit sector participants as one for which they needed information. Nearly 90 percent of the 78 respondents from this sector indicated a need for precipitation information. Winds, flooding, visibility, temperatures, and thunderstorms were identified by half or more of these respondents as weather conditions on which they needed information.

### 4.7.3 Impacts and Mitigation Actions, by Weather Element Group

This section discusses the effects that specific weather elements have on transit operations and the response actions that the study participants identified as potentially influenced by accurate information on each element. Mitigation actions can range from simply increasing awareness to taking specific corrective actions or curtailing or suspending activities. All these actions are intended to avoid unnecessary cost, damage to property, or safety risk to people. As discussed in Section 4.2, weather impacts can be mitigated or obviated to varying degrees by timely action, and response decisions are affected by many factors other than weather information.

Decisions not within the control of transit system managers can undo a transportation decision reasonably based on an accurate weather forecast. For example, businesses or agencies sometimes release their employees in mid-day when snow begins to fall, without regard to the regularly scheduled public transportation slow-down between the morning and afternoon rush hours. This action creates a tremendous surge in demand for public transit services just when the system's capability is at a minimum, resulting in delays and overcrowding.

As noted in the discussion of the roadway sector, state police organizations that participated in the WIST survey indicated that knowledge of the local effects and variability of weather conditions gives their troopers an advantage in performing their duties. This knowledge, coupled with accurate and timely weather forecasts, improves the ability of all police agencies to refine staffing and enforce traffic control more effectively. Often, the police are the first on-scene weather observers, and this information can be relayed to transit command centers for redistribution. Some states (for example, the Minnesota Department of Transportation) even have observing systems on board their vehicles. These systems communicate directly to a traffic control center for immediate distribution and input to traffic control decision systems. Monitoring the environment in a proactive manner can increase public safety and help both the police and transit activities achieve their transportation missions despite adverse conditions.

### Precipitation Elements

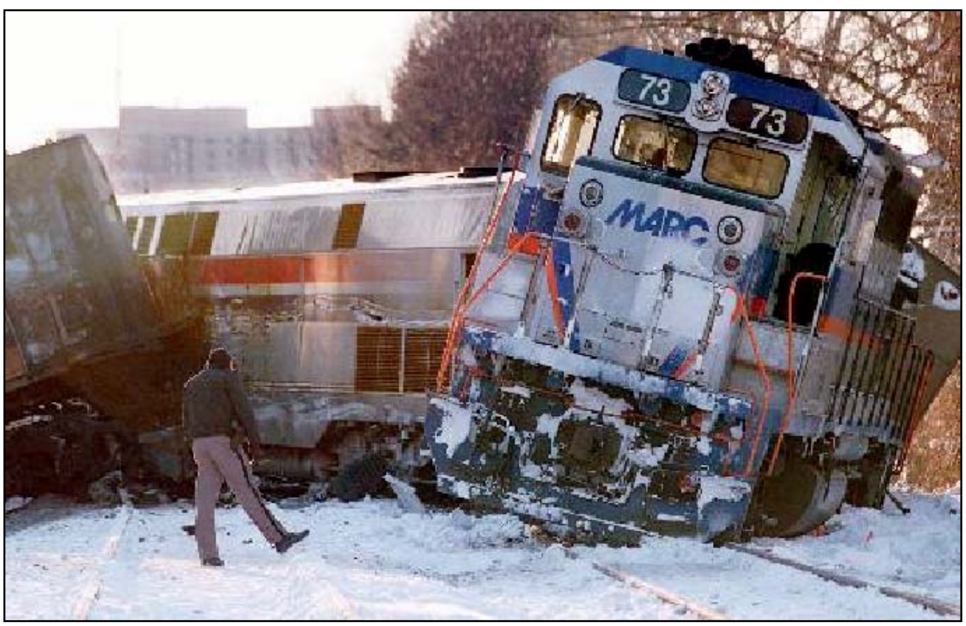
Precipitation, especially freezing or frozen precipitation (ice and snow), causes the greatest impacts for the roadway sector. Most of the activities list safety and health risks to people and property damage risks as potential consequences of any freezing precipitation. Almost all list similar risks for frozen precipitation (snow) as well, with the risks increasing as snow depth increases. Road maintenance activities are most concerned with freezing and frozen precipitation because these conditions typically cause the greatest expenditure of resources in areas where such precipitation occurs. They have the most impact on public safety, other than perhaps a major hurricane. Ice or snow on the roadways mean loss of traction, stability and maneuverability; impaired mobility; roadway obstructions; loss of control; and increased occurrence of vehicle mishaps, with attendant injuries and risks to life and property. For almost all users, it means probable schedule and travel delays.

The first snowstorm of the season slows the morning school bus commute on I-35W near Minneapolis. School superintendents rely on timely and accurate weather information to make the right decisions regarding school closing or delayed opening. Copyright AP Wide World Photos.

In addition to impediments to safe travel resulting directly from ice or snow, bus operations are hampered by traffic congestion and accidents, delays of operations, and routes that require detours. The risk of damage to buses increases, and inclement weather causes delays in maintenance of facilities, the bus fleet, and bus stops. Operators are advised to drive with extreme caution. Operations are modified, restricted, or suspended as necessary, especially on hills. Trolley buses face the additional complication of ice on overhead electric wires, which can cause malfunctions that disrupt operations. At the onset of precipitation, they can be equipped with ice cutters to keep the wires clear of ice.

School systems are concerned not only with large numbers of school buses but also with large numbers of young, inexperienced drivers who may have never driven before in adverse weather conditions. The mitigation options include deciding to close schools prior to opening for the day, delaying opening of schools in the morning, or dismissing early if school is already in session. School officials who participated in the WIST study underscored the critical importance for this decision process of accurate local weather forecasts with sufficient lead times.

Rail operations face similar difficulties. Ice buildup on the third rail or catenary lines (overhead wires) causes power outages for trains. The risk of mishaps increases when ice builds up on the rails, affecting braking action, and on the platforms where personnel safety is the issue. Delays occur as trains operate at slower speeds for safety reasons. Mitigation actions include inspecting and clearing ice buildup from rails and overhead wires, using ice scrapers and snow brakes on the trains, running service vehicles or snow trains to keep the tracks and overhead wires clear, activating heaters in the third rail and switches, removing ice from platforms and parking lots, and, as a last resort, restricting or suspending operations as necessary.




Winter storms increase the risks of track signal malfunctions. Here, a passenger transit train has collided with an inter-city passenger train using the same rail line during a winter storm in Maryland. Copyright AP Wide World Photos.

The lead times these users require for information on winter precipitation events vary by activity, but two time frames stand out. The first is a longer range planning time frame, which varies by activity as follows:

- 12 hours for school administrations (allowing them to make decisions and disseminate the information to the public and employees)
- 12–24 hours for bus operations
- 24 hours for train operations
- 24–48 hours for road maintenance operations (allowing preparations to begin, prediction of the threatened area, selection of treatment strategy, and preparation and deployment of treatment assets).

The second lead time window of major value extends roughly from 0 to 6 hours before precipitation begins. This corresponds to the execution phase of mitigation actions planned earlier. For road maintenance crews, this means final decisions and initial operations to treat and clear roads of snow, ice and debris; deployment of treatment crews and assets; and initiating changes in traffic flow management. This phase makes use of current observations, as well as near-term forecasts and nowcasts.

Liquid precipitation affects most transit sector activities less than frozen or freezing precipitation does, unless it is heavy precipitation. Road maintenance operations are an exception because of concerns with traction, road submersion, drainage, and reduced visibility. The impact threshold for this activity is any liquid precipitation at all.

Conditions that produce flooding of any sort are of concern to all transit activities. Local knowledge of flooding is critical to transit operations, especially where low-lying underpasses are affected. The local transit authorities know where flooding tends to occur; but they also need to know when a weather event will generate sufficient precipitation (intensity and duration) to produce flooding. For most activities, the lead times desired by decision makers for forecast of flood conditions range from 12 to 24 hours. The lead time and format of information must be adequate to convey the information to the traveling public efficiently and effectively.

Mitigation actions for flooding vary by sector activity. Buses may be rerouted, diverted, taken out of service, or used to help evacuate people from flood-prone areas. If not in use, they may need to be moved to high ground. Rail transit operators may need to suspend or reroute service through areas that are likely to flood or are already flooded. After the flooding has receded, they must clear rails and wires and inspect and repair track, roadbed, bridges, and culverts.

### Temperature-Related Elements

Most of the temperature-related activity–elements in the transit sector come from the road maintenance community. Of the 30 activity–elements in this group, 11 are for air temperature (including maximum and minimum temperature, temperature relative to freezing with rising or falling trend, temperature change rate, and degree cooling/heating days). Another 8 are for heat index and wind chill temperature. Six are for pavement, subsurface, and rail temperatures.

Road maintenance operations for this sector, as for the roadway sector, depend on temperature information, particularly the combination of pavement temperature and air temperature with rising or falling trend. Accurate temperature information, coupled with precipitation information, allows maintenance managers to select the correct strategy and material to treat road surfaces to minimize the effects of winter weather on vehicle traction and traffic flow.

In most cases, the mitigation actions in response to temperature extremes include advising operators, transit customers, and the driving public, as well as modifying or restricting non-essential operations as necessary. Transit bus operators normally do not curtail operations during extremes of temperature because of concern for passengers waiting at bus stops and the need to minimize their exposure time. During extreme cold temperatures, public transit buses may be used to transport homeless persons to shelters.

High temperatures, as well as low extremes, are a weather concern for transit operators, private vehicle drivers, and transit passengers. High temperatures require that work crews take precautions for their own safety and to prevent damage to equipment. They also pose risks for vehicles. High pavement temperatures increase the risk of tire blow-outs for heavy loads. Rail operations are particularly affected by air temperatures above 85 °F, as rails will then expand enough to kink and older catenary wires will sag. Rail operators must increase the frequency of rail inspections and reduce train speeds under these conditions.

### Thunderstorm-Related Elements

Although the impacts of some of the phenomena associated with thunderstorms can be very severe, including loss of life and damage to property, they generally affect smaller areas and for shorter durations than do some other weather elements. When severe thunderstorms do occur, all the transit activities recognize the potential risks to their personnel, passengers, students, vehicles and vehicle drivers, and equipment, as well as indirect consequences from loss of power or communications, impeded mobility, and increased traffic congestion. The protective actions are similar: most activities cease outdoor operations (particularly such things as refueling and maintenance) in the path of the threatening weather and take evasive actions as necessary. Road maintenance activities try to predict where the threatened areas will be, prepare to implement warning and evacuation plans, then respond to roads blocked or damaged by debris. Transit bus operations normally are not suspended because of concern for passengers waiting at exposed bus stops. School transportation officials may implement schedule changes to prevent exposure of students who are in transit between school and home.

### Visibility

Visibility and sun glare are the two elements in this group, with five activity–elements apiece. Reduced visibility from air-borne obscurants (e.g., fog, smoke, precipitation, dust) is not a concern until visibility decreases to a quarter-mile or less. At that point, safety is affected and road vehicles simply slow down and exercise more caution. These mitigation actions introduce schedule delays and increase congestion. Visibility thresholds for rail operations vary, depending on factors such as the length of a train, the degree of cab control, and operator difficulty in monitoring signals and switch alignments. Thus, visibility thresholds for transit rail operations vary from a quarter-mile up to 3 miles. For sun glare, the standard mitigation action for transit activities is to reduce speed.

The Staten Island Ferry moves through New York Harbor in the fog. On February 21, 1996, one of the ferries collided with the pier while docking in heavy fog. Copyright AP Wide World Photos.

### Winds

High winds are a concern to all transit activities. The critical thresholds for most activities are 30 mph for moderate risk and 50 mph for severe risk and significant impact to safety and transit operations. High winds produce roadway debris, flying debris, downed live electric lines and poles, traffic slowdowns and congestion, operational delays, and drifting snow in winter. Maintenance of vehicles, facilities, and bus stops may be suspended or postponed. Mitigation actions include prepositioning barriers to debris or snow (such as snow fences in the winter); advising transit operators, passengers, and the driving public; and implementing detours where necessary. Operations and traffic patterns may be modified, particularly to allow for removal of debris or drifted snow. Rail operators slow their trains and, when winds reach 70 mph, suspend service over bridges.

### Miscellaneous Elements

Several of the weather elements and weather-related phenomena in the miscellaneous group are worth noting for their impact on transit activities. Among these are tropical cyclones and the associated storm surge. A number of weather conditions associated with a tropical cyclone (wind, rain, reduced visibility, and tornadoes) affect all surface transportation activities in the area where a storm occurs. Storm surge may affect the coastal area where a storm makes landfall. The mitigation action includes suspending travel or vacating the area. Road maintenance activities mobilize maintenance forces for disaster response and damage repair. Transit bus systems prepare to assist in evacuations and other emergency preparedness actions. The lead-time required for adequate preparation and implementation of these actions can be up to 72 hours.

Another element in this category is weather information relevant to incidents of release and atmospheric dispersion of nuclear, biological or chemical hazards. These events are life-threatening, and the responses by transit activities are either to cease operations and clear the area or participate as part of a previously trained response team. A related element, albeit less critical in potential health effects, is air quality, which typically has the greatest impact in urban areas. Many of the meteorological conditions that influence the movement of a plume from a hazardous-materials release are also of importance in forecasting air quality conditions and the areas affected.

A third element of special interest in the miscellaneous group is space weather. As transit systems become increasingly dependent on electronic and wireless systems for communication, navigation, and data transfer, the need increases to monitor and manage system components that can be temporarily disrupted or permanently damaged by space weather hazards.

## 4.8 Airport Ground Operations

The assessment of weather information needs for airport ground operations is a small but critical piece of an overall assessment of how weather elements affect surface transportation and what information can be useful in improving actions to deal with these weather impacts. Airport ground operations constitute the interface between other surface transportation modes and the airborne movement of people and cargo. Weather information support for the multimodal operations that occur at or near this interface is critical because the effectiveness, efficiency, and safety of these airport ground operations bear directly and substantially on the overall throughput of aircraft, passengers, and cargo (the capacity of the air transportation system). This support is also critical to the timeliness of air transport of both goods and travelers. The weather impacts and the general types of mitigation responses available to sector operations are more like those of other surface transportation modes (for example, urban transit operations or port operations of the MTS) than the weather concerns of aircraft in flight. It is therefore reasonable to include consideration of airport ground operations as a distinct transportation sector in a WIST study.

Airport ground operations include wing de-icing prior to takeoff, as well as all ramp operations and passenger ground traffic. Copyright AP Wide World Photos.

### 4.8.1 Sector Activities

This transportation sector includes airport operations on the ground but not flight operations, since the latter are relevant to aviation weather support rather than weather information for surface transportation. The sector does include factors that affect the ability of people to get to and from the airport, as well as ground traffic on the airfield, between aircraft and airport facilities. The sector activities used in the WIST needs template for airport ground operations (Appendix B-6) are listed and defined in Table 4-7.

### 4.8.2 Analysis of Activity–Elements

The airport ground operations sector had the second smallest population of participants in the WIST study; responses were received from 27 agencies or entities. These participants identified nine weather elements as affecting the sector activities listed in Table 4-7.

**Table 4-7** Sector Activities for Airport Ground Operations

**Aircraft movement.** Includes all ground movement of aircraft and safety of flight considerations that affect aircraft ground movement.
**Vehicle movement.** Vehicle movement and traffic flow on the airfield and on approaches to the airfield
**Gate accessibility**. Includes operations for the transfer of baggage and cargo and general aircraft servicing (cleaning, catering, minor maintenance) while an aircraft is parked at a gate.
**Aircraft maintenance.** All ground maintenance conducted away from the gate.
**Refueling aircraft.** Includes transportation of fuels from at-airport storage to aircraft and the operations during transfer from fuel truck to aircraft fuel tanks.
**Foot traffic.** All pedestrian movement on the airfield.
**Construction and maintenance projects.** All vehicular movement and operations related to construction or structural maintenance of airport and airfield facilities, while the airport continues to operate.

Development of the WIST needs template for this sector, like the efforts for the other sectors, involved identifying the weather elements of concern to participants, the threshold(s) at which each element becomes significant to sector activities, and the activities most affected by each element. For each activity–element combination, the template includes impacts when an element occurs and the mitigation actions available, if accurate weather information with sufficient lead time is in the hands of activity decision makers. The participants were also asked to specify the lead times desired, if a weather warning or weather advisory for a specific weather element were to be most useful and effective for the impacted activities.

More than 20 civilian airports, 4 major airlines, and 2 military airfields were contacted; each provided a response useful in developing the sector's WIST template. In addition, the Federal Aviation Administration (FAA) identified five key weather-related areas that affect airport ground operations:

- Snow removal
- Aircraft de-icing operations
- Aircraft refueling operations
- Equipment protection

- Ground support personnel effectiveness.

Figure 4-11 shows the distribution among weather element groups of the 38 activity–element combinations in the WIST needs template for airport ground operations. The precipitation group has 15 activity–elements, providing 39 percent of the total. The temperature-related and thunderstorm-related groups account for 8 activity–elements apiece (21 percent). There are four activity–elements for wind and three for visibility. Conspicuously absent are any activity–elements for tropical cyclone (i.e., hurricane) information. None of the airports that participated were located in coastal regions where storm surge might be an issue, and other phenomena associated with tropical cyclones are accounted for by the precipitation, wind, thunderstorm-related, or visibility activity–elements. Nor did any of the participants report a need for information on weather elements in the miscellaneous category. If the survey were repeated now, homeland defense issues that have grown since September 11, 2001, would very likely lead to an interest in air transport and dispersion information in the event of release of a nuclear, chemical, or biological hazard.

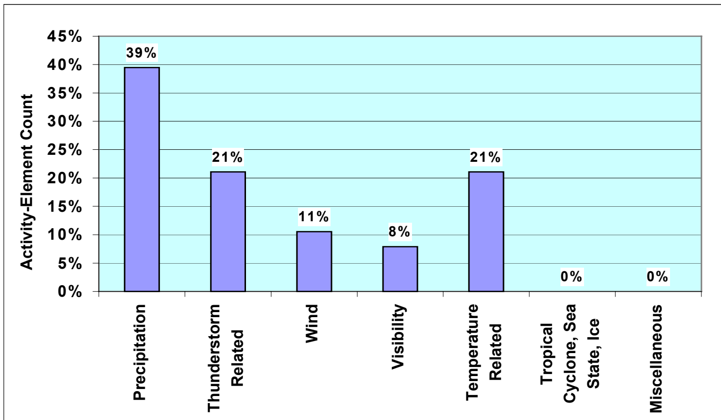



**Figure 4-11** Airport ground operations activity-elements by weather group.

## 4.8.3 Impacts and Mitigation Actions, by Weather Element Group

This section discusses the effects that specific weather elements have on airport ground operations and the response actions that the WIST study participants identified as potentially influenced by accurate information on each element. Mitigation actions can range from simply increasing awareness to taking specific corrective actions or curtailing or suspending activities. All these actions are intended to avoid unnecessary cost, damage to property, or safety risk to people. As discussed in Section 4.2, weather impacts can be mitigated or obviated to varying degrees by timely action, and response decisions are affected by many factors other than weather information.

### Precipitation Elements

With any amount of freezing or frozen precipitation (ice or snow), the sector activities experience impacts to safety of personnel, impaired operations, and risk to aircraft and equipment. Heavy liquid precipitation (rain) impairs operations primarily because it reduces visibility and creates flooding risks to personnel and equipment.

Aircraft icing is a critical condition that affects safety of flight. Thus, the effective and assured de-icing of aircraft on the ground before take-off is essential.

Safety of flight is paramount, and it begins on the ground. Aircraft icing is a critical condition that affects safety of flight. Ice on aircraft caused by freezing or frozen precipitation of any kind, along with frost and rime icing picked up on descent, all affect the aerodynamic performance of aircraft. Lift is dramatically affected, most often during the critical take-off and landing phases of flight. Thus, the effective and assured de-icing of aircraft on the ground before take-off is essential. When conditions conducive to icing are forecast to occur, airport and airline operations managers are advised of the threat. They plan for the availability and readiness of equipment, supplies, and manpower. Airport tenants are alerted, and de-icing pads are prepared for use. The airport continues to issue advisories to tenants on type of precipitation expected, expected accumulation and duration, temperature, and wind. Airlines may implement personnel recall to cover the additional function of de-icing airplanes.

The acceptable "hold-over-time"—the time between the beginning of de-icing and take-off—varies with weather conditions and the type of de-icing fluid used. Based on the forecast and observation of the type and rate of precipitation, wind speed, and temperature, a fluid is selected that will be most effective. When feasible, operators begin applying de-icing fluid before precipitation begins, using an agent that prevents precipitation from bonding (freezing) to the wing surface. Then, on take-off roll, the accumulated precipitation will slide off the wing. Other agents can be applied to remove frozen precipitation from aircraft surfaces. Frost and "cold wing" icing are routinely dealt with, even when freezing precipitation is not present. Efficient and well-planned de-icing operations can minimize schedule impacts.

Aircraft icing is by no means the only threat from freezing or frozen precipitation. Accumulation of ice and snow affects all aspects of airport operations. It increases risks to personnel safety and equipment and causes operational delays and cancellations. It may close runways, limit airport parking, and generally inhibit all activities that require surface movement about the airfield and airport grounds. To mitigate these effects, airport operators rely on early planning to ensure availability and readiness of equipment and supplies (stockpile of salt/sand for roadways and parking areas and of other materials for runways and taxiways). They plan manpower availability and implement personnel recall plans (some airlines use a 24–30 hour forecast for a preliminary staffing estimate); advise carriers, the fixed base operator, and all tenants; and prepare de-icing pads for use. As an anticipated event occurs, they decide on choice of surface treatments (anti-ice, sand, etc.); execute snow and ice control plan(s); begin treating runways, taxiways, roads, parking areas, and walkways; and monitor pavement subsurface and surface temperatures for continued snow removal strategy. Airlines may begin de-icing aircraft at the gate with activation of the snow plan; they may also implement schedule changes and plan for reconstitution of normal operations.

In general, if freezing precipitation is observed to be moderate or greater, and ice is accumulating on surfaces and structures, airport flight operations will likely cease. Heavy snow coupled with high winds will cause blizzard conditions and “white outs,” in which case snow removal ceases until visibility improves.

Intense liquid precipitation (rain) also impairs airport ground operations. It impedes construction projects, reduces visibility, slows down all vehicular movement on the airfield (both on the ramp and on access roads and parking areas), impedes foot traffic, and presents a safety risk for employees and passengers. These direct effects, as well as some of the mitigating responses, can cause schedule delays. Mitigating actions for heavy rain include issuing advisories to all airlines and all other airfield tenants, planning for vehicular traffic flow to bypass known trouble areas, coordinating with other agencies in the vicinity for opening drainage control points, preparing equipment for sweeping or pushing standing water, and ensuring that adequate equipment and trained personnel are available.

### Thunderstorm-Related Elements

Thunderstorms and their related phenomena can be very severe, causing loss of life and property, but they generally affect smaller areas for shorter periods of time than do some other weather elements. When severe thunderstorms do occur in the immediate vicinity of an airport or are forecast to move over it, all sector activities respond to the potential risks to people, aircraft, and other equipment. The range of protective actions is similar, with most activities ceasing outdoor operations in the vicinity of the threatening weather and personnel required to take shelter as necessary.

Lightning is the most common thunderstorm-related threat. Most activities begin halting noncritical activities when lightning is observed at or near the outer boundaries of their lightning detection grid. When lightning is observed within 3 nautical miles of the airfield, all refueling operations are halted and personnel are moved inside or under cover. (Some operators reported that they take their people off the line when lightning is observed at or within 10 nautical miles of the airfield.)

A passenger maneuvers her luggage cart through rain at the Atlanta airport. A forecast of snow and ice for this day led Delta Airlines to cancel many of its Atlanta flights, causing delays throughout the nation. Copyright AP Wide World Photos.

Hail can damage cargo, equipment, and vehicles, as well as injuring personnel. Hail greater than 1 inch in diameter can severely damage aircraft sitting exposed on the ramp. Hail also affects aircraft servicing (refueling and maintenance) and causes operational delays and cancellations. It impedes construction and airfield maintenance projects. Protective actions include curtailing outside activities where possible and moving personnel inside or under cover.

In almost all cases, the desired lead times for forecasts of thunderstorm-related weather begin with a “heads up” advisory 12 to 24 hours in advance, followed by a warning 4 to 6 six hours before onset. This is followed by a “take cover” type of warning an hour or less from the actual occurrence of the severe weather, with real-time updates when a storm is actually occurring and affecting operations.

### Temperature-Related Elements

Temperature-related activity–elements, specifically air temperatures less than zero °F and wind chill temperatures below -20 °F, account for 21 percent of the total for this sector. These cold temperatures primarily affect personnel working outside, including aircraft maintenance, refueling and servicing, baggage and cargo handling, and construction projects. The primary risks are hypothermia and frost bite for personnel and, to a lesser extent, risks from water freezing on aircraft as they are being serviced. In addition, cold temperatures can result in delays because ground crew personnel are limited in the amount of time they can work outdoors under these harsh conditions.

To mitigate the effects of cold weather, personnel are equipped with proper cold weather protective clothing, exposure time outdoors is limited to periods of 12–15 minutes, ground crews are provided with warm fluids to help them warm up and avoid dehydration, and extra personnel are scheduled as necessary. Outdoor construction and maintenance projects are rescheduled or adjusted as necessary.

### Winds

Sustained high winds primarily affect aircraft movement, aircraft servicing and maintenance, and construction projects. Short-lived wind events, such as microbursts and gust fronts can also affect airport ground operations, primarily through their effects on takeoffs, approaches, and landings. Large changes in wind speed or direction affect the choice of runways, and the need to change runways in use at busy times contributes to schedule delays. Likewise, maintenance on large aircraft, especially work on areas high above the ground, is impeded or prevented altogether. Servicing of aircraft is slowed, and more wind-blown foreign objects are present in aircraft movement areas. All of these impacts contribute to delays in aircraft departures. Snow removal and de-icing operations are also affected, as snow blower and aircraft de-icing operations must respond to wind direction and speed. Construction materials are more prone to blow away in high winds, and blowing dust from construction sites can become a hazard.

Mitigating actions include advising air traffic control and all airfield tenants and planning for more frequent ramp, taxiway, and runway inspections (to reduce or eliminate damage from wind-blown foreign objects). Operators will ensure that motorized carts not in use are braked and chocked for the duration of high winds. Equipment or objects not in immediate use or being handled (e.g., igloo containers, baggage) are stored in protected areas. If de-icing of aircraft or snow removal operations are required, operators will decide where and how these activities will be conducted to control blowing spray and snow. Construction contractors and maintenance personnel are advised of impending high winds, and they may adjust their work and project schedules.

### Visibility

Visibility of less than a quarter-mile affects aircraft ground movement, flight operations, vehicle movement (including aircraft servicing and maintenance vehicles), and construction projects. It increases the probability of runway incursion incidents. Because all aircraft and vehicular movement is slowed, reduced visibility can delay schedules significantly. Construction and repair projects may also be delayed.

Mitigating actions include coordinating with air traffic control and ensuring that "follow me" guidance vehicles are available for aircraft on request. At some airports, when the runway visual range drops to 600 feet, no take-offs or landings are allowed. If necessary, airport operations will also coordinate with construction contractors on project schedules.

An American Airlines jet at LaGuardia airport in New York is delayed in thick fog. Visibility of less than one-quarter mile restricts airport ground operations. Copyright AP Wide World Photos.

## 4.9 Overarching Themes from the WIST Needs Identification and Validation Activity

This section highlights four themes that emerged from the WIST needs analysis in this chapter and from participants' comments during the two WIST symposia, other meetings, and interviews conducted during the study.

**Theme 1. The WIST study provides a validated baseline of user needs for moving forward with a coordinated WIST initiative.**

Representatives from user communities throughout six surface transportation sectors participated in the WIST study. These participants, representing federal, state, and local governmental agencies and commercial interests in each sector, provided the initial responses compiled in the WIST needs templates and validated the templates. The templates thus provide a validated baseline of user-defined weather information needs for these six surface transportation sectors.

Users' needs for weather information, identified and coordinated through the WIST study process described in Chapter 3, are compiled in Appendix B of this report. The templates have been reviewed and validated by the federal, state, and local government agencies with oversight and operational missions in these transportation sectors, as well as by representatives of commercial firms operating in the sectors. This coordination process revealed an unequivocal need among the various user communities for weather information that is more accurate, timely, and relevant.

**Theme 2. The benefits from improving WIST data sources, infrastructure, and applications will be substantial.**

The nation can benefit significantly from improved weather information for surface transportation. The safety benefits will include reductions in injuries and loss of life. The economic benefits will include reduced economic losses and increased productivity. The challenge is to gather the necessary data, turn it into relevant and accurate weather information, and put it into the hands of people who must make decisions about various activities.

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## Reduction in Injuries and Loss of Life

As noted in Chapter 1, precise numbers for injuries and deaths attributable directly or indirectly to weather conditions and their impacts on surface transportation systems are difficult to establish, even for the nation's highway system. The WIST Needs Templates support abundant anecdotal evidence that snow, rain, ice, fog, freezing or rapidly changing temperatures, and numerous other weather elements, as defined in Table 2-1, increase the safety risks to personnel and travelers in all of the surface transportation sectors. Table 4-8 shows that users identified risks to safety as an impact of more than three-fourths of the activity–element combinations in every sector.

**Table 4-8** Activity–Elements with Safety Impacts, by Sector

| | Activity-Elements with Safety Impact | |
|---|---|---|
| **Transportation Sector** | **Activity–Element Count** | **Percent of All Sector Activity–Elements** |
| Roadway | 223 | 87% |
| Long-Haul Rail | 98 | 76% |
| MTS operations | 156 | 83% |
| Pipelines | 98 | 77% |
| Transit | 110 | 78% |
| Airport ground operations. | 33 | 87% |

Reliable information on surface transportation elements—what conditions are now or are forecast to be—allows transportation system managers and operators, as well as travelers, to make choices that reduce these safety risks. A study, cited in Chapter 1, of one stretch of Idaho highway reported an 83 percent decrease in accidents after forecast-activated pavement anti-icing was implemented (Breene 2001). Surveys of travelers' attitudes, such as those conducted for the ATWIS in the Midwest (Owens 2000) or the Gallup survey of information desired for "511" travel advisory service (ITSA 2002b), show that travelers value reliable surface transportation weather information. Finally, the "Actions" listed in the WIST Needs Templates for weather elements with a safety impact show that transportation decision makers in every sector have a range of options available to them to lessen safety risks—***provided they get accurate information with the lead time needed to inform their decision processes***.

### Reduced Economic Losses

> The "Actions" entries in the WIST Templates detail mitigating actions that can be taken in every transportation sector to lessen the economic impacts of weather events or weather-related conditions.

NHTSA has estimated that the economic costs just from weather-related crashes on U.S. highways amounts to nearly $42 billion annually (Lombardo 2000). Fog, snow, and icy conditions on highway capacity caused an estimated 544 million vehicle-hours of delay on the nation's freeways and principal highway arteries in a single year (Chin et al. 2002). Snow and ice treatment costs state and local highway maintenance departments about $2.1 billion annually (FHWA 1998). Chapter 1 cited examples of how the intermodal system for freight and cargo that links surface transportation sectors can be impacted by weather conditions, with ripple effects across the economy, as well as across transportation sectors. The "Actions" entries in the WIST Needs Templates detail mitigating actions that can be taken in every sector activity to lessen the economic impacts of a weather event or weather-related condition.

However, the importance of accurate, timely information, at the needed spatial and temporal scales, becomes critical in ensuring that the ***net value*** of preparing for and responding to an adverse weather event or condition is an economic benefit rather than a loss. Most of the actions listed in the templates have an economic cost associated with them. If the weather information received is timely and accurate, the cost of acting is often less than the cost of failing to act. If a predicted event does not occur, however, the cost of the unnecessary preemptive action remains. Users' perceptions of the reliability of the transportation weather information they receive determine how much they rely on that information in making difficult economic choices.

Forecasts that correctly predict that an adverse event or condition will not occur are also of economic value. As an example, for a local government a single correct weather forecast that prevents the unnecessary deployment of snow and ice crews can mean the difference between operating within budget and becoming seriously overextended, requiring the cancellation or deferment of other critical highway maintenance projects.

### Increase in Productivity

Weather affects the efficiency and effectiveness of each of the major modes of surface transportation. A good example is the freight community, with its concept of multimodal just-in-time delivery. In moving goods across the country, freight companies must plan for, or cope with, weather of all types and severity. The efficiency of the system depends on a high level of coordination among producers and shippers. All the transportation modes used in the supply chain rely on weather information to sustain this tight coordination. To the extent that disruptive weather conditions can be anticipated and communicated, mitigating actions can be taken to maintain the overall coordination of a just-in-time delivery system. Throughout the economy, as well as within transportation systems, efficiency and effectiveness can be improved.

Across all the sectors studied, two lead-time periods for weather information to be useful to surface transportation activities stand out. There is a planning window at 12–24 hours and a response-implementation window at 0–3 hours (extending to 6 hours in some sectors).

**Theme 3. Substantial near-term benefits can be reaped just by increasing the utility of currently available data and products to WIST users.**

Many of the weather information needs specified in the WIST templates (and discussed at the general level of activity–elements in this chapter) can be met to some degree today, simply by distributing existing weather data and products more quickly and widely through open systems. The utility to WIST users of available weather-related data and information products can be increased in the near term simply by:

- Making more information more accessible to more users through open information systems
- Tailoring the format and content of information products to be readily understood by potential users and easily incorporated into their decision procedures or decision support systems.

> "The mechanism for providing the (weather) information is not nearly as important as the accuracy of the information…. For K-12 education systems such as Fairfax County Public Schools, the specific timing of weather events is critical to effective decision making."
>
> Dean Tistadt, Assistant Superintendent, Fairfax County Public Schools, Virginia

The ability of a WIST user to incorporate weather information into decisions often depends on how quickly and easily the information can be assimilated into that user's planning window or operational decision time frame. There are roles for both the public and private sectors in meeting these needs. The disparities among various users with respect to their knowledge of the sources and availability of weather information present opportunities for commercial providers. They can meet many of the validated WIST needs by tailoring generic data and products from the public sector, then delivering the results with existing and emerging information technologies. Some of the many issues involved in expanding this public–private partnership in meeting WIST needs will be addressed in Chapter 5, as part of suggested next steps for a coordinated WIST initiative.

**Theme 4. Over the next decade, additional and substantial benefits to the nation, in terms of safety, reduced economic losses, and increased productivity, are possible with (1) better spatial and temporal resolution in both forecasts and observations and (2) better forecast accuracy.**

Almost all participants in the WIST needs validation stressed the critical importance of ***accurate*** weather information. Across sector activities, weather elements, and thresholds, increased accuracy is essential for meeting user needs. Most WIST users desire weather information that is more precisely specified in terms of spatial and temporal resolution than what is now available.

They want weather information that matches the geographic and temporal scales of the sector activity they conduct and the mitigation actions they have available for responding to threatening weather. These needs include weather information that is valid both at the current time and at some specified time in the future.

As accuracy and consistency increase, user confidence in weather information products increases, which leads to increased reliance upon it in the users' decision-making processes. Thus, improved accuracy is a requirement for improving the safety, efficiency, and effectiveness in surface transportation systems by making more use of weather information.

Uncertainty and risk in weather predictions need to be addressed by both the research and operations communities. Probabilistic forecast products may help to convey the full range of uncertainty present in a prediction. However, either the user needs to be skilled in interpreting probabilistic information or a decision support tool is needed that interprets the probability information in terms the user can comprehend and use.

## 4.10 Summary: Meeting the Needs and Addressing the Concerns of WIST User Communities

The WIST needs collection and validation effort provides ample evidence that the nation can benefit greatly by improving the weather information provided to the activities responsible for surface transportation systems and services. The benefits will accrue not only to the traveling public but also to the various levels of government and to the commercial enterprises that rely on transportation to accomplish their missions or to satisfy their customers' demands.

Many of these benefits could be achieved now, by improving the delivery of currently available weather data and forecast products through open systems and integrating them into formats and information products tailored to the needs of decision support processes throughout the spectrum of surface transportation activities. These near-term results will substantially improve the value of WIST to surface transportation in all sectors. Beyond this near-term "low-hanging fruit," additional benefits will require observations and forecasts at higher spatial and temporal resolution than the current state of practice. It will also require improved forecast accuracy across the range of spatial and temporal scales needed by WIST users.

Some progress has been made in improving weather information for surface transportation decision makers. Still, this WIST study process gathered many concerns from participants who are either WIST users themselves or are well acquainted with users' needs. The deficiencies and gaps identified through this process require attention if WIST users' needs are to be met. Chapter 5 suggests next steps toward addressing these concerns.

# Chapter 5
# WIST Strategic Thrust Areas

## 5.0 Introduction

This chapter defines six strategic thrust areas for next steps in addressing validated user needs for weather information for surface transportation (WIST):

1. Identifying and specifying the gaps in coverage of WIST user needs
2. Expanding coordination among research and development (R&D) programs and providers of WIST products and services
3. Clarifying and defining roles and responsibilities in the information provider and disseminator communities that acquire, interpret, and tailor WIST to meet user needs.
4. Translating research results and new technologies into WIST applications
5. Supporting research to expand and fill gaps in the fundamental knowledge that enables and supports future technology development and application
6. Expanding outreach and education to both current and potential WIST users.

The purpose of this chapter is to characterize each of these strategic thrust areas well enough to specify one or more broad goals in each area, plus suggested next steps toward these goals. To this end, the discussion addresses courses of action to overcome barriers and meet the challenges in each strategic thrust area. The chapter closes with a vision of how future surface transportation systems in the United States could be improved by a concerted effort to meet the user needs documented by the WIST needs study.

## 5.1 Strategic Thrust Area 1: Identifying and Specifying the Gaps in Coverage of WIST User Needs

This report culminates the initial phase of needs identification and verification in a coordinated effort to understand and address WIST user needs. The needs compiled in the WIST templates include many that can be met with data already available to users, plus others that could be met with information derivable from available data. For the remainder, however, the data generally available are not at the levels of reliability, timeliness, or spatial and temporal specificity required for WIST users in making operational decisions. An important thrust area for continuing the WIST effort is to conduct a detailed analysis of the gaps in coverage, the nature of the gap (why is current data not adequate?), and how a diverse provider community of both public and private sector providers can best cover these gaps.

### 5.1.1 Barriers and Challenges in Identifying Unmet WIST User Needs

Meteorological support and services from the public sector have traditionally focused on the needs of the general public (for information to protect life and property) and on aviation weather support. Weather information providers have not met the needs of the surface transportation communities for accurate information at high spatial and temporal resolutions. This information also must be provided with sufficient lead-time (for forecasts) or currency (for observations) to guide operational decisions. With the rapid increase of applications for weather information in surface transportation activities and the increasing importance of WIST, information providers in both the public and private sectors need to pay more attention, in the form of resource investment and priority, to WIST users' needs. As noted in Section 1.3.3, specialized weather information services and products evolved over time, and sometimes belatedly, to meet the needs of diverse users within the aviation community. Thus, the history of aviation weather provides a precedent—with both positive and negative lessons—from which the WIST provider community can learn.

From the perspective of WIST users, limitations in the available weather data and forecasts have restricted their utility for surface transportation operations, even though the right kinds of information, if received with adequate lead time, could improve many types of surface transportation decisions. As noted in Chapter 4, many of the WIST needs identified by this study require very high resolution weather information to meet the need fully. This information is not generally available, from either observations or predictions based on numerical modeling, with the reliability and access times needed to influence decisions. There are also a large number of nontraditional or sector-unique weather (and environmental) elements that are important to WIST user communities.

Private-sector participants in providing (including producing, adding value to, or disseminating) WIST services and products will set their own criteria for defining their potential roles and responsibilities. However, a mechanism is needed to coordinate federal roles and responsibilities that cut across the transportation information infrastructure. For example, if a roadway weather capability for highway users is being developed or demonstrated operationally, some mechanism

Railroad cars are stranded on a stretch of flooded track after Tropical Storm Alberto doubled back over the area. Good advance warning as Alberto came off the Gulf of Mexico in July 1994 led to very little damage. The lack of warning when the storm came back caused considerable damage to rail operations.

is needed to recognize and push for the opportunities to leverage the technology in other sectors, such as the U.S. Marine Transportation System (MTS) or railways.

Participants in the WIST user meetings conducted for this survey supported a proposal to establish a nationwide baseline of weather information needs for surface transportation and endorsed the pursuit of solutions that would meet these needs. This report provides a first attempt at such a baseline of WIST needs. Next, a joint effort is needed to determine which needs are not fully met and how these gaps should be addressed. Finally, this initial baseline of WIST needs will require extension to other sectors and activities, as well as continued monitoring, advocacy, and validation, to ensure it continues to comprehend and represent the needs of surface transportation communities.

### 5.1.2 Next Steps for Strategic Thrust Area 1

**Goal for Identifying Gaps in Coverage of WIST Needs.** Identify validated user needs for surface transportation weather information that cannot be met with existing information resources of the public–private provider community. Determine whether technology development in progress will meet the need or if additional technical development and/or research is needed.

**Next Step 1A.** The federal partners in the WIST effort should charter an appropriate entity (e.g., a task force or program council) to:

- Ascertain (1) which WIST user needs in the initial baseline compilation are fully met now, (2) which could be met more fully through improved presentation and interpretation of current observational and forecast data, and (3) which require data that are not yet available or that have attributes (e.g., accuracy, spatial and temporal scale, timeliness) beyond what is now available
- Review and sustain or adjust priorities for research programs and for transitioning promising tools and other technologies into operations
- Support agency processes to validate and update user needs and provider community programs and approaches for addressing them.

**Next Step 1B.** Sustain and expand the dialogue between the meteorological community as information providers and surface transportation communities as information users.

**Next Step 1C.** Use the baseline of WIST needs represented by the templates developed during this study as a work in progress, to be refined, extended, updated, and validated by the participants in a continuing assessment of where capabilities can be delivered that fill an identified gap or enhance value.

## 5.2 Strategic Thrust Area 2: Expanding Coordination Among WIST R&D Programs and WIST Providers

### 5.2.1 Barriers and Challenges to Expanded Coordination of WIST Efforts

Funds for improvements in weather information for surface transportation systems do not enjoy a high priority in state or federal agencies. As a result, programs and projects to increase the application of science and technology innovations are sponsored and funded haphazardly across the nation. This uncoordinated approach leads to duplication of effort and to lost opportunities for leveraging programs that could be applied in other states or nationwide. To accelerate the application and use of new or emerging technologies and capabilities for WIST support, technology transfer processes (concepts, capabilities, practices, and tools) linking the government and private sectors need to be enhanced.

Work to be done in this area includes more, and better, coordination and agreement among federal, state, and local governments and the private sector on the provision of data and services. The National Oceanic and Atmospheric Administration (NOAA) and commercial value-added vendors of weather information have been making progress on this "division of labor" in disseminating general meteorological information. Successful examples of coordination and active partnering can also be seen in the maturation of R&D projects that began under the Road Weather Management Program of the Federal Highway Administration (FHWA) and are now moving toward commercial operation (see Section 1.3.1). The FHWA and the Intelligent Transportation Society of America (ITSA) have worked out many areas of coordination and partnering for technology transfer related to intelligent highway systems, as represented in the *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision* (ITSA 2002a). The Transportation Research Board of the National Academies has long served as an important coordinating and technology transfer agent for federal, state, academic, and private-sector entities concerned with transportation-related research and technology. However, the opportunities to meet ***weather-related information needs of surface transportation decision makers***, made possible by the advances in science and technology described in Chapter 1, open up new domains for coordination and partnering.

The guiding principle for expanded coordination and partnering must be to transfer the results of R&D programs, typically funded with federal support, to whichever entities are most capable of implementing effective and efficient delivery of WIST services and products to the users.

- Partnering is needed to guide and support the R&D agenda and to secure and maintain advocacy and funding for infusing technology (through technology transfer and implementation) into operations. New relationships among public and private sector groups will require changes in how federal agencies support, coordinate, and participate in the rapidly expanding WIST provider community.
- These evolving relationships may require changes in the roles and responsibilities of the federal partners in the Federal Committee for Meteorological Services and Supporting Research (FCMSSR), both as sponsors of R&D and as partners in WIST technology transfer and information dissemination.

- Designation of the Federal Aviation Administration as lead agency was critical for progress in coordinating the federal effort on aviation weather (see Section 1.3.3). Similarly, designation of a lead agency for WIST may be critical for coordinating WIST programs and related activities. As Figure 5-1 indicates, a number of Department of Transportation administrations, as well as other departments and agencies, have significant responsibilities and interests in surface transportation sectors.

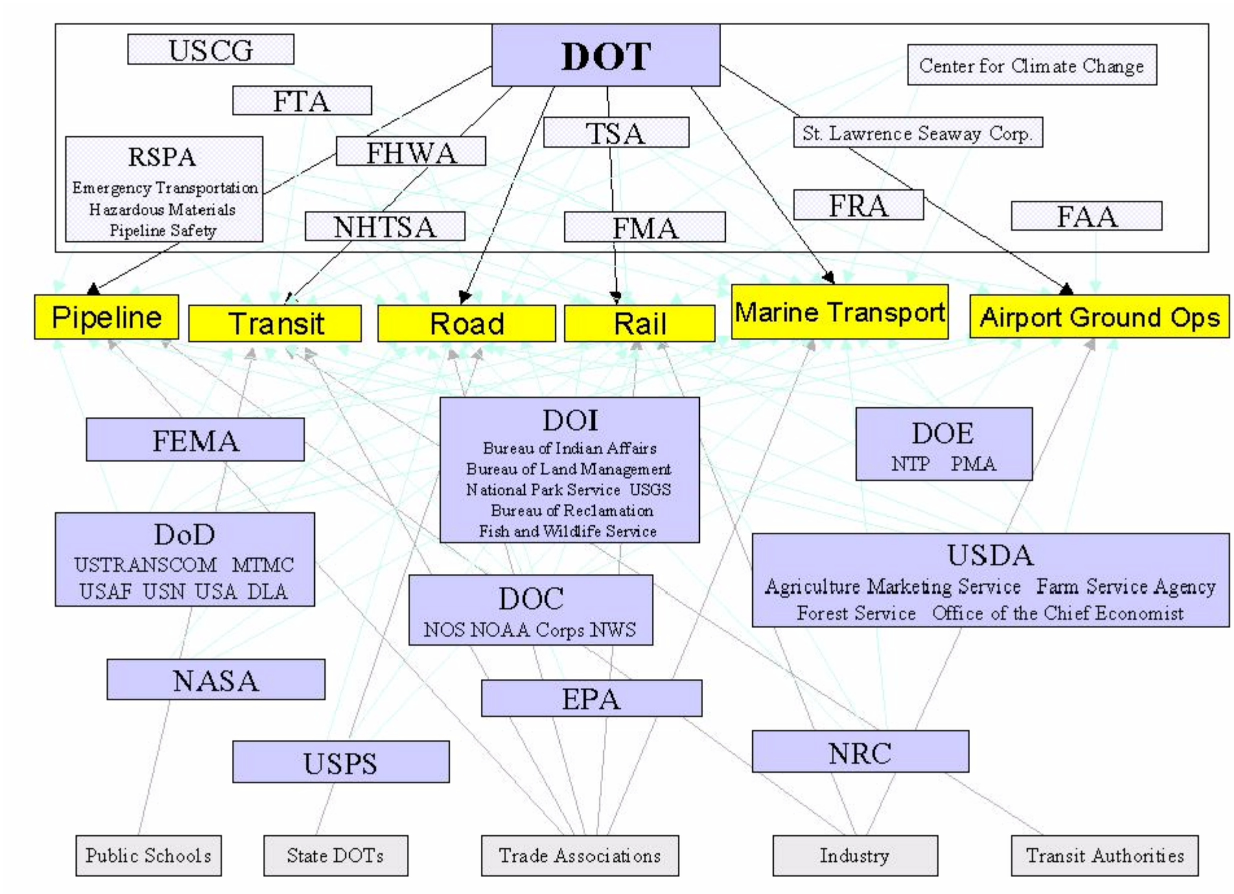



**Figure 5-1** WIST users in each of the transportation sectors.

## 5.2.2 Next Steps for Strategic Thrust Area 2

**Goal for Coordinating R&D and Technology Transfer.** Expand and improve the coordination and communication among both WIST-relevant R&D programs and field implementation programs and projects aimed at incorporating WIST elements in the decision processes and decision support systems used by transportation activities in all sectors. New and expanded partnerships among government entities, the private sector, the academic R&D community, and public-private entities for provision of WIST services and products should aim at increasing the efficiency and effectiveness of translating R&D results into operational value for WIST users.

**Next Step 2A.** Coordinate the WIST-related R&D research efforts and technology transfer programs of federal agencies, including but not limited to the U.S. Weather Research

Program, the national Intelligent Transportation Systems research efforts, and a WIST R&D Program as proposed in Section 5.4 of this report. Transfer of research results and technology demonstrations to operational capabilities, services, and products available to WIST users should be a major component of this expanded coordination effort.

**Next Step 2B.** Prepare for and form strategic partnerships and alliances among government entities (federal, state, and regional/local), the private sector, the academic R&D community, and public-private entities.

**Next Step 2C.** To provide the legislative basis and funding support for expanded coordination, the provider communities, with the support of the WIST user communities, should give immediate attention to:

- Reauthorization of the U.S. Department of Transportation surface transportation program under the Transportation Equity Act for the 21st Century (TEA-21)
- Full support for the MTS as proposed by the Marine Transportation System National Advisory Council and the Interagency Committee for the Marine Transportation System.

## 5.3 Strategic Thrust Area 3: Clarifying and Defining Provider Roles and Responsibilities

### 5.3.1 Barriers and Challenges to Clearly Defined Roles and Responsibilities

In all of the surface transportation sectors, information and communication linkages between transportation system users and providers are proliferating. The challenge is to use these new capabilities to maximize management and efficiency in the nation's surface transportation systems. WIST products and services are one piece—but an important piece—of this infusion of information and communications technologies into surface transportation systems.

A significant barrier to improving the products and services available to WIST users is that the roles of federal entities versus those of state and local governments or the private sector are neither clear nor consistent. Fuzzy boundaries in the roles and responsibilities of the public and private sectors in generating, tailoring, and communicating WIST to users have at times fostered strained and even adversarial relationships between these sectors. For example, some commercial weather services have disagreed about the type or amount of products or services that should be provided to the public by NOAA's National Weather Service (NWS). The disagreements reflect differences between broad and narrow interpretations of NWS responsibilities.

Continued cooperative efforts by all parties in the WIST provider community will be necessary to resolve these conflicts and gaps in the service, guidance, and regulatory structures that influence delivery of weather information to WIST user communities. Explicit policy guidance on the roles and responsibilities of public and private sector participants in providing and tailoring weather information would provide a solid basis for expediting provision of new and improved products and services to WIST user communities.

The two subsections below describe avenues through which provider roles and responsibilities can be clarified:

- Supporting data standards and a national data collection system
- Pursuing an open systems approach in WIST information systems.

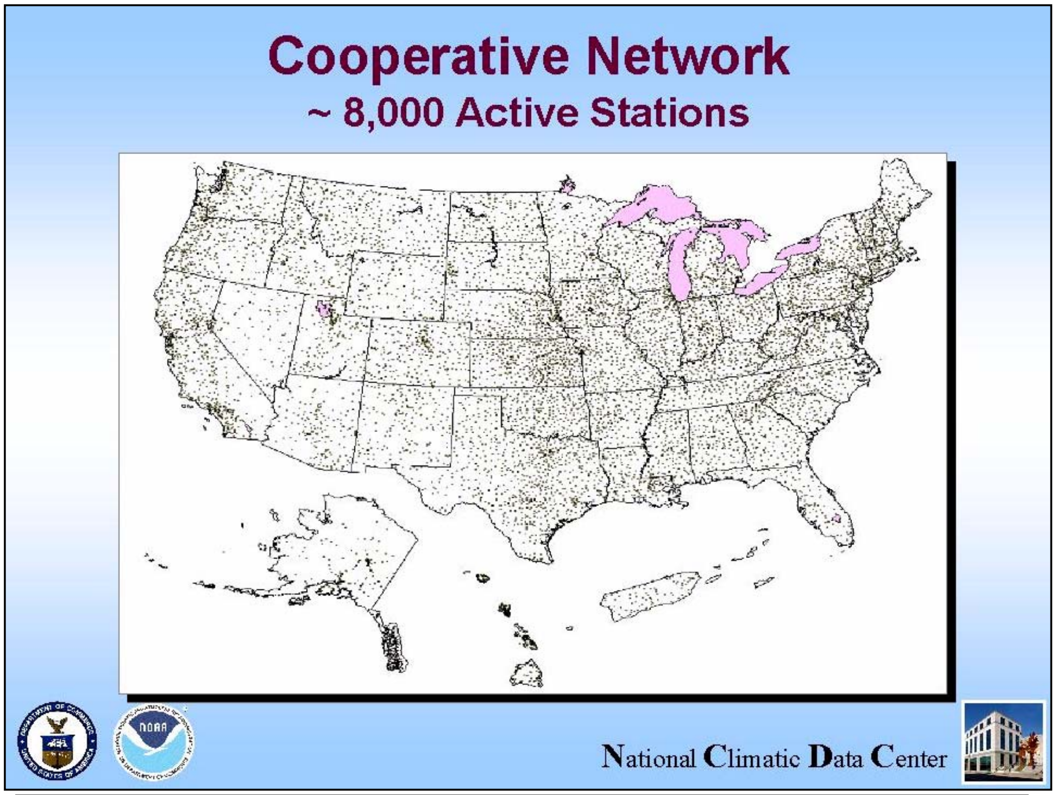
### 5.3.2 Next Steps for Data Standards and a National Data Collection System

Surface transportation operations require timely and reliable data. However, the means of generating, obtaining, transferring, and applying weather information are not standardized at present. This lack of standards significantly hinders dissemination and application. Nonstandard or erratic updates to observations and forecasts undermine the value of weather information for transportation-related decision processes and systems. Restrictions on the radio frequency spectrum complicate the choice and availability of the communication system used to report and distribute data.

The WIST user communities to be supported with timely data are numerous and diverse. This diversity presents a special challenge for standardization efforts. Nearly every user has unique aspects of its operation, so any specific solution is unlikely to be broadly applicable across all the WIST user communities. Some users are seeking and obtaining high-resolution weather observations from nontraditional sources, but data standardization and quality control issues may encumber wider dissemination and broader application.

Mesonets have been implemented in several states to support state and federal programs, as well as academic research and private sector applications. Issues associated with increasing the value of such networks include standardizing sensor technology and calibration methods, siting the sensors, collecting and processing the data (whether it is proprietary or public), access to the data, and integration of mesonet data with data from federal systems. Through the Meteorological Assimilation Data Ingest System (MADIS) program, the FHWA has been working with the NOAA Forecast Systems Laboratory to highlight the benefits of making observations from roadway weather information systems, operated by state departments of transportation, available to other surface transportation and meteorological communities. MADIS access to mesonets provides for data acquisition and data quality control. In selected cases, the information is made available to users for further processing. To date, 10 states have agreed to participate in MADIS. The Cooperative Observer Network, operated by the NWS, is a nationwide weather and climate observing network that, when modernized, will provide a useful framework for more extensive national collection and integration of weather and environmental data from regional mesonets.

**Goal for Data Standards.** Provide guidance on the roles and responsibilities of the public and private sectors for various types of observations and networks, particularly in light of better understanding of the accuracy needed to support the nontraditional weather/environmental elements and the new higher-resolution observation and modeling products required by WIST users.




The NOAA/NWS Cooperative Observer Network spans the nation. Each dot represents an observing location. Source: National Climatic Data Center.

A nationwide collection of local weather data does not exist and has not been mandated. These data are usually of greatest value locally, but ideally they should then be passed to a national collection location, where the data can be subjected to quality controls, aggregated, synthesized, and archived. Lack of advocacy by the states and other users has hampered funding and development of a national collection process. Other factors inhibiting a national collection process include commercial profit requirements of the private sector and the sometimes adversarial relationship between the public and private sectors with respect to roles and responsibilities.

**Goal for Nationwide Data Collection.** Integrate proliferating surface weather observations and networks and incorporate their data, along with data from the Cooperative Observer Network, into a nationwide data system. This data system should provide access to related geophysical data of value to surface transportation operations. This effort should address:

- Equipment (measurement/sensor adequacy and accuracy, siting criteria, calibration, metadata, and legacy systems)
- Communications protocols and standards
- Data standards for quality control, accessibility, compatibility, interoperability, and archiving.

**Next Step 3A.** Determine the roles of NOAA/NWS and/or other public and private sector partners in pursuing the above Goal for Nationwide Data Collection.

**Next Step 3B.** Address issues of observation standards and protocols, equipment siting, data collection, processing, archiving, access, and proprietary data through the use of a task force or similar action group.

**Next Step 3C.** Examine, test, and implement operationally current and emerging technologies for system definition and transition, system optimization, modal optimization, and environmental considerations.

### 5.3.3 Next Steps for an Open Systems Approach for WIST

For an information network with many providers of services and products, serving a diverse community of consumers, there are technical advantages to open systems architectures for communications and interfaces. Decision support tools should be implemented as an application layer on top of this open-systems foundation. Education of users and providers about these advantages is critical to efficient delivery of WIST services and products that are tailored to the needs of surface transportation decision makers and their decision support systems.

The national Intelligent Transportation System (ITS) architecture and other elements of the ITS initiative can provide a framework and starting point for deciding on technical issues of data management and accessibility (e.g., format standards) for WIST communications in all surface transportation sectors. These elements of technical infrastructure can also aid in resolving the more difficult issues of the boundary between public information and commercial or proprietary tools for presenting and interpreting information to support users with special needs and interests. There must also be attention to security issues, including protecting the integrity of shared data resources and managing the risk that open information will be used in hostile actions.

**Goal for Open Systems in WIST Communications.** Resolve the technical aspects of providing open access to weather information in a manner that benefits diverse WIST users fairly, while providing commercial or mixed public-private value-added suppliers with a level playing field and reasonable incentives for participating. Address issues of data system security.

**Next Step 3D.** Work toward full compatibility of transportation-related communications and information systems with the national Intelligent Transportation system Architecture.

**Next Step 3E.** Establish a task force to develop a security strategy for national weather information networks, addressing issues of data integrity and the balance between open access to data and restrictions to avoid hostile use of data systems and resources.

## 5.4 Strategic Thrust Area 4: Translating Research Results and New Technologies into WIST Applications

A number of currently unmet WIST user needs can be met in the near term (within 5 years) through applied research or development of technology applications. Some of these technologies incorporate advances in observing or forecasting meteorological parameters; others involve weather-affected conditions such as black ice on highways or railbed ground heave. Still others involve information technology and software to make WIST data easier to incorporate and apply in users' decision processes. For these areas, translating research results and science into practical information for users is the near-term objective.

User needs that will require more fundamental research—such as major advances in misoscale forecast models—are likely to require longer time horizons. These needs are addressed by Strategic Thrust Area 5.

### 5.4.1 Highlights of Applied Research and New Technology with Near-Term Payoffs for WIST Users

Appendix E provides a detailed list of research topics and technology development relevant to WIST user needs. The following bullets highlight some of the areas in which significant results for WIST users appear feasible within the next 5 years:

- Integration into operational transportation information systems of newly developed technologies for observing and predicting fine-scale weather-related hazards such as:
  - Temperature-dependent effects on infrastructure that are difficult for operators to identify with unaided visual information, such as black ice on roadways or railbed frost heave
  - Sun glint and glare
- Better forecasts of MTS weather and environmental conditions by improving and expanding oceanographic sensor systems and improving models that incorporate weather data with water levels, tides, and currents

Vehicles pass through a flooded underpass in Chicago on August 22, 2002, after 5-8 inches of rain fell. Copyright AP Wide World Photos.

- Weather elements and related conditions that can be observed with existing technology as point measurements but require accurate fine-scale spatial distribution modeling for surface transportation applications such as:
  - Frost heave of road surfaces and railways
  - Spatial distribution of pavement or rail/railbed conditions (temperature, frost, ice, etc.) between the point measurements available with roadway or railway monitoring sites
  - Spatial variability in rainfall and rainfall rates, leading to hydroplaning and other localized flooding hazards along transportation routes
  - Hydrologic implications of rainfall for surface transportation infrastructure and systems (all transportation sectors)
  - Spatial distribution of blowing or drifting snow and its impact on transportation route visibility (roadways, railways, waterways)
  - Dissipation of anti-icing chemicals

- Information technology for access to and applications of WIST, including WIST inputs to intelligent transportation systems and the MTS, such as:
  - Refined in-vehicle and in-vessel displays for WIST and for decision support tools that incorporate WIST information in their graphical output
  - Filtering and fusion processes to tailor meteorological, environmental, and route condition data and information for decision support systems and user procedures specific to surface transportation applications
  - Advanced communication technologies (e.g., wireless, automatic voice response) and graphical products applied to decision support systems, particularly those for mobile and remote nodes of intelligent transportation systems
  - Development and distribution of tools and guidance to assist decision makers when contaminants or hazardous materials in transit are released to the ground, the atmosphere, or surface waters

- Improved sensing and measurement technologies and collection/processing of observation data, including:

Road weather information can be integrated into "intelligent dashboard" information systems for highway travelers. Courtesy OnStar Corp. Copyright 2002, all rights reserved.

- Metadata standards for all observational systems
- Definition of roles for remote sensing technologies in planning for sensor systems and in complementing, supplanting, and expanding in situ sensing
- Standardized methodologies for collecting, processing, and archiving observation data.

There are many more research requirements listed in Appendix E for which some near-term results with operational value are likely, but longer-term R&D effort will probably be needed to meet WIST user needs completely. These requirements are indicated as both near-term and far-term in Appendix E.

### 5.4.2 Challenges to Current Technological Capabilities and Understanding

Uncertainty and risk in predictive information pose challenges for both weather research and information technology developers. Uncertainty in predictions of environmental conditions depends in part on the quality and density of observations on which predictions are based. The uncertainty usually increases as the predictive time horizon increases. Many operational decisions for transportation systems and activities require lead times of 12 to 24 hours. Although current mesoscale (grid points separated by 10 km or less) weather models provide forecasts out to 48 hours, the spatial and temporal accuracy of the forecasts is not high enough to meet the reliability needs of many transportation decision makers. Forecasts at longer times are available only at synoptic-scale resolutions, which are much less useful for many transportation decisions and still do not provide the reliability (forecast skill) WIST users need.

Decision support systems will need to incorporate techniques for working with the predictive uncertainty inherent in high-resolution forecasting at longer lead times. For example, various predictive sources can be weighted according to their reliability, and risks can be represented in ways that are useful for decision making (Nelson 2001, p. 6).

For a number of activities in the surface transportation sectors, an accurate forecast of favorable weather is often just as important as a forecast of adverse or mission-limiting weather. For understandable reasons, most meteorological research and technology development have focused on understanding the precursors for adverse weather, to aid in predicting it more reliably. In many respects, the basis already exists in observational data and model predictions for more detailed predictive information on favorable weather, including measures of uncertainty in forecasts of fair weather.

A major challenge in translating advances in meteorological and related science into practical and useful information is to present the information in terms that users understand and can incorporate effectively in their planning and operational decisions. Advanced decision support systems will be increasingly important in translating observations and forecast data into useful inputs to decision processes. However, more professionals will be needed who have training in meteorology and related science fields but also understand and can communicate in the ***perspective of the users***. These "WIST communicators" are an essential complement to the software tools. They will play a major role in developing better tools, applying them to specific users' needs, and continuing to improve them.

## 5.4.3 Opportunities in Current and Emerging Technologies

### Opportunities in Weather-Related Research and Technology Development

As the principal source of meteorological observations and forecasts for the nation, the NWS benefits from continuing improvements to its NEXRAD radar system, Advanced Surface Observing System (ASOS), weather satellites, and AWIPS—the information processing and networking system that ties all these observation platforms to the national forecast centers and local forecast offices. The broad range of users of NWS data and products—including end users, communications media, and providers of value-added meteorological services—benefit from this new technology as it improves NWS capabilities.

This weather satellite in geosynchronous Earth orbit uses advanced technology to provide weather and environmental information to the National Weather Service and many other users. Courtesy NOAA Photo Library

The U.S. Weather Research Program plays a key role in providing the fundamental knowledge and application development that feed this ongoing and vital stream of new meteorological technology (see text box next page). This program has substantial value as an umbrella program through which all federal entities with weather-relevant program objectives contribute resources to a coordinated R&D effort. Increased support for areas in which the U.S. Weather Research Program is ***clearly addressing WIST needs*** is an efficient and effective option for coordinating the federal R&D effort.

A multi-faceted WIST research and development program, coordinated with the U.S. Weather Research Program, is needed to address validated user needs.

However, the limited portfolio of the U.S. Weather Research Program, together with its emphasis on research rather than operational implementation, constrains its capability to serve all the WIST R&D needs of federal agencies. The range of R&D required, and particularly the specificity of applications tailored to the needs of the surface transportation communities, argues for a separate ***WIST Research and Development program***. This program would address issues relevant to weather impacts on surface transportation (all sectors) and to improving the capability to move meteorological and other weather-related information into users' decision processes. A major focus should be near-term and longer-term technology development and transfer, and the related applied research, to address validated WIST user needs.

An important objective for a WIST R&D program would be to exploit relevant scientific and technical capabilities across the country. These capabilities can be tapped through partnerships

**U.S. Weather Research Program**

The U.S. Weather Research Program is a partnership of federal entities—currently NOAA, the National Aeronautics and Space Administration, the National Science Foundation, and the Navy participate—with the academic and commercial communities. The program's overarching goal is to accelerate improvement in high-impact weather forecasting capability—in particular improvement in forecast timing, location, and specific rainfall amounts associated with hurricane landfall and flood events that significantly affect the lives and properties of U.S. inhabitants (USWRP 2001, p3.).

Portfolio development for the program begins with a ***prospectus development team*** of experts, which identifies research needs and opportunities related to a topic of importance to the program goal. The second step is to develop an ***implementation plan*** for the research identified by this team. Just two of the program's highest priorities, hurricanes at landfall and quantitative precipitation forecasting (QPF), have reached this second stage. Research projects to address the hurricanes at landfall implementation plan are underway, but funding constraints have limited implementation of the QPF research plan.

In August 1998, a new prospectus development team met to "identify and delineate critical issues related to the short-term prediction of weather in urban forecast zones" (Dabberdt et al. 2000). Funding limitations have kept the recommendations of this and other prospectus development teams from moving to the implementation plan stage, after which actual research would be funded. Even within this limited portfolio, the U.S. Weather Research Program is pursuing some of the research required to meet some WIST user needs validated in this study. If the prospectus development team's priorities for research on short-term weather prediction in urban forecast zones could be implemented, the research investment with direct application to WIST needs would be even greater. Close coordination between the U.S. Weather Research Program and other efforts to support WIST-relevant R&D is essential.

However, there are two structural reasons why the U.S. Weather Research Program by itself is insufficient to provide the R&D required by WIST needs. First, its overarching goal constrains it to just a subset of the weather and environmental elements of interest to WIST user communities, particularly in the context of funding limits that prevent it from pursuing fully even its highest priorities. Second, the program is intended to complement, not substitute for, agency-specific implementation programs that move the results of research into operations and services. Many of the technology development requirements listed in Appendix E are thus outside the intended scope of this research program.

with the private sector and mixed public-private service providers, where appropriate, as well as through university-based R&D consistent with the program's portfolio. Finally the two multi-agency programs—a new WIST R&D program and the existing U.S. Weather Research Program—should be fully coordinated to ensure that federal R&D investments are made wisely and productively.

In addition to the U.S. Weather Research Program, R&D programs under a number of federal departments and agencies provide technology for various surface transportation communities. (See Appendix F for a detailed description of these federal R&D activities.)

- The FHWA has major R&D initiatives in Intelligent Transportation Systems, Road Weather Information Systems, and decision support systems that exploit WIST and related information about roadway conditions.
- NOAA's National Ocean Service has programs to improve the observation systems and modeling capability for water levels, currents, and under-keel clearances in the MTS.

Greater coordination of the R&D effort across these and other intramural programs, as discussed in Section 5.2, in conjunction with an interagency WIST R&D program, would leverage the federal investment in improving and expanding WIST.

Partnering between federal agencies and the academic community will continue to play a key role in translating research into practical WIST applications. The Collaborative Science, Technology, and Applied Research Program (CSTAR) was established to provide structure to the variety of collaborative research and education efforts sponsored by the NWS. All CSTAR efforts are meant to enhance scientific interactions leading to a transfer of improved scientific understanding and technological advances into the total forecast system. CSTAR includes the NWS Cooperative Institutes, which are long-term agreements between NOAA and a university to share the costs of an institute focusing on a limited number of agreed-upon research topics. Also within the CSTAR Program is the Cooperative Program for Operational Meteorology, Education, and Training (COMET), administered by the University Corporation for Atmospheric Research. These CSTAR efforts represent important avenues for improving educational opportunities related to transportation weather and WIST applications. In addition, more than a dozen NWS Weather Forecast Offices are located on or near university campuses, including five of the Collaborative Institutes.

The Department of Transportation supports 33 University Transportation Centers, which conduct research or related support for the nation's transportation systems. However, only a few of these centers now focus on weather-related research for surface transportation.

With respect to both general meteorology and transportation systems, these examples show that an academic research and education infrastructure already exists. What is missing is substantial commitment within this infrastructure to surface transportation weather and addressing the needs of WIST users.

Many federal agency laboratories and academic research centers participate in WIST R&D. In some cases, they are partners in a consortium of investigators and researchers, as in the National Consortium on Remote Sensing in Transportation, which is addressing infrastructure; traffic flows; environment; and disaster assessment, safety, and hazards. The consortium includes representatives from the University of New Mexico's Earth Data Analysis Center, the University of Utah's Center for Natural Technological Hazards, George Washington University's Space Policy Institute and Center for Disaster Management, and Oak Ridge National Laboratory's Center for Transportation Analysis. The aim of this consortium is to expand applications of spatial and spectral technologies in transportation. Its strategy is to expedite the development of innovative remote sensing applications through proof-of-concept and demonstration phases, then quickly make the successful applications operational and available to commercial entities, which will become the ongoing suppliers of the information to specialized WIST users. The challenge for this and similar consortia and their associated technology projects is to serve as bridges linking the interests of state, local, and federal entities in mapping and spatial information with the private sector's capabilities to provide the information in relevant formats and interpretations.

Another aspect of applied R&D is the international nature of transportation problems and solutions. Many R&D efforts are in progress in Europe and other areas. These efforts and their results are shared through participation in various national and international meetings and through publication in the scientific and technical literature. However, mechanisms for more sustained interaction and cooperation are possible and worth exploring.

The bottom line is that many avenues for R&D exist. Cooperative planning and participation by all levels of government, the university research community, and the private sector can leverage the investments made in research to obtain the greatest benefit for and from the transportation systems of the future.

### Information Technologies

Interest in weather information for surface transportation has its roots in the growth of information technology, as well as in better observation systems and forecasting. The demand by transportation managers for more accurate and timely weather information has been stimulated by innovations in telecommunications, improved computer capabilities at lower prices, and dissemination via the Internet of weather and environmental information packaged in useful formats by commercial providers. These technology applications represent just the leading edge of emerging possibilities. The ultimate goal in incorporating new technologies is to aid transportation system managers and operators, system maintenance personnel, and vehicle/vessel operators involved with any mode of surface transportation in making decisions that enhance the safety and efficiency of their transportation-related activities. This goal requires putting information into the hands of these decision makers when and where they need it, in forms they can understand and use.

Users require weather information tailored to their specific decision or operation. Reliable and timely information about current and future weather conditions can enable people to make better decisions about their activities and contribute to their safety, as well as improving the efficiency and effectiveness of those activities. Adoption of an open systems philosophy, together with the recognition and development of decision support software as a distinct application layer on top of open systems, will facilitate the tailoring of weather information to meet the diverse and specialized needs of different user groups.

The ultimate goal in incorporating new technologies is to put information into the hands of decision makers when and where they need it, in forms they can understand and use.

The enabling information technologies have supported applications of weather information in decision support systems for winter road maintenance and in travel information systems. Improvements in mesoscale weather prediction models, road condition models, and forecasting systems that incorporate artificial intelligence have facilitated more extensive use of weather information in the surface transportation community.

Although current off-the-shelf technologies do not address the information needs of all surface transportation communities fully, a number of current information technologies and applications already provide substantial benefits. Examples include the Internet, display and visualization technologies, wireless communications, and global positioning satellites. Among the services incorporating these information technologies are pagers, cell phones, NOAA Weather Radio, weather news and information on cable and broadcast television stations, “511” telephone advisory services for road information, the FHWA-funded decision support systems described in Section 1.3.1, and proprietary in-vehicle systems that provide personalized, real-time traffic and road condition reports. The attributes desired in systems using new technologies include capabilities for data aggregation and integration, ease of distribution to consumers and businesses, two-way sharing of data with public and private sector partners, and ease of operation and maintenance of the supporting infrastructure.

Among the emerging information technologies for WIST applications is the use of Dedicated Short Range Communications (DSRC) to provide safety and traffic advisory information directly to the traveler in a private vehicle or other transportation conveyance. On-board displays and audio systems would provide real-time data to the traveler. Prototype systems are being developed and tested in the United States, Canada, and Europe.

The roadway transportation community has expressed support for the opportunities represented by concepts such as integration, interoperability, and intermodalism as ways to foster the development of intelligent transportation systems. The *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision,* builds on past major ITS initiatives such as the national ITS architecture, the Standards Development program, the Metropolitan Model Deployment Initiative, and others. The stakeholders called upon by this ITS program plan to contribute to its realization include the public sector at all governmental levels, the private sector, and the academic research community. The plan describes the impacts of weather on transportation systems and issues in weather information needs for transportation. Among the actions it calls for are creation of a Surface Transportation Weather Applications Research Program and a National Surface Transportation Weather Observing System (ITSA 2002a, pp. 1, 7–11, 44, 52, 55).

There are also significant near-term opportunities to translate technology advances into operations supporting the MTS. Ensuring safe and efficient port operations is vital to maintaining the competitiveness of the U.S. port industry and U.S. exports. One key to reducing risks while increasing efficiency is to invest in the national information infrastructure that supports the maritime movement of goods and people. This infrastructure includes weather predictions and forecast models that use both meteorological and oceanographic data to forecast oceanographic conditions for navigation.


A traffic advisory sign warns users of Interstate 70 in Denver that the highway is closed east of the city due to a winter storm. Copyright AP Wide World Photos.

### 5.4.4 Next Steps for Strategic Thrust Area 4

**Goal for Translating R&D into WIST Applications.** Establish a WIST R&D Program. This program should be coordinated with and complement the U.S. Weather Research Program, as well as other R&D programs in transportation weather, including work in progress, planned, or funded by federal entities, state and local public sector entities, universities, or private sector organizations.

Coordinating the federal R&D programs relevant to WIST will provide the nation with a comprehensive, multifaceted R&D effort that addresses information needs of the full range of current and potential WIST users in surface transportation sectors. In conjunction with this coordination, a WIST R&D Program should include mechanisms for transitioning research results and new technology into WIST applications. Special attention should be given to leveraging research that has linkages, synergy, or applications in other high priority programs such as homeland security.

This goal emerged over the course of WIST meetings and symposia, as described in Chapter 2. Potential research topics for a WIST R&D program include the highlights listed in Section 5.4.1. Appendix E provides a more comprehensive list of applied R&D topics with potential for near-term payoffs (indicated by an '**NT**' after the list item).

The following actions are proposed as next steps and enabling mechanisms for Strategic Thrust Area 4. The order of actions is not chronological; they can and should be undertaken in parallel.

**Next Step 4A.** Users and providers need access to information about the technology developments and research initiatives relevant to their WIST needs.

- This information must be structured and presented in ways that allow users to understand how they can best exploit available and emerging technology and information resources.
- Access to the information can be facilitated through interdepartmental cooperation at the federal level, coupled with strategic partnerships and alliances within and among the weather information provider communities of the public and private sectors.

**Next Step 4B.** The federal partners in FCMSSR should propose a significant, cohesive research and development program that will provide the basis for improved, integrated weather information, tailored to supporting users' decision processes across all surface transportation sectors and activities.

## 5.5 Strategic Thrust Area 5: Providing the Fundamental Knowledge to Support Future Technology Development and Application

As noted in Section 1.3.2 and overarching theme 4 (Section 4.9.4), substantial benefits to the nation, in terms of safety, reduced economic losses, and increased productivity, are possible with (1) better spatial and temporal resolution in both forecasts and observations and (2) better forecast accuracy. This improved observational and predictive information must also be available to users within their planning and operational lead times. And the information must be provided through products that users can readily understand and incorporate in their decision processes.

### 5.5.1 Highlights of Longer-Term Research Topics

From the list in Appendix E of R&D needed to meet WIST user needs, the following bullets highlight gaps in the knowledge base that will require fundamental research to address WIST user needs fully.

- High-resolution detection and prediction of roadway and railway conditions in complex terrains, including interpolation schemes for measurement systems, data fusion techniques, and numerical models
- Advanced decision support systems that incorporate high-resolution, quantitative models for complex factors such as the effects of traffic volume on road conditions, snow depth, snow drift, subsurface moisture near roadways, and effects of chemical–precipitation mixtures on road temperature and condition
- Data fusion and analysis systems for detecting and forecasting low visibility, at high resolution and accuracy, from multiple information sources, including ground and space based sensors and numerical models
- Validated models for the uncertainties, risks, and cost–benefit outcomes involved in incorporating weather and other environmental/geophysical observations and predictions in surface transportation decision processes

Hazardous materials spills on a highway require emergency managers to consider how weather conditions affect plume transport and diffusion. In some cases, such as this accident during heavy fog on a coastal highway, weather can also be a factor in causing the accident. Copyright AP Wide World Photos.

- Determination of the total observational requirements, including those from transportation facilities, to achieve the quality of numerical weather prediction sufficient for all WIST user needs.

With respect to ***meteorological*** R&D, whether for observing systems or modeling, the research focus for WIST is the entire boundary layer of the atmosphere (roughly, up to about 1 km), not just ground-level conditions. In addition, much of the needed R&D will require investigating land-air-water interactions that affect transportation system conditions not represented by traditional meteorological parameters. Table 2-1, which lists the weather and weather-related elements identified during development of the WIST Needs Templates, indicates the range of "weather elements" of interest to WIST users.

As noted in Section 5.4, many of the research topics listed in Appendix E, if promptly addressed, would produce near-term results of operational value, as well as longer-term results from continuing R&D efforts. These requirements are shown with both **Near Term (NT)** and **Far Term (FT)** indicators in Appendix E.

### 5.5.2 Barriers and Challenges

Prior to this WIST study, there was little definitive information on the spatial and temporal scales required for WIST products to be useful in the decisions and actions of potential users. Nor were there specific thresholds defined for weather and related elements that impact surface transportation. The information gathered during this study and compiled in the WIST Needs templates represents a major advance in defining these thresholds and spatial and temporal scales. However, more work is needed to determine the scales and thresholds of input data and computational parameters necessary to provide information products with the reliability, as well as the spatial and temporal specificity, required by users.

The spatial and temporal resolution of weather information needed for surface transportation applications in general and for decision support systems in particular is typically in the misoscale horizontally (grid spacing of 40 meters to 4 km) and in a very shallow layer vertically (from ground level to about 2 meters above it). To meet operational time lines, updates must be rapid—on a scale of minutes to hours—and coupled with lead times of 48 hours. These spatial and temporal requirements present formidable scientific challenges. Meeting them will require improved understanding in areas such as boundary layer meteorology, misoscale thermodynamics, the effects of small local variations, probability and statistics, high-resolution numerical modeling that includes land-air-water interactions, the verification and quality control of nonstandard data, and the preparation and communication of probabilistic forecasts. Processing data at these finer scales will require expanded computational capabilities.

### 5.5.3 Next Step for Strategic Thrust Area 5

**Goal for Providing the Fundamental Knowledge Base.** Identify and support fundamental research representing a longer-term investment in acquiring the knowledge base needed to meet important WIST user needs that cannot be fully satisfied on the basis of current knowledge.

This goal emphasizes the value of including some longer-term research areas, aimed at addressing limitations in the fundamental knowledge needed to meet WIST user needs, in the R&D programs discussed in Section 5.4.3. Often, the research questions that are strong candidates for these longer-term investments are described as "basic research." However, even though the increase in knowledge resulting from such research may not deliver operational results to WIST users in the near term, the topics should be selected and tested for ***strategic***

***potential*** in addressing validated needs. Examples of areas where this type of longer-term investment is warranted are indicated in Appendix E by an '**FT**' indicator after the research item.

**Next Step 5a.** Include in the coordinated R&D programs for WIST a substantial level of fundamental research with strategic potential for expanding the fundamental knowledge needed to meet WIST users' needs.

**Next Step 5b.** The federal agency partners in the FCMSSR should present a unified rationale to Congress and the Administration for the strategic potential of the fundamental research topics included in the WIST R&D Program and other coordinated R&D programs, similar to what has been done in the past for the U.S. Global Change Program.

## 5.6 Strategic Thrust Area 6: Expanding Outreach and Education

### 5.6.1 Barriers and Challenges in WIST Outreach

There are major cultural differences between the meteorology and transportation disciplines. As noted in Section 4.1.4, potential WIST users vary widely in their knowledge about the availability and sources of weather information. In the course of this study, there was significant variation among the transportation sectors, as well as within each sector, in the range and detail of needs that representative users were able to bring to the effort, particularly in initial meetings. Understanding how weather affects a transportation activity does not automatically give users an understanding of how better weather information can benefit the activity. Users need assistance and training to achieve maximum benefit from applications of weather information.

At the same time, those with training in the meteorological and environmental sciences, as well as expertise in the technologies and techniques of observing and forecasting weather and related phenomena of concern to WIST users, must do better at communicating the significance of their knowledge and technology to the users. A two-pronged approach is essential if "weather professionals" are to provide the information and tools to support surface transportation decision processes. Formal training in the conceptual frameworks, operational environments, and technical systems within which transportation decision makers work should be coupled with direct experience working with these user communities.

To help with educating WIST users, universities can offer surface transportation weather courses in programs for transportation management degrees. Training programs for users and managers of transportation systems that provide emphasis on weather factors and the use of weather information will clearly benefit the transportation industry and its consumers. Just as important are courses in both degree programs and continuing education programs that educate meteorologists and other scientific specialists to understand surface transportation systems and management processes.

As traveler-oriented weather information services evolve, the general public needs to be informed about them. Broad support for WIST initiatives can be fostered by communicating the values of WIST, in improving both transportation safety and economic efficiency, beyond the communities of transportation system managers and operators. Outreach to the public served by these systems can be accomplished through the media and embedded in primary and secondary (K–12) education. Only through a range of educational activities such as these will the full potential of WIST applications be realized.

### 5.6.2 Next Steps for Strategic Thrust Area 6

**Goals for WIST Outreach and Education.** (1) Incorporate mechanisms for education of potential WIST users, including interactions between the users and providers of weather information, in WIST service delivery processes. Include current information on WIST applications and the value of WIST in transportation systems operations in the training for surface transportation professionals. (2) Provide and promote educational opportunities for meteorologists and related professionals to learn about surface transportation systems where weather and related environmental information can improve system performance. (3) Include information about WIST applications and ways that the public can access and use WIST in their own transportation activities in "weather education" outreach to the general public and in school weather education programs.

**Next Step 6.** Conduct a WIST Education Forum on the status of and directions for expanded efforts in, education, training, and outreach for delivery of services and products to meet WIST user needs. There should be broad participation from the provider and user communities, as well as from the FCMSSR partners. Include topics on:

- Mechanisms for education of WIST users
- Opportunities for meteorologists and related professionals to learn about surface transportation systems
- Outreach to the general public through the media and school programs.

## 5.7 A Vision for Surface Transportation Weather in the Future

The vision is to be able to move anyone or anything, anywhere, anytime, on time, whatever the weather may be!

Transportation demand is predicted to double in the next 20 years and triple in 50 years. No substantial increase in the nation's transportation infrastructure is planned. Innovative solutions to meet this anticipated growth in demand include new technology and concepts, such as the expansion of information technology, nanotechnology, and technologies that are more energy-efficient and environmentally friendly. Implementing solutions will require a joint effort that includes critical roles for the Congress, state and local government, industry, labor, academia and nongovernmental organizations, all working together to set priorities and solve problems.

This study envisions a national capability to provide timely, accurate, and relevant information on surface transportation weather. This information will be tailored to specific transportation needs, allowing all users to anticipate and exploit the weather, for maintaining the national surface transportation infrastructure efficiently and for moving anyone or anything, anywhere, anytime, on-time, efficiently, safely, and securely.

Technologies for collecting, storing, processing, communicating, and managing information can revolutionize transportation. These technologies generate information on physical parameters at a given time; temporal trends in these parameters; geographic location of transport carriers, goods, and physical conditions of interest; and the overall environmental and situational context of the transportation system. They will be included in all facets of transportation—vehicles, vessels, and infrastructure. Not only will they improve efficiency in the individual transportation sectors; they will improve the efficiency of interfaces between the sectors and the efficiency of the nation's entire intermodal transportation system. The result will be true intermodal service, providing transportation options to maximize safety, convenience, and efficiency for travelers by facilitating seamless transitions in the use of all transportation modes. However, most of these technologies will require a much more advanced and capable weather information support system than is currently planned or funded for the future.

Weather information must be an integral part of transportation systems of the future that can safely and economically move anyone and anything, anywhere, anytime, on time. This vision is compatible with the FHWA strategic goals of improving the infrastructure and operations of the highway system in a manner that promotes productivity, safety, and national security, as well as mobility without jeopardizing the quality of the natural environment. Tailored weather information will facilitate decision processes in a transportation system with far fewer fatalities or injuries per mile traveled.

The WIST user needs identified by this study (see Appendix B and Chapter 4) set the stage for the vast improvements in weather information products and services that will be required for decision support in activities across the spectrum of surface transportation systems. The future WIST infrastructure will evolve from developments that exploit the open Intelligent Transportation System and the national weather information infrastructure. Environmental sensors and networks in parallel with explosive growth in computer and communications capabilities will provide the basis for a high-resolution weather data collection system. The resulting database, coupled with advanced numerical and transportation models and modernized distribution systems, will make real-time, accurate, and timely weather information available for integration with other key information elements useful to every traveler and every transportation system decision maker.

For this advanced WIST infrastructure and array of tailored WIST services and products to become a reality, attention must be given to the overall system architecture. This architecture must comprehend the optimal mix of weather observations with mesoscale and misoscale modeling; the definition, development and testing of tailored products and information; and the infrastructure that supports the entire system. Explicit policy guidance will be needed to resolve public and private sector issues regarding roles and responsibilities in the generation and application of weather information. Planning and implementation should also provide for education, outreach, and advocacy for users and providers of WIST services and products.

The vision of a vastly improved, safe, and efficient transportation system requires WIST users and providers to leverage research plans and funding in a mutually beneficial way. These communities must work together to apply the results of weather research and technology development to the spectrum of decision processes involved in surface transportation activities.

Adopting, advocating, and implementing the thrust area goals and next steps outlined in this report can provide a basis for achieving the vision of moving anyone or anything, anywhere, any time, on time, whatever the weather may be.

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# Appendix A

## *Entities Participating in WIST Needs Identification and Validation*

| Participating Entities | Transportation Sectors | | | | | |
|---|---|---|---|---|---|---|
| **Federal Departments and Agencies** | **Road** | **Rail** | **Marine Transportation System** | **Pipeline Systems** | **Transit** | **Airport Ground Operations** |
| Department of Transportation | | | | | | |
| Federal Aviation Administration | | | | | | X |
| Federal Highway Administration | X | | | | | |
| Federal Railroad Administration | | X | | | | |
| Federal Transit Administration | X | X | X | | X | |
| Maritime Administration | | | X | | | |
| National Highway Traffic Safety Admin. | X | X | | | | |
| Research & Special Programs Administration | X | X | X | X | X | X |
| Office of Pipeline Safety | | | X | | | |
| U.S. Coast Guard | | | X | | | |
| Department of Energy | | | | | | |
| National Transportation Program | X | X | X | | | X |
| Power Marketing Administration | X | | | | | |
| Department of Defense | | | | | | |
| USTRANSCOM | X | X | X | | X | X |
| Military Traffic Mgmt. Command | X | X | X | | X | X |
| U.S. Air Force | X | | | | | X |
| U.S. Army | X | X | | | | |
| U.S. Navy | | | X | | | X |
| Defense Logistics Agency | | | | X | | |
| Department of Commerce (NOAA) | | | | | | |
| National Ocean Service | | | X | | | |
| National Weather Service | X | X | X | X | X | X |
| NOAA Corps | | | X | | | |
| Department of Interior | | | | | | |
| Park Service | X | | X | | | |
| Bureau of Reclamation | X | | X | | | |
| U.S. Geological Survey | | | X | | | |
| Department of Agriculture | | | | | | |
| Agricultural Marketing Service | X | X | X | X | X | X |
| Farm Service Agency | X | X | X | X | X | X |
| Forest Service | X | X | X | X | X | X |
| Office of Chief Economist | X | X | X | X | X | X |
| Environmental Protection Agency | X | | X | | | |
| Federal Emergency Management Agency | X | X | X | | | |
| National Aeronautics and Space Administration | X | X | X | | | |
| Nuclear Regulatory Commission | X | X | X | | | |
| U.S. Postal Service | X | X | X | | | |

| Participating Entities | Transportation Sectors | | | | | |
|---|---|---|---|---|---|---|
| State Departments of Transportation [a] | Road | Rail | Marine Transportation System | Pipeline Systems | Transit | Airport Ground Operations |
| State Departments of Transportation (Western Region) | | | | | | |
| Alaska | X | | | | | |
| Arizona | X | | | | | |
| California | X | | | | | |
| Idaho | X | | | | | |
| Nevada | X | | | | | |
| Utah | X | | | | | |
| Washington | X | | | | | |
| State Departments of Transportation (Central Region) | | | | | | |
| Iowa | X | | | | | |
| Illinois | X | | | | | |
| Kentucky | X | | | | | |
| Minnesota | X | | | | | |
| North Dakota | X | | | | | |
| South Dakota | X | | | | | |
| State Departments of Transportation (Southern Region) | | | | | | |
| Arkansas | X | | | | | |
| Louisiana | X | | | | | |
| Mississippi | X | | | | | |
| Tennessee | X | | | | | |
| State Departments of Transportation (Eastern Region) | | | | | | |
| Connecticut | X | | | | | |
| Maryland | X | | | | | |
| Maine | X | | | | | |
| New Hampshire | X | | | | | |
| New York | X | | | | | |
| Pennsylvania | X | | | | | |
| South Carolina | X | | | | | |
| Virginia | X | | | | | |
| Vermont | X | | | | | |

[a] Various state departments of transportation have responsibilities in other sectors than roadways. However, during this initial round of WIST needs template development, they were involved only in validating the roadways template.

| Participating Entities | Transportation Sectors | | | | | |
|---|---|---|---|---|---|---|
| **Transit Authorities** | **Road** | **Rail** | **Marine Transportation System** | **Pipeline Systems** | **Transit** | **Airport Ground Operations** |
| Transit Authorities (Western Region) | | | | | | |
| Alaska – Anchorage | | | | | X | |
| Alaska – Fairbanks | | | | | X | |
| Arizona – Phoenix | | | | | X | |
| California - Los Angeles | | | | | X | |
| California – Oakland | | | | | X | |
| California – Sacramento | | | | | X | |
| Hawaii – Honolulu | | | | | X | |
| Montana - Great Falls | | | | | X | |
| Oregon – Salem | | | | | X | |
| Utah - Salt Lake City | | | | | X | |
| Washington - Bremerton | | | | | X | |
| Transit Authorities (Central Region) | | | | | | |
| Colorado – Denver | | | | | X | |
| Illinois – Rockford | | | | | X | |
| Illinois - Centrailia | | | | | X | |
| Michigan - Grand Rapids | | | | | X | |
| Minnesota - Minneapolis/St. Paul | | | | | X | |
| Missouri - Kansas City | | | | | X | |
| Nebraska - Omaha | | | | | X | |
| Wisconsin - Milwaukee | | | | | X | |
| Wyoming - Cheyenne | | | | | X | |
| Transit Authorities (Southern Region) | | | | | | |
| Alabama - Birmingham | | | | | X | |
| Florida - Palm Beach | | | | | X | |
| Georgia - Atlanta | | | | | X | |
| Oklahoma - Oklahoma City | | | | | X | |
| Tennessee - Memphis | | | | | X | |
| Texas - Corpus Christi | | | | | X | |
| Texas - Fort Worth | | | | | X | |
| Transit Authorities (Eastern Region) | | | | | | |
| Connecticut - Hartford | | | | | X | |
| Maryland - Montgomery County | | | | | X | |
| Massachusetts - Boston | | | | | X | |
| North Carolina - Charlotte | | | | | X | |
| North Carolina - Research Triangle | | | | | X | |
| New Jersey - Newark | | | | | X | |
| New York - Brooklyn | | | | | X | |
| Ohio - Cleveland | | | | | X | |
| Ohio - Dayton | | | | | X | |
| Pennsylvania - Philadelphia | | | | | X | |
| South Carolina - Charleston | | | | | X | |
| Virginia - Hampton Roads | | | | | X | |
| Virginia - Potomac & Rappahannock | | | | | X | |

| Participating Entities | Transportation Sectors | | | | | |
|---|---|---|---|---|---|---|
| **Trade Associations and Private Sector Entities** | **Road** | **Rail** | **Marine Transportation System** | **Pipeline Systems** | **Transit** | **Airport Ground Operations** |
| Trade Associations (Road & Transit) | | | | | | |
| Intelligent Transportation Society of America | X | | | | X | |
| American Public Transportation Assn | | | | | X | |
| American Assn of State Highway & Trans. Officials | X | | | | X | |
| American Automobile Assn | X | | | | X | |
| American Trucking Assn | X | | | | | |
| American Bus Assn | X | | | | X | |
| American Traffic Safety Services Assn | X | | | | X | |
| Intermodal Assn of North America | X | X | X | | | |
| Motor Freight Carriers Assn | X | | | | | |
| National Assn of Fleet Administrators | X | | | | | |
| Comm Vehicle Safety Alliance | X | | | | | |
| Truckload Carriers Assn | X | | | | | |
| National Assn of Home Builders | X | | | | | |
| Trade Associations (Rail) | | | | | | |
| Assn of American Railroads | | X | | | | |
| Intermodal Assn of North America | X | X | X | | | |
| Rail Industry | | | | | | |
| Burlington Northern Santa Fe | | X | | | | |
| Canadian National | | X | | | | |
| Canadian Pacific Railway | | X | | | | |
| Consolidated Rail Corporation (CONRAIL) | | X | | | | |
| CSX Transportation | | X | | | | |
| Metra (Northeast Illinois Reg. Commuter Railroad Corp. | | X | | | | |
| Norfolk Southern Corp | | X | | | | |
| Union Pacific Railroad | | X | | | | |
| Trade Associations (Marine Transportation System) | | | | | | |
| American Assn of Port Authorities (AAPA) | | | X | | | |
| Port of Portland, OR | | | X | | | |
| Intermodal Assn of North America | X | X | X | | | |
| Weathernews/Ocean Routes Inc | | | X | | | |
| Tropical Prediction Center/National Hurricane Center | | | X | | | |
| American Boating Assn | | | X | | | |
| Jersey Coast Anglers Assn | | | X | | | |
| The American Waterways Operators (AWO) | | | X | | | |
| Ingram Barge Co. | | | X | | | |
| Trade Associations (Pipeline Systemss) | | | | | | |
| American Petroleum Institute | | | | X | | |
| Assn of Oil Pipelines | | | | X | | |
| Independent Petroleum Assn of America | | | | X | | |
| Interstate Natural Gas Assn of America | | | | X | | |
| Natural Gas Supply Assn | | | | X | | |

| Participating Entities | Transportation Sectors | | | | | |
|---|---|---|---|---|---|---|
| Trade Associations and Private Sector Entities (Continued) | Road | Rail | Marine Transportation System | Pipeline Systems | Transit | Airport Ground Operations |
| Energy Industry (Pipeline Systems) | | | | | | |
| Exxon/Mobil | | | | X | | |
| Equilon Pipeline Co. | | | | X | | |
| Chevron | | | | X | | |
| Plantation Pipe Line Co. | | | | X | | |
| Colonial Pipeline Co. | | | | X | | |
| MN Office of Pipeline Safety | | | | X | | |
| Buckeye Pipeline Co. | | | | X | | |
| Professional Associations | | | | | | |
| National State Troopers Assn | X | | | | X | |

| Participating Entities | Transportation Sectors | | | | | |
|---|---|---|---|---|---|---|
| **Airports, Airlines, School Districts** | **Road** | **Rail** | **Marine Transportation System** | **Pipeline Systems** | **Transit** | **Airport Ground Operations** |
| Regional Airports (Western Region) | | | | | | |
| Alaska - Anchorage (ANC) | | | | | | X |
| Arizona - Phoenix (PHX) | | | | | | X |
| California - Los Angeles (LAX) | | | | | | X |
| Utah - Salt Lake City (SLC) | | | | | | X |
| Washington - Seattle (SEA) | | | | | | X |
| Regional Airports (Central Region) | | | | | | |
| Colorado- Denver (DIA) | | | | | | X |
| Illinois - Chicago (ORD) | | | | | | X |
| Minnesota - Minneapolis/St. Paul (MSP) | | | | | | X |
| Nebraska - Omaha (OMA) | | | | | | X |
| Nebraska - Offutt AFB (OFF) | | | | | | X |
| North Dakota - Grand Forks (GFK) | | | | | | X |
| Regional Airports (Southern Region) | | | | | | |
| Florida - Miami (MIA) | | | | | | X |
| Georgia - Atlanta (ATL) | | | | | | X |
| Texas - Dallas/Fort Worth (DFW) | | | | | | X |
| Regional Airports (Eastern Region) | | | | | | |
| Massachusetts - Boston (BOS) | | | | | | X |
| North Carolina - Charlotte (CLT) | | | | | | X |
| New York - New York (JFK) | | | | | | X |
| Virginia - Andrews AFB (ADW) | | | | | | X |
| Virginia - Dulles (IAD) | | | | | | X |
| Washington, DC (DCA) | | | | | | X |
| Airlines | | | | | | |
| American | | | | | | X |
| Delta | | | | | | X |
| Northwest | | | | | | X |
| United | | | | | | X |
| School Districts | | | | | | |
| Arizona – Phoenix | | | | | X | |
| Georgia – Atlanta | | | | | X | |
| Illinois – Chicago | | | | | X | |
| Louisiana - New Orleans | | | | | X | |
| Minnesota – Minneapolis | | | | | X | |
| Mississippi – Jackson | | | | | X | |
| Missouri - Kansas City | | | | | X | |
| Montana – Bozeman | | | | | X | |
| North Carolina – Charlotte | | | | | X | |
| Ohio – Cleveland | | | | | X | |
| Oregon – Salem | | | | | X | |
| Utah - Salt Lake City | | | | | X | |
| Virginia – Fairfax | | | | | X | |

# Appendix B

## *WIST Needs Templates by Sector*

# WIST Needs Template Column Headings

**Weather Element.** A weather element is a particular weather condition or a consequence of weather conditions that WIST participants identified as affecting (1) transportation system operations (e.g., road or railway maintenance; traffic management on rail, road, or marine transportation systems) or (2) the safety, economic value, or efficiency (time as well as cost) of transportation activities using those systems (e.g., ship or barge movement on the MTS, truck and car movement on roadways). The categories of weather elements included in the templates are precipitation elements; temperature-related elements; thunderstorm-related elements; winds; visibility; tropical cyclone, sea state, and ice (on waterways); and miscellaneous elements. The individual weather elements in each category are listed in Table 2-1.

**Threshold.** The responses to the initial WIST questionnaire (see Chapter 2) emphasized the importance of specific ***thresholds*** at which a weather element affects a transportation activity or (in the case of multiple thresholds) affects it differently. In some cases, any occurrence of a weather element has impacts and requires action. For other elements, thresholds are critical to defining the users' information need.

**(Sector) Activity.** A sector activity is a grouping of functionally similar or identical WIST users within a transportation sector. For example, WIST user activities within the roadways sector include road maintenance operations, bus operations, and state police. The long-haul railways sector has activities for railroad stations and depot operations. Among the activities in the Marine Transportation System are inland waterway recreational boating and open water cargo/freight operations. The rationale for delineating an activity within a sector was either the uniqueness of the activity's needs and requirements or differences in institutional operations among activities within a sector. Each template begins with a table of sector activity descriptions. (The same descriptions appear in Chapter 4.)

**Impacts.** The Impacts column lists potential economic and safety consequences of a particular weather element, once the stated threshold is reached, on the stated sector activity or activities.

**Actions.** The Actions column lists mitigating activities and key decisions available to WIST users in the stated sector activity, if they receive accurate information about the stated weather element with the lead time shown in the last column. Impacts and actions are discussed by sector in Chapter 4.

**Lead Time.** The forecast lead time required for users' to take action and make decisions is a critical factor in supporting surface transportation with weather information. For the WIST needs identification, lead time is defined as the advance warning prior to an event. This advance warning gives the decision maker the time needed to make the necessary preparations to minimize the effects of the weather on the specified event or activity.

# Appendix B–1

## *Roadway Sector WIST Needs Template*

## Roadway Sector Activities

**Road maintenance**. This activity is generally where the requirements of the state transportation departments are compiled. It includes road surface treatment for snow and ice control in the winter, as well as road and infrastructure maintenance year-round to repair damage.

**Truck operations**. The primary example for this activity is commercial trucking operations, both local and long haul.

**Fleet utility and transport vehicle operations**. This activity includes small to medium size fleets of utility vehicles, such as those maintained by telephone or cable television companies, as well as the large, nationwide fleets of mail and parcel delivery vehicles.

**Bus operations**. This activity is intended to cover primarily long-haul bus operations, such as interstate travel, rather than school buses or local transit system buses, both of which are covered by the Rural and Urban Transit Operations sector.

**Private vehicle operations**. Private vehicle operators, daily commuters, long-distance travelers, and local drivers, as well as rental car operators, are included in this activity.

**State/local emergency managers**. This activity encompasses emergency managers at state and local levels.

**State police**. Although state police and highway patrol entities provided the input on WIST needs for this activity, the information is generally valid for law enforcement and public safety officials anywhere with roadway traffic safety responsibilities.

**Forest Service**. The roadway operations of the U.S. Forest Service role are limited to unimproved roads under its jurisdiction within national forests and grasslands. But the ways in which the weather affects these roads has major impact on all the uses of these areas.

**Special Groups**

**NASA spacecraft and equipment transport**. NASA's principal concern with roadways is in transporting spacecraft and components by land routes between its various centers and the launch facilities.

**Power generating operations.** The WIST needs of the power marketing administrations (see Section 3.1.2) are limited to road conditions that affect the ability of repair crews in utility vehicles to reach transmission lines and facilities.

**Manufactured home transport**. This specialized activity has WIST needs that represent the general class of high-profile vehicles, which have special sensitivities to wind and other weather elements, such as those that affect tire traction.

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Freezing Precipitation (ice) | Any | Road maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, loss of communications/power, slope instability (avalanche risk) | Advise operators, begin preparation procedures, warn the public through press releases to ensure public awareness and allow adjustment to travel plans. Predict threatened area, select treatment strategy. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | Operational and travel delays, increased workload | Anti-icing, de-icing treatment of roadways. Prepare, deploy and track treatment assets. Apply treatment chemicals/abrasives, manage traffic flow. Remove debris and repair damage. | 3-6 hours |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | | Driveaway-towaway (manufactured home transport) | Possible loss of control, endangering other drivers | Advise operators and reduce speed or stop, if necessary. | 6 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds when roads have been treated for ice, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | | Fleet utility and transport vehicle operations | Safety risk to operators, damage risk, schedule delays | Advise operators, reschedule, or reroute. | 12 hours |
| | | Bus operations | Increased safety risk to operators and passengers, injuries and resulting claims, traffic congestion, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property | Implement preparation procedures, reschedule, reroute. Advise operators to drive with extreme caution, modify or restrict operations (especially on hills), suspend operations as appropriate. Advise passengers via bus radio system. Clear station parking lots and platforms. | 12-24 hours |
| | | Private vehicles | Safety risk to motorists, travel delays | Advise motorists, reschedule, reroute. | 12 hours |
| | | State emergency management | Safety risk to motorists, hazardous cargo risks | Advise operators, reschedule. | 12 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | | U.S. Forest Service | Closed roads, blocked roads, recreationists (e.g. hikers, campers) trapped or stranded, threats to safety and survival | Warn campers/hikers to evacuate threatened area. Initiate search and rescue operations if necessary. Repair/reopen closed roads. | 24-48 hours |
| | | Power generating operations | Impaired mobility of commuters and line repair operations, line repair accomplished by overland dispatch of personnel, potential for "line conductor galloping" (a power distortion that may occur during transition of precipitation from rain to wet snow and then to snow or ice) | Alert and advise commuters and line repair personnel. | 24-72 hours |
| Structure Ice Accumulation (inches) | Any | Road maintenance | Loss of communications/power, property and structural damage, safety risk | Select and implement treatment strategy. Remove debris and repair damage. | Current observation |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Pavement Ice Accumulation (inches) | Any | Road maintenance | Impaired mobility, loss of stability/maneuverability, loss of traction, pavement damage, pavement temperature, safety risk, snow removal/ice treatment operations | Select and implement snow removal and/or ice treatment strategy. Remove debris and repair damage. | Current observation |
| | | | | | |
| Frozen Precipitation (snow, inches) | Any to <2 | Road maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, slope instability (avalanche risk) | Advise operators, begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn public through press releases to ensure public awareness and allow adjustments to travel plans. Predict threatened area, select treatment strategy. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | Operational delays, increased workload | Conduct snow fighting operations. Prepare, deploy and track treatment assets. Apply treatment chemicals/abrasives, manage traffic flow. | 3-6 hours |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | | Driveaway-towaway (manufactured home transport) | Possible loss of control, danger other drivers. | Advise operators and reduce speed or stop if necessary. | 6 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, plan for decreased movement speeds, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | | Fleet utility and transport vehicle operations | Safety risk to operators, damage risk, schedule delays | Advise operators, reschedule, reroute. | 12 hours |
| | | Bus operations | Increased safety risk to operators and passengers, injuries and resulting claims, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delays of facility maintenance | Advise operators, reschedule, reroute. Advise operators to drive with extreme caution. Modify, restrict operations (especially on hills), suspend operations (in some regions). Advise passengers via bus radio system. Clea station parking lots and platforms. | 12 hours |
| | | Private vehicles | Safety risk to motorists, travel delays | Advise motorists, reschedule, reroute. | 12 hours |
| | | State emergency management | Safety risk to motorists, hazardous cargo | Advise operators, reschedule. | 12 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | | U.S. Forest Service | No significant impact | Advise recreationists. | 12 hours |
| | | Power generating operations | Impaired mobility of commuters and line repair operations, line repair accomplished by overland dispatch of personnel, potential for "line conductor galloping" (a power distortion that may occur during transition of precipitation from rain to wet snow and then to snow or ice) | Alert and advise commuters and line repair personnel. | 24-72 hours |
| | | | | | |
| Frozen Precipitation (snow, inches) | ≥2 to <8 | Road maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, slope instability (avalanche risk) | Advise operators, begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn public through press releases to ensure public awareness and allow adjustments to travel plans. Predict threatened area, select treatment strategy. | 24-48 hours (starting time of event is critical to DOT operations) |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | | | Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, plow snow. Manage traffic flow, implement tire chain controls, restrict access to designated vehicle types, restrict access to roadways/bridges. | 3-6 hours |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | | Driveaway-towaway (manufactured home transport) | Possible loss of control, danger to other drivers | Advise operators. Reduce speed or stop if necessary. | 6 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, plan for decreased movement speeds, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | | Fleet utility and transport vehicle operations | Safety risk to operators, damage risk, schedule delays | Advise operators, reschedule, reroute. | 12 hours |
| | | Bus operations | Increased safety risk to operators, passenger injuries and resulting claims, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delayed facility maintenance | Advise operators, reschedule, reroute. Advise operators to drive with extreme caution, modify or restrict operations (especially on hills), suspend operations (in some regions). Advise passengers via bus radio system. Clear station parking lots and platforms. | 12-24 hours |
| | | Private vehicles | Safety risk to motorists, travel delays | Advise motorists, reschedule, reroute. | 12 hours |
| | | State emergency management | Safety risk to motorists, hazardous cargo | Advise operators, reschedule. | 12 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | | U.S. Forest Service | No significant impact | Advise recreationists. | 12 hours |
| | | Power generating operations | Impaired mobility of commuters and line repair operations, line repair accomplished by overland dispatch of personnel, potential for "line conductor galloping" (a power distortion that may occur during transition of precipitation from rain to wet snow and then to snow or ice) | Alert and advise commuters and line repair personnel. | 24-72 hours |
| | | | | | |
| Frozen Precipitation (snow, inches) | ≥8 | Road maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, loss of communications/power, slope instability (avalanche risk) | Advise operators, begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn the public through press releases to ensure public awareness and allow adjustments to travel plans. Predict threatened area, select treatment strategy. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | | Implement snow fighting, tire chain control operations. Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, plow snow. Manage traffic flow (restrict access to designated vehicle types, restrict access to roadways/bridges, close roadways/bridges). | 3-6 hours |

| Weather Needs for Roadway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | | Fleet utility and transport vehicle operations | Safety risk to operators, damage risk, schedule delays | Restrict or suspend operations, reschedule, reroute. | 12 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds when roads have been plowed, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | | Bus operations | Increased safety risk to operators, passenger injuries and resulting claims, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delayed facility maintenance | Advise operators, begin preparation procedures to implement snow routes. Put snow routes into effect as appropriate. Advise operators to drive with extreme caution. Modify or restrict operations (especially on hills), suspend operations as appropriate. Advise passengers via bus radio system. Clear station parking lots and platforms. | 12-24 hours |
| | | Private vehicles | Safety risk to motorists, travel delays | Restrict/suspend travel, reschedule, reroute | 12 hours |
| | | State emergency management | Safety risk to motorists, hazardous cargo | Advise operators, reschedule. | 12 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | ≥8 (primarily significant early snowfall) | U.S. Forest Service | Closed roads, blocked roads, recreationists (e.g. hikers, campers) trapped or stranded, threats to safety and survival | Warn campers/ hikers to evacuate threatened area. Initiate search and rescue operations if necessary. Repair/reopen closed roads. | 24-48 hours |
| | ≥8 | Power generating operations | Impaired mobility of commuters and line repair operations, line repair accomplished by overland dispatch of personnel, potential for "line conductor galloping" (a power distortion that may occur during transition of precipitation from rain to wet snow and then to snow or ice) | Alert and advise commuters and line repair personnel. | 24-72 hours |
| | | | | | |
| Drifting Snow (inches, must include wind speed and direction) | Any | Road maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction (Winds >15 mph can lead to blowing snow and drifting in some areas. The amount of snow already on the ground may not be the determining factor; if snow storage areas are full, even a few inches can cause drifting problems. Drifting snow can cause continuous and prolonged clearing operations, which strain manpower resources.) | Consider road closures and treatment strategy. Begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn public through press releases to ensure awareness and allow adjustment to travel plans. Predict threatened area. Construct and place living and structural snow fences. | 24-48 hours |
| | ≥8 | | Operational delays, increased workload, loss of visibility, loss of traction, lane obstruction, impaired mobility | Select treatment strategy. Implement snow fighting and tire chain control operations. Prepare, deploy, and track treatment assets. Plow snow, apply treatment chemicals/abrasives. Modify lane configuration, Manage snow removal/ice treatment operations. | 3-6 hours |
| | ≥8 | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |

| Weather Needs for Roadway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Fleet utility and transport vehicle operations | Safety risk to operators, damage risk, schedule delays | Restrict or suspend operations, reschedule, reroute. | 12 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds when roads have been plowed, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | | Bus operations | Increased safety risk to operators, passenger injuries and resulting claims, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property | Advise operators, begin preparation procedures to implement snow routes. Put snow routes into effect as appropriate. Advise operators to drive with extreme caution. Modify or restrict operations (especially on hills), suspend operations as appropriate. Advise passengers via bus radio system. Clear station parking lots and platforms. | 12-24 hours |
| | | Private vehicles | Safety risk to motorists, travel delays | Restrict or suspend travel, reschedule, reroute. | 12 hours |
| | | State emergency management | Safety risk to motorists, hazardous cargo | Advise operators, reschedule. | 12 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | | Power generating operations | Impaired mobility of commuters and line repair operations, line repair accomplished by overland dispatch of personnel, potential for "line conductor galloping" (a power distortion that may occur during transition of precipitation from rain to wet snow and then to snow or ice) | Alert and advise commuters and line repair personnel. | 24-72 hours |
| | | | | | |
| Snow Accumulation Observation (inches) | Any | Road maintenance | Drifting snow, impaired plowing, lane obstruction, loss of stability/maneuverability, loss of traction, effects of pavement temperature on snow pack, slope instability (avalanche risk) | Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, manage traffic flow. Remove debris and repair damage. | Current observation |
| | | | | | |
| Snow Drift Levels Observation (inches) | Any | Road maintenance | Impaired plowing, lane obstruction | Select treatment strategy. | Current observation |
| | | | | | |
| Roadway Snow Depth Observation (inches) | Any | Road maintenance | Loss of traction, impaired mobility, effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| | | | | | |
| Roadway Snow Pack Depth Observation (inches) | Any | Road maintenance | Loss of traction, impaired mobility, effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| | | | | | |
| Adjacent Snow Depth Observation (inches) | Any | Road maintenance | Drifting snow, roadway snow depth | Select treatment strategy. | Current observation |
| | | | | | |
| Snow/Ice Bonding Observation (inches) | Any | Road maintenance | effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| | | | | | |
| Liquid Precipitation (inches) | Any | Road maintenance | Safety risk, maintenance activity delays, DOT operational activity delays, public travel delays, loss of visibility, decreased traction and stability/ maneuverability, lane obstruction or submersion, road | Advise operators, travelers, planning activities. Predict threatened area. Begin preparation procedures. Induce drainage where blocked. | 12-24 hours |
| | | | | Finalize decisions. | 6 hours |
| | Heavy | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | Any | Driveaway-towaway (manufactured home transport) | Possible loss of control, danger to other drivers | Some states prohibit travel if roadway is wet. | 6 hours |
| | Heavy | Fleet utility and transport vehicle operations | Safety risk, schedule delays | Modify/restrict operations, reschedule, reroute. | 12 hours |
| | Heavy | NASA (Goddard) spacecraft and equipment Transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | Heavy | Bus operations | Increased safety risk, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delayed maintenance c facilities, fleet, and bus stops | Modify or restrict operations (reschedule, reroute). Advise operators of wet road conditions or areas of pooling water. Advise operators to drive with extreme caution. | 12-24 hours |
| | Heavy | Private vehicles | Safety risk, travel delays | Modify or restrict travel, reschedule, reroute. | 12 hours |
| | Heavy | State emergency management | Safety risk to motorists, hazardous cargo | Advise operators, reschedule. | 12 hours |
| | Heavy | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | Heavy | U.S. Forest Service | Safety risk to motorists, storm water on roadways, culverts washed away by down-hill cascading, roads washed away, recreational activities and timber cutting halted, people trapped in remote areas | Initiate storm patrols. Pre-stage equipment and personnel to prevent damage during rain event. Move in equipment after event for emergency repairs to rebuild roadways. | 24 hours |
| | | | | | |
| Precipitable Water Vapor Observation (inches) | Any | Observation (by satellite imagery interpretation) | Precipitation patterns and rates | Predict threatened area, select treatment strategy. | Current observation |
| | | | | | |
| Flooding | Any | Road maintenance | Safety risks, road submersion, loss of life and property road damage, bridge damage, travel delays | Begin preparations, plan detour routes. | 1-2 weeks |
| | | | | Plan for contingencies, issue alerts. | 12-24 hours |
| | | | | Conduct local mobilization. Advise travelers, close roads, prepare to monitor/induce drainage. | 6-12 hours |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment, Delay, postpone, reschedule, reroute as appropriate. | 12 hours |
| | | Driveaway-towaway (manufactured home transport) | Impassable roads | Avoid flooded areas. | 12 hours |
| | | Fleet utility and transport vehicle operations | Safety risk, schedule delays | Restrict or suspend operations, reschedule, reroute. | 12 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft/vehicles/equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48 hours |
| | | Bus operations | Increased safety risk, traffic congestion, vehicle damage risk, routes may require detours, traffic accidents, increased risk of damage to busses/property, delayed or suspended bus service in affected areas, notification of road authorities and public relations required | Restrict, reschedule, reroute, or suspend operations. Advise operators, roadway authorities, and public relations of real time road conditions. Divert routes where flooding may be occurring or the risk of flooding is high. | 12 - 24 hours |
| | | Private vehicles | Safety risk, travel delays | Restrict or suspend travel, reschedule, reroute. | 12 hours |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | State emergency management | Safety risk to motorists, hazardous cargo | Advise operators, reschedule. | 24 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| | | U.S. Forest Service | Safety risk to motorists, storm water on roadways, culverts washed away by down-hill cascading, roads washed away, recreational activities and timber cutting halted, people trapped in remote areas | Initiate storm patrols. Pre-stage equipment and personnel to prevent damage during rain event. Move in equipment after event for emergency repairs to rebuild roadways. | 24 hours |
| Thunderstorms with Lightning (proximity to route or operational area in miles) | ≤5 miles | Road maintenance | Loss of life, property damage, loss of communications/power, safety risk, maintenance activity delays, travel delays | Advise operators, advise travelers. | 6-12 hours |
| | | | | Cease refueling, restrict or suspend outdoor operations. | 3-6 hours |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 3 hours |
| | | Fleet utility and transport vehicle operations | Safety risk, damage risk, operational delays | Advise operators, cease refueling, restrict or suspend outdoor activities. | 3 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays | Advise transport operators, reroute (long haul) or delay movement. If underway, take evasive actions as appropriate. | 3 hours |
| | | Bus operations | Safety risk, damage risk, operational delays | Advise operators, cease refueling, restrict or suspend outdoor activities. | 3 hours |
| | | Private vehicles | Safety risk, damage risk, travel delays | Advise operators, cease refueling, restrict or suspend outdoor activities. | 3 hours |
| | | State emergency management | Safety risk, damage risk, hazardous cargo vulnerability | Advise operators, cease refueling, restrict or suspend outdoor activities. | 3 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, cease refueling, restrict or suspend outdoor activities. | 3 hours |
| | | U.S. Forest Service | Safety risk to workforce, often no communications mechanism to get lightning warnings to forest service workers (Workers sometime travel as much as 2 days into remote forest areas.) | When communications (e.g. Forest Service radio) are available, advise field personnel to take cover. | 3 hours |
| | Any | Power generating operations | efficient power transmission impaired or interrupted | Alert operators and line repair personnel. | 24 hours |
| Thunderstorms with Hail (hail size and proximity to route or operational area) | Any size, ≤5 miles | Road maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction, loss of life/property, loss of communications/power | Predict threatened area, prepare to implement warning and evacuation plans, advise travelers. | 6-12 hours |
| | | | | Select treatment strategy, advise operators and travelers. | 3-6 hours |
| | >1/4 inch, ≤5 miles | Road maintenance | Safety risk, hail damage | Advise operators, suspend outdoor operations. | 3-6 hours |
| | Any size, ≤5 miles | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 3-6 hours |
| | | Driveaway-towaway (manufactured home transport) | Possible hail damage to manufactured home | Change route and/or adjust speed to avoid storm. | 3-6 hours |
| | | Fleet utility and transport vehicle operations | Safety risk, hail damage, schedule delays | Advise operators, suspend travel, reroute. | 3-6 hours |

| Weather Needs for Roadway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays | Advise transport operators, reroute (long haul) or delay movement. If underway, take evasive actions as appropriate. | 3-6 hours |
| | | Bus operations | Safety risk, hail damage, schedule delays | Advise operators, suspend travel, reroute. | 3-6 hours |
| | | Private vehicles | Safety risk, hail damage, travel delays | Advise motorists, suspend travel, reroute. | 3-6 hours |
| | | State emergency management | Safety risk, hail damage | Advise operators, suspend outdoor activities. | 3-6 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, suspend outdoor activities. | 3-6 hours |
| | | U.S. Forest Service | Safety risk to workforce, often no communications mechanism to get hail warnings to forest service workers (Workers sometime travel as much as 2 days into remote forest areas.) | When communications (e.g. Forest Service radio) are available, advise field personnel to take whatever cover is available. | 3-6 hours |
| | Any size, <5 miles | Power generating operations | Impairs or interrupts efficient power transmission | Alert operators and line repair personnel. | 24 hours |
| | | | | | |
| Thunderstorms with Tornado (proximity to route or operational area in miles) | ≤10 miles | Road maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction, loss of life and property, loss of communications/power | Predict threatened area, advise operators and travelers. Review and implement warning and evacuation plans. | 6-12 hours |
| | | | | Advise operators and travelers, suspend outdoor operations. | 3-6 hours |
| | ≤20 miles | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 3-6 hours |
| | | Driveaway-towaway (manufactured home transport) | Loss of driver and cargo | Avoid at all costs. | 3-6 hours |
| | | Fleet utility and transport vehicle operations | Safety risk, damage to cargo, schedule delays | Advise operators, suspend travel, reroute. | 3-6 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays | Advise transport operators, reroute (long haul) or delay movement. If underway, take evasive actions as appropriate. | 3-6 hours |
| | | Bus operations | Safety risk, damage to cargo, schedule delays | Advise operators, suspend travel, reroute. | 3-6 hours |
| | | Private vehicles | Safety risk, damage, travel delays | Advise motorists, suspend travel, reroute. | 3-6 hours |
| | | State emergency management | Safety risk, damage | Advise operators, suspend outdoor activities. | 3-6 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, suspend outdoor operations. | 3-6 hours |
| | | U.S. Forest Service | Access roads blocked by debris and fallen timber, valuable timber blown down (Downed timber requires timely salvage before its value is lost.) | Respond immediately to clear roadways. Plan for timely salvage of downed timber. | 3-6 hours |
| | Observation | U.S. Forest Service | Blocked roads, downed valuable timber | Determine where downed timber and blocked roads may have occurred in remote areas without depending on visual observations and field reports. Determine trac using weather radar, etc. | Current observation |
| | | | | | |
| Severe Storm Cell Track—Location, Direction, Speed, Severity (proximity to route or operational area in miles) | ≤20 miles | Road maintenance | Credibility of evacuation orders, flood risk, loss of life, property damage, road damage, loss of visibility, loss of traction, impaired mobility, lane obstruction/ submersion, loss of communications/power | Predict threatened area, select treatment strategy, mobilize maintenance personnel, implement warning and evacuation plans, issue evacuation orders, operate outflow devices, manage traffic flow. Remove debris, repair damage. | 1-3 hour forecast and current observation |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | Current observation |
| | | U.S. Forest Service | Trapped, stranded, injured recreationists | Issue warnings and advisories. Implement evacuation or search and rescue plans as necessary. | Current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays | Advise transport operators, reroute (long haul) or delay movement. If underway, take evasive actions as appropriate. | Current observation |
| | | | | | |
| **Major Storms** | | | | | |
| Blizzard—35 mph Sustained Winds, Visibility ≤1/4 mile, Blowing Snow (proximity to route or operational area in miles) | ≤50 miles | Road maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction/ submersion, loss of life, property damage, loss of communications/power | Predict threatened area, advise operators and travelers, suspend outdoor operations, select treatment strategy. Implement warning and evacuation plans, mobilize maintenance forces. | 48-96 hour forecast and current observation |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 48-96 hour forecast and current observation |
| | | U.S. Forest Service | Trapped, stranded, injured recreationists | Issue warnings and advisories. Implement search and rescue and evacuation plans as necessary. | 48-96 hour forecast and current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds when roads have been treated for ice conditions, rerout (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48-96 hour forecast and current observation |
| | | | | | |
| Hurricane Force Winds (wind speed in mph and proximity to route or operational area in miles) | ≥74 mph, ≤50 miles | Road maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction/ submersion, loss of life, property damage, loss of communications/power | Predict threatened area, advise operators and travelers, suspend outdoor operations, select treatment strategy, implement warning and evacuation plans. Mobilize maintenance forces. | 48-96 hour forecast and current observation |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 48-96 hour forecast and current observation |
| | | U.S. Forest Service | Trapped, stranded, injured recreationists | Issue warnings and advisories. Implement search and rescue and evacuation plans as necessary. | 48-96 hour forecast and current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds when roads have been treated for ice conditions, rerout (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48-96 hour forecast and current observation |
| | | | | | |
| Tropical Storm Force Winds (wind speed in mph and proximity to route or operational area in miles) | ≥39 mph to < 74 mph, ≤50 miles | Road maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction/ submersion, loss of life, property damage, loss of communications/power | Predict threatened area, advise operators and travelers, suspend outdoor operations, select treatment strategy, implement warning and evacuation plans. Mobilize maintenance forces. | 48-96 hour forecast and current observation |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 48-96 hour forecast and current observation |
| | | U.S. Forest Service | Trapped, stranded, injured recreationists | Issue warnings and advisories. Implement search and rescue and evacuation plans as necessary. | 48-96 hour forecast and current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds when roads have been treated for ice conditions, rerout (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts. | 48-96 hour forecast and current observation |
| **General Weather/Environmental Parameters** | | | | | |
| Air Temperature Including Maximum and Minimum (degrees F) | Variable, based on impact criteria | Road maintenance | Air quality, loss of communications/power, precipitation type, pavement temperature, slope instability (avalanche risk), snow removal/ice treatment operations | Advise operators, monitor surface moisture, modify operations. | 12-24 hour forecast and current observation |
| | Variable, trends and ranges based on impact criteria | Power generating operations | Power transmission loads and capacity affected by temperature extremes | Advise managers, operators, and line repair personnel. | 7-13 days |
| Air Temperature (degrees F) | ≥85-95 | Road maintenance | Health and safety risk, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment stress. | 12-24 hours |
| | | | | Take prescribed actions | 3-6 hours |
| | ≥85 | Truck operations | Health and safety risk, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment stress. | 12 hours |
| | ≥85-90 | Driveaway-towaway (manufactured home transport) | Possible tire blow out on trailer | Reduce speed and check tire pressures. | 6 hours |
| | ≥85 | Fleet utility and transport vehicle operations | Health and safety risk, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment stress. | 12 hours |
| | Variable, based on cargo humidity requirements | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment) | Advise transport operators, ensure sufficient air conditioning equipment available to maintain cargo humidity requirements. | 24 hours |
| | ≥85 | Bus operations | Health and safety risk, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment stress. Ensure air conditioning units are operating properly. | 12 hours |
| | ≥85 | Private vehicles | Health and safety risk, engine heat stress | Advise motorists. | 12 hours |
| | ≥85 | State emergency management | Health and safety risk, engine/equipment heat stress | Advise operators. | 12 hours |
| | ≥85 | State police | Health and safety risk, engine/equipment heat stress | Advise operators. | 12 hours |
| Air Temperature (degrees F) | ≥110 | Road maintenance | Health and safety risk, engine/equipment heat stress | Advise operators, modify/restrict operations. | 12-24 hours |
| | | | | Take prescribed actions. | 3-6 hours |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. | 12 hours |
| | | Fleet utility and transport vehicle operations | Health and safety risk, engine/equipment heat stress | Advise operators, modify/restrict operations. | 12 hours |
| | | Bus operations | Health and safety risk, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment stress. Ensure air conditioning units are operating properly. | 12 hours |
| | | Private vehicles | Health and safety risk, engine heat stress | Advise motorists to modify or restrict travel. | 12 hours |
| | | State emergency management | Health and safety risk, engine/equipment heat stress | Advise operators, modify/restrict operations. | 12 hours |
| | | State police | Health and safety risk, engine/equipment heat stress | Advise operators, modify/restrict operations. | 12 hours |
| | | | | | |
| Air Temperature Relative to Freezing and Trend (degrees F and rising or falling trend) | Decrease to less than 32° or increase to exceed 32°, with moisture | Road maintenance | Safety and health risks, ice/snow removal operations affected, traveler delays | Provide early warning, advise operators and travelers. Monitor surface moisture. | 12-24 hours |
| | | | | Begin treatment actions as appropriate. | 3-6 hours |
| | | Truck operations | Safety and health risks, potential operational delays | Advise operators, monitor surface moisture. | 12 hours |
| | | Driveaway-towaway (manufactured home transport) | loss of control on icy roads, trailer handling difficulties on changing surface conditions. | Advise operators to adjust speed or avoid the area. | 12 hours |
| | | Fleet utility and transport vehicle operations | Safety and health risks, potential operational delays | Advise operators, monitor surface moisture. | 12 hours |
| | | Bus operations | Safety and health risks, potential operational delays | Advise operators, monitor surface moisture. | 12 hours |
| | | Private vehicles | Safety and health risks, potential operational delays | Advise operators, monitor surface moisture. | 12 hours |
| | | State emergency management | Operations affected by ice formation | Advise operators, monitor surface moisture. | 12 hours |
| | | State police | Operations affected by ice formation | Advise operators, monitor surface moisture. | 12 hours |
| | | U.S. Forest Service | Logging hauling operations on frozen/snow packed roads affected by melt/thaw (Thawing may penetrate/damage structural support of roads and shut down heavy truck hauling.) | Place thermistors in roads to monitor melt/thaw and road integrity. | 12-24 hours |
| | | | | | |
| Dew Point Temperature (degrees F) | Variable, based on temperature and impact criteria | Road maintenance | Precipitation type, fog formation, air quality, slope instability (avalanche risk), snow removal/ice treatment operations | Predict threatened area, select treatment strategy, advise operators. Monitor surface moisture, modify operations. | 12-24 hour forecast and current observation |
| | Variable, based on cargo humidity requirements | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (Spacecraft, vehicles, and equipment must be maintained at specified humidity thresholds.) | Advise transport operators, ensure sufficient air conditioning equipment available to maintain cargo humidity requirements. | 12-24 hour forecast and current observation |
| | | | | | |
| Air Temperature Change Rate (degrees F per 24 hours) | Approx. 60° | Road maintenance | Precipitation type, pavement temperature, pavement buckling damage due to rapid expansion and contraction | Predict threatened area, select treatment strategy. Repair roadways. | 12-24 hour forecast and current observation |
| | | | | | |
| Time and Air Temperature Integrals (heating/cooling degree days) | Variable | Road maintenance | Road/property damage risk under extreme heating degree days or cooling degree days | Determine stockpile or resources needed to repair damage. | Forecast and actual tally |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Wet Bulb Temperature (degrees F) | Variable, based on temperature and impact criteria | Road maintenance | Air temperature, fog dispersal effectiveness | Predict threatened area, select treatment strategy. Disperse fog (cold fog) using $CO_2$ application. | 12-24 hour forecast and current observation |
| Relative Humidity (percent) | Variable, based on impact criteria | Road maintenance | Precipitation type, visibility restrictions | Predict threatened area, select treatment strategy. | 12-24 hour forecast and current observation |
| | Variable, based on cargo humidity requirements | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (Spacecraft, vehicles, and equipment must be maintained at specified humidity thresholds.) | Advise transport operators, ensure sufficient air conditioning equipment available to maintain cargo humidity requirements. | 12-24 hour forecast and current observation |
| Air Stability | Stable/ unstable | Road maintenance | Air quality (Stable atmosphere inhibits dispersion of pollutants.) | Modify operations. | 12-24 hour forecast and current observation |
| | | Atmospheric transport & diffusion & HAZMAT response | Health and safety risks, operational delays (Stable atmosphere inhibits dispersion of hazardous materials.) | Initiate HAZMAT (hazardous materials) spill reaction and mitigation plan. Ensure proper authorities are notified. | 1-3 hours |
| Subsurface Temperature (degrees F) | Variable, based on other contributing factors such as wind, shade, sun | Road maintenance | Pavement effects (Subsurface temperature affects pavement temperature, along with wind, insolation, shade, and other contributing factors.) | Predict threatened area, select treatment strategy | 12-24 hour forecast and current observation |
| Pavement Freeze Point Temperature with Dew Point Temperature (degrees F) | $\leq 32^{o}$ with moisture (observation and forecast) | Road maintenance | Loss of traction, safety risk to maintenance personnel and motorists, impacts on preventative treatment of roadways for ice (Some ice-preventative treatment operations can be completed in one shift; others require two shifts.) | Select treatment strategy, advise operators. Begin preparation procedures for applying chemicals (prepare liquid chemical tanks or hoppers for salt application) 12 hours prior to time for applying treatment to roadways. | Current observation and 12-48 hour forecast |
| | | | Operational delays, increased workload, anti-icing and/or de-icing operations required | Treat/clear roadways with anti-icing, de-icing treatments. Adjust traffic flow management. | 12 hours |
| | $\leq 32^{o}$ with moisture | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | | Driveaway-towaway (manufactured home transport) | Possible loss of control due to icy road surface. | Reduce speed and exercise caution. | 6 hours |
| | | Fleet utility and transport vehicle operations | Safety risk to operators, damage risk, schedule delays | Advise operators, reschedule, reroute. | 12 hours |
| | | Bus operations | Safety risk to operators/passengers, schedule delays | Advise operators, reschedule, reroute. | 12 hours |
| | | Private vehicles | Safety risk to motorists, travel delays | Advise motorists, reschedule, reroute. | 12 hours |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | State emergency management | Safety risk to motorists, hazardous cargo risks | Advise operators, reschedule. | 12 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 12 hours |
| Pavement Temperature (degrees F) | $\geq 85^{o}$ | Road maintenance | Personnel health and safety, engine/equipment heat stress, pavement buckling | Provide early warning, monitor equipment and personnel for heat stress, modify maintenance activities as required. | 12-24 hours |
| | | | | Take prescribed health/safety and repair actions. | 3 hours |
| | $\geq 90^{o}$ | Driveaway-towaway (manufactured home transport) | Possible tire blow out on trailer | Reduce speed and check tire pressures. | 6 hours |
| Pavement Temperature when Moisture is Present (degrees F) | >(15-18$^{o}$) but <32$^{o}$ | Road maintenance | Effects on snow/ice bonding and on snow removal/ice treatment operations, loss of traction | Predict threatened area, select treatment strategy. Prepare, deploy and track treatment assets. Apply treatment chemicals/abrasives. | 12 hours |
| | <15-18$^{o}$ | | Effects on snow/ice bonding and on snow removal/ice treatment operations, loss of traction, changes in treatment chemical effectiveness | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Plow snow, apply abrasives. | 12 hours |
| Pavement Temperature | Variable, based on impact criteria | Road maintenance | Effects on snow/ice bonding and snow removal/ice treatment operations, loss of traction, changes in treatment chemical effectiveness and snow/ice melting | Predict threatened area, select treatment strategy. Prepare, deploy and track treatment assets. Plow snow apply treatment chemicals/abrasives. | Current observation |
| Pavement Condition | Wet | Road maintenance | Impaired mobility, loss of traction, loss of stability/maneuverability, safety risk | Predict threatened area, manage traffic flow. | Current observation |
| | Snow, snowpack | Road maintenance | Impaired mobility, loss of traction, loss of stability/maneuverability, safety risk | Predict threatened area, select treatment strategy. Prepare, deploy and track treatment assets. Apply treatment chemicals/abrasives, plow snow, manage traffic flow. | Current observation |
| | Ice | Road maintenance | Impaired mobility, loss of traction, loss of stability/maneuverability, safety risk | Predict threatened area, select treatment strategy, prepare, deploy and track treatment assets, apply treatment chemicals/abrasives, manage traffic flow. | Current observation |
| Chemical Concentration (in-road sensor or mobile infrared) | Variable, based on application, residue | Road maintenance | Safety risk, snow removal/ice treatment operations, snow/ice bonding | Select treatment strategy, deploy and track treatment assets. Apply treatment chemicals/abrasives, operate outflow devices. | Current observation |
| Visibility, Including Restricting Conditions such as Fog, Haze, Dust, Smoke (statute miles) | <1/4 to $\leq$ 1/2 mile | Road maintenance | Safety risk, loss of visibility, impaired mobility | Provide early warning to operators and motorists. | 6-12 hours |
| | | | | Take prescribed actions, advise operators and maintenance personnel. Modify operations, consider application of $CO_2$ to disperse fog. | 3-6 hours and current observation |
| | <1/4 mile | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 6 hours |
| | | Driveaway-towaway (manufactured home transport) | Ability to see and be seen within safe reaction distance greatly reduced | Stop travel. | 3 hours |
| | | Fleet utility and transport vehicle operations | Safety risk, schedule delays | Advise operators, modify operations. | 6 hours |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds, reroute (long haul) or delay movement, preposition cargo at air transport site and transport earlier to avoid weather impacts | 6 hours |
| | | Bus operations | Safety risk, schedule delays | Advise operators, modify operations, reduce speeds. | 6 hours |
| | | Private vehicles | Safety risk, travel delays | Advise motorists, modify travel. | 6 hours |
| | | State emergency management | Transport risk to hazardous cargo | Advise operators, modify operations. | 6 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, modify operations. | 6 hours |
| Sun Glare | Any | Road maintenance | Restricted visibility in glare quadrant of horizon | Advise operators and maintenance personnel, reduce speed. | 3 hours and current observation |
| | | Truck operations | Restricted visibility in glare quadrant of horizon, safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators, reduce speed. | 3 hours |
| | | Fleet utility and transport vehicle operations | Restricted visibility in glare quadrant of horizon | Advise operators, reduce speed. | 3 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Restricted visibility in glare quadrant of horizon, safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment) | Advise transport operators, slow movement speeds. | 3 hours |
| | | Bus operations | Restricted visibility in glare quadrant of horizon | Advise operators, reduce speed. | 3 hours |
| | | Private vehicles | Restricted visibility in glare quadrant of horizon | Advise motorists, reduce speed. | 3 hours |
| | | State emergency management | Restricted visibility in glare quadrant of horizon | Advise operators, reduce speed. | 3 hours |
| | | State police | Restricted visibility in glare quadrant of horizon | Advise operators, reduce speed. | 3 hours |
| Wind: Head, Cross, or Tail (wind speed in miles per hour) | >30 and <50 mph | Road maintenance | Safety risk to personnel and motorists, increased roadway and lane obstruction (debris), reduced or lost visibility, drifting snow, loss of stability and maneuverability, road damage, loss of life or property, treatment chemical dispersion, loss of communications and power, toxicity and environmental damage (Speed and direction are most important when snow has accumulated.) | Predict threatened area, advise travelers, select treatment strategy, implement early warning procedures. Consider implementation of evacuation plans. Construct and place living and structural snow fences to manage snow drifting. | 12-24 hours |
| | | | | Modify operations, prepare for snow drift removal. Manage traffic flow (restrict access to roadways and bridges, restrict access to specific vehicle types), remove debris, repair damage. | 6-12 hours and current observation |
| | >30 and <50 mph | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | >25 mph and gusty | Driveaway-towaway (manufactured home transport) | Difficult handling of trailer and load (manufactured home or section) | Stop travel. | 6 hours |
| | >30 and <50 mph | Fleet utility and transport vehicle operations | Safety risk to operators | Advise operators, modify operations. | 12 hours |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | >30 mph | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators, slow movement speeds, reroute (long haul) or delay movement. Preposition cargo at air transport site and transport earlier to avoid weather impacts | 24-48 hours |
| | >30 and <50 mph | Bus operations | Increased safety risk, roadway debris, flying debris, traffic congestion, downed live electric lines and or poles, increased risk of damage to busses and property, schedule delays | Advise operators, plan route detours. If high wind watches issued, modify, restrict, or suspend operations. Notify passengers (public address system). | 6 hours |
| | >30 and <50 mph | Private vehicles | Safety risk to operators/passengers | Advise motorists, modify travel. | 6 hours |
| | >30 and <50 mph | State emergency management | Transport risk to hazardous cargo | Advise operators, modify operations. | 6 hours |
| | >30 and <50 mph | State police | Increased workload due to hazardous travel conditions | Advise operators, modify operations. | 6 hours |
| | >35 mph and sustained | Power generating operations | Line damage, transmission impairment or loss | Alert managers, dispatch line repair personnel as needed. | 48, 24, and 12 hours |
| Wind: Head, Cross, or Tail (wind speed in miles per hour) | ≥50 mph | Road maintenance | Safety risk to personnel and motorists, increased roadway and lane obstruction (debris), reduced or lost visibility, impaired mobility, drifting snow, loss of stability and maneuverability, road damage, loss of life or property, treatment chemical dispersion, loss of communications and power, toxicity and environmental damage (Speed and direction are most important when snow has accumulated.) | Predict threatened area, advise travelers, select treatment strategy, implement early warning procedures. Review and consider implementation of evacuation plans. Construct and place living and structural snow fences to manage snow drifting. | 12-24 hours |
| | | | | Modify operations, implement snow removal. Manage traffic flow (restrict access to roadways and bridges, restrict access to specific vehicle types), remove debris repair damage. | 6-12 hours |
| | | Truck operations | Safety risk to operators, freight/cargo damage risk, schedule delays, increased risk of collisions/spills of hazardous cargo | Advise operators and managers, conduct risk assessment. Delay, postpone, reschedule, or reroute as appropriate. If underway, especially when hauling hazardous materials, find a safe stopping point. | 12 hours |
| | | Fleet utility and transport vehicle operations | Safety risk to operators | Advise operators, reschedule, reroute. | 12 hours |
| | | Bus operations | Increased safety risk, roadway debris, flying debris, traffic congestion, downed live electric lines and or poles, increased risk of damage to busses and property, schedule delays, detours required on routes | Advise operators, plan route detours. If high wind watches issued, modify, restrict, or suspend operations. Notify passengers (public address system). | 6 hours |
| | | Private vehicles | Safety risk to operators/passengers | Advise motorists, reschedule, reroute. | 6 hours |
| | | State emergency management | Transport risk to hazardous cargo | Advise operators, plan route detours. If high wind watches issued, modify, restrict, or suspend operations. Notify passengers (public address system). | 6 hours |
| | | State police | Increased workload due to hazardous travel conditions | Advise operators, reschedule, adjust traffic management. | 6 hours |
| | | U.S. Forest Service | Access roads blocked by debris and falled timber, valuable timber blown down/damaged (Downed timbe requires timely salvage before its value is lost.) | Move in emergency equipment to clear roadways and perform timber salvage operations. | 3 hours |
| | | | | Determine where downed timber and blocked roads may have occurred in remote areas without depending on visual observations and field reports. Determine trac using weather radar, etc. | Current observation |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Surface Wind Direction | Any speed | Road maintenance | Drifting snow, wild fire tracking, toxicity and environmental damage | Predict threatened area, select treatment strategy. Remove debris, repair damage. | 2 hour forecast and current observation |
| | | | | | |
| Upper Air Winds | Standard levels | Road maintenance | Air quality, storm cell tracking, toxicity and environmental damage | Predict threatened area, select treatment strategy. Remove debris, repair damage. | 12 hours and most recent upper air data |
| | | | | | |
| Wind Chill (degrees F) | $\leq 32^{o}$ | Road maintenance | Safety risks (hypothermia, frost bite) | Provide early warning. | 12-24 hours |
| | | | | Advise maintenance personnel, cancel/curtail operations. | 3-6 hours and current observation |
| | $\leq 20^{o}$ | Truck operations | Safety risks (hypothermia, frost bite) | Advise operators, modify operations. | 6 hours |
| | | Driveaway-towaway (manufactured home transport) | Safety risks for drivers (hypothermia, frost bite) | Advise operators and minimize outside exposure. | 6 hours |
| | | Fleet utility and transport vehicle operations | Safety risks (hypothermia, frost bite) | Advise operators, modify operations | 6 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risks (hypothermia, frost bite) | Advise operators, delay operations. | 6 hours |
| | | Bus operations | Safety risks (hypothermia, frost bite) | Advise operators, modify operations. | 6 hours |
| | | Private vehicles | Safety risks (hypothermia, frost bite) | Advise motorists, modify travel. | 6 hours |
| | | State emergency management | Safety risks (hypothermia, frost bite) | Advise operators, modify operations. | 6 hours |
| | | State police | Safety risks (hypothermia, frost bite) | Advise operators, modify operations. | 6 hours |
| | | | | | |
| Heat Index (degrees F) | $\geq 105^{o}$ | Road maintenance | Personnel heat exhaustion | Provide early warning. | 12-24 hours |
| | | | | Advise operators, modify/restrict operations. | 3-6 hours |
| | | Truck operations | Personnel heat exhaustion | Advise operators, modify/restrict operations. | 6 hours |
| | | Driveaway-towaway (manufactured home transport) | Safety risk for driver (heat exhaustion) | Advise operator, have water available, exercise caution. | 6 hours |
| | | Fleet utility and transport vehicle operations | Personnel heat exhaustion | Advise operators, modify/restrict operations. | 6 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Personnel heat exhaustion | Advise operators, modify/restrict operations. | 6 hours |
| | | Bus operations | Personnel heat exhaustion | Advise operators, modify/restrict operations. | 6 hours |
| | | Private vehicles | Personnel heat exhaustion | Advise motorists, modify/restrict travel. | 6 hours |
| | | State emergency management | Personnel heat exhaustion | Advise operators, modify/restrict operations. | 6 hours |
| | | State police | Personnel heat exhaustion | Advise operators, modify/restrict operations. | 6 hours |
| | variable extremes based on impact criteria | Power generating operations | Existing and anticipated power loads and transmission capacities altered by temperature extremes | Adjust marketing strategies to ensure cost effective transmissions. Advise managers, alert operators and line repair personnel. | 7 days |
| | | | | | |
| Air Quality | Code orange or red | Road maintenance | Potential health and safety risks, operational delays | Provide early warning, advise operators, modify operations in urban areas. | 12-24 hours |
| | | | | Modify operations in urban areas. | 3-6 hours |

| Weather Needs for Roadway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Truck operations | Potential health and safety risks, operational delays | Advise operators, modify operations in urban areas. | 12 hours |
| | | Fleet utility and transport vehicle operations | Potential health and safety risks, operational delays | Advise operators, modify operations in urban areas. | 12 hours |
| | | Bus operations | Potential health and safety risks, operational delays | Advise operators, modify operations in urban areas. | 12 hours |
| | | Private vehicles | Potential health and safety risks, operational delays | Advise motorists, modify travel in urban areas. | 12 hours |
| | | State emergency management | Potential health and safety risks, operational delays | Advise operators. | 12 hours |
| | | State police | Potential health and safety risks, operational delays | Advise operators. | 12 hours |
| | | Atmospheric Transport and Diffusion and HAZMAT response | Potential health and safety risks, operational delays | Initiate HAZMAT spill reaction and mitigation plan. Ensure proper authorities are notified. | 1-3 hours |
| | | | | | |
| Space Weather (solar flares, etc.) | Any | Road maintenance | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hour forecast and current observation |
| | | Truck operations | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | Fleet utility and transport vehicle operations | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | Bus operations | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | Private vehicles | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | State emergency management | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | State police | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | U.S. Forest Service | Possible loss of communications, power, GPS navigation | Advise operators, monitor communication outages. | 12 hours |
| | | | | | |
| Total Sun (insolation hours per day) | All | Road maintenance | Air temperature, pavement temperature, toxicity, and environmental damage | Modify operations as necessary. | 12-24 hour forecast and current observation |
| | | | | | |
| Cloud Cover Forecast | Scattered, broken, overcast | Road maintenance | Air temperature, pavement temperature, toxicity, and environmental damage | Modify operations as necessary. | 12-24 hour forecast and current observation |
| | | | | | |
| Water Course Flow Volume (cubic meters per second) | Variable, based on flood stage criteria | Road maintenance | Flood risk, lane submersion, loss of life and property, road damage | Predict threatened area, select treatment strategy, operate outflow devices, develop warning and evacuation plans. | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Flood risk, road submersion, loss of life and property, road damage | Predict threatened area, operate outflow devices, develop warning and evacuation plans. | 12-24 hour forecast and current observation |

| Weather Needs for Roadway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | State emergency management | Transport risk to hazardous cargo | Advise operators. | 12-24 hour forecast and current observation |
| Water Body Depth (feet) | Variable, based on flood stage criteria | Road maintenance | Flood risk, lane submersion, loss of life and property, road damage | Predict threatened area, select treatment strategy, operate outflow devices, develop warning and evacuation plans. | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Flood risk, road submersion, loss of life and property, road damage | Predict threatened area, operate outflow devices, develop warning and evacuation plans. | 12-24 hour forecast and current observation |
| | | State emergency management | Transport risk to hazardous cargo | Advise operators. | 12-24 hour forecast and current observation |
| Hurricane Storm Surge | Any | Road maintenance | Safety risk, damage to vehicles, road damage, evacuation route delays | Predict threatened area, repair damage. | 12-24 hour forecast and current observation |
| | | Truck operations | Safety risk, damage to vehicles, road damage, evacuation route delays | Advise operators. Reroute or suspend operations. | 12-24 hour forecast and current observation |
| | | Fleet utility and transport vehicle operations | Safety risk, damage to vehicles, road damage, evacuation route delays | Advise operators. Reroute or suspend operations. | 12-24 hour forecast and current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk, damage to vehicles, road damage, evacuation route delays | Advise operators. Reroute or delay transport operations. | 12-24 hour forecast and current observation |
| | | Bus operations | Increased safety risk, damage to busses, delays to scheduled operations, complete disruption of service for busses that travel coastal roads | Advise operators and road supervisors of pending conditions. Modify, restrict, or suspend operations. Request radio reports of observed storm surge crossing the highway. | 12-24 hour forecast and current observation |
| | | Private vehicles | Safety risk, damage to vehicles, road damage, evacuation route delays | Advise motorists. Reroute, restrict, or suspend travel. | 12-24 hour forecast and current observation |
| | | State emergency management | Safety risk, damage to vehicles, road damage, evacuation route delays | Implement emergency response procedures as appropriate. | 12-24 hour forecast and current observation |
| | | State police | Safety risk, damage to vehicles, road damage, evacuation route delays | Implement emergency response procedures as appropriate. | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Potential safety risks, stranded recreationists | Advise field personnel and recreationists. | 24 hours and current observation |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| High Surf (wave height in feet) | >8 feet | Road maintenance | Safety risk, damage to vehicles, road damage, evacuation route delays | Predict threatened area, repair damage. | 12-24 hour forecast and current observation |
| Avalanche Danger | High, moderate, low | Road maintenance | Impaired mobility, loss of life and property, lane obstruction, effects on snow removal/ice treatment operations | Close roadways, release avalanche, remove snow, modify operations as necessary. | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Life threat, safety risk to recreationalists, Forest Service workers | Pass warnings to forest users, workers. | 12-24 hour forecast and current observation |
| Seismic Activity | Any seismic activity | Road maintenance | Road/property damage risk, impaired mobility, loss of life and property | Manage traffic flow, modify operations, remove debris, repair damage. | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Life threat, safety risk to recreationalists, Forest Service workers | Pass warnings to forest users, workers. | 12-24 hour forecast and current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft/vehicles/equipment), transport schedule delays, potential launch schedule delays | Advise transport operators. Reroute (long haul) or delay movement. | 12-24 hour forecast and current observation |
| Volcanism | Any volcanic activity | Road maintenance | Road/property damage risk, impaired mobility, loss of life and property, air quality | Manage traffic flow, modify operations. | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Cataclysmic devastation of large areas (Mt. St. Helens National Monument is administered by the Forest Service. Many dormant volcanos are on National Forest land: Shasta, Medicine Lake, Three Sisters, Mt Hood, etc.) | Issue warnings and advisories. Implement search and rescue or evacuation plans, as necessary. | 12-24 hour forecast and current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators. Reroute (long haul) or delay movement. | 12-24 hour forecast and current observation |
| Soil Moisture | Saturated, unsaturated | Road maintenance | Flood risk, road/pavement damage, pavement condition | Select treatment strategy, select road repair strategy. | 12-24 hour forecast and current observation |
| Fire | Any fire event or activity | Road maintenance | Loss of visibility, loss of life and property, air quality | Manage traffic flow (close roadways, bridges). | 12-24 hour forecast and current observation |
| | | U.S. Forest Service | Life threat, safety risk | Conduct fire fighting operations. | 12-24 hour forecast and current observation |

# Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | NASA (Goddard) spacecraft and equipment transport | Safety risk to transport vehicle operators, damage risk to unique cargo (spacecraft, vehicles, equipment), transport schedule delays, potential launch schedule delays | Advise transport operators. Reroute (long haul) or delay movement. | 12-24 hour forecast and current observation |
| Fair Weather (duration in days) | 1 to 10 days | Road maintenance | Operational planning (The tasks that will be undertaken in periods of good weather depend somewhat on how much good weather is anticipated. Crews work year round; there are no reserves or part-time personnel to call in for snow or other severe weather events. Details of crew assignments vary day to day, some days plowing and sanding, some days working on drainage, some days on signs and guardrail, etc. A certain amount of mobilization is required for some tasks.) | Examples: (1) Ditching requires removing the sanders, mounting a truck box, and replacing the blower attachment on a loader with a bucket. These jobs would probably take 2 days. Such actions cannot be started without a forecast of 10 days of good (non-snow) weather because of the time needed to reconvert the equipment. (2) In urban areas, snow hauling is necessary following a storm. The same amount of work is needed to clean up after a 6-inch fall as a 12-inch one. If good weather is forecast following a 6" snow event, hauling might be started. If another snow event is forecast within several days, hauling may be delayed. (3) Forecasts of good weather, as well as bad, aid managers in deploying crews efficiently. | 24-48 hours |
| | Variable, based on impact criteria | Truck operations | Risks to weather sensitive operations, cargo, or time constraints | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | | Fleet utility and transport vehicle operations | Risks to weather sensitive operations, cargo, or time constraints | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | | NASA (Goddard) spacecraft and equipment transport | Risks to weather sensitive operations, cargo with unique weather parameter requirements, or travel time requirements | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | | Bus operations | Risks to weather sensitive operations or time constraints | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | | Private vehicles | Risks to weather sensitive travel or travel time requirements | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | | State emergency management | Risks to weather sensitive operations, cargo with unique weather parameter requirements, or travel time requirements | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | | State police | Risks to weather sensitive operations or time requirements | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| | 1 to 10 days of mean temperatures $\geq$50-60$^o$ F | U.S. Forest Service | Risks to seal coating operations (Resurfacing of roads with road oil and gravel to seal road cracks is often done during the fall. Seal coating fails if temperatures fall below 50-60$^o$ F during resurfacing.) | Carry out operations and travel/transport schedules, based on forecast of fair weather for specific period. | 24-48 hours |
| Nuclear, Biological, or Chemical Release | Any | Road maintenance | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Close or detour roadways. Assist in Atmospheric Transport and Diffusion and HAZMAT response operations as needed. | 1-3 hours current observation |
| | | Truck operations | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Cease transport operations/travel or reroute. | 1-3 hours current observation |
| | | Fleet Utility and Transport Vehicle Operations | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Cease transport operations/travel or reroute. | 1-3 hours current observation |

## Weather Needs for Roadway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | Fleet utility and transport vehicle operations | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Cease transport operations/travel or reroute. | 1-3 hours current observation |
| | | NASA (Goddard) spacecraft and equipment transport | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Cease transport operations/travel or reroute. | 1-3 hours current observation |
| | | Bus operations | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Cease transport operations/travel or reroute. | 1-3 hours current observation |
| | | Private vehicles | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Cease transport operations/travel or reroute. | 1-3 hours current observation |
| | | State emergency management | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Close or detour roadways. Implement Atmospheric Transport and Diffusion and HAZMAT response operations as needed. | 1-3 hours current observation |
| | | State police | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Close or detour roadways. Assist in Atmospheric Transport and Diffusion and HAZMAT response operations as needed. | 1-3 hours current observation |
| | | U.S. Forest Service | Severe threat to life, health and safety risks from dispersion of extremely dangerous hazardous materials, agents, substances | Close or detour roadways. Assist in Atmospheric Transport and Diffusion and HAZMAT response operations as needed. | 1-3 hours current observation |

# Appendix B–1.1

## *Federal Highways WIST Needs Template*

## Federal Highway Activities
## (Same as Roadway Sector Activities in Appendix B-1)

**Road maintenance**. This activity is generally where the requirements of the state transportation departments are compiled. It includes road surface treatment for snow and ice control in the winter, as well as road and infrastructure maintenance year-round to repair damage.

**Truck operations**. The primary example for this activity is commercial trucking operations, both local and long haul.

**Fleet utility and transport vehicle operations**. This activity includes small to medium size fleets of utility vehicles, such as those maintained by telephone or cable television companies, as well as the large, nationwide fleets of mail and parcel delivery vehicles.

**Bus operations**. This activity is intended to cover primarily long-haul bus operations, such as interstate travel, rather than school buses or local transit system buses, both of which are covered by the Rural and Urban Transit Operations sector.

**Private vehicle operations**. Private vehicle operators, daily commuters, long-distance travelers, and local drivers, as well as rental car operators, are included in this activity.

**State/local emergency managers**. This activity encompasses emergency managers at state and local levels.

**State police**. Although state police and highway patrol entities provided the input on WIST needs for this activity, the information is generally valid for law enforcement and public safety officials anywhere with roadway traffic safety responsibilities.

**Forest Service**. The roadway operations of the U.S. Forest Service role are limited to unimproved roads under its jurisdiction within national forests and grasslands. But the ways in which the weather affects these roads has major impact on all the uses of these areas.

**Special Groups**

- **NASA spacecraft and equipment transport**. NASA's principal concern with roadways is in transporting spacecraft and components by land routes between its various centers and the launch facilities.
- **Power generating operations.** The WIST needs of the power marketing associations (see Section 3.1.2) are limited to road conditions that affect the ability of repair crews in utility vehicles to reach transmission lines and facilities.
- **Manufactured home transport**. This specialized activity has WIST needs that represent the general class of high-profile vehicles, which have special sensitivities to wind and other weather elements, such as those that affect tire traction.

## Weather Needs for Federal Highway Operations

| Weather Element | Threshold | Forecast/Observation | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Freezing Precipitation (ice) | Any | Forecast | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, loss of communications/power, slope instability (avalanche risk), operational delays (increased workload) | Predict threatened area, select treatment strategy, advise operators, begin preparation procedures. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | | Prepare, deploy and track treatment assets. Apply treatment chemicals/abrasives. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). Remove debris, repair damage. | 3-6 hours |
| Structure Ice Accumulation (inches) | Any | Observation | Loss of communications/power, property and structural damage, safety risk | Predict threatened area, select treatment strategy. Remove debris, repair damage. | Current observation |
| Pavement Ice Accumulation (inches) | Any | Observation | Safety risk, impaired mobility, loss of stability/ maneuverability, loss of traction, pavement damage, pavement temperature, effects on snow removal/ice treatment operations | Predict threatened area, select treatment strategy. Remove debris, repair damage. | Current observation |
| Frozen Precipitation (snow, inches) | Any to <2 inches | Forecast | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, slope instability (avalanche risk) | Predict threatened area, select treatment strategy, advise operators. Begin preparation procedures for equipment, crew planning, shift changes, geographic reassignment and deployment. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | Operational delays (increased workload) | Prepare, deploy, and track treatment assets. Plow snow, apply treatment chemicals/abrasives. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 3-6 hours |
| | $\geq$2 to <8 inches | Forecast | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, slope instability (avalanche risk) | Predict threatened area, select treatment strategy, advise operators. Disseminate warning information to travelers (press releases, dynamic message signs, roadside highway advisory radio, transmitters, the Internet etc.). Begin preparation procedures for equipment, crew planning, shift changes, geographic reassignment and deployment. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | | Prepare, deploy, and track treatment assets. Plow snow, apply treatment chemicals/abrasives. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 3-6 hours |

| Weather Needs for Federal Highway Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Forecast/Observation** | **Impacts** | **Action** | **Lead Time** |
| | ≥ 8 inches | Forecast | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, slope instability (avalanche risk) | Advise operators. Disseminate warning information to travelers (press releases, dynamic message signs, roadside highway advisory radio, transmitters, the Internet, etc.). Begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. | 24-48 hours (starting time of event is critical to DOT operations) |
| | | | | Plow snow, apply treatment chemicals/abrasives, implement tire chain control operations. Prepare, deploy and track treatment assets. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, restrict access to designated vehicle types). | 3-6 hours |
| Drifting Snow (inches) | Any to <8 inches | Forecast | Safety risk to maintenance personnel and motorists, travel delays, impaired plowing, lane obstruction, loss of visibility, loss of traction, impaired mobility, effects on snow removal/ice treatment operations (Winds greater than 15 mph can lead to blowing snow and drifting in some areas. The amount of snow already on the ground may not be the determining factor. If snow storage areas are full, even a few inches can cause drifting problems. Drifting snow requires continuous and prolonged clearing operations, which strains manpower resources.) | Predict threatened area, select treatment strategy, consider road closures. Disseminate warning information to travelers (press releases, dynamic message signs, roadside highway advisory radio, transmitters, the Internet, etc.). Begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Construct and place living and structural snow fences. | 24-48 hours |
| | ≥ 8 inches | | | | 24-48 hours |
| | | | | Select treatment strategy. Prepare, deploy, and track treatment assets, Manage snow removal/ice treatment operations (plow snow, treat/clear roadways). Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire chain controls, restrict access to designated vehicle types). | 3-6 hours |
| Snow Accumulation (inches) | Any | Observation | Drifting snow, impaired mobility, impaired plowing, lane obstruction, loss of stability and maneuverability, loss of traction, pavement temperature effects, slope instability (avalanche risk) | Prepare, deploy, and track treatment assets. Plow snow, apply treatment chemicals/abrasives, remove debris, repair damage. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | Current observation |
| Snow Drift Levels (inches) | Any | Observation | Impaired plowing, lane obstruction | Predict threatened area, select treatment strategy. | Current observation |
| Roadway Snow Depth (inches) | Any | Observation | Loss of traction, impaired mobility, effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| Roadway Snow Pack Depth (inches) | Any | Observation | Loss of traction, impaired mobility, effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |

| Weather Needs for Federal Highway Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Forecast/Observation** | **Impacts** | **Action** | **Lead Time** |
| Adjacent Snow Depth (inches) | Any | Observation | Drifting snow, roadway snow depth | Select treatment strategy. | Current observation |
| Snow/Ice Bonding (inches) | Any | Observation | Effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| Liquid Precipitation (inches) | Any | Forecast | Impaired mobility, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction/ submersion, road damage, treatment chemical dispersion, toxicity and environmental damage, slope instability (landslide risk) | Predict threatened area, advise operators, disseminate warning information to travelers. Start preparation procedures and planning activities. | 12-24 hours |
| | | | | Manage traffic flow, operate outflow devices and induce drainage, finalize decisions. | 3-6 hours |
| Precipitable Water Vapor (inches) | Any | Observation (by satellite imagery interpretation) | Precipitation patterns and rates | Predict threatened area, select treatment strategy. | Current observation |
| Flooding | Any | Forecast | Safety risks, road submersion, loss of life and property, road damage, bridge damage, travel delays | Begin preparation procedures, plan detour routes. | 1-2 weeks |
| | | | | Review/revise contingency plans, issue alerts. | 12-24 hours |
| | | | | Disseminate warning information to travelers. Implement local mobilization, response actions. Manage traffic flow (close roadways and bridges), prepare to monitor/induce drainage. | 6-12 hours |
| Thunderstorms with Lightning (proximity to route or operational area in miles) | $\leq$ 5 miles | Forecast and observation | Safety risks, loss of life, property damage, loss of communications/power, operational delays | Predict threatened area, advise operators, cease refueling, restrict/suspend operations. | 6-12 hours and current observation |
| Thunderstorms with Hail (hail size, proximity to route or operational area in miles) | Any size, $\leq$5 miles | Forecast and observation | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, loss of communications/power, operational delays | Predict threatened area, advise operators, cease refueling, restrict/suspend operations. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 6-12 hours and current observation |
| | >1/4 inch, $\leq$5 miles | Forecast and observation | | | 3 hours |
| Thunderstorms with Tornado or Waterspout (proximity to route or operational area in miles) | $\leq$10 miles | Forecast and observation | Loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life, property damage, loss of communications/power | Predict threatened area, select treatment strategy, develop warning and evacuation plans, mobilize maintenance forces. | 3-6 hours and current observation |
| | $\leq$5 miles | Forecast and observation | Loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life, property damage, loss of communications/power | Issue evacuation orders. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). Operate outflow devices, remove debris, repair damage. | 1-3 hours and current observation |

## Weather Needs for Federal Highway Operations

| Weather Element | Threshold | Forecast/Observation | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Severe Storm Cell Track—Location, Direction, Speed, Severity (proximity to route or operational area in miles, based on radar observation) | $\leq$20 miles | Forecast and observation | Credibility of evacuation orders, loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life, property damage, loss of communications/ power, flood risk, road damage | Predict threatened area, develop warning and evacuation plans, issue evacuation orders, select treatment strategy. Mobilize maintenance personnel. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). Operate outflow devices, remove debris, repair damage. | 1-6 hours and current observation |
| **Major Storms** | | | | | |
| Blizzard—35 mph Sustained Winds, Visibility <1/4 mile, Blowing Snow (proximity to route or operational area in miles) | $\leq$50 miles | Forecast and observation | Safety risks, loss of life, property damage, road damage, loss of visibility, loss of traction, impaired mobility, evacuation route delays, lane obstruction, loss of communications/power | Predict threatened area, disseminate warning information to operators and travelers, select treatment strategy. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage. | 48-96 hours and current observation |
| Hurricane Force Winds (wind speed in mph and proximity to route or operational area in miles) | $\geq$74 mph, $\leq$50 miles | Forecast and observation | Safety risks, loss of life, loss of visibility, loss of traction, impaired mobility, evacuation route delays, lane obstruction/submersion, loss of communications/power, property damage, road damage | Predict threatened area, disseminate warning information to operators and travelers. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage. | 48-96 hours and current observation |
| Tropical Storm Force Winds (wind speed in mph and proximity to route or operational area in miles) | $\geq$39 mph but <74 mph, $\leq$50 miles | Forecast and observation | Safety risk, potential loss of life, loss of visibility, loss of traction, impaired mobility, evacuation route delays, lane obstruction/submersion, loss of communications/ power, property damage, road damage | Predict threatened area, disseminate warning information to operators and travelers. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage. | 48-96 hours and current observation |
| Hurricane Storm Surge | Any | Forecast and observation | Safety risks, flood risk, loss of life, loss of traction, impaired mobility, evacuation route delays, lane obstruction/submersion, loss of communications/power, property damage, road damage | Predict threatened area, disseminate warning information to operators and travelers. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage. | 12-24 hours and current observation |
| **General Weather/Environmental Parameters** | | | | | |
| Air Temperature including Maximum and Minimum (degrees F) | Variable, based on impact criteria | Forecast and observation | Air quality, loss of communications/power, precipitation type, pavement temperature, slope stability (avalanche risk), effects on snow removal/ice treatment operations | Advise operators, monitor surface moisture, modify operations. | 12-24 hours and current observation |
| Air Temperature Relative to Freezing and Trend (degrees F and rising or falling trend) | Decrease to less than 32$^{o}$ or increase to exceed 32$^{o}$, with moisture | Forecast | Precipitation type, pavement temperature, loss of communications/power, slope instability (avalanche risk), effects on snow removal/ice treatment operations, road damage | Disseminate early warning information to travelers and operators, monitor surface moisture, modify operations. | 12-24 hours |
| Air Temperature (degrees F) | >85$^{o}$ | Forecast | Health and safety risks, engine/equipment heat stress | Advise operators, monitor personnel and equipment stress, take prescribed and precautionary measures. | 6-12 hours |
| | >110$^{o}$ | Forecast | Severe and immediate health and safety danger to personnel and heat stress risk to equipment | Conduct immediate risk assesment, advise operators and supervisors to ensure continuous monitoring of personnel and equipment. Cease activities. | 6-12 hours |
| Dew Point Temperature (degrees F) | Variable, based on temperature and impact criteria | Forecast and observation | Air quality, precipitation type, fog formation | Predict threatened area, select treatment strategy. | 12-24 hours and current observation |

## Weather Needs for Federal Highway Operations

| Weather Element | Threshold | Forecast/Observation | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Air Temperature Change Rate (degrees F per 24 hours) | Approx. 60° in 24 hours | Forecast and observation | Precipitation type, pavement temperature, road damage (pavement buckling damage due to rapid expansion and contraction) | Predict threatened area, select treatment strategy, repair damage. | 12-24 hours and current observation |
| Time and Air Tempeerature Integrals (heating/cooling degree days) | 24 hour | Forecast and observation | Road damage, property damage (risk under extreme heating degree days or cooling degree days) | Determine stockpile or needed resources, repair damage. | 12-24 hours and actual tally |
| Wet Bulb Temperature (degrees F) | Variable, based on temperature and impact criteria | Forecast and observation | Air temperature, fog dispersal effectiveness | Predict threatened area, select treatment strategy, disperse fog (cold fog). | 12-24 hours and current observation |
| Relative Humidity (percent) | Variable, based on impact criteria | Forecast and observation | Precipitation type, loss of visibililty | Predict threatened area, select treatment strategy. | 12-24 hours and current observation |
| Air Stabililty | Stable/unstable | Forecast and observation | Air quality (Stable atmosphere inhibits dispersion of pollutants.) | Modify operations, manage traffic flow. | 12-24 hours and current observation |
| Air Quality | Code orange or red | Forecast | Health and safety risk, operational delays | Disseminate warning information to operators and travelers, modify operations in urban areas. | 12-24 hours |
| | | | | Modify operations. | 3-6 hours |
| Subsurface Temperature (degrees F) | Variable, based on contributing factors such as wind, shade, sun | Forecast and observation | Pavement temperature | Predict threatened area, select treatment strategy. | 12-24 hours and current observation |
| Pavement Temperature (degrees F) | >85-90° | Forecast | Health and safety risks, engine/equipment heat stress, pavement "blow-ups" (Subsurface temperature affects pavement temperature, but other factors such as wind, insolation, and shade also contribute.) | Disseminate early warning information to operators, monitor equipment/personnel heat stress, modify operations. | 12-24 hours |
| | | | | Take prescribed health/safety and repair actions. | 3 hours |
| Pavement Freeze Point Temperature with Dew Point Temperature (degrees F) | <32° with moisture (observation and forecast) | Forecast and observation | Loss of traction, safety risk to operations personnel and motorists, effects on snow/ice removal operations. (Some treatment operations can be completed in one shift, others require two shifts.) | Select treatment strategy, advise operators, begin preparation procedures. At 12 hours prior to projected roadway treatment start time, prepare chemical-handling equipment for application (e.g., fill liquid chemical tanks or hoppers for salt application). | 12-48 hours and current observation |
| Pavement Temperature (degrees F) | >15-18° but ≤32° | Forecast | Impaired mobility, snow/ice bonding, effects on snow removal/ice treatment operations, loss of traction | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives. | 12-24 hours |
| | <15-18° | Forecast | Impaired mobility, snow/ice bonding, effects on snow removal/ice treatment operations, loss of traction, effects on treatment chemical effectiveness | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Plow snow, apply abrasives. | 12-24 hours |
| | Variable, based on impact criteria | Observation | Impaired mobility, snow/ice bonding, effects on snow removal/ice treatment operations, loss of traction, effects on treatment chemical effectiveness, melting | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Plow snow, apply treatment chemicals/abrasives. | Current observation |

| Weather Needs for Federal Highway Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Forecast/Observation** | **Impacts** | **Action** | **Lead Time** |
| Pavement Condition | Wet | Forecast and observation | Safety risks, impaired mobility, loss of traction, loss of stability/maneuverability | Predict threatened area. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 12 hours and current observation |
| | Snow/slush | Forecast and observation | Safety risks, impaired mobility, loss of traction, loss of stability/maneuverability | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Plow snow. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 12 hours and current observation |
| | Ice | Forecast and observation | Safety risks, impaired mobility, loss of traction, loss of stability/maneuverability | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 12 hours and current observation |
| Chemical Concentration | Variable, based on application, residue | Observation (sensor or mobile infrared) | Safety risks, effects on snow removal/ice treatment operations, snow/ice bonding | Select treatment strategy, apply treatment chemicals/abrasives, deploy and track treatment assets. | Current observation |
| Visibility (statute miles) | <1/4-1/2 mile | Forecast and observation | Safety risk, loss of visibility (due to fog, haze, dust, smoke), impaired mobility | Disseminate warning information to operators and travelers, modify operations, consider fog dispersal options (e.g., $CO_2$ application). | 6-12 hours and current observation |
| Glare | Any | Forecast and observation | Loss of visibility in glare quadrant of horizon | Advise operators, modify operations (reduce speed). | 3 hours and current observation |
| Wind: Head, Cross, Tail (speed in miles per hour) | >30 mph but <50 mph | Forecast | Safety risk, drifting snow, loss of visibility, loss of stability/maneuverability, lane obstruction (debris), road damage, loss of life and property, treatment chemical dispersion, loss of communications/power, toxicity and environmental damage, pavement temperature | Predict threatened area, modify operations, select treatment strategy, develop warning and evacuation plans. Remove debris, repair damage. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 12-24 hours |
| | $\geq$50 mph | Forecast | Safety risk, drifting snow, loss of visibility, loss of stability/maneuverability, impaired mobility, lane obstruction (debris), road damage, loss of life and property, treatment chemical dispersion, loss of communications/power, toxicity and environmental damage, pavement temperature | Predict threatened area, select treatment strategy, restrict/suspend operations, develop warning and evacuation plans. Remove debris, repair damage. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 12 hours |
| Surface Wind Direction | Any speed | Forecast and observation | Drifting snow, wild fire tracking, toxicity and environmental damage, pavement temperature | Predict threatened area, select treatment strategy. Remove debris, repair damage. | 2 hours and current observation |

## Weather Needs for Federal Highway Operations

| Weather Element | Threshold | Forecast/Observation | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Upper Air Winds | Standard levels | Forecast | Air quality, storm cell tracking, toxicity and environmental damage, air stability | Predict threatened area, select treatment strategy. Remove debris, repair damage. | 12 hours and most recent upper air data |
| High Winds | Variable, based on impact criteria | Observation | Safety risk, drifting snow, loss of visibility, loss of stability/maneuverability, impaired mobility, lane obstruction (debris), road damage, loss of life and property, treatment chemical dispersion, loss of communications/power, toxicity and environmental damage | Predict threatened area, select treatment strategy, modify operations, develop warning and evacuation plans. Remove debris, repair damage. Manage traffic flow (e.g. disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | Current observation |
| Wind Chill (degrees F) | $\leq 20^{\circ}$ to $32^{\circ}$ | Forecast and observation | Safety risk (hypothermia, frost bite) | Advise operators, restrict or suspend operations. | 3-6 hours and current observation |
| Heat Index (degrees F) | $>105^{\circ}$ | Forecast | Health and safety risk (heat exhaustion) | Disseminate warning information to operators and travelers. | 12-24 hours |
| | | | | Advise operators, modify/restrict operations. | 3-6 hours |
| Space Weather (solar flares, etc.) | Any | Forecast and observation | Loss of communications/power, impaired GPS location/navigation | Advise operators, monitor communications outages. | 12 hours and current observation |
| Total Sun (insolation) | Total hours | Forecast and observation | Air temperature, pavement temperature, toxicity and environmental damage, air quality | Modify operations. | 12-24 hours and current observation |
| Cloud Cover | Scattered, broken, overcast | Forecast and observation | Air temperature, pavement temperature, toxicity and environmental damage | Modify operations. | 12-24 hours and current observation |
| Water Course Flow Volume (cubic meters per second) | Variable, based on flood stage criteria | Forecast and observation | Flood risk, lane submersion, loss of life and property, road damage | Predict threatened area, select treatment strategy, develop warning and evacuation plans, operate outflow devices. | 12-24 hours and current observation |
| Water Body Depth (feet) | Variable, based on flood stage criteria | Forecast and observation | Flood risk, lane submersion, loss of life and property, road damage | Predict threatened area, select treatment strategy, develop warning and evacuation plans, operate outflow devices. | 12-24 hours and current observation |
| High Surf (wave height in feet) | >8 feet | Forecast and observation | Safety risk, property damage, road damage, evacuation route delays | Predict threatened area, disseminate warning information to operators and travelers. Repair damage. | 12-24 hours and current observation |
| Avalanche Danger | High, moderate, low | Forecast and observation | Impaired mobility, loss of life and property, lane obstruction, effects on snow removal/ice treatment operations | Manage traffic flow (close roadways), modify operations, release avalanche, remove snow. | 12-24 hours and current observation |
| Seismic Activity | Any seismic activity | Forecast and observation | Road damage, property damage, impaired mobility, loss of life and property | Manage traffic flow, modify operations, remove debris, repair damage. | 12-24 hours and current observation |

| Weather Needs for Federal Highway Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Forecast/Observation** | **Impacts** | **Action** | **Lead Time** |
| Volcanism | Any volcanic activity | Forecast and observation | Road damage, property damage, impaired mobility, loss of life and property, air quality | Manage traffic flow, modify operations. | 12-24 hours and current observation |
| Soil moisture | Saturated, unsaturated | Forecast and observation | Flood risk, road/pavement damage, pavement condition | Select treatment strategy. | 12-24 hours and current observation |
| Fire | Any fire event or activity | Forecast and observation | Loss of visibility, loss of life and property, air quality | Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). | 12-24 hours and current observation |
| Fair Weather | 1 to 10 days (variable, based on impact criteria) | Forecast | Operations planning (Forecasts of good or bad weather aid managers in deploying raod crews efficiently on short and long term weather-sensitive operations with specific time constraints. Crews work year round with no reserve personnel, and mobilization is required for some tasks. Work details vary day to day; undertaking tasks that require good weather depends on how much good weather is anticipated.) | Modify operations. Examples: (1) Ditching requires removing the sanders, mounting a truck box, and replacing the blower attachment on a loader with a bucket. These jobs would probably take 2 days. Such actions cannot be started without a forecast of 10 days of good (non-snow) weather because of the time needed to reconvert the equipment. (2) In urban areas, snow hauling is necessary following a storm. The same amount of work is needed to clean up after a 6-inch fall as a 12-inch one. If good weather is forecast following a 6" snow event, hauling might be started. If another snow event is forecast within several days, hauling may be delayed. | 24-48 hrs |
| Nuclear, Biological, or Chemical Release | Any | Forecast and observation | Health and safety risk (potential severe threat to life), dispersion of hazardous materials | Close/detour roadways. Assist in Atmospheric Transport and Diffusion and HAZMAT response operations. | 1-3 hours and current observation |

# Appendix B - 2

## *Long Haul Rail*

## Long-Haul Railway Activities

**Railway/control center operations.** The control center monitors the railroad system and advises train and station operators and dispatchers. It controls system integrity.
**Station and depot operations.** Operations at and in the vicinity of stations, involving tracks, rolling stock, and platforms.
**Hump yard operations.** Includes maintenance, inspections, and local operations.
**Construction.** Includes scheduling, maintenance, and repair activities.
**Hazardous material.** Includes monitoring the transport and handling of materials, as well as mitigation, reclamation, and reporting of events or incidents.
**Surveillance**. Includes inspections, monitoring, and maintenance of trackage, supporting structure, and facilities.
**Personnel safety.** Safety of train crews, station and depot personnel, and passengers.

| Weather Needs for Long-Haul Railway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Freezing Precipitation (ice, inches) | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing ice off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, possible malfunction of track sensors and signal sensors, possible signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.) | Advise and update dispatch centers, crews, and stations. Predict affected areas, review and prepare treatment options. Initiate ice/snow plan, choose applicable chemical treatment, if warranted. Modify operations to forecast conditions. Plan for reroute if feasible, plan for slowing or stopping, consider delayed departures. Inspect tracks, repair as necessary. Distribute advisories and updates regarding weather situation and track conditions. Prepare to initiate crew recall or re-crew notification. | 24 hours |
| | | | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing ice off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, possible malfunction of track sensors and signal sensors, possible signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.), increased attention to hazardous material (monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Predict affected areas, prepare treatment options, initiate and execute ice/snow plan, apply chemical treatment if warranted. Modify operations for conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks, repair as necessary. Publish and distribute advisories and updates warning of weather situation and track conditions. Initiate crew recall and re-crew notification. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 6 hours |
| Frozen Precipitation (snow, inches) | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, possible malfunction of track sensors and signal sensors, possible signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.) | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, review and prepare treatment options, initiate ice/snow plan, apply chemical treatment if warranted. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks, repair as necessary. Publish and distribute advisories and updates warning of weather situation and track conditions. Make preparations for or initiate crew recall or re-crew notification. | 24 hours |
| Frozen Precipitation (snow, inches) | $\geq$2 and <6 inches | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), possible malfunction of track sensors or signal sensors, possible signal malfunctions, rail inspection crews may be required, signal maintenance crew may be required | Advise and update dispatch centers, crews, and stations. Predict affected areas, review and prepare treatment options, review ice/snow plan (if warranted), apply chemical treatment if warranted. Review procedures for the conditions present or forecast. Distribute advisories and updates warning of weather situation and track conditions. Review crew recall plan. | 24 hours |
| | | | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), possible malfunction of track sensors or signal sensors, possible signal malfunctions, rail inspection crews may be required, signal maintenance crew may be required, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise and update dispatch centers, crews, and stations. Predict affected areas, implement treatment options, review and initiate ice/snow plan (if warranted), apply chemical treatment as appropriate. Review procedures for current or forecast conditions. Distribute advisories and updates warning of weather situation and track conditions. Initiate crew and re-crew recall plan. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 6 hours |

## Weather Needs for Long-Haul Railway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Frozen Precipitation (snow, inches) | ≥6 and <8 inches | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Restricted ability of employees to get to work, impedeed/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, probable malfunctions of track sensors and signal sensors, probable signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting), potential increase in ridership (Passenger service increases because roadway mode may not be viable.) | Advise and update dispatch centers, crews, and stations. Predict affected areas, implement treatment options, execute ice/snow plan, apply chemical treatment as appropriate. Review and modify operations to conditions present or forecast. Inspect tracks. Publish and distribute advisories, warnings, and updates regarding weather situation and track conditions. Prepare for crew recall and/or re-crew notification/recall. | 24 hours |
| | | | Restricted ability of employees to get to work, impedeed/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, probable malfunctions of track sensors and signal sensors, probable signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting), potential increase in ridership (Passenger service increases because roadway mode may not be viable.) | Warn and update dispatch centers, crews, and stations. Outline affected areas, prepare and implement treatment options, initiate ice/snow plan, apply chemical treatment as appropriate. Prepare for and initiate crew recall, re-crew notification/recall. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 6 hours |
| Frozen Precipitation (snow, inches) | ≥8 | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Restricted ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety when boarding and leaving train), train speed reductions with attendant delays, switch failure likely, malfunctions of track sensors or signal sensors likely, signal malfunction likely, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.) | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, prepare treatment options, execute ice/snow plan, apply chemical treatment if warranted. Review and modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks and repair as necessary. Distribute advisories, warnings, and updates regarding weather situation and track conditions. Initiate and execute crew recall, re-crew notification. | 24 hours |
| | | | Restricted ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety when boarding and leaving train), train speed reductions with attendant delays, switch failure likely, malfunctions of track sensors or signal sensors likely, signal malfunction likely, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.), increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise, warn, and update dispatch centers, crews, and stations. Outline affected areas, review and initiate treatment options, execute ice/snow plan, apply chemical treatment as appropriate. Review and modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks and repair as necessary. Distribute advisories and updates warning of weather situation and track conditions. Initiate/execute crew recall and re-crew notification/recall. If HAZMAT spill occurs, initiate reaction/mitigation plan. | 6 hours |
| Drifting Snow (inches) | ≥8 | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, possible malfunction of track sensors and signal sensors, possible signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.) | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, prepare treatment options, execute ice/snow plan, apply chemical treatment if warranted. Review and modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks and repair as necessary. Publish and distribute advisories and updates warning of weather situation and track conditions. | 24 hours |

## Weather Needs for Long-Haul Railway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | | Reduced ability of employees to get to work, impeded/restricted foot traffic and road use by inspection crews, transportation platform safety (clearing snow off platform, passenger safety boarding and leaving train), train speed reductions with attendant delays, possible switch failure, possible malfunction of track sensors and signal sensors, possible signal malfunction, rail inspection crews may be required, signal maintenance crew may be required, potential increase in ridership (Passenger service increases because other modes are not available.), increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise, warn, and update dispatch centers, crews, and stations. Identify affected areas, initiate treatment options, execute ice/snow plan, apply chemical treatment, as appropriate. Review and modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Publish and distribute advisories and updates warning of weather situation and track conditions. Initiate/execute crew recall, re-crew notification/recall. Inspect tracks and repair as necessary. If HAZMAT spill occurs, initiate reaction/mitigation plan. | 6 hours |
| Liquid Precipitation | Heavy | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work; possible train speed reductions with attendant delays; possible malfunctions of track sensors or signal sensors; possible wash-outs, slides, or high water impacts; potential signal malfunctions; rail inspection crews may be required; signal maintenance crew may be required; possible missed signals due to reduced visibility in heavy rain; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise, warn, and update dispatch centers, crews, and stations. Identify affected areas, stage equipment and inspection teams. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks and repair as necessary. Distribute warnings and updates regarding the weather situation and track conditions. Review and initiate crew recall, re-crew notification/recall. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 6 hours |
| Flooding | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work; possible train speed reductions with attendant delays; possible malfunctions of track sensors or signal sensors; possible wash-outs, slides, or high water impacts; potential signal malfunctions; rail inspection crews may be required; signal maintenance crew may be required; possible missed signals due to reduced visibility in heavy rain | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, outline affected areas for pre-staging of equipment and inspection crews. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks and repair as necessary. Distribute advisories and updates warning of weather situation and track conditions. Review and initiate crew recall, re-crew notification/recall. | 24 hours |
| | | | Reduced ability of employees to get to work; possible train speed reductions with attendant delays; possible malfunctions of track sensors or signal sensors; possible wash-outs, slides, or high water impacts; potential signal malfunctions; rail inspection crews may be required; signal maintenance crew may be required; possible missed signals due to reduced visibility in heavy rain; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise, warn, and update dispatch centers, crews, and stations. Outline affected areas, stage response teams and equipment. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks and repair as necessary. Distribute advisories and updates warning of weather situation and track conditions. Initiate/execute crew recall, re-crew notification/recall. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| Thunderstorms with Wind, Lightning, or Hail (hail size, proximity to route or operational area in miles) | >1/4 inch, ≤5 miles | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Refueling operations delayed, track signal sensor malfunction resulting in possible train delays and stops, crew safety (delay or suspend operations), increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise, warn, and update dispatch centers, crews, and stations. Predict/define affected areas. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks, track sensors, and signals. Publish and distribute advisories and updates warning of weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| | | | Refueling operations delayed, track signal sensor malfunction resulting in possible train delays and stops, crew safety (delay or suspend operations), increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute warnings and updates regarding weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 30 minutes |

| Weather Needs for Long-Haul Railway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Thunderstorms with Tornadoes (proximity to route or operational area in miles) | $\leq$5 miles | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Reduced ability of employees to get to work, possible train speed reductions with attendant delays, possible malfunctions of track sensors and signals, possible damage to track and/or signals, rail inspection crews may be required, signal maintenance crew may be required, crew, personnel and passenger safety, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise, warn, and update dispatch centers, crews, and stations. Predict/define affected areas. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect tracks, track sensors, and signals. Publish and distribute advisories and updates warning of weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| | | | Reduced ability of employees to get to work, possible train speed reductions with attendant delays, possible malfunctions of track sensors and signals, possible damage to track and/or signals, rail inspection crews may be required, signal maintenance crew may be required, crew, personnel and passenger safety, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas. Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute wanings and updates regarding weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 30 minutes |
| Air Temperature (degrees F, first occurrence of season) | $\leq 32^{o}$ | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | increased rail contraction and rail warning signals (The first time each season that the air temperature drops to or below $32^{o}$ F causes occurrence of track warning signals and potential for derailment.); possible malfunction of track sensors and signals; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; crew, personnel, and passenger safety | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Inspect and repair tracks, track sensors, and signals as needed. Distribute advisories, warnings, and updates regarding weather situation and track conditions. | 3 days |
| | | | Increased rail contraction (The first time each cold season that the air temperature drops to or below 32o F causes rail contractions with increased occurrence of track warning signals and potential for derailment.); possible malfunction of track sensors and signals; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; crew, personnel, and passenger safety; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas, stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute advisories, warnings, and updates regarding the weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| Air Temperature (degrees F, first occurrence of season) | $>70^{o}$-$75^{o}$ | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Increased rail expansion (The first time each warm season that the air temperature rises to or above 70-$75^{o}$ F, rail expansion causes increased numbers of track warning signals and potential for derailment.); possible malfunction of track sensors and signal sensors; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; crew, personnel, and passenger safety. | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Inspect and repair tracks, track sensors, and signals as needed. Distribute advisories, warnings, and updates regarding weather situation and track conditions. | 3 days |
| | | | Increased rail expansion (The first time each warm season that the air temperature rises to or above 70-$75^{o}$ F, rail expansion causes increased numbers of track warning signals and potential for derailment.); possible malfunction of track sensors and signal sensors; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; crew, personnel, and passenger safety; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas, stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute advisories, warnings, and updates regarding the weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |

| Weather Needs for Long-Haul Railway Transportation | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Air Temperature (degrees F) | ≤0° | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Continued risk of track contraction, potential for derailment, possible malfunction of track sensors and signal sensors, possible track and/or signal damage, rail inspection crews may be required, signal maintenance crew may be required, health and safety risks (hypothermia, frost bite likely) | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Inspect and repair tracks, track sensors, and signals as needed. Distribute advisories, warnings, and updates regarding weather situation and track conditions. | 24 hours |
| | | | Continued risk of track contraction, potential for derailment, possible malfunction of track sensors and signal sensors, possible track and/or signal damage, rail inspection crews may be required, signal maintenance crew may be required, health and safety risks (hypothermia, frost bite likely), increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas, stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute advisories, warnings, and updates regarding the weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| Air Temperature (degrees F) | ≥90° | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Continued risk of track expansion potential for derailment, possible malfunction of track sensors and signal sensors, possible track and/or signal damage, rail inspection crews may be required, signal maintenance crew may be required, health and safety risks (heat exhaustion likely) | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Inspect and repair tracks, track sensors, and signals as needed. Distribute advisories, warnings, and updates regarding weather situation and track conditions. | 24 hours |
| | | | Continued risk of track expansion potential for derailment, possible malfunction of track sensors and signal sensors, possible track and/or signal damage, rail inspection crews may be required, signal maintenance crew may be required, health and safety risks (heat exhaustion likely), increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas, stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute advisories, warnings, and updates regarding the weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| Rail Temperature (degrees F) | ≤32° with moisture | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Safety and damage risks (Continued risk of track contraction exists when rail temperature drops to or less than 32° F.), potential for derailment, possible malfunction of track sensors and signal sensors, possible track and/or signal damage, rail inspection crews may be required, signal maintenance crew may be required, health and safety risks (hypothermia, frost bite possible) | Advise and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Distribute advisories and updates regarding weather situation and track conditions. | 24 hours |
| | | | Safety and damage risks (Continued risk of track contraction exists when rail temperature drops to or less than 32° F.), potential for derailment, possible malfunction of track sensors and signal sensors, possible track and/or signal damage; rail inspection crews may be required, signal maintenance crew may be required, health and safety risks (hypothermia, frost bite possible) | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Distribute advisories, warnings, and updates regarding weather situation and track conditions. | 12 hours |
| Rail Temperature (degrees F) | ≥110° | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Continued risk of track expansion when rail temperature rises to or above 110° F (~20° to 30° F above the neutral installation temperature); potential for derailment; possible malfunction of track sensors and signal sensors; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; crew, personnel, and passenger safety | Advise, warn, and update dispatch centers, crews, and stations. Predict affected areas, pre-stage resources (equipment and crews). Modify operations for current or forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Review maintenance records to determine areas susceptible to track motion. Inspect and repair tracks, track sensors, and signals as needed. Distribute advisories, warnings, and updates regarding weather situation and track conditions. | 2-3 days |
| | | | Continued risk of track expansion when rail temperature rises to or above 110° F (~20° to 30° F above the neutral installation temperature); potential for derailment; possible malfunction of track sensors and signal sensors; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; crew, personnel, and passenger safety; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Warn and update dispatch centers, crews, and stations. Define affected areas, stage resources (equipment and crews). Modify operations for current and forecast conditions. Slow or stop trains, reroute if feasible, delay departure from station. Inspect and repair tracks, track sensors, and signals. Distribute advisories, warnings, and updates regarding the weather situation and track conditions. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |

# Weather Needs for Long-Haul Railway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Soil Temperature, Freezing or Thawing Trend (degrees F) | Decreasing to <32° or increasing to >32° | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations**: monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Risk of railbed motion/movement from ground heave (Ground heave is most prevalent during autumn freezes and spring thaws.), construction and inspection delays likely, possible failure of track and railbed; possible derailment; increased risk of HAZMAT incidents, public relations effects | Issue advisories to rail management and operators. Consider increasing rail remote sensing interval or physical inspection. Schedule additional system monitoring queries, assign additional crews/re-crews as required. Initiate alternative construction/ maintenance work schedule. Ensure personnel have proper clothing and footwear for snow and ice. Consider the effects of topography and failure location for remediation and reclamation. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 6 hours |
| Wind Chill (degrees F) | ≤-20° | **Construction**: scheduling, maintenance, repair. **Personnel Safety** **Railway/Control Center Operations:** monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. | Crew, personnel, and passenger safety (hypothermia, frost bite); potential operational delays. | Advise operators, monitor personnel, modify or restrict operations. Plan to increase available manpower. Insist that crews are clothed appropriately for cold weather and ensure that other cold weather gear is available. | 24 hours |
| | | | Crew, personnel, and passenger safety (hypothermia, frost bite); potential operational delays. | Advise operators, monitor personnel, modify or restrict operations. Limit personnel time outside, increase available manpower. Insist that crews are clothed appropriately for cold weather. | 12 hours |
| Heat Index (degrees F) | ≥105° | **Construction**: scheduling, maintenance, repair. **Personnel Safety** **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations**: monitor local operations, advise Control Center. **Hump Yard Operations**: maintenance, inspections, local operations, advise Control Center. | Safety and health risk (heat exhaustion), potential operational delays | Advise operators, break shifts, restrict or suspend operations. Plan to increase available manpower, insist that crews are clothed appropriately for hot weather. | 24 hours |
| | | | Safety and health risk (heat exhaustion), potential operational delays | Advise operators, break shifts, restrict or suspend operations. Limit personnel time outside, increase available manpower. Insist that crews are clothed appropriately for hot weather. | 12 hours |

## Weather Needs for Long-Haul Railway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Visibility, including Restriction (statute miles) | $\leq$1 mile, <1/2 mile | **Railway/Control Center Operations**: monitor, advise, control system integrity.<br>**Station & Depot Operations:** monitor local operations, advise Control Center.<br>**Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center.<br>**Construction:** scheduling, maintenance, repair.<br>**Hazardous Material:** monitoring, mitigation, reclamation, reporting.<br>**Surveillance:** inspections, monitoring, maintenance.<br>**Personnel Safety** | Crew, personnel and passenger safety risks; missed signals, obstructions on track, etc.; increasing risks of collisions and derailments; reduced speed; delays in service; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise operators, reduce speeds or stop trains, modify operations. If HAZMAT incident occurs, initiate spill reaction/mitigation plan. | 12 hours |
| | | | Crew, personnel and passenger safety risks; missed signals, obstructions on track, etc.; increasing risks of collisions and derailments; reduced speed; delays in service; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise operators, reduce speeds or stop trains, modify operations. If HAZMAT incident occurs, initiate spill reaction/mitigation plan. | 6 hours |
| Wind: Head, Cross, or Tail (wind speed in miles per hour) | $\geq$50 mph | **Railway/Control Center Operations**: monitor, advise, control system integrity.<br>**Station & Depot Operations:** monitor local operations, advise Control Center.<br>**Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center.<br>**Construction:** scheduling, maintenance, repair.<br>**Hazardous Material:** monitoring, mitigation, reclamation, reporting.<br>**Surveillance:** inspections, monitoring, maintenance.<br>**Personnel Safety** | Crew, personnel, and passenger safety risks; damage risk; rail car blow over likely; schedule delays; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise operators/operations, review options, restrict or suspend operations. If HAZMAT incident occurs, initiate HAZMAt spill reaction/mitigation plan. | 12 hours |
| | | | Crew, personnel, and passenger safety risks; damage risk; rail car blow over likely; schedule delays; possible track and/or signal damage; rail inspection crews may be required; signal maintenance crew may be required; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise operators/operations, review options, restrict or suspend operations. If HAZMAT incident occurs, initiate spill reaction/mitigation plan. | 1 hour |
| Hurricane: Winds, Sea State, Tidal Surge, Flooding | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity.<br>**Station & Depot Operations:** monitor local operations, advise Control Center.<br>**Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center.<br>**Construction:** scheduling, maintenance, repair.<br>**Hazardous Material:** monitoring, mitigation, reclamation, reporting.<br>**Surveillance:** inspections, monitoring, maintenance.<br>**Personnel Safety** | Safety risks to personnel and equipment (possible injury or death from accidents); railway roadbed scoured, buried, damaged or destroyed; rail damage from line stretch and foreign debris impact; winds, seas, tides may restrict or suspend coastal rail traffic; rail sensor failure likely; possible railbed or track failures and derailments; increased monitoring of crews and equipment required; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting); potential for disrupted construction or maintenance cycles; public relations effects | Acquire hurricane advisories and/or warnings. Issue advisories and/or warnings to rail management and operators. Increase the number of visual inspections and rail remote monitoring efforts. Increase rail surveillance; check for bridge, trestles, railbed integrity. Consider the effects of topography and failure location for remediation and reclamation. Assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Restrict or suspend rail operations. Reschedule, restrict, or suspend aerial and vehicle track inspections based on weather safety. Initiate alternate construction/maintenance work schedule. Ensure proper clothing and footwear are worn by crews for slick and flooded walkways and road surfaces. | 12-24 hours |
| Earthquake: Land Motion, Landslides, Avalanches, Etc. | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity.<br>**Station & Depot Operations:** monitor local operations, advise Control Center.<br>**Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center.<br>**Construction:** scheduling, maintenance, repair.<br>**Hazardous Material:** monitoring, mitigation, reclamation, reporting.<br>**Surveillance:** inspections, monitoring, maintenance.<br>**Personnel Safety** | Safety risks to personnel and equipment (accidents are likely with possible injury or death); railway roadbed scoured, buried, damaged or destroyed; rail damage from line stretch and foreign debris impact likely; rail sensor failure likely; increased monitoring of crews and equipment; increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting); public relations effects | Issue advisories to rail management and operators. Increase the number of visual inspections and rail remote monitoring efforts. Consider the effects of topography and derailment location for remediation and reclamation. Schedule additional system monitoring queries, assign additional crews/re-crews, as required. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc) based on impact of land motion. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12-24 hours and current observation |

## Weather Needs for Long-Haul Railway Transportation

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Nuclear, Biological or Chemical Release | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | Safety risks to personnel and equipment; increased monitoring of crews and equipment (During a rail failure, vapors and toxins are released to the envrionment with possible/likely catastrophic results. Accidents are likely with possible injury or death.) | Acquire output from atmospheric transport & diffusion model depicting the horizontal and vertical distribution of the toxin or vapor. Issue advisories and/or warnings to rail management and operators. Initiate/execute HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. | 1-3 hours and current observation |
| Space Weather (solar flares etc.) | Any | **Railway/Control Center Operations**: monitor, advise, control system integrity. **Station & Depot Operations:** monitor local operations, advise Control Center. **Hump Yard Operations:** maintenance, inspections, local operations, advise Control Center. **Construction:** scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance:** inspections, monitoring, maintenance. **Personnel Safety** | GPS navigation disrupted, radio/cellular phone communications disrupted, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise operators, monitor communication interruptions. Prepare for alternate communications methods. | 2-3 days |
| | | | GPS navigation disrupted, radio/cellular phone communications disrupted, increased risk of hazardous material spill (increased monitoring, mitigation, reclamation, reporting) | Advise operators, monitor communication interruptions. Initiate alternate communications methods. | 12 hours |

# Appendix B–3

## *U.S. Marine Transportation System WIST Needs Template*

## U.S. Marine Transportation System Sector Activities

**Inland water activities**

Ferries

Commerce. Includes barge traffic on major rivers.

Recreational Boating. Includes fresh water lakes, rivers and streams.

**Open water activities**

Cargo/freight. Includes large ocean-going vessels, including U.S. Navy ships

Cruise lines

Commercial fishing. Primarily includes near-shore and off-shore salt water operations.

Recreational Boating. Salt-water operations.

**Port operations.** Operations include keeping port facilities open and safe movement of vessels in and out.

**St. Lawrence Seaway operation.** Operation of locks and canals, control of navigation and movement of vessels.

**NASA movement of launch vehicle/payload elements via barge.** Primarily external fuel tank and solid rocket boosters moving to and from the launch facility.

**Marine Modeling.** Forecasting oceanographic conditions for waterway and coastal operations to specifically improve predictions of water levels to facilitate ships entering/leaving ports.

| Weather Needs for the Marine Transportation System, including Inland Waterway and Open Water Activities | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Freezing Rain | Any | All inland activities (ferries, boating, commerce), all open water activities (boating, cargo/freight, cruise lines, and fishing) | Possible injury to personnel because of ice covered decks and walkways, impaired equipment operation due to ice cover, line handling difficult because of ice, schedule delays due to time required for ice removal | Take precautions such as limiting ondeck activities. Cover equipment to keep it clear of ice. Avoid operating during periods or in areas of freezing rain. | 12 hours/ current observation |
| | | NASA movement of launch vehicle and payload elements via barge | Risk to personnel, equipment and cargo from ice buildup | Consider restricting ondeck activities. Cover equipment and cargo. Delay barge movement. | 12 hours |
| | | St. Lawrence Seaway operations | Vessel lockage operations delayed/suspended (dangerous conditions for lock linehandlers) | Apply sand and salt to surfaces. | 12 hours |
| | | Port operations | Difficult ground travel, cargo handling, equipment operation, etc., because of ice | Implement snow/ice emergency plan. | 12 hours/ current observation |
| Snow (inches) | Any | All inland activities (ferries, boating, commerce), all open water activities (boating, cargo/freight, cruise lines, and fishing) | Possible injury to personnel from snow-covered decks and walkways, reduced visibility (depending on rate of snowfall), impaired equipment operation | Take precautions such as limiting ondeck activities. Cover equipment to keep the equipment clear of snow. | 12 hours/ current observation |
| | Any | NASA movement of launch vehicle and payload elements via barge | Risks to personnel, equipment, and cargo from snow buildup | Consider restricting ondeck activities. Cover equipment and cargo. Delay barge movement. | 12 hours |
| | >4 inches | Port operations | Difficult ground travel, cargo handling, equipment operation, etc., because of snow | Implement snow/ice emergency plan. | 24 hours/ 12 hours |
| | Heavy | St. Lawrence Seaway operations | See Visibility weather element | If equipped with radar, use it for navigation and maintaining clearance. Otherwise exercise extra vigilance and reduce speed as conditions require. | 24 hours/ 12 hours |
| Drifting Snow | Any | Port operations | Travel difficult due to blowing snow and reduced visibility, snow clearing operations hampered | Impement snow/ice emergency plan. | 6 hours |
| Rain (intensity) | Heavy | All inland activities (ferries, boating, commerce) | Impaired operations due to reduced visibility, danger to personnel, and equipment from flooding | Exercise caution and reduce speed. If visibility is reduced below 1 statute mile, modify or delay operations until conditions improve. | 6 hours/ current observation |
| | | All open water activities (boating, cargo/freight, cruise lines, and fishing) | Operations impaired by reduced visibility | Increase vigilance and reduce speed as conditions require. | 6 hours/ current observation |
| | | NASA movement of launch vehicle and payload elements via barge | Operations impaired by reduced visibility | Increase vigilance and reduce speed as conditions require. | 12 hours |
| | | St. Lawrence Seaway operations | Visual navigation restricted, risk of collisions increased | If equipped with radar, use it for navigation and maintaining clearance. Otherwise exercise extra vigilance and reduce speed as conditions require. | 24 hours/ 12 hours |
| | | Port operations | Flooding possible | Move equipment to high ground and take precautions. | 12 hours |
| | Any | Marine modeling | Freshwater inputs important to models | Improve model results by making more data available. | 48 hours |
| Flooding | Any | All inland activities (ferries, boating, commerce) | Danger to all inland activities, including lock operations, from high water levels and swift currents | Restrict/suspend operations until the flood threat has passed. | 24 hours |

| Weather Needs for the Marine Transportation System, including Inland Waterway and Open Water Activities | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | NASA movement of launch vehicle and payload elements via barge | Potential problems in handling barges because of high water levels and swift currents | Restrict/suspend operations until the flood threat has passed. | 12 hours |
| | | Port operations | Operations disrupted, facilities damaged | Implement emergency procedures. | 48 hours |
| | | Marine modeling | Modeling of estuarine dynamics affected by freshwater ir | Make more data available (e.g., hydrologic models and the real-time data needed to provide boundary conditions for estuarine models). | 24-48 hours |
| | | | | | |
| Storm Surge or Abnormal High/Low Tides | Any | Port operations | Potential damage to port facilities from flooding and from vessals tied alongside | Exercise extra vigilance in tending mooring lines for ships alongside. Decide whether large ships should put to sea. | 24 hours |
| | | Recreational boating | Potential damage to moored boats | Arrange mooring lines for significantly higher water levels. | 24 hours |
| | | Ferries | Increased potential for groundings, potential damage t docks and terminals, impaired accessibility for passengers (particularly those with disabilities) | Modify operations as required. | 12 hours |
| | | Marine modeling | Estuarine models affected by coastal boundary conditions | Iimprove model results by making more data on boundary conditions available. | 48 hours |
| | | | | | |
| Wind Wave Height (feet) | 2 to 4 feet | Inland recreational boating | Reduced passenger comfort, increased risk to small boats | Warn small boats to exercise caution. | 12 hours/ current observation |
| | | Open water recreational boating | Reduced passenger comfort, increased risk to small boats | Exercise caution, adjust speed accordingly. | 12 hours/ current observation |
| | 4 to 6 feet | Inland recreational boating, ferries, and commerce | Potential safetly risks to crew and passenge; potential hull damage to small boats; open barges may take on water, depending on loading | Exercise extreme caution, stop small boat activities. Advise passengers. Modify ferry operations. Reduce speed or suspend operations. | 12 hours/ current observation |
| | | Open water recreational boating, open water cruise lines | Risks to personnel, possible hull damage, reduced passenger comfort | Boats should reduce speed, exercise caution. Advise passengers. | 12 hours |
| | | Port operations | Possible damage to port facilities | Implement emergency procedures. | 12 hours |
| | 6 to12 feet | Inland ferries | Safety risk to crew and passegers, damage risk to cargo | Advise passengers, secure cargo. | 24 hours/ current observation |
| | | Open water recreational boating, cargo/freight, cruise lines, and fishing | Safety risk to crew and passengers | If encounter unavoidable, adjust course/speed for best ride. Ensure cargo is secure, consider restricting ondeck activities. | 24 hours/ current observation |
| | | Port operations | Likely damage to port facilities | Implement emergency procedures. | 24 hours |
| | $\geq$10 feet | NASA movement of launch vehicle and payload elements via barge | Risk to personnel, possible damage to very sensitive, high value space program resources | Consider delaying movements until conditions improve. | 24 hours |
| | $\geq$12 feet | Open water cargo/freight, cruise lines, and fishing | Safety risk to crew and passengers, potential for damage to cargo and structural damage to the ship | Ensure cargo is secure. Consider restricting personnel fron weather decks. Ensure freeing ports are clear. Adjust speed/course for best ride. Implement Heavy Weather Bill. | 24 hours |
| | Any | Marine modeling | Wave effects on model dynamics, mixing | Include waves in models to improve model results. | 48 hours |
| | | | | | |
| Inland Waterway Ice (coverage) | Any | All inland activities (ferries, boating, commerce) | All activities threatened by potential hull damage from ice | Change course and/or speed to avoid areas of ice. Request ice breaking services. | 12 hours/ current observation |

| Weather Needs for the Marine Transportation System, including Inland Waterway and Open Water Activities | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| River Ice, Ice Gorging (coverage) | Any | Inland commerce | Damage risk to vessels, vessels may become icebound | Reduce tow size for better maneuverability. Stop operation if conditions prevent safe passage. Request ice breaking services. | 12 hours/ current observation |
| Open Water Sea Ice | Any | All open water activities (cargo/freight, cruise lines, and fishing) | All activities threatened by potential hull damage from sea ice | Change course and/or speed to avoid areas of ice. | 12 hours |
| | | Port operations | Possible damage to port facilities including docks, piers, and watercraft | Be prepared to keep ice away from facilities. | 24 hours |
| Freezing Spray (seas and low temperature) | Any | All open water activities (boating, cargo/freight, cruise lines, and fishing) | Reduced stability, ice loading may exceed maximum weight limit | Change heading and/or speed to reduce amount of spray. Remove as much ice as possible. If conditions do not improve, seek shelter. | 12 hours/ current observation |
| Thunderstorms with Lightning or Hail (distance from operation in statute miles) | 5 statute miles | All inland activities (ferries, boating, commerce) | Risk to personnel from lightning, potential damage to damage to cargo and injury to crew and passengers from hail, threats to barge tow equipment and personnel from reduced visibility and wind | Stop boating activities. Exercise caution. Stop refueling. Stop outside work, reduce speed. | 3 hours/ current observation |
| Thunderstorms with Lightning or Hail (distance from operation in nautical miles) | 5 nautical miles | All open water activities (boating, cargo/freight, cruise lines, and fishing) | Risk to personnel from lightning, potential damage to cargo and injury to crew and passengers from hail, impaired ability to see and be seen from reduced visibility | Delay departure until storm has passed. Adjust course and speed to avoid storm. Consider restricting personnel from weather decks. | 3 hours/ current observation |
| | | NASA movement of launch vehicle and payload elements via barge | Potential for injury to personnel, possible damage to very sensitive, high value space program resources | Delay departure until conditions improve. Restrict outside activities. Adjust course and speed to avoid storm if possible. | 3 hours |
| | | Port operations | Safety risk to personnel, damage risk to port facilities | Implement wind/hurricane/tornado emergency plan. | 3 hours/ current observation |
| Thunderstorms with Tornado or Waterspout (distance from operation in statute miles) | 25 statute miles | All inland activities (ferries, boating, commerce) | Serious threat to all inland activities from tornadoes or waterspouts | Adjust course and/or speed to avoid storm. | 3 hours/ current observation |
| Thunderstorms with Tornado or Waterspout (distance from operation in nautical miles) | 20 nautical miles | All open water activities (boating, cargo/freight, cruise lines, and fishing) | Serious threat to all open water activities from waterspouts | Adjust course and/or speed to avoid storm. | 3 hours/ current observation |
| | | Port operations | Safety risk to personnel, damage risk to port facilities | Implement wind/hurricane/tornado emergency plan. | 3 hours/ current observation |
| Air Temperature (degrees F) | $\leq 32^{o}$ | Inland ferries and commerce | Risks to crew, passengers, and equipment | Ensure that proper clothing is available. Monitor equipment. | 12 hours |
| | | Open water cargo/freight, cruise lines, and fishing | Health hazard to personnel, equipment operation impaired | Ensure proper clothing is available for personnel. Ensure equipment is properly maintained for cold weather operations. | 12 hours |
| | | Port operations | Risk to operators and equipment | Ensure that proper clothing is available. Monitor equipment. | 24 hours |
| | $\geq 90^{o}$ | All MTS activities (10) | Risk to personnel from heat exhaustion, risk to equipment from overheating | Advise operators. Ensure proper clothing and water are available. Monitor equipment and limit outside activities. | 12 hours |

## Weather Needs for the Marine Transportation System, including Inland Waterway and Open Water Activities

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | $\geq 90^\circ$ | NASA movement of launch vehicle and payload elements via barge | Risk to personnel from heat exhaustion, risk to equipment from overheating, possible damage to very sensitive, high value space program resources | Advise operators. Ensure proper clothing and water are available. Monitor equipment and limit outside activities. Protect cargo. | 12 hours |
| | All | Marine modeling | Air temperature effects on heat flux in models | Include data on air temperature and modeling of heat flux interactions to improve model results. | 48 hours |
| | | | | | |
| Water Temperature (degrees F) | $\leq 32^\circ$ | All inland activities (ferries, boating, commerce) | Threat to all inland activities if waterways freeze over | Monitor water conditions and modify/restrict operations as required. | 24 hours/ current observation |
| | | St. Lawrence Seaway operations | Underpowered vessels may become icebound | Restrict certain vessels from operating, based on their power-to-length ratio. | 24 hours |
| | All | Marine modeling | Water temperature important as initial condition for models | Improve model results by incorporating water temperature data. | Current observation |
| | | | | | |
| Heat Index (degrees F) | $\geq 105^\circ$ | All MTS activities (10) | Risk to personnel from heat exhaustion | Ensure that personnel wear proper clothing, drink water, and limit exposure. | 12 hours |
| | | | | | |
| Wind Chill (degrees F) | $\leq 20^\circ$ | All MTS activities (10) | Risk to personnel from hypothermia and frost bite | Ensure that personnel wear proper clothing and limit exposure. | 12 hours |
| | | | | | |
| Visibility (statute miles) | 1 statute mile | Inland recreational boating | Visual navigation restricted, risk of collisions increased | If equipped with radar, use it for navigation and maintaining clearance. Otherwise exercise extra vigilance and reduce speed as conditions require. | 6 hours/ current observation |
| | 3 statute miles | Inland ferries | | | |
| | 1 mile or less | Inland commerce | | | |
| Visibility (nautical miles) | $\leq$1/8 nautical mile | NASA movement of launch vehicle and payload elements via barge | No movement when visibilities are below threshold | Wait for improved conditions. | 24 hours/ current observation |
| | 3 nautical miles | All open water activities (boating, cargo/freight, cruise lines, and fishing) | Reduced ability to maintain visual clearance, visual navigation restricted | If equipped with radar, use it for navigation and maintaining clearance. Otherwise exercise extra vigilence and reduce speed as conditions require. | 6 hours/ current observation |
| | 1 nautical mile | Port operations | Reduced ability to maintain visual clearance | Consider delaying ship movement (departures and arrivals). | 6 hours/ current observation |
| | 1/4-1/2 nautical mile | St. Lawrence Seaway operations | Reduced ability to maintain visual clearance | Suspend two-way navigation. Continue one-way navigation. | 6 hours/ current observation |
| | $\leq$1/4 nautical mile | | Reduced ability to maintain visual clearance | Stop all vessel movements. | Current observation |
| | | | | | |
| Glare | Any | All MTS activities | Difficult to see for navigation and avoidance | Consider adjusting heading and/or reducing speed. | Current observation |
| | | | | | |
| Wind Speed and Direction (speed in miles per hour) | 25 mph | All inland activities (ferries, boating, commerce) | Small boat handling may be difficult; control during ferry docking may be impaired; difficulty handling empty barges in tow; depending on wind direction, tows may become windbound; if wind opposes tidal current, expect increased wave heights | Warn all operators to exercise caution. If appropriate, stop small boat operations. | 12 hours/ current observation |
| | All | Marine modeling | Wind provides surface momentum flux to models | To improve models, include wind data and model effects of | 48 hours |

| Weather Needs for the Marine Transportation System, including Inland Waterway and Open Water Activities | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Wind Speed and Direction (speed in knots or miles per hour) | 20 knots | Open water boating and fishing | Boat handling difficulties because of wind and seas | Advise all operators to exercise caution. If appropriate, stop small boat operations. | 24 hours/ current observation |
| | 25 knots | Port operations | Possible wind damage to port facilities | Implement Emergency Wind Procedures. Consider delaying ship movements. | 24 hours |
| | 35 mph | All inland activities (ferries, boating, commerce) | Small boat handling and control difficulties because of wind and seas, control during docking impaired, difficulty handling empty barges in tow | Operations by small boats are not recommended. Operators of ferries and commerce traffic should exercise caution. If appropriate, stop operations until conditions | 24 hours/ current observation |
| | 30 knots | All open water activities (boating, cargo/freight, cruise lines, and fishing) | Minimal to extreme difficulty maintaining control, depending on size of vessel | Operations by small boats are not recommended. Cargo/freight, cruise line, and fishing operators should exercise caution and modify operations as conditions require. | 24 hours/ current observation |
| | 15-20 knots | St. Lawrence Seaway operations | Winds may affect vessel maneuverability, especially vessels in ballast conditions; normal flow of canal traffic may be interrupted | Require Seaway Entities to enforce "Wind Rules." Order vessels to anchor, as appropriate. | 24 hours/ current observation |
| | 30 knots | Port operations | Possible damage to port facilities | Implement Emergency Wind Procedures. Consider delaying ship movements. | 24 hours/ current observation |
| | 50 mph | All inland activities (ferries, boating, commerce) | Extreme difficulty with handling and maintaining control likely | Modify operations as required by conditions. | 24 hours/ current observation |
| | 45 knots | Open water cargo/freight, cruise lines, and fishing | Likely difficulty with handling and maintaining control | Adjust course and speed for best ride. | 24 hours/ current observation |
| | 45 knots | Port operations | Likely damage to port facilities | Begin preparation activities. | 24-36 hours |
| | | | Ship handling becomes difficult | Implement emergency wind procedures. Consider delaying ship movements. | 12 hours |
| | | | | | |
| Air Qualilty (characterization/code) | Unhealthful/ red | All MTS activities (10) | Health and safety risks to operators, passengers, and crew | Advise operators and modify operations as required. | 12 hours |
| | | | | | |
| Space Weather (solar flares, etc.) | Any | All MTS activities (10) | Degraded GPS navigation and radio/cellular communications | Advise operators and monitor communications. | 12 hours |
| | | | | | |
| Volcanic ash | Any | All MTS activities (10) | Reduced visibility, health hazard, damage to equipment from ash accumulation | Protect equipment, have breathing masks available. Make preparations to clear ash, curtail operations. | 24 hours |
| | | | | | |
| Nuclear, Biological, or Chemical Dispersion | Any | All MTS activities (10) | Severe threat to life, health and safety risks (dispersion of extremely dangerous hazardous materials, agents, or substances) | Notify operators. Do not travel in affected areas. | 1-3 hours/ current observation |

# Appendix B–4

## *Pipeline Sytems WIST Needs Template*

## Pipeline Systems Sector Activities

**Control center operations.** Operations to monitor the pipeline system, advise system operators, and control system integrity.

**Pumping station operations.** Responsible for fuel movement, allocation, storage, and distribution.

**Well head/drill site operations.** Includes operations for fuel pumping, storage, and distribution near source wells.

**Tank farm operations.** Includes fuel storage, distribution, and maintenance at tank farms.

**Construction.** Operations include construction, maintenance, and repair, as well as the scheduling of these operations.

**Hazardous material.** Includes monitoring storage and transport of hazardous materials and any mitigation, reclamation, and reporting operations associated with their accidental release while within the pipeline system.

**Surveillance.** Includes inspections, monitoring, and maintenance.

**Personnel safety.** Any operation where safety and health risks to workers or others may be present.

**Fuel barge operations.** Includes barge docking, fuel movement by barge, and transfer to/from fuel barges.

## Weather Needs for Pipeline System Operations

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Freezing Precipitation (ice) | Any | **Control Center Operations** : monitor, advise, control system integrity.<br>**Pumping Station Operations** : fuel movement, allocation, storage, distribution.<br>**Well-head/Drill Site Operations** : pumping, storage, distribution.<br>**Tank Farm Operations** : storage, distribution, maintenance.<br>**Construction** : scheduling, maintenance, repair.<br>**Hazardous Material** : monitoring, mitigation, reclamation, reporting.<br>**Surveillance** : inspections, monitoring, maintenance.<br>**Personnel Safety** | Inoperative valves or valve failure from freezing, damage to valves or gauges during ice removal, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pipeline sensor failure likely, possible disruption of construction or maintenance cycles, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (accidents are likely due to icy conditions, proper clothing and monitoring of crews and equipment required), possible injury or death, buried pipeline inspections (digging out an inspection trench or bore hole) may be complicated by ice and frozen soil, construction and inspection delays likely, satellite/radio/cellular phone communications may be disrupted, communications and data distribution from pipeline sensors may fail during ice storms | Issue communication advisories and/or warnings to pipeline management and operators. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.). The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate any schedule disruptions. Initiate de-icing or anti-icing program for roads, walkways, valves, gauges, etc. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections, assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for icy conditions.<br><br>Monitor crews and equipment. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid for homogeneity and purity. Report any communication failure to NSC. Monitor communications outages and use alternative modes as necessary. Initiate backup contingencies for pipeline sensor data distribution. | 12 hours |
| Frozen Precipitation (snow, inches) | Any to <8 inches | **Control Center Operations** : monitor, advise, control system integrity.<br>**Construction** : scheduling, maintenance, repair.<br>**Hazardous Material** : monitoring, mitigation, reclamation, reporting.<br>**Surveillance** : inspections, monitoring, maintenance.<br>**Personnel Safety** | Inoperative valves or valve failure from freezing, damage to valves or gauges during snow removal, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, possible disruption of construction or maintenance cycles, safety of personnel and equipment (proper clothing and monitoring of crews and equipment required), buried pipeline inspections (digging out an inspection trench or bore hole) may be complicated by ice and frozen soil, construction and inspection delays likely, public relations impacts | Issue advisories to pipeline management and operators. Initiate snow removal program (roads, walkways, valves, gauges, etc.). Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections, assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for snow and ice. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid for homogeneity and purity. | 12 hours |
| Frozen Precipitation (snow, inches) | ≥8 inches | **Control Center Operations** : monitor, advise, control system integrity.<br>**Pumping Station Operations** : fuel movement, allocation, storage, distribution.<br>**Well-head/Drill Site Operations** : pumping, storage, distribution.<br>**Tank Farm Operations** : storage, distribution, maintenance.<br>**Construction** : scheduling, maintenance, repair.<br>**Hazardous Material** : monitoring, mitigation, reclamation, reporting.<br>**Surveillance** : inspections, monitoring, maintenance.<br>**Personnel Safety** | Inoperative valves or valve failure from freezing, damage to valves or gauges during snow removal, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pipeline sensor failure likely, possible disruption of construction or maintenance cycles, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (accidents are likely on snow-covered walkways and roads, proper clothing and monitoring of crews and equipment required), possible injury or death, buried pipeline inspections (digging out an inspection trench or bore hole) may be complicated by ice and frozen soil, construction and inspection delays likely, satellite/radio/cellular phone communications may be disrupted, communications and data distribution from pipeline sensors may fail during heavy snow events | Issue communication advisories and/or warnings to pipeline management and operators. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.). The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate any schedule disruptions. Initiate snow removal and de-icing or anti-icing program for roads, walkways, valves, gauges, etc. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections, assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for icy conditions. | 12 hours |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | | | Monitor crews and equipment. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid for homogeneity and purity. Report any communication failure to NSC. Monitor communications outages and use alternative modes as necessary. Initiate backup contingencies for pipeline sensor data distribution. | |
| Drifting Snow (inches) | ≥8 inches | **Control Center Operations:** monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Inoperative valves or valve failure from freezing, damage to valves or gauges during snow removal, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pipeline sensor failure likely, possible disruption of construction or maintenance cycles, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (accidents are likely on snow-covered walkways and roads, proper clothing and monitoring of crews and equipment required), possible injury or death, buried pipeline inspections (digging out an inspection trench or bore hole) may be complicated by ice and frozen soil, construction and inspection delays likely, satellite/radio/cellular phone communications may be disrupted, drifting snow may cause communications and data distribution failures from pipeline sensors | Issue communication advisories and/or warnings to pipeline management and operators. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.). The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate any schedule disruptions. Initiate snow removal and de-icing or anti-icing program for roads, walkways, valves, gauges, etc. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections, assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Initiate alternate construction/ maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for icy conditions.<br><br>Monitor crews and equipment. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid for homogeneity and purity. Report any communication failure to NSC. Monitor communications outages and use alternative modes as necessary. Initiate backup contingencies for pipeline sensor data distribution. | 12 hours |
| Liquid Precipitation | Heavy | **Control Center Operations** : monitor, advise, control system integrity. **Construction:** scheduling, maintenance, repair. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Safety of personnel and equipment, possible workplace injury or death (Accidents are likely on rain slick surfaces; proper clothing is required.), possible disruption of inspection, construction, or maintenance cycles, inspections of buried pipeline (digging out an inspection trench or bore hole) may be complicated by standing water, satellite/radio/cellular phone communications disruptions, possible failure of communications and data distribution from pipeline sensors during heavy precipitation | Issue advisories to pipeline management and operators. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for slick conditions. Reschedule/restrict aerial and vehicle pipeline inspections based on weather safety. Inspect floating tank roofs, sumps, and water impounds; drain/pump out if needed in preparation for the heavy rain. Issue communication advisories. Report communication failure to NSC. Monitor communications outages, utilize alternative modes. Initiate backup contingencies for pipeline sensor data distribution. | 12 hours |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Flooding | Any | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Pipeline roadbed scoured or buried pipeline unearthed, pipeline damage from line stretch and foreign debris impact, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pumping may be restricted or suspended, pipeline sensor failure likely, possible disruption of construction or maintenance cycles, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (monitoring of crews and equipment required; accidents are likely with possible injury or death), buried pipeline inspections (digging out an inspection trench or bore hole) may be complicated by standing water | Issue advisories and/or warnings to pipeline management and operators. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.). The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate the schedule disruption. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections; check for bridge, trestles, pipeline roadbed integrity. Assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/ mitigation plan. Ensure proper authorities are notified. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. | 24 hours |
| | | | | Ensure proper clothing and footwear for slick and flooded walkways and road surfaces. Reschedule. restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid homogeneity and purity. Drain or fill pipelines to decrease damage susceptibility, as appropriate. | |
| Thunderstorms with Lightning, Hail, or Tornadoes (proximity to route or operational area in miles) | within 5 miles | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. **Hazardous Material:** monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Pipeline roadbed scoured or buried pipeline unearthed, pipeline damage from line stretch and foreign debris impact, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pumping may be restricted or suspended, pipeline sensor failure likely, possible disruption of construction or maintenance cycles (Fuel tank construction/repair is very wind sensitive--large sail area.), possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (monitoring of crews and equipment required; accidents are likely with possible injury or death), satellite/radio/cellular phone communications disruptions, communications and data distribution from pipeline sensors may fail during thunderstorms (effects of tornadoes, lightning, hail) | Acquire wind advisories and/or warnings prior to and during barge operations and tank construction, maintenance, or repair. If conditions become unsafe, controllers will evacuate the building and go to the strategic back-up site (SBS). From the SBS controllers can monitor and operate the pipelines. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.) based on impact of lightning or tornado. The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate the schedule disruption. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections; check for bridge, trestles, pipeline roadbed integrity. Assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Initiate alternate construction/maintenance work schedule. Ensure proper clothing and footwear are worn. | 6 hours |
| | | | | Restrict or suspend fueling operations. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid homogeneity and purity. Issue communication advisories, report communications failure to NSC, monitor outages, utilize alternative modes. Initiate backup contingencies for sensor data distribution. | |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Air Temperature (degrees F) | <32° with moisture | **Control Center Operations** : monitor, advise, control system integrity. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Inoperative valves or valve failure from freezing, damage to valves or gauges during ice/snow removal, possible disruption of construction or maintenance cycles, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, safety of personnel and equipment (proper clothing and monitoring of crews and equipment required) | Issue advisories to pipeline management and operators. Initiate snow removal program (roads, walkways, valves, gauges, etc.). Schedule additional system monitoring queries, assign additional crews/re-crews, as required. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Consider increasing the number of visual inspections and pipeline remote monitoring efforts. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for snow and ice. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid homogeneity and purity. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. | 12 hours |
| | <-20° | **Construction** : scheduling, maintenance, repair. **Personnel Safety** | 49 CFR 193.2137 sanctions for plastic pipes, safety of personnel and equipment (proper monitoring of crews and equipment required) | Advise operators of exposure danger. Monitor personnel and equipment. Enforce prohibition on plastic pipe. | 12 hours |
| | ≥100° | **Construction** : scheduling, maintenance, repair. **Personnel Safety** | Safety of personnel and equipment (proper monitoring of crews and equipment for heat stress required), 49 CFR 193.2137 sanctions for plastic pipes. | Advise operators of heat stress potential. Monitor personnel and equipment. Review and follow CFR restrictions on plastic pipe. | 6 hours |
| | >150° | **Construction** : scheduling, maintenance, repair. | 49 CFR 193.2137 sanctions for plastic pipes | Enforce prohibition on thermosetting plastic pipe. | 12 hours |
| Soil Temperature (degrees F) | <32° | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Possible pipeline motion/movement from ground heave (Ground heave is most prevalent during autumn freezes and spring thaws.), buried pipeline inspections (digging out the inspection trench or bore hole) may be complicated by frozen soil, construction and inspection delays likely, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, potential regulatory restrictions on gas lines under 49 CFR 193.2137 and 193.2065 | Issue advisories to pipeline management and operators. Consider increasing pipeline remote sensing frequency or physical inspections. Schedule additional system monitoring queries, assign additional crews/re-crews, as required. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for snow and ice. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks, sample the liquid homogeneity and purity. | 6 hours |
| Wind Chill (degrees F) | ≤20° | **Control Center Operations** : monitor, advise, control system integrity. **Construction** : scheduling, maintenance, repair. **Personnel Safety** | Personnel exposure (hypothermia, frost bite), limited time outside for maintenance personnel, personnel safety procedures strictly enforced (buddy system, time outside limited and actively managed) | Limit personnel time outside. Increase available manpower. Insist that ground crews are clothed appropriately for cold weather; ensure that cold weather gear is available. | 12 hours |
| Heat Index (degrees F) | ≥105° | **Control Center Operations** : monitor, advise, control system integrity. **Construction** : scheduling, maintenance, repair. **Personnel Safety** | Personnel exposure (heat stroke/heat exhaustion), personnel safety procedures strictly enforced | Limit personnel time outside. Increase available manpower. Insist that ground crews are clothed appropriately for hot weather. | 12 hours |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Cooling or Heating Degree-Days | Vairable | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. | Fuel management impacts (Based on prediction of cooling and heating degree days, fuel demand can vary dramatically. Proper fuel types can be readied for distribution based on customer demand. Although this is principally a petroleum industry concern, it also affects management of pipeline fuel distribution.) | Issue advisories to pipeline management and operators. Reallocate resources to respond to changes in client/customer demand, if feasible. | Current data, as needed |
| Visibility (statute miles) | <1/4 mile | **Control Center Operations** : monitor, advise, control system integrity. **Tank Farm Operations** : storage, distribution, maintenance. **Fuel Barge Operations** : docking, fuel movement. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Restricted or suspended movement of barge and tanker traffic from/to off-shore drill sites to/from coastal pumping facilities, restricted or suspended surveillance of pipelines by air or truck, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pumping may be restricted or suspended, safety of personnel and equipment (monitoring of crews and equipment required), accidents are likely with possible injury or death, possible disruption of construction or maintenance cycles | Issue advisories to pipeline management and operators. Modify, restrict, or suspend barge and tanker operations. Reallocate resources to respond to increased client/customer demand, if feasible. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. | 12 hours |
| Winds, Speed and Direction (speed in miles per hour) | >60 mph | **Control Center Operations** : monitor, advise, control system integrity. **Tank Farm Operations** : storage, distribution, maintenance. **Fuel Barge Operations** : docking, fuel movement. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Restricted or suspended movement of barge traffic from/to off-shore drill sites to/from coastal pumping facilities, disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pumping may be restricted or suspended, pipeline sensor failure likely, possible disruption of construction or maintenance cycles (Fuel tank construction/repair is very wind sensitive--large sail area.), possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (Accidents are likely with possible injury or death, monitoring of crews and equipment is required.) | Acquire wind advisories and/or warnings prior to and during barge operations and tank construction, maintenance, or repair. Issue advisories and/or warnings to pipeline management and operators. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.) based on impact of high winds. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections; check for bridge, trestles, pipeline roadbed integrity. Assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears.<br><br>Modify, restrict, or suspend tank construction, maintenance, or repairs. Restrict or suspend fueling operations. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. | 12 hours |
| | >200 mph | **Construction** : facility regulations. | Facility design must conform to wind restrictions in 49 CFR 193.2067 | Ensure construction compliance with all applicable requirements as spelled out in the CFR. | 12 hours |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Hurricane with Winds, High Sea State, Tidal Surge, or Flooding | Any | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Fuel Barge Operations** : docking, fuel movement. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Pipeline roadbed scoured or buried pipeline unearthed, pipeline damage from line stretch and foreign debris impact, restricted or suspended movement of barge traffic from/to off-shore drill sites to/from coastal pumping facilities (due to high winds, seas, tides), disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage), pumping may be restricted or suspended, pipeline sensor failure likely, possible disruption of construction or maintenance cycles, possible leaks or other pipeline failures, HAZMAT procedures may be initiated, public relations impacts, safety of personnel and equipment (monitoring of crews and equipment required; accidents are likely with possible injury or death) | Acquire hurricane advisories and/or warnings prior to and during barge operations and tank construction, maintenance, or repair. Issue advisories and/or warnings to pipeline management and operators. If conditions become unsafe at the control center, controllers will evacuate the building and go to the strategic back up site (SBS). From the SBS controllers can monitor and operate the pipe lines and will return to the primary control center when conditions are safe. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.) based on impact of hurricane. The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate the schedule disruption. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Increase pipeline surveillance; check for bridge, trestles, pipeline roadbed integrity. Assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. Ensure proper clothing and footwear for slick and flooded walkways and road surfaces. Restrict or suspend fueling operations. Reschedule, restrict, or suspend aerial and vehicle pipeline inspections based on weather safety. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. Drain or fill pipelines to decrease damage susceptibility, as appropriate. | 12 - 24 hours |
| Seas (wave height in feet) | $\geq$12 feet | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations:** fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Fuel Barge Operations** : docking, fuel movement. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Seafloor pipeline damaged or destroyed; buried pipeline unearthed, damaged or destroyed; pipeline damage from line stretch, foreign debris impact, and corrosion from damaged coating; restricted or suspended movement of barge traffic from/to off-shore drill sites to/from coastal pumping facilities due to high seas; disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage); pumping may be restricted or suspended; pipeline sensor failure likely; possible disruption of construction or maintenance cycles; possible leaks or other pipeline failures; HAZMAT procedures may be initiated; public relations impacts; safety of personnel and equipment (monitoring of crews and equipment required; accidents are likely with possible injury or death) | Acquire seas advisories and/or warnings prior to and during barge operations and off-shore drill site construction, maintenance, or repair. Issue advisories and/or warnings to pipeline management and operators. The pipeline scheduler will make arrangements with shippers and terminals/ customers to accommodate the schedule disruption. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.) based on impact of seas. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections; check pipeline integrity. Assign additional crews/re-crews, as required. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Ensure proper clothing and footwear for slick and flooded walkways and exposed shipboard surfaces. Initiate alternate construction/ maintenance work schedule. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. Drain or fill pipelines to decrease damage susceptibility, as appropriate. | 24 hours |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Tsunami, Tidal Surge | Any | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Fuel Barge Operations** : docking, fuel movement. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Seafloor pipeline damaged or destroyed; buried pipeline unearthed, damaged or destroyed; pipeline damage from line stretch, foreign debris impact, and corrosion from damaged coating; disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage); pumping may be restricted or suspended; pipeline sensor failure likely; possible disruption of construction or maintenance cycles; possible leaks or other pipeline failures; HAZMAT procedures may be initiated; public relations impacts; safety of personnel and equipment (monitoring of crews and equipment required; accidents are likely with possible injury or death) | Acquire seas advisories and/or warnings prior to and during barge operations and off-shore drill site construction, maintenance, or repair. Issue advisories and/or warnings to pipeline management and operators. The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate the schedule disruption. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.) based on impact of tidal surge. Consider the effects of sea-floor topography and leak/pipe failure location for remediation or reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. Schedule additional inspections; check pipeline integrity. Assign additional crews/re-crews, as required. If required, initiate HAZMAT spill reaction/mitigation plan.<br><br>Ensure proper authorities are notified. Ensure proper clothing and footwear for slick and flooded walkways and exposed shipboard surfaces. Initiate alternate construction/ maintenance work schedule. Postpone any work that can wait. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. Drain or fill pipelines to decrease damage susceptibility, as appropriate. | 24 hours |
| Earthquakes (any land motion, land slides, avalanches, etc) | Any | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Pipeline roadbed scoured, buried, damaged or destroyed; buried pipeline unearthed, damaged or destroyed; pipeline damage from line stretch and foreign debris impact likely; disruption of fuel delivery resulting in fuel management emergency procedures (re-allocation, transfer delays, re-routing, unscheduled storage); pumping may be restricted or suspended; pipeline sensor failure likely; possible disruption of construction or maintenance cycles; possible leaks or other pipeline failures; HAZMAT procedures may be initiated; public relations impacts; safety of personnel and equipment (Accidents are likely with possible injury or death, monitoring of crews and equipment is required.) | Issue advisories to pipeline management and operators. Schedule additional system monitoring queries, assign additional crews/re-crews, as required. Initiate fuel management contingency plans (re-route, store, cancel transfers, etc.) based on impact of land motion. The pipeline scheduler will make arrangements with shippers and terminals/customers to accommodate the schedule disruption. Consider the effects of topography and leak/pipe failure location for remediation and reclamation. Increase the number of visual inspections and pipeline remote monitoring efforts. If HAZMAT incident occurs, initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. | 12-24 hours |
| Atmospheric Transport & Diffusion | Any | **Control Center Operations** : monitor, advise, control system integrity. **Personnel Safety** | Release of vapors and toxins to the environment from a leak or pipeline failure may have catastrophic results, safety of personnel and equipment (Accidents are likely with possible injury or death, monitoring of crews and equipment is required.) | Acquire output from an (the) atmospheric transport & diffusion model depicting the horizontal and vertical distribution of toxins or vapors. Issue advisories and/or warnings to pipeline management and operators. Initiate HAZMAT spill reaction/mitigation plan. Ensure proper authorities are notified. Check integrity of pipelines, tanks, and valves. Check liquid level in tanks; sample the liquid homogeneity and purity. | 1 - 3 hours |
| Air Quality (characterization or code) | Poor, red | **Control Center Operations** : monitor, advise, control system integrity. **Personnel Safety** | Safety of personnel and equipment (monitoring of crews and equipment required) | Issue advisories to pipeline management and operators. Initiate alternate construction/maintenance work schedule. Postpone any work that can wait until the weather clears. | 12 hours |

| Weather Needs for Pipeline System Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Space Weather (e.g., solar flares) | Any | **Control Center Operations** : monitor, advise, control system integrity. **Pumping Station Operations** : fuel movement, allocation, storage, distribution. **Well-head/Drill Site Operations** : pumping, storage, distribution. **Tank Farm Operations** : storage, distribution, maintenance. **Construction** : scheduling, maintenance, repair. **Hazardous Material** : monitoring, mitigation, reclamation, reporting. **Surveillance** : inspections, monitoring, maintenance. **Personnel Safety** | Possible disruptions of satellite, radio, and cellular phone communications; communications and data distribution from pipeline sensors may fail during solar storms (Leaks or pipeline failures may be detected without a method to relay the sensed information to the pumping station, tank farm. or control center.); safety of personnel and equipment (monitoring of crews and equipment required); possible disruption of construction or maintenance cycles | Issue advisories to pipeline management and operators. Report communication failure to NSC and advise them of the solar flares. Monitor communications outages, utilize alternative modes of communications. Initiate backup contingencies for pipeline sensor data distribution. | 12 hours |

# Appendix B–5

## *Rural and Urban Transit Systems WIST Needs Template*

## Sector Activities for Rural and Urban Transit Systems

**Roadway maintenance.** This activity includes roadway surface treatment for snow and ice control in the winter, as well as maintenance to repair damage to roads and infrastructure.

**Bus operations.** In addition to bus driving, this activity includes road supervision and maintenance of the bus fleet, terminals and other facilities, and bus stops.

**Trolley bus.** This activity refers primarily to electric trolleys with overhead wires.

**School transportation**. This activity includes transportation of students by bus and commuting to school by young, inexperienced drivers.

**Rail operations.** This activity includes passenger rail operations above and below ground, and station and platform areas. Trains are predominantly electric, using a power rail (“third rail”) or overhead wires.

**Traffic management.** Activity consists primarily of managing traffic signals and traffic routing to enhance safety and efficiency.

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Freezing Precipitation (ice) | Any | Roadway maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, loss of communications/power | Predict threatened area, select treatment strategy, advise operators. Begin preparation procedures. Warn the public through press releases, to ensure public awareness and allow adjustment to travel plans. | 24 hours |
| | | | Operational and travel delays, increased workload, ice treatment requirements | Prepare, deploy, and track treatment assets. Apply anti-icing, de-icing treatment chemicals/abrasives, manage traffic flow, remove debris, repair damage. | 6- 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, passenger injuries and resulting claims, traffic congestion, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/ property, delays in maintenance (facilities, fleet, bus stops) | Advise operators, implement preparation procedures. | 12-24 hours and current observation |
| | | | (During ice/snow episodes, minor accidents are common for busses, snow removal vehicles and equipment. Striking poles, curbs, or fixed objects often results in damage, which can range from $500 to $2500. Source: Rockford, Illinois, Transit.) | Advise operators to drive with extreme caution, modify or restrict operations (especially on hills), suspend operations as appropriate. Advise passengers via bus radio system. Clear station parking lots and platforms. | 3-6 hours |
| | | Trolley busses | Malfunctions due to ice and heavy frost on wires | Remove ice from wires, equip trackless trolleys with ice cutters at start of precipitation. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |
| | | Rail operations | Safety risk (sliding, braking), collisions, passenger injuries and resulting claims, damage risk | Advise operators, begin preparation procedures. | 24 hours |
| | | | Power outages (ice buildup on third rail, catenary lines) | Inspect and clear rails, railbeds, catenary wire. | 6 hours |
| | | | Operational delays (slower operations for safety reasons), increased workload (extra manpower hired), ice on passenger platforms | Restrict or suspend operations, treat/remove ice from platforms and parking lots, activate third rail and switch heaters, remove graded tracks from service. | 2-4 hours |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes. | 6 hours |
| Structure Ice Accumulation (inches) | Any | Roadway maintenance | Safety risk, loss of communications/power, property and structural damage | Select treatment strategy, remove debris, repair damage. | Current observation |
| Pavement Ice Accumulation (inches) | Any | Roadway maintenance | Safety risk, impaired mobility, loss of stability/maneuverability, loss of traction, pavement damage, pavement temperature, effects on snow removal/ice treatment operations | Select treatment strategy, remove debris, repair damage. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Frozen Precipitation (snow, inches) | Any to <2 inches | Roadway maintenance | Safety risk to maintenance personnel, motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life and property damage | Predict threatened area, select treatment strategy, advise operators. Begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn the public through press releases, to ensure public awareness and allow adjustments to travel plans. | 24 hours |
| | | | Operational delays, increased workload, snow accumulation on roadways | Prepare, deploy, and track treatment assets. Implement roadway treatment/clearing (sanding, plowing, applying treatment chemicals/abrasives, snow removal). Manage traffic flow. | 6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, passenger injuries and resulting claims, traffic congestion, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/ property, delays in maintenance (facilities, fleet, bus stops) | Advise operators, begin preparation procedures. | 12-24 hours and current observation |
| | | | | Advise operators to drive with extreme caution, modify or restrict operations (especially on hills), suspend operations (in some regions). Advise passengers via bus radio system. Clear station parking lots and platforms. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |

## Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | | Rail operations | Safety risk (sliding, braking), collisions, passenger injuries and resulting claims, damage risk, power outages (ice buildup on third rail, catenary lines) | Advise operators, preparation procedures. | 24 hours |
| | | | Operational delays, increased workload, snow on passenger platforms | Modify operations, increase manpower for increased operations and maintenance, remove snow from passenger platforms and parking lots. | 2-4 hours |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes. | 6 hours |
| | | | | | |
| Frozen Precipitation (snow, inches) | > 2 to <8 inches | Roadway maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage | Predict threatened area, select treatment strategy, advise operators. Begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn the public through press releases, to ensure public awareness and allow adjustments to travel plans. | 24 hours |
| | | | Operational delays, increased workload, snow accumulation on roadways | Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, plow snow. Manage traffic flow (implement tire chain controls, restrict access to designated vehicle types, restrict access to roadways and bridges). | 6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, passenger injuries and resulting claims, traffic congestion, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/ property, delays in maintenance (facilities, fleet, bus stops) | Advise operators, begin procedures to implement snow routes. | 12-24 hours and current observation |
| | | | | Advise operators to drive with extreme caution, modify or restrict operations (especially on hills), suspend operations (in some regions). Advise passengers via bus radio system. Clear station parking lots and platforms. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |
| | | Rail operations | Safety risk (sliding, braking), collisions, passenger injuries and resulting claims, damage risk, power outages (ice buildup on third rail, catenary lines), operational delays, increased workload, snow on passenger platforms | Advise operators, begin preparation procedures. | 24 hours |
| | | | | Inspect and clear rails, railbeds, catenary wires. Modify operations, increase manpower for increased operations and maintenance, remove snow from passenger platforms and parking lots. | 3-6 hours |
| | | | | Run service vehicles or snow trains to keep third rail and overhead catenary lines clear. Remove graded storage tracks from service, use ice scrapers and snow brakes. | Current observation |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes. | 6 hours |
| | | | | | |
| Frozen Precipitation (snow, inches) | > 8 inches | Roadway maintenance | Safety risk to maintenance personnel and motorists, travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction, impaired mobility, road damage, loss of life, property damage, slope instability (avalanche risk) | Advise operators. Begin preparation procedures for equipment, crew planning, shift changes, geographical reassignment and deployment. Warn the public through press releases, to ensure public awareness and allow adjustments to travel plans. | 24 hours |
| | | | | Prepare, deploy, and track treatment assets. Conduct snowfighting operations to treat/clear roadways (apply treatment chemicals/abrasives, plow snow), implement tire chain controls. Manage traffic flow (restrict access to designated vehicle types, restrict access to roadways and bridges, close roadways and bridges). | 6 hours |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, passenger injuries and resulting claims, traffic congestion, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delays in maintenance (facilities, fleet, bus stops) | Advise operators, preparation procedures to implement snow routes. | 12-24 hours and current observation |
| | | | | Put snow routes into effect, advise operators to drive with extreme caution. Modify or restrict operations (especially on hills), suspend operations as necessary. Advise passengers via bus radio system. Clear station parking lots and platforms. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |
| | | Rail operations | Safety risk (sliding, braking), collisions, passenger injuries and resulting claims, damage risk, power outages (ice buildup on third rail, catenary lines), operational delays, increased workload, snow on passenger platforms | Advise operators, begin preparation procedures. | 24 hours |
| | | | | Inspect and clear rails, railbeds, catenary wires. Modify operations, increase manpower for increased operations and maintenance, remove snow from passenger platforms and parking lots. | 3-6 hours |
| | | | Slower train movement, snow buildup on switches and trucks, potential power problems if snow level is above third rail | Run service vehicles or snow trains to keep third rail and overhead catenary lines clear. Remove graded storage tracks from service, use ice scrapers and snow brakes, continuously clear rail switching areas, monitor third rail and switch heater performance, use plows if necessary. | Current observation |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes. | 6 hours |
| Drifting Snow (inches) | ≥6-8 inches | Roadway maintenance | Safety risk to maintenance personnel and motorists, travel delays (Winds >15 mph can lead to blowing snow and drifting in some areas. The amount of snow already on the ground may not be the determining factor; if snow storage areas are full, even a few inches can cause drifting problems. Drifting snow can cause continuous and prolonged clearing operations, which strain manpower resources.) | Predict threatened area, consider road closures. Construct and place living and structural snow fences. Begin equipment preparation, crew planning, shift changes, geographical reassignment and deployment. Warn public through press releases, to ensure awareness and allow adjustment to travel plans. | 24 hours |
| | | | Operational delays, increased workload, loss of visibility, loss of traction, lane obstruction, impaired mobility | Select treatment strategy. Prepare, deploy, and track treatment assets. Conduct roadway treatment/clearing operations (sanding, plowing, snow removal), implement tire chain controls, manage traffic flow, modify lane configuration. | 6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, passenger injuries and resulting claims, traffic congestion, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/ property, delays in maintenance (facilities, fleet, bus stops) | Advise operators, begin preparation procedures. | 12-24 hours and current observation |
| | | | | Advise operators to drive with extreme caution, modify or restrict operations (especially on hills), suspend operations (in select areas). Advise passengers via bus radio system. Clear station parking lots and platforms. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |
| | | Rail operations | Safety risk (sliding, braking), collisions, passenger injuries and resulting claims, damage risk, power outages (ice buildup on third rail, catenary lines), operational delays, increased workload, snow on passenger platforms | Advise operators, preparation procedures. | 24 hours |
| | | | | Inspect and clear rails, railbeds, catenary wires. Modify operations, increase manpower for increased operations and maintenance, remove snow from passenger platforms and parking lots. | 3-6 hours |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | | Slower train movement, snow buildup on switches and trucks, potential power problems if snow level is above third rail | Run service vehicles or snow trains to keep third rail and overhead catenary lines clear. Remove graded storage tracks from service, use ice scrapers and snow brakes, continuously clear rail switching areas, monitor third rail and switch heater performance, use plows if necessary. | Current observation |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes. | 6 hours |
| Snow Accumulation Observation (inches) | Any | Roadway maintenance | Drifting snow, impaired plowing, lane obstruction, loss of stability/ maneuverability, loss of traction, pavement temperature effects, slope instability (avalanche risk) | Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, manage traffic flow, remove debris, repair damage. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Snow Drift Levels Observation (inches) | Any | Roadway maintenance | Impaired plowing, lane obstruction | Select treatment strategy. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Roadway Snow Depth Observation (inches) | Any | Roadway maintenance | Loss of traction, impaired mobility, effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Roadway Snow Pack Depth Observation (inches) | Any | Roadway maintenance | Loss of traction, impaired mobility, effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Adjacent Snow Depth Observation (inches) | Any | Roadway maintenance | Drifting snow, roadway snow depth | Select treatment strategy. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Snow/Ice Bonding Observation (inches) | Any | Roadway maintenance | Effects on snow removal/ice treatment operations | Select treatment strategy. | Current observation |
| Liquid Precipitation | Any | Roadway maintenance | Safety risk, maintenance activity delays, public travel delays, loss of visibility, loss of traction, loss of stability/maneuverability, lane obstruction /submersion, road damage, treatment chemical dispersion, toxicity and environmental damage | Predict threatened area, advise operators and travelers. Begin preparation procedures, induce drainage. | 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delays in maintenance (facilities, fleet, bus stops) | Begin preparation procedures. | 12-24 hours and current observation |
| | | | Operational delays | Advise operators of wet road conditions or areas of pooling water, drive with extreme caution, modify operations. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Advise operators, modify operations as necessary. | 12 hours |
| | | Rail operations | Safety risk, damage risk | Advise operators, begin preparation procedures. | 12 hours |
| | Moderate to heavy | | Operational delays, potential flood damage to railroad line, bridges, culverts | Modify operations. Inspect railroad lines, bridges, and culverts. | 2-6 hours |
| | Any | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes. | 6 hours |
| Flooding | Any | Roadway maintenance | Safety risks, road submersion, loss of life and property, road damage, bridge damage, travel delays | Review contingency plans, issue alerts, advise operators. Begin preparation procedures. | 12-24 hours |
| | | | Maintenance activity delays, traffic slowdowns | Begin local mobilization/action and road closures, advise travelers. Prepare to monitor/induce drainage. | 6-12 hours |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Bus and trackless trolley operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, traffic congestion, vehicle damage risk, routes may require detours, delays of scheduled operations, traffic accidents, increased risk of damage to busses/property, delays in maintenance (facilities, fleet, bus stops), busses may be called upon to provide evacuation assistance. | Advise operators, begin preparation procedures. | 12-24 hours and current observation |
| | | | Operational delays, complete loss of bus service in affected areas, notification of road authorities and public relations required | Advise operators, roadway authorities, and public relations of real time road conditions. Modify, restrict, or suspend operations. Divert routes as necessary where flooding may be occuring or is at high risk of occurring. Shelter busses on high ground until water levels subside. Assist as requested in civil defense evacuation from flood-prone areas to safe shelters. | 3-6 hours |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |
| | | Rail operations | Safety risk (trains losing power, evacuations), damage risk (trackbed, electrical), operational delays | Advise operators, begin preparation procedures, acquire additional manpower for emergency operations and maintenance. Build dams if necessary. | 8-12 hours |
| | | | Operational delays | Modify, restrict, or suspend operations. | 6 hours |
| | | | Power outages (third rail blowouts); flood damage to railroad lines, bridges, culverts | Clear rails and catenary wires. Inspect and repair railroad lines, bridges, culverts. | 2-6 hours |
| | | | Passenger notification requirements | Check pumps and drains. Notify passengers (public address system, public broadcast). | 0-4 hours |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes, reroute. | 6 hours |
| | | | | | |
| Thunderstorms with Lightning (proximity to route or operational area in miles) | ≤5-10 miles | Roadway maintenance | Safety risk, loss of life and property damage, loss of communications/ power, maintenance activity delays, travel delays | Cease refueling, restrict or suspend operations and outdoor activities. | 3-6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, damage risk, operational delays | Advise operators, restrict or suspend outdoor activities. NOTE: During thunderstorms, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 3 hours and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 6 hours |
| | | Rail operations | Safety risk (personnel working in train yard or on tracks), damage risk (lightning striking switches or electrical boxes causing signal outages), operational delays | Advise operators, restrict or suspend outdoor activities. | 3 hours |
| | | Traffic management | Traffic congestion, damage to signal operations | Monitor/resequence traffic signals. | 6 hours |
| | | | | | |
| Thunderstorms with Hail (hail size and proximity to route or operational area in miles) | <1/4 inch, ≤ 5-10 miles | Roadway maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction, loss of life and property, loss of communications/power | Predict threatened area, prepare to implement warning and evacuation plans, advise travelers, advise operators, restrict or suspend outdoor activities. | 3-6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, damage risk, operational delays | Advise operators, restrict or suspend outdoor activities. NOTE: During thunderstorms, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 3 hours and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 6 hours |
| | | Rail operations | Safety risk, damage risk, operational delays | Advise operators, restrict or suspend outdoor activities. | 3 hours |
| | | Traffic management | Traffic congestion, damage to signal operations | Monitor/resequence traffic signals. | 6 hours |
| | | | | | |
| Thunderstorms with Tornado (proximity to route or operational area in miles) | Within 20-30 miles | Roadway maintenance | Safety risks and travel delays, loss of visibility, loss of traction, impaired mobility, lane obstruction, loss of life/property, loss of communications/power, maintenance activity delays | Predict threatened area, advise operators and travelers, review and implement warning and evacuation plans, suspend outdoor operations. | 3-6 hours and current observation |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, damage risk, operational delays | Advise operators, restrict or suspend outdoor activities. | 3 hours and current observation |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 6 hours |
| | | Rail operations | Safety risk, damage risk, operational delays | Advise operators, restrict or suspend outdoor activities. | 3 hours |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes, reroute. | 6 hours |
| Severe Storm Cell Track—Location, Direction, Speed, Severity (proximity to route or operational area in miles) | ≤20 miles | Roadway maintenance | Credibility of evacuation orders, flood risk, property damage, road damage loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life and property damage, loss of communications/power | Predict threatened area, select treatment strategy, mobilize maintenance personnel, implement warning and evacuation plans. Issue evacuation orders, operate outflow devices, manage traffic flow. Remove debris, repair damage. | 1-3 hour forecast and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 1-3 hour forecast and current observation |
| | | Rail operations | Safety risk, damage risk, operational delays | Advise operators, restrict or suspend outdoor activities. | 1-3 hour forecast and current observation |
| | | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes, reroute. | 1-3 hour forecast and current observation |
| **Major Storms** | | | | | |
| Blizzard | Within 25-50 miles | Roadway maintenance | Loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life, property damage, loss of communications/power | Predict threatened area, select treatment strategy, advise operators and travelers, suspend outdoor operations. Implement warning and evacuation plans, mobilize maintenance forces. | 24-48 hour forecast and current observation |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Disruption of scheduled service, disruption of local business operations, schedule delays, increased safety risk, damage to busses and property, scheduled operations modified/restricted/suspended | Advise bus operators, road supervisors, and other personnel. Operate with extreme caution. Begin preparation procedures. Modify, restrict, or suspend operations in inundated areas. Coordinate transportation and other action requirements in support of civil defense evacuation operations, including evacuation of the elderly and disabled. Halt all activity on the road prior to the estimated time of arrival of the leading edge of the storm. Deploy all busses and other personnel designated evacuation shelters or return them to bus facilities. | 24-48 hour forecast and current observation |
| Tropical Cyclone/Hurricane | Any within a radius of 900 nautical miles | Roadway maintenance | Loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life, property damage, loss of communications/power | Predict threatened area, select response strategy, implement warning and evacuation plans. Advise operators and travelers, suspend outdoor operations, mobilize maintenance forces. | 72 hours or 900 naut. miles |
| | | | | Review prediction of threatened area and response strategy, update and reissue warnings and advisories. | 48 hours or 600 naut. miles |
| | | | | Weather Service issues official hurricane/cyclone watch. | 36 hours |
| | | | | Weather Service issues official hurricane/cyclone warning. | 24 hours or 300 naut. miles |
| | | | | Depending on conditions, begin planned evacuation procedures. | 12 hours or 150 naut. miles |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Disruption of scheduled service, disruption of local business operations, schedule delays, increased safety risk, damage to busses and property, operations modified/restricted/suspended | Advise bus operators, road supervisors, and other personnel of pending storm. Operate with extreme caution. Begin preparation procedures. Modify, restrict, or suspend operations in inundated areas. Coordinate transportation and other action requirements in support of civil defense evacuation operations, including evacuation of the elderly and disabled. Halt all road activity 45 minutes prior to estimated time of arrival on shore of leading edge of 40 mph winds. Deploy all busses and other personnel to designated evacuation shelters or return them to bus facilities. | Lead time sequence same as for road maintenance, above |
| **General Weather/Environmental Parameters** | | | | | |
| Air Temperature including Maximum and Minimum (degrees F) | Variable, based on impact criteria | Roadway maintenance | Air quality, loss of communications/power, precipitation type, pavement temperature, slope instability (avalanche risk), effects on snow removal/ice treatment operations | Advise operators, monitor surface moisture, modify operations. | 12-24 hour forecast and current observation |
| Air Temperature Relative to Freezing and Trend (degrees F and rising or falling trend) | Decrease to less than 32° or increase to exceed 32°, with moisture | Roadway maintenance | Safety and health risk, potential effects on ice/snow removal operations, traveler delays | Provide early warning, advise operators and travelers, monitor surface moisture, begin preparation procedures. Apply salt to city streets or conduct other treatment actions as appropriate. | 6-12 hours |
| | <40° | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Life threat to homeless | Transport homeless to shelters. | 12 hours and current observation |
| | ≤32° with moisture | Bus operations | Safety and health risk, passenger injuries and resulting claims, potential operational delays | Advise operators, modify or restrict operations (especially on hills). | 12 hours |
| | <20 | Bus operations | Safety and health risk, inoperable vehicles, wayside equipment | Issue cold weather alert to operators and passengers, implement cold weather plan.<br>NOTE: During extreme temperatures, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 12 hours |
| | ≤32° with moisture | School transportation | Safety risk, vehicle damage risk, schedule delays | Advise operators, modify or restrict operations. | 12 hours |
| | ≤32° with moisture | Rail operations | Safety and health risk, passenger injuries and resulting claims, potential operational delays | Advise operators, modify or restrict operations. | 12 hours |
| | <20° | Rail operations | Safety and health risk, inoperable vehicles, wayside equipment | Issue cold weather alert to operators and passengers, implement cold weather plan.<br>NOTE: During extreme temperatures, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 12 hours |
| | ≤32° with moisture | Traffic management | Traffic congestion | Resequence traffic signals, clear major routes, reroute. | 6 hours |
| Air Temperature (degrees F) | ≥85-95° | Roadway maintenance | Health and safety risk, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment for signs of heat stress, modify or restrict operations as needed. | 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Personnel safety, engine/equipment heat stress | Advise operators (issue heat alert), modify operations, ensure climate control units are operating properly.<br>NOTE: During extreme temperatures, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 12 hours and current observation |
| | | Rail operations | Personnel safety, engine/equipment heat stress | Advise operators (issue heat alert), modify or restrict operations. | 12 hours |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Air Temperature (degrees F) | $\geq$100-110° | Roadway maintenance | Personnel safety, heat exhaustion, engine/equipment heat stress | Advise operators, monitor personnel safety and equipment for signs of heat stress, modify or restrict operations as needed. | 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Personnel safety, heat exhaustion, engine/equipment heat stress | Modify or restrict operations, ensure climate control units are operating properly. | 12 hours and current observation |
| | | School transportation | Health/safety risk, vehicle damage risk, schedule delays | Modify operations, dismiss school early. | 12 hours |
| | | Rail operations | Personnel safety, heat exhaustion, engine/equipment heat stress | Restrict or suspend operations, ensure climate control units are operating properly, reduce speeds. | 12 hours |
| Dew Point Temperature (degrees F) | Variable, based on temperature and impact criteria | Roadway maintenance | Precipitation type, effects on fog formation and air quality, slope instability (avalanche risk), effects on snow removal/ice treatment operations | Predict threatened area, select treatment strategy, advise operators, monitor surface moisture, modify operations. | 12-24 hour forecast and current observation |
| Air Temperature Change Rate (degrees F per 24 hours) | Approx. 60° in 24 hours | Roadway maintenance | Precipitation type, pavement temperature, pavement buckling damage due to rapid expansion and contraction | Predict threatened area, select treatment strategy, repair roadways. | 12-24 hour forecast and current observation |
| Time and Air Temp Integrals (heating/cooling degree days) | Variable | Roadway maintenance | Road and property damage risks under extreme heating degree days or cooling degree days | Determine stockpile or resources needed to repair damage. | Forecast and actual tally |
| Wet Bulb Temperature (degrees F) | Variable, based on temperature and impact criteria | Roadway maintenance | Air temperature, fog dispersal effectiveness | Predict threatened area, select treatment strategy, disperse fog (cold fog) using $CO_2$ application. | 12-24 hour forecast and current observation |
| Relative Humidity (percent) | Variable, based on impact criteria | Roadway maintenance | Precipitation type, visibililty restrictions | Predict threatened area, select treatment strategy. | 12-24 hour forecast and current observation |
| Air Stabililty | Stable/ unstable | Roadway maintenance | Air quality (Stable atmosphere inhibits dispersion of pollutants.) | Modify operations. | 12-24 hour forecast and current observation |
| Subsurface temperature | Variable, based on contributing factors such as wind, shade, sun | Roadway maintenance | Pavement effects (Subsurface temperature affects pavement temperature, along with wind, insolation, shade, and other contributing factors.) | Predict threatened area, select treatment strategy. | 12-24 hour forecast and current observation |
| Pavement Temperature (degrees F) | $\geq$85-90° | Roadway maintenance | Personnel health and safety, heat exhaustion, engine/equipment heat stress, pavement "blow-ups" | Provide early warning, monitor equipment/personnel heat stress. Modify or restrict maintenance activities as required. Take prescribed health and safety precautions and road repair actions as needed. | 6-12 hours |
| | $\leq$32° but >15°, with moisture | Roadway maintenance | Safety and health risk, effects on ice/snow removal operations | Apply appropriate ice/snow removal chemicals. | 12 hours |

## Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| | $<15^{\circ}$ with moisture | Roadway maintenance | Safety and health risk, effects on ice/snow removal operations | Because ice removal chemicals ineffective, apply abrasives or plow. | 12 hours |
| Pavement Freeze Point Temperature with Dew Point Temperature (degrees F) | $<32^{\circ}$ with moisture (observation and forecast) | Roadway maintenance | Safety risk to maintenance personnel and motorists, loss of traction, operational delays, increased workload, anti-icing and de-icing operations required (Applying ice preventative treatment to roadways requires preparation of equipment and crews.) | Select treatment strategy, advise operators. Begin preparation procedures for applying chemicals (prepare liquid chemical tanks or hoppers for salt application) 12 hours prior to time for applying treatment to roadways. Treat/clear roadways with anti-icing, de-icing treatments. Manage traffic flow. | Current observation and 12-48 hour forecast |
| Pavement Temperature, Moisture Present (degrees F) | $>(15\text{-}18)^{\circ}$ but $<32^{\circ}$ | Roadway maintenance | Snow/ice bonding, effects on snow removal/ice treatment operations, loss of traction | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives. | 12 hours |
| | $<(15\text{-}18)^{\circ}$ | Roadway maintenance | Snow/ice bonding, effects on snow removal/ice treatment operations, loss of traction, treatment chemical effectiveness | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Plow snow, apply abrasives. | 12 hours |
| Pavement Temperature | Variable, based on impact criteria | Roadway maintenance | Snow/ice bonding, effects on snow removal/ice treatment operations, loss of traction, treatment chemical effectiveness, melting | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Plow snow, apply treatment chemicals/abrasives. | Current |
| Pavement Condition | Wet | Roadway maintenance | Safety risk, impaired mobility, loss of traction, loss of stability/ maneuverability | Predict threatened area, manage traffic flow. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement appropriate precautionary measures. | Current observation |
| | Snow | Roadway maintenance | Safety risk, impaired mobility, loss of traction, loss of stability/ maneuverability | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, plow snow, manage traffic flow. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| | Ice | Roadway maintenance | Safety risk, impaired mobility, loss of traction, loss of stability/ maneuverability | Predict threatened area, select treatment strategy. Prepare, deploy, and track treatment assets. Apply treatment chemicals/abrasives, manage traffic flow. | Current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | Current observation |
| Chemical Concentration (in-road sensor or mobile infrared) | Variable, based on application, residue | Roadway maintenance | Safety risk, effects on snow removal/ice treatment operations, snow/ice bonding | Select treatment strategy, apply treatment chemicals/abrasives, deploy and track treatment assets, operate outflow devices. | Current observation |
| Visibility, Including Restricting Conditions such as Fog, Haze, Dust, Smoke (statute miles) | <1/4 mile | Roadway maintenance | Safety risk, loss of visibility, impaired mobility | Advise operators, modify operations, reduce speeds. | 6 hours |
| | <1/4 mile | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, schedule delays | Advise operators, modify operations, reduce speeds. | 6 hours and current observation |
| | <1/4 mile | School transportation | Safety risk, vehicle damage risk, schedule delays | Modify operations, consider/implement delayed school start or early dismissal. | 12 hours |
| | <1/4 to 3 miles | Rail operations | Safety risk, schedule delays, difficulty monitoring switch alignment | Advise operators, modify operations (reduce speed). | 2-6 hours |
| | <1/4 mile | Traffic management | Traffic congestion | Modify operations. | 6 hours |
| Sun Glare | Any | Roadway maintenance | Safety risk, restricted visibility in glare quadrant of horizon | Advise operators, reduce speeds, modify operations. | 3 hours |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, restricted visibility in glare quadrant of horizon | Advise operators, reduce speeds, modify operations. | 3 hours and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Advise operators, reduce speeds, modify operations. | 12 hours |
| | | Rail operations | Safety risk, restricted visibility in glare quadrant of horizon, difficulty monitoring switch alignment | Advise operators, reduce speeds, modify operations. | 3 hours |
| | | Traffic management | Safety risk, restricted visibility in glare quadrant of horizon | Advise operators, reduce speeds, modify operations. | 3 hours |
| Wind: Head, Cross, or Tail, including Convective Winds (wind speed in miles per hour) | >30 mph but <50 mph | Roadway maintenance | Safety risk, increased roadway debris, potential operational slowdown (Speed and direction are most important when snow has accumulated and drifting results.) | Predict threatened area, select treatment strategy. Modify operations, increase debris removal operations. When snow drifting is likely, implement early warning procedures, advise travelers, construct and place living and structural snow fences for snow drift management. | 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, roadway debris, flying debris, traffic congestion, downed live electric lines and or poles, routes may require detours, increased risk of damage to busses and property, schedule delays, delays of scheduled operations, delays in maintenance (facilities, fleet, bus stops), speed restrictions for express routes | Advise operators when high wind watches are issued. Modify, restrict, or suspend operations. Detour routes as needed. Notify passengers (public address system, public broadcast). | 12-24 hours and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Advise operators, modify operations. | 12 hours |
| | | Rail operations | Safety risk; downed live electric lines, catenary wires, and poles; schedule delays | Advise operators, modify operations (reduce speed) of high-profile cars. | 2-6 hours |
| | | Traffic management | Traffic congestion, potential damage to traffic management systems | Monitor traffic management systems. | 6 hours |
| | $\geq$50 mph | Roadway maintenance | Safety risk, increased roadway debris, operational slowdown (Speed and direction are most important when snow has accumulated and drifting results.) | Predict threatened area, select treatment strategy. Modify operations, increase debris removal operations. When snow drifting is likely, implement early warning procedures, advise travelers, construct and place living and structural snow fences for snow drift management. | 12 hours |
| | $\geq$50 mph | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, roadway debris, flying debris, traffic congestion, downed live electric lines and or poles, increased risk of damage to busses and property, routes may require detours, schedule delays, delays in maintenance (facilities, fleet, bus stops) | Advise operators when high wind warnings are issued. Modify, restrict, or suspend operations. Detour routes as required. Reschedule delayed operations and maintenance. | 12-24 hours and current observation |
| | $\geq$50 mph | School transportation | Safety risk, vehicle damage risk, schedule delays | Advise operators, modify or restrict operations. | 6 hours |
| | $\geq$50 mph | Rail operations | Safety risk; downed live electric lines, catenary wires, and poles; schedule delays | Advise operators, modify or restrict operations. | 6 hours |
| | >70 mph | | Service over bridges suspended | | 3 hours |
| | $\geq$50 mph | Traffic management | Traffic congestion, potential damage to management systems | Monitor management systems. | 6 hours |
| Rail Temperature (degrees F) | $\leq 32^{o}$ with moisture | Rail operations | Potential safety risk, damage to track | Inspect tracks, modify operations. | 6 hours |
| | $\geq$ 85-130$^{o}$ | Rail operations | Heath and safety risk, equipment heat stress, sagging catenary wires, potential for track damage (heat kink in rails) | Advise operators, modify or restrict operations. Inspect rails while hot, reduce speed of trains. | 2-6 hours |
| Wind Chill (degrees F) | $\leq 20^{o}$ | Roadway maintenance | Safety and health risk (hypothermia, frost bite) | Advise operators, restrict or suspend operations as necessary. | 6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety and health risk (hypothermia, frost bite) | Advise operators, modify operations. NOTE: During extreme temperatures, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 6 hours and current observation |
| | | School transportation | Safety and health risk (hypothermia, frost bite) | Modify operations. If necessary, select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12 hours |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| | | Rail operations | Safety and health risk (hypothermia, frost bite), frozen switches/vehicles/equipment | Advise operators, rotate personnel working out of doors, modify operations. Exercise switches constantly, exercise doors and equipment while not in use. | 6 hours |
| Heat Index (degrees F) | ≥100-105° | Roadway maintenance | Safety and health risk (heat exhaustion) | Advise operators, restrict or suspend operations. | 6 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety and health risk (heat exhaustion) | Advise operators, modify operations. NOTE: During extreme temperatures, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 6 hours and current observation |
| | | School transportation | Health and safety risk, vehicle damage risk, schedule delays | Modify operations. Dismiss school early, if appropriate. | 12 hours |
| | | Rail operations | Safety and health risk (heat exhaustion) | Advise operators, modify operations. NOTE: During extreme temperatures, transits will normally not suspend operations because of safety concerns for passengers waiting at bus stops. | 6 hours |
| Air Quality | Poor/code red | Roadway maintenance | Potential health and safety risk | Advise operators, modify or restrict operations. | 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Potential health and safety risk | Reschedule, increase passenger capacities. | 24 hours and current observation |
| | | School transportation | Potential health and safety risk | Reschedule, increase passenger capacities. | 12 hours |
| | | Rail operations | Potential health and safety risk | Reschedule, increase passenger capacities. | 24 hours |
| | | Traffic management | Traffic congestion | Advise motorists to take mass transit. | 6 hours |
| Space Weather (e.g., solar flares) | Any | Roadway maintenance | Radio/cellular phone communication disruptions | Advise operators, monitor communications outages. | 12 hours |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Radio/cellular phone communication disruptions | Advise all operators, road supervisors, and other users of the bus radio system of temporary disruptions in communications. | 12 hours |
| | | School transportation | Radio/cellular phone communication disruptions | Advise operators, monitor communications outages. | 12 hours |
| | | Rail operations | Radio/cellular phone communication disruptions | Advise operators, monitor communications outages, place communications personnel on standby to address disruptions. | 12 hours |
| | | Traffic management | Potential impact on traffic management systems | Monitor traffic management systems. | 12 hours |
| Total Sun (insolation per 24 hours) | Total per 24 hour period | Roadway maintenance | Air temperature, pavement temperature, toxicity and environmental damage | Modify operations as necessary. | 12-24 hour forecast and current observation |
| Cloud Cover Forecast | Scattered, broken, overcast | Roadway maintenance | Air temperature, pavement temperature, toxicity and environmental damage | Modify operations as necessary. | 12-24 hour forecast and current observation |
| Water Course Flow Volume (cubic meters per second) | Variable, based on flood stage criteria | Roadway maintenance | Flood risk, lane submersion, loss of life and property, road damage | Predict threatened area, select treatment strategy, operate outflow devices, develop warning and evacuation plans. | 12-24 hour forecast and current observation |
| Water Body Depth (feet) | Variable, based on flood stage criteria | Roadway maintenance | Flood risk, lane submersion, loss of life and property, road damage | Predict threatened area, select treatment strategy, operate outflow devices, develop warning and evacuation plans. | 12-24 hour forecast and current observation |

## Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Storm Surge (height above mean high tide, in feet) | Any | Roadway maintenance | Safety risk, damage to vehicles, road damage, evacuation route delays | Predict threatened area, repair damage. | 12-24 hour forecast and current observation |
| | >5 feet | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Increased safety risk, damage to busses, delays to scheduled operations or complete disruption of service on routes through coastal areas | Advise operators and road supervisors of pending conditions, request radio reports of observed storm surge crossing the highway. Modify, restrict, or suspend operations. | 12-24 hour forecast and current observation |
| High Surf (wave height in feet) | >8 feet | Roadway maintenance | Safety risk, damage to vehicles, road damage, evacuation route delays | Predict threatened area, repair damage. | 12-24 hours |
| | 18-20 feet | Bus operations | Increased safety risk, damage to busses, delays to scheduled operations or complete disruption of service on routes through coastal areas | Advise operators and road supervisors of pending conditions, request radio reports of observed surf crossing the highway. Modify, restrict, or suspend operations. As requested, assist Civil Defense in evacuation of coastal areas to safe shelters. | 12-24 hours and current observation |
| Avalanche Danger | High, moderate, low | Roadway maintenance | Impaired mobility, loss of life and property, lane obstruction, effects on snow removal/ice treatment operations | Close roadways, release avalanche, remove snow, modify operations as necessary. | 12-24 hour forecast and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12-24 hour forecast and current observation |
| | | Bus operations | Bus routes and service likely impacted due to blocked roads, possible requests to provide evacuation assistance | Modify routes as required, be prepared to provide assiatance. | 12-24 hour forecast and current observation |
| Seismic Activity (earthquakes) | Any seismic activity | Roadway maintenance | Road damage, property damage, impaired mobility, loss of life and property | Manage traffic flow, modify operations, remove debris, repair damage. | 12-24 hour forecast and current observation |
| | | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, damage to buses and property, potential for tsunami in coastal areas, disrupted operations, operations modified/restricted/ suspended | Conduct immediate, spontaneous, unassisted evacuation. If communications are still up, advise fleet of event. Take roll of operators and supervisors. Assist police department, civil defense, and the public as needed. | 12-24 hour forecast and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select response strategy, e.g., school opening delays, closure, or early dismissal. | 12-24 hour forecast and current observation |
| Tsunami (Japanese for "wave in the harbor") | Any alert or warning from the Pacific Tsunami Warning Center | Bus operations (road supervision, facility, fleet, bus stop maintenance) | Safety risk, disrupted operations, service delays, damage to equipment, operations modified/restricted/suspended | Advise operators and road supervisors. Begin preparation procedures. Modify, restrict, or suspend operation in inundated areas. Coordinate transportation and other action requirements in support of civil defense evacuation operations, including evacuation of the elderly and disabled. As situation and time permit, provide service for endangered residents/visitors from tsunami evacuation areas to designated tsunami evacuation shelters. Terminate service 45 minutes prior to the estimated time of arrival of the tsunami wave. | From a maximum of 15 hours to a minimum of 5 minutes |

| Weather Needs for Rural and Urban Transit System (Local Roads and Light Railway) Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Volcanism | Any volcanic activity | Roadway maintenance | Road damage, property damage, impaired mobility, loss of life and property, air quality | Manage traffic flow, modify operations. | 12-24 hour forecast and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12-24 hour forecast and current observation |
| Soil moisture | Saturated, unsaturated | Road maintenance | Flood risk, road and pavement damage, effects on pavement condition | Select treatment strategy. | 12-24 hour forecast and current observation |
| Fire | Any fire event or activity | Roadway maintenance | Loss of visibility, loss of life and property, air quality | Manage traffic flow (e.g., close roadways and bridges). | 12-24 hour forecast and current observation |
| | | School transportation | Safety risk, vehicle damage risk, schedule delays | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 12-24 hours forecast and current observation |
| Fair Weather | 1 to 10 Days | Roadway maintenance | Operational planning (The tasks that will be undertaken in periods of good weather depend somewhat on how much good weather is anticipated. Crews work year round; there are no reserves or part-time personnel to call in for snow or other severe weather events. Details of crew assignments vary day to day, some days plowing and sanding, some days working on drainage, some days on signs and guardrail, etc. A certain amount of mobilization is required for some tasks.) | Examples: (1) Ditching requires removing the sanders, mounting a truck box, and replacing the blower attachment on a loader with a bucket. These jobs would probably take 2 days. Such actions cannot be started without a forecast of 10 days of good (non-snow) weather because of the time needed to reconvert the equipment. (2) In urban areas, snow hauling is necessary following a storm. The same amount of work is needed to clean up after a 6-inch fall as a 12-inch one. If good weather is forecast following a 6" snow event, hauling might be started. If another snow event is forecast within several days, hauling may be delayed. (3) Forecasts of good weather, as well as bad, aid managers in deploying crews efficiently. | 24-48 hours |
| Nuclear, Biological, or Chemical Release | Any | Roadway maintenance | Severe threat to life, health and safety risk, dispersion of extremely dangerous hazardous materials, agents, substances | Close/detour roadways, assist in Atmospheric Transport and Diffusion and HAZMAT response operations as needed. | 1-3 hours and current observation |
| | | School transportation | Severe threat to life, health and safety risk, dispersion of extremely dangerous hazardous materials, agents, substances | Select and implement response strategy, e.g., 2-hour delay, school closure, early dismissal. | 1-3 hours and current observation |

# Appendix B–6

## *Airport Ground Operations WIST Needs Template*

## Sector Activities for Airport Ground Operations

**Aircraft movement.** Includes all ground movement of aircraft and safety of flight considerations that affect aircraft ground movement.

**Vehicle movement.** Vehicle movement and traffic flow on the airfield and on approaches to the airfield

**Gate accessibility.** Includes operations for the transfer of baggage and cargo and general aircraft servicing (cleaning, catering, minor maintenance) while an aircraft is parked at a gate.

**Aircraft maintenance.** All ground maintenance conducted away from the gate.

**Refueling aircraft.** Includes transportation of fuels from at-airport storage to aircraft and the operations during transfer from fuel truck to aircraft fuel tanks.

**Foot traffic.** All pedestrian movement on the airfield.

**Construction and maintenance projects.** All vehicular movement and operations related to construction or structural maintenance of airport and airfield facilities, while the airport continues to operate.

## Weather Needs for Airport Ground Operations

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Frozen Precipitation (snow, inches) | >1/2 inch per hour | Aircraft movement, vehicle movement, gate accessibility, foot traffic, aircraft maintenance | Personnel safety risk, equipment damage risk, operational delays and cancellations, potential runway closure (biggest impact on intersecting runways), parking limitations, airport access road conditions (Heavy snow coupled with high winds will cause blizzard conditions and "white-outs." All snow removal ceases until visibility improves.) | Conduct early planning to ensure availability/readiness of equipment and supplies (stockpile of salt/sand for roadways and parking areas, other materials for runways and taxiways). Plan manpower availability. Advise carriers, Fixed Base Operator, and all tenants. Prepare de-icing pads for expected use. (Some airlines use a 24-30 hour forecast for a preliminary staffing estimate.) | 12-24 hours (advisory) |
| | | | | Implement personnel recall, go to 12-hour shifts. Decide on choice of application (anti-ice, sand, etc.). Airlines may implement schedule changes and plan reconstitution. Issue advisories (and updates) to all airport tenants. Execute snow and ice control plan(s) airlines could begin de-icing aircraft at the gate with activation of the snow plan. Form the snow desk/snow removal team, issue NOTAMS, track expected storm duration and accumulation. Issue and update advisories and plan activities accordingly. Begin treating runways, taxiways, roads, parking areas, and walkways. Monitor pavement subsurface and surface temperatures for continued snow removal strategy. Alert staff to the potential for white-out conditions. | 3-6 hours (warning) |
| Freezing Precipitation (all ice forms) | Any | Aircraft movement, vehicle movement, gate accessibility, foot traffic, aircraft maintenance | Personnel safety risk, equipment damage risk, operational delays/cancellations, potential runway closure, airport parking limitations, decreased traction/maneuverability on airport access roads | Conduct early planning for availability/readiness of equipment and supplies (stockpile of anti-ice and de-ice materials). Plan manpower availability, ready designated aircraft de-icing pads. Advise carriers, Fixed Base Operator, and all tenants. | 12-24 hours (advisory) |
| | | | | Implement personnel recall, go to 12-hr shifts (the choice of 8 or 12 hour shifts is driven by manpower availability). Decide on choice of anti-ice/de-ice application material, and start time (timing is critical to derive the greatest benefit/effectiveness from material applied). Airlines could implement flight schedule changes and plan reconstitution. Issue advisories (and updates) to all tenants, execute snow and ice control plan(s) (with temperature below 34° F and high humidity, airlines could begin de-icing at the gate). Issue NOTAMS, track storm onset and expected duration. Begin treating runways, taxiways, roads, parking areas, and walkways. Monitor pavement subsurface and surface temperatures for strategy to remove freezing precipitation. | 3-6 hours (warning) |
| Freezing Precipitation (ice, inches)<br>***Note:** This section treats aircraft de icing as responsibility of the airline/ pilot-in-command. | Any | Safety of flight | Safety risk, equipment damage risk, schedule delays and cancellations (Frozen precipitation of any kind, along with frost and rime icing picked up on descent, affects the aerodynamic performance features of an aircraft. Lift is dramatically affected and is most critical on take-off/climb-out. "Hold-over-time," the maximum allowable time between the start of de-icing and actual take-off, varies with the weather conditions and the type of de-icing fluid used. The proper selection must be made for effectiveness, efficiency, and above all, safety. Efficient de-icing operations minimize schedule impacts.) | Airline meteorology/operations/dispatch function advises station managers of potential threat. Station de-icing coordinator, or "iceman," plans for availability/readiness of equipment, supplies, and manpower. Airport operations alerts tenants and prepares de-icing pads for expected use. Airport continues to issue advisories to tenants on type of precipitation expected, expected accumulation and duration, temperature, and wind. | 12-24 hours (advisory) |
| | | | | Use the latest forecast (type and rate of precipitation, wind, and temperature) to select the de-icing material with the greatest effectiveness. (Airlines may implement personnel recall to cover the additional function of de-icing in turning airplanes.) Begin applying de-icing fluid before precipitation begins. This agent prevents precipitation from bonding (freezing) to the wing surface; at take-off roll, the accumulated precipitation slides off the wing. Other agents can be applied to remove frozen precipitation from aircraft surfaces. Frost and "cold wing" icing are routinely dealt with when freezing precipitation is not present.<br>**Note:** If rate of freezing precipitation is moderate or greater in current observation, operations will likely stop at a station. | 3-6 hours (warning) |

# Weather Needs for Airport Ground Operations

| Weather Element | Threshold | Activity | Impacts | Action | Lead Time |
|---|---|---|---|---|---|
| Thunderstorms with Lightning, including Microburst Event | Within 3, 5, 17 nautical miles of the airfield | Refueling aircraft, construction and maintenance projects, general aircraft servicing (cleaning, catering, minor maintenance), baggage/cargo transfer | Personnel safety risk, equipment damage risk, operational delays/cancellations, summer construction projects delayed, airfield maintenance projects delayed, aircraft servicing (refueling, maintenance) delayed | Airlines advise station managers of impending threat of lightning; airport operations advises all tenants. Plan options for construction and maintenance projects. | 12-24 hours (advisory) |
| | | | | Continue issuing advisories to all airfield tenants. Begin movement of construction equipment. Hangar or tie-down equipment that is no in use or not needed in short term. Monitor lightning observation grid. Begin shutting down noncritical activities when lightning is observed at or near outer boundaries of lightning detection grid. | 4-6 hours (warning) |
| | | | | Halt all refueling when lightning is observed within 3 nautical miles of the airfield, get personnel inside and under cover. **Note:** Some operators pull their personnel off the line when lightning is observed at or within 10 nautical miles of the airfield. | 0-1 hour (nowcast) |
| Thunderstorms with Hail | Within 5 nautical miles of airfield | Refueling aircraft, construction and maintenance projects, general aircraft servicing (cleaning, catering, minor maintenance), baggage/cargo transfer | Personnel safety risk, equipment damage risk, operational delays/cancellations, summer construction projects delayed, aircraft servicing (refueling, maintenance) delayed (Hail greater than 1 inch can severely damage aircraft not in flight.) | Airlines advise station managers of impending threat of hail; airport operations advises all tenants. Plan options for construction and maintenance projects. | 12-24 hours (advisory) |
| | | | | Continue issuing advisories to all airfield tenants. Begin moving construction equipment. Hangar or tie-down equipment that is not ir use or not needed in short term. Begin shutting down all noncritical activities when hail is observed within 5-10 nautical miles of the airfield. Hangar aircraft. | 4-6 hours (warning) |
| | | | | When hail is observed within 3 nautical miles of airfield, halt all refueling. Get personnel inside and under cover. **Note:** Some operators pull their people off the line when hail is observed at or within 10 nautical miles of the airfield. | 0-1 hour (nowcast) |
| Wind Speed and Direction, including Microburst Event (knots) | >25-35 knots | Construction projects, aircraft movement, aircraft servicing (cleaning, catering), baggage/cargo transfer | Construction materials blow loose, increased incidence of foreign objects present in aircraft movement areas, maintenance at high locations on large aircraft impeded/slowed, delays in turning aircraft and runway changes contribute to schedule delays, snow removal and de-icing operations affected (Crosswind factors and dramatic wind shifts affect choice of runway. Runway changes at busy times contribute to schedule delays. Snow blower and aircraft de-icing operations must consider wind direction and speed. Blowing dust from construction sites presents a hazard.) | Advise construction contractor and maintenance of impending high winds. Examine options for construction schedule adjustments. Advise all airfield tenants, advise air traffic control. Plan for more frequent ramp, taxiway, and runway inspections (to reduce or eliminate foreign object damage). | 12-24 hours (advisory) |
| | | | | If de-icing of aircraft is required, decide where and how it will be done, to control blowing spray. Select pattern for snow removal operation. Continue advisories to tenants. Begin increased ramp, taxiway, and runway inspections. Ensure that motorized carts, igloo containers, baggage, etc., that are not in use are braked and chocked for the duration of high winds. Inspect aircraft movement areas frequently for foreign objects (to prevent foreign object damage). Store equipment that is not needed in protected areas. | 4-6 hours (warning) |
| Temperature and Chill Factor (degrees F) (counts as 2 weather elements) | $<0^{o}$ F (with or without wind) or wind chill factor of $<-20^{o}$ F | Construction projects, aircraft servicing (cleaning, catering, minor maintenance), baggage and cargo transfer, routine refueling | Personnel exposure (hypothermia, frost bite), water onboard aircraft may freeze during routine servicing, minor delays in turning aircraft because servicing personnel are limited in time they can spend outside, personnel safety procedures strictly enforced (buddy system required, time outside is limited and actively managed) | Training for dealing with extremely cold conditions begins in September. Assure all personnel are equipped with appropriate clothing and other cold weather gear when reporting for work (two-way radios, cell phones, foot and hand coverings, etc.). Airlines alert station managers, airports alert all tenants. Plan how much and what kind of construction/repair might be possible, adjust schedule. Use easy-to-follow checklists to ensure no protection or safety detail is overlooked. | 12-24 hours (advisory) |
| | | | | Limit personnel time outside to periods of 12-15 minutes. Increase available manpower to account for time when part of the shift crew must take warm-up breaks inside. Insist that ground crews come to work with appropriate cold weather attire and other gear. Provide ground crew with warm fluids (tea, coffee, soup, etc.) to assist warm up and avoid dehydration. | 3-6 hours (warning) |

| Weather Needs for Airport Ground Operations | | | | | |
|---|---|---|---|---|---|
| **Weather Element** | **Threshold** | **Activity** | **Impacts** | **Action** | **Lead Time** |
| Heavy Rain | >1-2 inches per hour (produces standing water on tarmac) | Construction projects, aircraft movement, aircraft servicing, vehicle/traffic flow on airfield and approach to the airfield | Construction projects impeded, slowing of all vehicular movement on the airfield (both on the ramp and on access roads/parking areas), foot traffic impeded, safety risk for employees and passengers, schedule delays possible | Issue an advisory to all airlines and all other airfield tenants. Plan vehicular traffic flow to bypass known trouble areas. As appropriate, coordinate with other agencies in the vicinity to open drainage control points. Prepare equipment for sweeping or pushing standing water. Plan to have adequate equipment and trained personnel available | 12-24 hours (advisory) |
| | | | | Prepare to execute the plan for heavy rain mitigation. | 2 hours (warning) |
| Visibility: Any Obstruction to Vision, Primarily Fog (statute miles) | <1/4 mile | Construction projects (many at night, at non-peak air traffic hours, but at peak fog occurrence times), aircraft movement, vehicular movement | Potential delays to completion of construction and repair projects; increased probability for incursion incidents; all aircraft and vehicular movement slowed, with attendant schedule delays | Coordinate with construction contractor on schedule of events. Issue advisory to all airport tenants. Ensure that "Follow me" trucks are available for service. | 24 hours (advisory) |
| | | | | Coordinate with air traffic control. At some airports, when the Runway Visual Range reaches 600 ft, no take-offs are allowed. Ensure that "Follow me" guidance vehicles are available on request | 6-12 hours (warning forecast) |

# Appendix C

## *Abbreviations and Acronyms Listing*

## *Abbreviations and Acronyms Listing*

| | |
|---|---|
| AAR | Association of American Railroads |
| AFWA | Air Force Weather Agency |
| API | American Petroleum Institute |
| ATIS | Advanced Traveler Information System |
| ATWIS | Advanced Transportation Weather Information System |
| DOC | U.S. Department of Commerce |
| DoD | U.S. Department of Defense |
| DOI | U.S. Department of the Interior |
| DOT | U.S. Department of Transportation |
| EPA | U.S. Environmental Protection Agency |
| ESS | Environmental Sensor Station |
| FAA | Federal Aviation Administration |
| FCMSSR | Federal Committee for Meteorological Services and Supporting Research |
| FEMA | Federal Emergency Management Agency |
| FHWA | Federal Highway Administration |
| GDP | Gross Domestic Product |
| GPS | Global Positioning System |
| HAZMAT | Hazardous material(s) |
| ICMSSR | Interdepartmental Committee for Meteorological Services and Supporting Research |
| ISTEA | Intermodal Surface Transportation and Efficiency Act |
| ITS | Intelligent Transportation System |
| MADIS | Meteorological Assimilation Data Ingest System |
| MTS | U. S. Marine Transportation System |
| NASA | National Aeronautics and Space Administration |
| NHTSA | National Highway Traffic Safety Administration |
| NOAA | National Oceanic and Atmospheric Administration |
| NOTAM | Notice to Airmen |
| NRC | Nuclear Regulatory Commission |
| NTP | National Transportation Program [of the Department of Energy] |
| NWS | National Weather Service |
| OFCM | Office of the Federal Coordinator for Meteorological Services and Supporting Research |
| OPS | Office of Pipeline Safety |
| PMA | Power Marketing Administration |
| R&D | Research and Development |
| RSPA | Research and Special Programs Administration |
| RWMP | Road Weather Maintenance Program |
| USDA | U.S. Department of Agriculture |
| USGS | U.S. Geological Survey/Service |
| USTRANSCOM | U.S. Transportation Command |
| WIST | Weather Information for Surface Transportation |

# Appendix D

## *Glossary of Terms*

## Glossary of Terms

| Weather Element(s) | Definition |
|---|---|
| **A** | |
| **Adjacent Snow Depth** | The actual depth of snow on areas other than the surface of roadway pavement, drifts and plowed areas. (FHWA) |
| **Air Quality** | The AQI is an index for reporting daily air quality. It indicates how clean or polluted the air is, and the associated health concerns. The AQI focuses on health effects that can happen within a few hours or days after breathing polluted air. EPA uses the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect against harmful health effects. (EPA webpage)<br>GREEN: “Good” The AQI value for your community is between 0 and 50. Air quality is considered satisfactory and air pollution poses little or no risk.<br>YELLOW: “Moderate” The AQI for your community is between 51 and 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of individuals. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.<br>ORANGE: “Unhealthy for Sensitive Groups” Certain groups of people are particularly sensitive to the harmful effects of certain air pollutants. This means they are likely to be affected at lower levels than the general public. For example, children and adults who are active outdoors and people with respiratory disease are at greater risk from exposure to ozone, while people with heart disease are at greater risk from carbon monoxide. Some people may be sensitive to more than one pollutant. When AQI values are between 101 and 150, members of sensitive groups may experience health effects. The general public is not likely to be affected when the AQI is in this range.<br>RED: “Unhealthy” AQI values are between 151 and 200. Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects.<br>PURPLE: “Very Unhealthy” AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.<br>MAROON: “Hazardous” AQI values over 300 trigger health warnings of emergency conditions. The entire population is more likely to be affected. |

| Weather Element(s) | Definition |
|---|---|
| **Air Stability** | For the purposes of this report, air stability describes the tendency for air to rise or to be restricted from rising, normally described as stable or unstable. An unstable atmosphere is generally associated with convection and the potential for showers, thunderstorms. A stable atmosphere is generally associated with low clouds, fog, poor visibilities, and poor air quality. |
| **Air Temperature** | The degree of hotness or coldness of the air measured on a temperature scale by means of a thermometer. (AMS glossary derived) |
| **Air Temperature Change Rate** | For the purposes of this report, the change in temperature at a given location during a specified period of time, e.g. 6, 12, or 24 hours. |
| **Atmospheric Transport & Diffusion** | For the purposes of this report, the transportation and diffusion of toxic substances by atmospheric movement and turbulent processes. |
| **Avalanche** | A mass of snow (perhaps containing ice and rocks) moving rapidly down a steep mountain slope. (AMS Glossary) |
| **B** | |
| **Blizzard** | A severe weather condition characterized by temperatures near or below 10 degrees Fahrenheit, winds 32 mph or higher, and snow (mostly fine, dry snow picked up from the ground) reducing visibility to less than 500 feet. (AMS Glossary) |
| **C** | |
| **Chemical Concentration** | For the purposes of this report, the residual concentration of chemicals on the road surface as the result of the most recent application of treatment chemicals or substances. |
| **Cloud Cover** | That portion of the sky cover which is attributed to clouds. (AMS Glossary derived)<br>Scattered: Description of a sky cover 1/8 to 4/8, applied only when clouds or obscuring phenomena aloft are present.<br>Broken: Description of a sky cover of 5/8 to 7/8, applied only when clouds or obscuring phenomena aloft are present.<br>Overcast: Description of a sky cover of 8/8, when at least a portion of this amount is attributable to clouds or obscuring phenomena aloft. |
| **D** | |
| **Dew Point Temperature** | The temperature at which a given parcel of air must be cooled at constant pressure and constant water-vapor content in order for |

| Weather Element(s) | Definition |
|---|---|
| | saturation to occur. (AMS Glossary) |
| **Drifting Snow** | Snow raised from the surface of the earth by the wind to a height of less than six feet above the surface. When snow is raised to six feet or more above the surface, it is classified as blowing snow. Snow Drift: Snow deposited behind obstacles or irregularities of the surface, or collected in heaps by eddies in the wind. (AMS Glossary) |
| **F** | |
| **Fair Weather** | When this term is used in weather forecasts, it is meant to imply no precipitation, less than 3/8 sky cover of low clouds, and no other extreme conditions of cloudiness, visibility, or wind. (AMS Glossary derived) |
| **Fire** | For the purposes of this report, any fire event at or near areas of transportation operations. This includes the threat caused by the actual flames, fire induced winds, and visibility restrictions caused by smoke. |
| **Flooding** | The condition that occurs when water overflows the natural or artificial confines of a stream or other body of water, or accumulates by drainage over low-lying areas. (AMS Glossary) |
| **Freezing Precipitation** | Any form of liquid precipitation that freezes upon impact with the ground or exposed objects; i.e., freezing rain, or freezing drizzle. (AMS Glossary) |
| **Freezing Spray** | Sea spray transported through the air that freezes on ship's surfaces and structures. |
| **Frozen Precipitation** | Any form of precipitation that reaches the ground in frozen form; i.e. snow, snow pellets, snow grains, ice crystals, ice pellets, and hail. (AMS Glossary) |
| **G** | |
| **Glare** | Any hindrance to vision caused by scattering or reflection of light into an observer's line of sight. (AMS Glossary) |
| **H** | |
| **Hail** | Precipitation in the form of balls or irregular lumps of ice, always produced by convective clouds, nearly always cumulonimbus. (AMS Glossary) |

| Weather Element(s) | Definition |
|---|---|
| **Heat Index** | For the purposes of this report, sometimes referred to as the "apparent temperature" and given in degrees Fahrenheit. Heat Index is an accurate measure of how hot it really feels when the relative humidity (RH) is added to the actual air temperature. |
| **High Surf** | Surf: The sea-surface wave activity between the outermost line of breakers and the shore. (AMS Glossary) For the purposes of this report, high surf thresholds are variable depending on specific transportation activities, operations, and the vulnerability of roadway operations to surf damage. |
| **High Winds** | For the purposes of this report, any wind speed (normally in excess of 25 mph) that impacts normal or unique operations or activities. |
| **Hurricane (Tropical Cyclone)** | One of the most intense and feared storms of the world with winds of 74 mph or higher and torrential rains. (AMS Glossary) |
| **I** | |
| **Ice Gorging** | The stacking and packing of ice due to river currents and river constrictions. Ice often packs all the way to the river bottom. |
| **Inland Waterway Ice Coverage** | Percentage of rivers, bays, lakes, and inter-coastal waterways covered by surface ice. |
| **L** | |
| **Lightning** | Generally any or all of the various forms of visible electrical discharge produced by thunderstorms. (AMS Glossary) |
| **Liquid Precipitation** | Liquid water droplets that fall from the atmosphere and reach the ground. Liquid precipitation includes drizzle and rain. (AMS Glossary derived) |
| **N** | |
| **Nuclear, Biological, or Chemical Release** | For the purposes of this report, any release of nuclear, biological, or chemical substances onto the surface or into the atmosphere or waterways. |
| **Open Water Sea Ice** | Ice formed by the freezing of seawater. Forming first as lolly ice (frazil crystals), thickens into sludge, and coagulates into sheet ice, pancake ice, or into floes of various shapes and sizes. (AMS Glossary) |
| **P** | |
| **Pavement Condition** | The state of the surface of roadway pavement based on current or |

| Weather Element(s) | Definition |
|---|---|
| | recent weather conditions, road conditions, and traffic conditions. The pavement conditions are expressed as dry, wet, snow/slush and ice. (FHWA) |
| **Pavement Freeze Point Temperature** | The temperature at which the existing solution on the roadway will freeze. The critical temperature varies because the normal freeze point of water can be depressed by dissolved chemicals. (FHWA) |
| **Pavement Ice Accumulation** | The actual depth of ice on the surface of roadway pavement. (FHWA) |
| **Pavement Temperature** | The temperature of the surface of roadway pavement based on thermal energy flows to and from the subsurface (conduction), to and from the air (boundary layer conduction, convection and radiation), water phase changes at the surface (energy from condensation, energy to evaporation), radiation from the sun or surrounding objects that reflect solar energy, and terrestrial heat transfers, e.g. vehicles. (FHWA) |
| **Precipitable Water Vapor** | The total atmospheric water vapor contained in a vertical column of unit cross-sectional area extending between any two specified levels of the atmosphere. (AMS Glossary) |
| **R** | |
| **Rail Temperature** | The temperature of the surface of the rail based on thermal energy flows to and from the subsurface (conduction), to and from the air (conduction, convection and radiation), water phase changes at the surface (energy from condensation, energy to evaporation), radiation from the sun or surrounding objects that reflect solar energy, and terrestrial heat transfers, e.g. vehicles. |
| **Relative Humidity** | The (dimensionless) ratio of the actual vapor pressure of the air to the saturation vapor pressure . (AMS Glossary) |
| **River/Lake Ice** | Ice formed on the surface of a river/lake. (AMS Glossary) |
| **Roadway Snow Depth** | The actual depth of unpacked snow on the surface of roadway pavement. (FHWA) |
| **Roadway Snow Pack Depth** | The actual depth of packed snow on the surface of roadway pavement. (FHWA) |

| Weather Element(s) | Definition |
|---|---|
| **S** | |
| **Seismic Activity (earthquakes)** | For the purposes of this report: Any earthquakes or earth tremors. |
| **Snow Accumulation (also called snow depth)** | The actual depth of snow on the ground at any instant during the storm, or after any single snowstorm or series of storms. (AMS Glossary) |
| **Snow Drift Levels** | For the purposes of this report, the height of the crest of snowdrifts (see drifting snow above) measured in inches or feet. |
| **Snow/Ice Bonding** | The formation of a bonding layer of ice beneath snow accumulated on the surface of roadway pavement. (FHWA) |
| **Soil Temperature** | The temperature of the soil below the rail or roadway surface (same as subsurface temperature). |
| **Soil Moisture** | Moisture in the soil within the zone of aeration, including water vapor (also part of the soil air) present in the soil pores. In some cases this refers strictly to moisture within the root zone of plants. (AMS Glossary) |
| **Space Weather** | Space Weather refers to conditions on the sun and with the solar wind, magnetosphere, ionosphere, and the thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Adverse conditions in the space environment can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses. (National Space Weather Program, Strategic Plan) |
| **Storm Cell Track** | For the purposes of this report, the path of past locations, present location, direction of movement, speed of movement, and intensity of storm cells as indicated by a storm detection radar. |
| **Storm Surge** | An abnormal rise of the sea along the shore as the result, primarily, of the winds of a storm. (AMS Glossary) |
| **Structure Ice Accumulation** | The actual depth of ice on roadway structures. (FHWA) |
| **Subsurface Temperature** | The temperature of the soil below the surface. (FHWA) |

| Weather Element(s) | Definition |
|---|---|
| **T** | |
| **Time and Air Temp Integrals (heating/cooling degree days)** | Degree day: Generally, a measure of the departure of the mean daily temperature from a given standard: one degree day for each degree (C or F) of departure above (or below) the standard during one day. (AMS Glossary) |
| **Tornado or Waterspout** | A violently rotating column of air, pendant from a cumulonimbus cloud, and nearly always observable as a "funnel cloud" or tuba. On a local scale, it is the most destructive of all atmospheric phenomena. (AMS Glossary) |
| **Total Sun (Insolation)** | Insolation (incoming solar radiation). In general, solar radiation received at the earth's surface. (AMS Glossary) |
| **Tropical Storm Force Winds** | Winds equal to or greater than 39 mph but less than 74 mph. |
| **Tsunami** | Japanese for "wave in the harbor" (also called a seismic sea wave or tidal wave). An ocean wave produced by a submarine earthquake, landslide or volcanic eruption. These waves may reach enormous dimensions and have sufficient energy to travel across entire oceans. (AMS Glossary) |
| **V** | |
| **Visibility** | In United States weather observing practice, the greatest distance in a given direction at which it is just possible to see and identify with the unaided eye (a) in the daytime, a prominent dark object against the sky at the horizon, and (b) at night, a known, preferably unfocused, moderately intense light source. After visibilities have been determined around the entire horizon circle, they are resolved into a single value of prevailing visibility for reporting purposes. (AMS Glossary) |
| **Volcanism** | For the purposes of this report, any volcanic activity e.g. eruptions, earthquakes, ashfall which can impact transportation operations and activities. |
| **W** | |
| **Water body depths** | The measured depth of a water body, e.g. river or stream, from a specified datum at a specified location. (FHWA) |
| **Water course flow volume** | Volume of water that passes a given point within a given period of time. (FHWA) |

| Weather Element(s) | Definition |
|---|---|
| **Water Temperature** | The measure of the surface/near surface temperature of the water as measured by a thermometer. (AMS Glossary) |
| **Wet Bulb Temperature** | The temperature an air parcel would have if cooled to saturation. (AMS Glossary) |
| **Wind Chill** | That part of the total cooling of the body caused by air motion. (AMS Glossary) |
| **Wind Direction** | The direction from which the wind is blowing. (AMS Glossary)<br>Headwind: A wind that opposes the intended progress of an exposed, moving object.<br>Tailwind: A wind which assists the intended progress of an exposed, moving object.<br>Crosswind: A wind which has a component which is directed perpendicularly to the course (or heading) of an exposed, moving object. |
| **Wind Direction (upper air)** | Upper Air: That portion of the atmosphere which is above the lower troposphere. No distinct lower limit is set but the term is generally applied to the levels above 5 thousand feet (850mb). (AMS Glossary derived) |
| **Wind Speed** | The velocity of air in motion relative to the surface of the earth. (AMS Glossary derived) |
| **Wind Wave Height** | Height of the ocean surface wave generated by the wind. (AMS Glossary derived) |

# Appendix E

## *Weather Research and Technology Development Required to Meet WIST User Needs*

# *Weather Research and Technology Development Required to Meet WIST User Needs*

This list was compiled from information provided by agencies supporting research and application development specific to WIST user needs (e.g., FHWA), leaders in the surface transportation research community (e.g., University Corporation for Atmospheric Research, National Center for Atmospheric Research), and the representatives of WIST user communities who participated in the meetings and symposia held for this study.

Based on the information received and general knowledge of the state of R&D in specific areas, OFCM staff have *estimated* when R&D results can be anticipated for each item listed. An **NT** (near term results) after an item indicates that substantial work already in progress or a directed development effort can probably produce significant impact for WIST users within five years (end of fiscal year 2007). An **FT** (far term results) indicates that gaps in the knowledge base require more extensive research to support useful applications, with impacts for WIST users anticipated after 2007. In many instances, an R&D item is likely to have useful, but limited, real impact in the near term, with more extensive impacts on WIST user needs requiring more time. These items are marked with both the **NT** and **FT** flags.

## I. Requirements for Incorporating Observed Fine-Scale Weather and Related Elements into WIST Applications

A. Weather elements and related phenomena that can be observed and predicted with existing methods but require integration into operational roadway transportation information systems. **NT**

   1. Black ice on roadways (demonstrated in the Meridian SAFE ATIS program). **NT**
   2. Turbulent vortices around large vehicles (demonstrated in the Meridian SAFE ATIS program). **NT**
   3. Sun glint and glare (demonstrated in the Meridian SAFE ATIS program). **NT**

B. Weather elements and consequences that can be observed with existing technology as point measurements but require spatial distribution modeling for surface transportation applications. **NT**

   1. Frost heave of road surfaces and its impact on load-bearing capacity of roads and railbeds. (FHWA research underway at University of North Dakota). **NT**
   2. Spatial distribution of pavement conditions (temperature, frost, ice, etc.) beyond the point measurements available with roadway monitoring sites (RWIS). **NT, FT**
   3. Rainfall spatial variability leading to hydroplaning and other local flooding hazards. **NT**

C. Increase access to the Continuously Operating Reference System, which enables highly accurate height and position measurements using GPS for applications in waterways and other surface transportation uses. **NT**

## II. Prediction of Roadway and Railway Condition

The existing technologies for predicting road or rail condition are still primitive. Most of the best current prediction systems use two-dimensional heat transfer equations parameterized in very simple ways to account for cloud cover, total insolation, precipitation, and other weather factors. New methods uncovered by research in this area could significantly advance predictive capability. The following research areas are among the most promising but require further investigation. They are listed in *approximate* order of priority for WIST needs.

A. Detection and prediction of road/rail conditions in complex terrain. Complex terrain provides a particularly difficult setting for diagnostic/prognostic systems focused on road/rail conditions. Research is required to discover the best ways to deal with complex terrain at high resolution in numerical models, interpolation schemes, and data fusion systems. **FT**

B. Predicting precipitation type. For assessing the impact of precipitation on road and rail condition, predictive systems are required that provide much higher spatial and temporal resolution for occurrence of sleet, snow, freezing rain, or rain. **NT, FT**

C. Systems for predicting track/road washouts. Decision support systems are needed to determine the likelihood, presence of, and future location of debris flows that will result in track/road washouts. **FT**

D. Flood prediction systems. More accurate systems (models, decision support systems, real-time sensing systems, etc.) are required to provide more accurate prediction of road/track flooding, particularly in data-sparse regions. **NT, FT**

E. Land surface modeling. Land surface models coupled to atmospheric mesoscale models need more development. An efficient system could serve as a translator of atmospheric data into surface conditions near a roadway or railway. **NT, FT**

F. Thermal mapping. Surface-based and space-based thermal mapping has the potential to provide the spatial distribution between surface observation sites (point observations) along roadways and railways. Accurate interpolation of temperature at a high spatial resolution is necessary to predict microscale effects, and therefore necessary to provide a highly resolved and highly accurate forecast of road temperature. Investigators at Montana State University have developed a promising prototype that needs further support. **NT**

G. Snowdrift prediction from numerical models. (The U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory [CRREL] has done pioneering work in this area, but more emphasis and much more research is needed on application to surface transportation sectors.) **NT, FT**

H. Predicting precipitation rate and quantity. For assessing road and rail conditions, systems must be able to predict precipitation rate and quantity at much higher spatial and temporal resolution than is currently possible, particularly for the near-term forecast (0-6 hours) and for convection-induced precipitation events. **NT**

J. Mobile sensor systems. The number of temperature observations taken along roadways could be significantly increased using manufacturer-installed temperature sensors in automobiles, commercial vehicles, and government maintenance vehicles. An R&D program is needed to assess the value of such observations and design quality control, data collection, and distribution subsystems. **NT, FT**

K. Determination of surface insolation at high resolution (1 km) using remote sensors. University of Wisconsin investigators have done excellent work in this area for applications to agricultural crops and freeze warnings. Remote sensing data of this type could become a valuable component of data fusion systems designed to estimate road/rail surface temperatures. **NT, FT**

L. Measurement of snow depth near roadways/railways. Cost-effective and accurate systems to automatically measure snow depth along road/railways are needed. **NT**

M. Effect of contaminants (ice, water, snow, chemicals, etc.) on road temperature. Much work has been done in this area, but more is needed. **NT, FT**

N. Effects of traffic volume on road condition. Advanced decision support systems for winter road maintenance need to incorporate quantitative models of the effects of traffic on the temperature, wetness, snow depth, and ice compaction along roadways. **FT**

P. Estimating snow depth from radar remote sensing. Much work needs to be done to produce reliable algorithms for estimating snow depth and water equivalent. **NT, FT**

Q. Remote sensing of road contaminants. The ability to provide diagnostic and prognostic road condition information across all roads in the U. S. network requires methods of surveillance that go far beyond today's point sampling technologies using fixed observation sites or mobile platforms. **FT**

R. Measurement and prediction of subsurface conditions, such as frost and water flow, that affect road/rail stability and surface condition. **NT, FT**

### III. Detection and Prediction of Reduced Visibility

Unexpected low visibility caused by fog, smoke, dust, rain, snow, or other atmospheric obscurants along railways and roadways is responsible for many accidents annually. Research is required in the following areas.

A. Data fusion systems for detection of low visibility. (System development and research are needed to produce visibility *information* based on the fusion and analysis of raw data from various sources, including numerical models, satellite-based sensors, ground-based sensors, and others.) **FT**

B. Spatial distribution of blowing/drifting snow and its impact on roadway visibility. (FHWA research underway at University of North Dakota). **NT**

C. Visibility Prediction Systems. Forecast systems are needed that merge real-time-data and model data to provide near-term (0–6 hour) forecasts at high resolution and accuracy. Such systems could be used on highways to trigger variable message signs or in-vehicle information systems to give travelers warnings, advisories, and cautions. **FT**

**IV. Detection and Decision Support for High Wind Events**

High wind events such as tornadoes, downbursts associated with convective activity, strong density currents moving through narrow channels in high terrain, mountain downslope winds, and tropical systems making landfall can seriously affect traffic volume and safety of operators along roads and railways, particularly for high-profile vehicles.

A. Decision support systems are needed that combine the best information available from the atmospheric diagnostic and prognostic system with traffic operational data. Such a system would include algorithms that would diagnose and predict *crosswind, headwind and tailwind* components along all relevant road and railways. The crosswind components would trigger warnings, advisories and cautions. The headwind and tailwind data could be used for more efficient routing of commercial vehicles or large privately owned vehicles like RVs. **FT**

B. Wind Diagnosis Using Remote Sensors – Much more work is needed in developing algorithms that use satellite multispectral data, radar data, and lidar data to detect air movement, particularly to detect hazardous high winds. **NT, FT**

**V. Requirements for Improved Weather and Surface Sensing and Measuring Technologies (Satellite-based, Radars, Fixed and Mobile Surface or Near-Surface Platforms)**

A. Standards for accuracy and all data quality factors affecting the utility of the data. For example, review and adopt/adapt national and international standards for environmental data objects, message sets, and icons. **NT, FT**

B. Calibration and validation methods. **NT**

1. Use of remote sensing to complement/supplant in situ sensing. **NT**

2. Appropriate sensor investment and siting, by climate and functional class of sensor/facility. **NT**

C. Standard methodologies for collecting, processing, and archiving sensor/measurement data. **NT**

D. Technologies and standards for access to and assimilation of sensor/measurement data. **NT, FT**

1. Assimilation of ESS observations with other weather observations for quality control of ESS and augmentation of traditional weather observations. **NT**

2. Improved nowcasts and near-term forecast predictions of open water currents using new current measurement systems and improved forecast models. **NT,FT**

F. Facilitate ingest and assimilation of observations of “nontraditional” weather and environmental elements into WIST systems by developing improved metadata, standards, and calibration for such observations. **NT, FT**

G. Environmental sensor technologies for ITS and MTS that reduce cost and improve effectiveness. **NT, FT**

H. Tradeoffs between sensor-based time series prediction versus weather-based heat balance prediction for parameters such as surface freezing and temperature/rate extremes. **NT,FT**

**VI. Information Technology for Access and Application of WIST, Including WIST inputs to ITS**

A. Develop better computer-based systems for communicating and processing WIST, including the capability to integrate total environmental information from air, sea, and land sensors and other sources. Such systems should be able to incorporate information on evolving weather conditions and other environmental elements into an open system adhering to the information architectures of the national ITS and a national weather information system. **NT, FT**

B. Refine in-vehicle displays for WIST and other ITS decision-support tools that use WIST. **NT**

C. Develop filtering and fusion processes to tailor increasingly abundant information and data for specific decisions in mobile and fixed environments and for purposes of safety-warning, operations, and planning. **NT, FT**

1. Coordination of multiple local-domain NWP models (e.g., ensembles and boundary reconciliation) for transportation applications. **NT, FT**
2. Flexible “scripting” to tailor information dissemination from general information sources (e.g., ITS) to end users’ decision systems. **NT**

D. Develop “intelligent” decision support systems, e.g., systems that learn and can collaborate with other systems and with humans. **NT, FT**

E. Conduct human-factors research to improve the human-machine interface, impact of information, and standardization of graphical displays in decision support applications. **NT**

F. Apply advanced communication technologies and graphical products to decision support systems, particularly those for mobile and remote decision nodes of ITS. **NT, FT**

**VII. Requirements for Development and Improvement of Misoscale to Mesoscale Numerical Models for Transportation Applications**

A. Finer-scale forecast skill in mesoscale weather prediction models used for multiple purposes in addition to surface transportation weather. **NT, FT**

B. Incorporation of land-surface features near roadways into local-scale models of weather parameters. **NT, FT**

C. Improvement of pavement condition models and local-scale weather forecast models through incorporation of data from next-generation road condition reporting systems. **FT**

D. Use of artificial intelligence techniques to improve the spatial resolution of weather forecast models. **FT**

E. Impact of high spatial and temporal variability of land use and land cover on mesoscale models with grid spacing less than 4 km. (Research currently supported by the U.S. Army for non-roadway applications should be transferable to surface transportation applications.) **NT, FT**

F. Roadway weather modeling that incorporates the surface–atmosphere system along and adjacent to the road and provides a framework for traffic and road operations management decision-support systems. (Long-term effort currently at "vision" stage.) **FT**

G. Predictive models for air and water dispersion of chemical, biological, and nuclear hazards associated with HAZMAT transportation incidents. **NT, FT**

H. Improve oceanographic sensors and models that incorporate weather data with water levels, tides, and currents to improve forecasts of conditions on MTS waterways and open water routes. **NT,FT**

**VIII. Interactions of Transportation Weather with Other Decision Support Factors**

A. Improve understanding and models for the uncertainties, risks, and cost–benefit outcomes related to incorporating weather/geophysical observations and prediction in surface transportation decision processes. **FT**

B. Operational research to *understand* and *validate* the effects of weather on all transportation outcomes, including traffic management, maintenance, emergency management, travel planning, traveler warning, facility planning, and others. Each decision type requires operational research to determine and validate linkages between weather information and improved transportation outcomes. **NT, FT**

C. Improve understanding of and develop models for human performance and behavior in relation to the use of weather-related current information and forecasts (near term to very long term) in decision processes. **NT, FT**

D. Improve understanding of, and address the social, economic, educational, and institutional policy issues related to, open dissemination and application of weather information for surface transportation. **NT, FT**

E. Develop and distribute tools and guidance to assist decision makers when release of contaminants or hazardous materials (spills, accidental discharges, terrorist actions) occurs within waters of the Marine Transportation System and other coastal environments. **NT**

E. Develop an understanding of, and validate with operational research, climatic-scale effects on facility and operations planning in the surface transportation sectors. **NT, FT**

F. Improve the estimation and presentation of risk in all weather and geophysical measurements and predictions related to surface transportation decisions and outcomes. Validate that end users comprehend the risk information well enough to affect their decisions and outcomes. The decision areas and outcomes include safety, mobility, productivity, environmental quality, and security. Risk communication topics to be explored include:

   1. Dissemination of observation confidence and quality-control metrics from data assimilation processes. **FT**
   2. Increased use of model ensemble and output statistics. **NT, FT**
   3. Integrating the spatial, temporal, and intensity dimensions of risk in precipitation and other weather events. **NT, FT**

G. Transportation outcome quantification of improved environmental information, decision support and technique (generally requiring large cross-sectional or longitudinal studies with controlled interventions). **FT**

## IX. Requirements to Extend the Fundamental Knowledge Base Supporting WIST Technology Development and Application

A. Improve the scientific understanding of atmospheric scales (spatial and temporal) and the thresholds of weather and geophysical parameters that affect surface transportation. **NT, FT**

B. Statistical filtering and prediction techniques applicable to roadways, railways, and waterways. **NT, FT**

C. Assess and develop controls for electromagnetic effects (e.g., solar weather) on ITS equipment. **NT**

D. Develop improved weather forecasting and climate monitoring applications in support of the USDOT/NOAA Interagency Agreement for the Nationwide Differential GPS. **FT**

E. Determine the total observational requirements, including those from transportation facilities, to achieve numerical weather prediction (NWP) quality sufficient for all WIST user needs. **FT**

## X. Education and Training to Provide Human Resources in WIST R&D

A. Develop academic curricula and training that spans meteorology and transportation applications. (The growth of the private sector WIST provider community will create career opportunities for appropriately educated individuals.) **NT, FT**

B. Attract the interest of the meteorological research community and enhance its participation in WIST applications R&D. Encourage the development of academic research centers with a focus on transportation-related weather issues and meeting the evolving needs of WIST user communities. **NT, FT**

C. Make the United States competitive with international research capabilities in applied weather information. **NT, FT**

# Appendix F

## *Federal Entities and Program Activities Relevant to WIST*

# Federal Entities and Program Activities Relevant to WIST

## OVERVIEW

This appendix expands on the Chapter 3 summaries for the federal partners in the Federal Committee for Meteorological Services and Supporting Research (FCMSSR)

Each section begins with a table for the entities within one federal department or independent agency. These tables identify each transportation sector of significant interest to each federal entity's constituent groups, or otherwise of significant interest to that federal entity. The following federal entities are represented:

- Department of Transportation
- Department of Energy
- Department of Defense
- Department of Commerce and the National Oceanic and Atmospheric Administration
- Department of the Interior
- Department of Agriculture
- Environmental Protection Agency
- Federal Emergency Management Agency
- National Aeronautics and Space Administration
- Nuclear Regulatory Commission
- U.S. Postal Service

## DEPARTMENT OF TRANSPORTATION

**DOT Role:** Policy and oversight for all transportation systems in the nation

The mission of the Department of Transportation (DOT) is to develop and coordinate national transportation policies that will provide an efficient and economical national transportation system, with due regard for need, the environment, and national defense. The DOT is the federal entity with primary responsibility for shaping and administering policies and programs to protect and enhance the safety, adequacy, and efficiency of transportation systems and services. In addition, it promotes intermodal transportation.

"[T]he Act which I sign today is the most important transportation legislation of our lifetime ... It is one of the essential building blocks in our preparation for the future ... Transportation has truly emerged as a significant part of our national life. As a basic force in our society, its progress must be accelerated so that the quality of our life can be improved."

President Lyndon Johnson, signing the act that established the Department of Transportation, October 15, 1966

The DOT includes the Office of the Secretary and 13 operating administrations, each headed by a presidential appointee. Among these administrations are the Federal Highway Administration (FHWA), National Highway Traffic Safety Administration (NHTSA), Federal Transit Administration, Federal Railroad Administration, Federal Aviation Administration (FAA), Maritime Administration, Saint Lawrence Seaway Development Corporation, Research and Special Programs Administration (RSPA), the U.S. Coast Guard, and the Transportation Security Administration (TSA). These operating administrations within DOT provide policy and oversight for all the modes of surface transportation covered by the WIST needs study (Table F-1).

**Table F-1** Interests of DOT Constituencies in Transportation Sectors

| | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| **Department of Transportation** | **Road** | **Rail** | **MTS** | **Pipeline** | **Transit** | **Airport Ground Ops** |
| Federal Highway Administration | X | | | | | |
| Federal Transit Administration | X | X | X | | X | |
| National Highway Traffic Safety Admin. | X | X | | | | |
| Federal Railroad Administration | | X | | | | |
| Maritime Administration | | | X | | | |
| St. Lawrence Seaway Corporation | | | X | | | |
| U.S. Coast Guard | | | X | | | |
| Research & Special Programs Administration | X | X | X | X | X | X |
| Office of Emergency Transportation | X | X | X | X | X | X |
| Office of Hazardous Materials Safety | X | X | X | X | | X |
| Office of Pipeline Safety | | | | X | | |
| Federal Aviation Administration | | | | | | X |
| Center for Climate Change & Environ. Forecasting | X | | X | | X | |
| Transportation Security Administration | X | X | X | X | X | X |

The DOT Office of the Secretary oversees the formulation of national transportation policy and promotes intermodal transportation. Other responsibilities are negotiation and implementation of international transportation agreements, assuring the fitness of US airlines, enforcing airline consumer protection regulations, issuance of regulations to prevent alcohol and illegal drug misuse in transportation systems, and preparing transportation legislation.

### Federal Highway Administration

The roads and highways of the United States are planned, built, and operated through a division of responsibilities between the federal government and the states. The FHWA has division offices in each state, and four regional resource centers, as well as a headquarters office in Washington, D.C. It performs its mission through two main programs:

Snow on the Washington, D.C., beltway. Courtesy Blaine K. Tsugawa, OFCM staff.

- The Federal-Aid Highway Program provides federal financial assistance to the states to construct and improve the National Highway System, urban and rural roads, and bridges. The program includes emergency relief to help states conduct emergency and permanent repairs of damage from natural disasters or catastrophic failures.

- The Federal Lands Highway Program provides access to and within national forests, national parks, the Tribal nations, and other public lands by preparing plans, letting contracts, supervising construction, and conducting bridge inspections and surveys.

With the exception of the roads served by the Federal Lands Highway Program and some private roads, U.S. roads and highways are built, maintained, and operated by state and local agencies and toll authorities. The FHWA develops regulations, policies, and guidelines for federal-aid funding, with the aim of achieving FHWA goals for mobility, safety, productivity, the human and natural environment, and national security.

The Federal-Aid Highway Program funds state highway research, but the FHWA also manages a national research, development, and technology program that includes the Intelligent Transportation System (ITS), through the ITS Joint Program Office. The work on Surface Transportation Weather Decision Support Requirements (STWDSR), including the Maintenance Decision Support System (MDSS), described in Section 1.3.1, is part of the ITS initiative (Nelson 2001, Mahoney 2001, NCAR 2002).

The FHWA delivers technical training, education, and assistance to its own staff and partners in areas of:

- Roadway and bridge design, construction, and maintenance

- Value engineering and other project and program evaluation tools
- Policy and planning
- Highway safety
- Intelligent transportation systems
- Environmental protection and enhancement
- Innovative financing
- Land acquisition
- Research, development, and technology transfer.

The research program generally seeks to advance the state of the art in transportation systems quality. The FHWA works with government, industry, and research-community partners to develop, test, and implement the latest technology. Because the FHWA is charged with coordinating highway transportation programs in cooperation with the states and other partners, it is helping to lead the effort to revolutionize road weather information in America. Much of this effort will have spin-off effects for improving weather information for many other modes of surface transportation.

The offices within the FHWA that are most relevant to weather issues are the Office of Operations and the Office of Research, Development and Technology. However, weather issues cut across the FHWA's programs, goals, and organizational units. This has made it vital, although difficult, to give weather information needs a focus within the agency.

*The Road Weather Management Program*

Various FHWA infrastructure and research programs have long been concerned with weather, particularly winter road maintenance. Although the mission of the FHWA does not include producing weather information, the linkages between general weather information and relevant threats to surface transportation ("road weather") spans the interests of meteorology and transportation. In 1997 the Rural ITS program began a focus on road-weather information. This effort has evolved into the Road Weather Management Program (RWMP) within the Office of Operations (Row 2001).

The Office of Operations, created in 1999, represents the increasing role of FHWA as a leader in improving state and local road operations in response to synoptic scale (e.g., hurricane) and smaller-scale weather threats. It also hosts the emergency operations component of the FHWA, which plays a federal coordinating role during national-scale disasters. The experience with Hurricane Floyd in particular has shaped RWMP activities aimed at augmenting the emergency management role of the state transportation departments. The RWMP is also working with the traffic management staff within the Office of Operations to improve ITS-based practices for preserving mobility and safety in more common, and smaller-scaled, weather threats. Issues concerning road weather information for travelers are dealt with elsewhere in the Office of Operations and in the ITS program generally.

The RWMP includes work on road-weather sensing related to prediction techniques, dissemination of road-weather information through ITS, the development of decision support applications that use information on weather threats, and the improvement of transportation operations to respond to threats. The RWMP has taken the lead for the FHWA in interfederal coordination concerning road-weather information. This coordination occurs directly with agencies like the National Weather Service (NWS) in the National Oceanic and Atmospheric Administration (NOAA) and through the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM). The RWMP brings the interests of its constituencies, primarily the state departments of transportation, to the interfederal arena.

Winter road maintenance continues to be an RWMP focus. Through the STWDSR program, the RWMP is leading the FHWA activity in defining road-weather sensing requirements for integration with both ITS surveillance efforts and the national environmental observation system. In conjunction with the Office of Research, Development and Technology, the RWMP has been developing technology for sensing and treating winter road conditions. Among the RWMP efforts to develop and test advanced decision support systems for WIST users are the ATWIS and FORETELL projects, now operational in the Midwest, as well as the MDSS prototype development program (Section 1.3.1). Through the COMET program, the RWMP has sponsored five university-NWS-state research projects to improve deployment and application of road-weather sensors.

The RWMP has worked with the ITS Joint Program Office to define the flows of weather and related data in the National ITS Architecture (Section 1.3.1). This effort includes developing the ITS user service for Maintenance and Construction Operations and integrating weather data standards into Version 4 of the National ITS Architecture. Because the construction and operational interests of the FHWA are mostly indirect, the FHWA controls no large operating or project funds, comparable to programs of the FAA, NWS, or Department of Defense (DoD). However, the RWMP works through the interfederal coordination process to bring the requirements of the ITS into meteorological information systems and observing platforms.

*Climate Information and its Relevance to Surface Transportation*

Interests in road weather differ, within the FHWA and elsewhere in the DOT, depending on the temporal and spatial scales of weather information. Climate information is most relevant to infrastructure planning and the long-range management of operations resources. The Office of Planning and Environment is the FHWA unit that works most closely with the DOT Center for Climate Change and Environmental Forecasting, which focuses on climate issues and their impacts on the surface transportation system, such as long-term highway inundation.

### Federal Transit Administration

The Federal Transit Administration, through its funding program, assists in developing improved mass transportation systems for cities and communities across the country. Beyond typical bus and rail systems, it supports other forms of public transportation, including commuter ferryboat, trolleys, and people movers. A wide range of technical and planning assistance helps transit agencies' to develop their service operations, building and construction, capital investments, and joint development efforts. Through its technology programs, the Federal Transit Administration supports research on intelligent transportation systems, alternative fuels, and new communication technologies. System-wide applications of advanced new technologies have contributed to transit agencies becoming more integrated with other transportation and information networks, while also increasing access, cost-effectiveness, and convenience. Other programs play a significant role in helping to minimize air pollution and single-occupant vehicle traffic in congested urban environments. Programs and technologies such as the Bus Rapid Transit Initiative and communication-based train control are improving the viability of transit services in meeting current and future needs of the traveling public. Across the nation, the Federal Transit Administration is helping to create neighborhoods that are more amenable to transit and pedestrian travel, ultimately enhancing the quality of life and making communities more livable.

### National Highway Traffic Safety Administration

NHTSA is responsible for reducing deaths, injuries, and economic losses resulting from motor vehicle crashes. It sets and enforces safety performance standards for motor vehicles and equipment. Through grants to state and local governments, it enables them to conduct effective local highway safety programs. The statistics on highway accidents, including injuries and economic consequences of accidents, cited in this and most other WIST-related reports originate from NHTSA databases.

NHTSA investigates safety defects in motor vehicles; sets and enforces fuel economy standards; helps states and local communities reduce the threat of drunk drivers; promotes the use of safety belts, child safety seats, and air bags; investigates odometer fraud; establishes and enforces vehicle antitheft regulations; and provides consumer information on motor vehicle safety topics. It also conducts research on driver behavior and traffic safety, to develop the most efficient and effective means of bringing about safety improvements

### Federal Railroad Administration

The Federal Railroad Administration promotes safe and environmentally sound rail transportation. With its responsibility for ensuring railroad safety throughout the nation, it employs safety inspectors to monitor railroad compliance with federally mandated safety standards, including track maintenance, inspection standards, and operating practices. The Federal Railroad Administration conducts tests to evaluate research and development projects that support its safety mission and enhance the railroad system as a national transportation resource. It also administers public education campaigns on highway–rail grade crossing safety and the danger of trespassing on railroad property.

Railroad bridge washed out by hurricane flooding.

### Maritime Administration

The Maritime Administration promotes development and maintenance of an adequate, well-balanced, U.S. merchant marine, sufficient to carry the nation's domestic waterborne commerce and a substantial portion of its waterborne foreign commerce. The merchant marine can serve as a naval and military auxiliary in time of war or national emergency. The Maritime Administration also seeks to ensure that the United States enjoys adequate shipbuilding and repair service, efficient ports, effective intermodal water and land transportation systems, and reserve shipping capacity in time of national emergency.

### Saint Lawrence Seaway Development Corporation

The Saint Lawrence Seaway Development Corporation operates and maintains a safe, reliable and efficient waterway for commercial and noncommercial vessels between the Great Lakes and the Atlantic Ocean. In tandem with the Saint Lawrence Seaway Authority of Canada, it oversees operations safety, vessel inspections, traffic control, and navigation aids on the Great Lakes and the Saint Lawrence Seaway.

### U. S. Coast Guard

The Coast Guard ensures safe and secure transportation on America's waterways and protection of the marine environment. The Coast Guard's job of ensuring maritime safety and security will become even more challenging in the years ahead, driven by three transportation trends. First, domestic and ocean-borne trade and cruise ship demand are poised for explosive growth in the size and number of ships plying inland, coastal, and deepwater waterways. Second, fishing vessels and offshore platforms venture farther offshore in search of the sea's bounty. Third, a dramatic increase in personal watercraft and recreational boating is driving ever greater congestion on the nation's waters. Prevention, founded on expert risk assessments to reduce the probability of mishaps, will be the watchword of the future. Advanced technologies will continue to be embraced to increase the probability of success of the Coast Guard mission.

Among the Coast Guard's weather related duties is participation in the International Iceberg Patrol, which aims to provide safe navigation in the northwest Atlantic Ocean by monitoring the location and movement of icebergs.

A sinking tanker leaking oil. Photo courtesy NOAA Photo Library.

## Research and Special Programs Administration

The RSPA oversees rules governing the safe transportation and packaging of hazardous materials by all modes of transportation, excluding bulk transportation by water. It also assists local and state authorities with training for hazardous materials emergencies. Research and development play a major role in RSPA's mission. In addition, RSPA operates the Volpe National Transportation Systems Center in Cambridge, Massachusetts, which is dedicated to enhancing the effectiveness, efficiency, and responsiveness of other federal organizations with critical transportation-related functions. Three entities within the RSPA have special relevance to WIST needs and applications: the Office of Emergency Transportation, Office of Hazardous Materials Safety, and Office of Pipeline Safety.

### *Office of Emergency Transportation*

Transportation is a vulnerable lifeline, but during and after disasters it becomes essential for helping a community recover and restore its economy. To provide a centralized, effective program, the Office of Emergency Transportation performs coordinated crisis management functions for multimodal transportation emergencies. An emergency may result from:

- Natural disasters
- Technological incidents and accidents
- Labor strikes
- Security situations, such as domestic criminal acts or acts of terrorism
- National defense mobilization.

Extreme weather falls under the category of natural disasters. Adverse weather events in this category include hurricanes, tornadoes, major flooding, and similar events that cause disruptions in transportation systems for which coordinated crisis management is required. Preparation and training for emergency events include exercising every component of the team and every aspect of the plan, so that surprises will be minimal when critical decisions must be made and implemented. The Office of Emergency Transportation also works with other federal and state agencies to ensure relationships are in place before the stress of disaster response begins.

Activities within the Office of Emergency Transportation include:

- Managing the DOT Crisis Management Center to collect, analyze, and disseminate critical transportation infrastructure information to senior DOT officials, and to ensure that communications and other equipment are ready at any time

- Managing the Alternate Relocation Site for core DOT functions so that the Department can continue to work even if the headquarters is unusable

- Developing and continually revising and testing plans and procedures to meet new threats and take advantage of new technology and other advances

- Training DOT staff for disaster functions that are essential but not performed frequently.

*Office of Hazardous Materials Safety*

The mission of the Office of Hazardous Materials Safety is to promulgate a national safety program that will minimize the risks to life and property inherent in commercial transportation of hazardous materials. The functions of the Office of Hazardous Materials Safety fall into five categories: regulatory development, enforcement, training and information dissemination, domestic and international standards, and interagency cooperative activities. The standard form used by the Office to report a transportation incident includes questions on weather conditions at the time of the incident, such as precipitation, pavement condition, winds, or sun glare.

Weather events affect the transportation of hazardous materials in two ways. First, exposure to specific kinds of weather may increase the vulnerability of hazardous materials in transit. Second, weather and related condition can affect the consequences of a release of hazardous materials through atmospheric dispersion, water contamination, and other routes.

*Office of Pipeline Safety*

The Office of Pipeline Safety administers the DOT's national regulatory program to ensure the safe transportation of natural gas, petroleum, and other hazardous materials by pipeline. It develops regulations and other approaches to risk management, to assure safety in design, construction, testing, operation, maintenance, and emergency response of pipeline facilities. Pipeline safety standards are established and maintained by the Office of Pipeline Safety to ensure public safety and environmental protection from gas and hazardous liquids transported by pipeline.

Various types of weather phenomena can be listed as causal events in the standard form used by the Office of Pipeline Safety for reports of accidents and incidents involving natural gas or hazardous liquid pipelines. A section on the form called "Apparent Cause" lists "Natural Forces" as a subsection, with four types of weather events among the list of choices: lightning, heavy rains/floods, temperatures, and high winds. Heavy rains are further categorized by their effects (washouts, flotation, scouring, other). Temperature as a cause is also further categorized as thermal stress, frost heaves, frozen components, or other.

## Federal Aviation Administration

The FAA oversees the safety of civil aviation. The agency is responsible for certification of airports serving air carriers. It also regulates a program to protect the security of civil aviation and enforces regulations under the Hazardous Materials Transportation Act for shipments by air. In addition to operating a network of airport towers, air route traffic control centers, and flight service stations, the FAA develops air traffic rules, allocates the use of airspace, and provides security control of air traffic to meet national defense requirements.

Holman Field, St. Paul, Minnesota, flooded by the Mississippi River, April 2001. Copyright AP Wide World Photos.

At air terminals, the FAA is responsible for coordinating or controlling operational movements on the ground. This responsibility includes movement of aircraft, freight vehicles, baggage movers, and support equipment such as fuel, food, and maintenance vehicles.

The FAA supports the collection of weather information for aviation and for all other weather services and databases through a large number (767) of automated observing systems. It also continues to fund contracts for human weather observers (198) at critical locations. It also supports R&D on aviation weather, to ensure the safety, capacity, and efficiency of the national aviation system.

### Center for Climate Change and Environmental Forecasting

The Center for Climate Change and Environmental Forecasting was established within DOT in 1999 to coordinate Departmental strategies and policies for mitigating transportation's contribution to greenhouse gas emissions and assessing the effects of climate change on the transportation system. The Center functions as a DOT-wide virtual organization, led by a steering committee composed of senior executives from nine of the DOT operating administrations and the Office of the Secretary. This cross-modal, virtual structure helps to ensure strong participation throughout the Department, while avoiding unnecessary administrative and institutional costs. The operating administrations support the Center's work through contributions of funds, staff, and technical expertise. They participate in the Center's efforts to share information, build partnerships, and coordinate activities related to climate change.

The Center sponsors several projects including the following:

- **Impacts of Climate Change on Transportation.** The Center is undertaking a series of research projects to assess how short and long term changes in climate could affect transportation, and how transportation decision makers could address these possible impacts.
- **Fuel Options.** This study compares the energy use, emissions of greenhouse gases and criteria pollutants, and cost-effectiveness of current and alternative fuels for light-duty and heavy-duty highway vehicles.
- **Transportation Greenhouse Gas Data and Modeling.** This study analyzes data and models being used to improve understanding of greenhouse gas emissions from the transportation sector and the implications of policy options.

### Transportation Security Administration

The TSA was established by Public Law 107-71 following the terrorist attacks of September 11, 2001. Its primary objective is to stop terrorist incidents before they can be implemented. When fully operational, the TSA will have thousands of federal law enforcement, security, and regulatory employees at 429 airports across the country. Although protecting the traveling public in airports and on airplanes may be the most visible responsibility of the TSA, it also has lead responsibility for security of the nation's highways, waterways, seaports, railways, public transit, and pipelines (DOT 2002). Thus, all the surface transportation sectors studied for this WIST report are within its purview.

Weather conditions have direct and indirect implications for the mission of the TSA. First, as in any emergency response situation, weather conditions may influence the ability of responders to a homeland security incident. Second, prevailing and forecast conditions can be critical to effective response and recovery, if an attack disperses a chemical, biological, or radiological hazard. Third, heightened security measures after September 11 may increase the impact of adverse weather on the efficiency and effective capacity of transportation systems (e.g, bridge and facility entrances) or intermodal connections (e.g, airport parking lots and passenger terminals, seaport-to-rail/roadway carrier links).

## DEPARTMENT OF ENERGY

The mission of the Department of Energy (DOE) is to foster a secure and reliable energy system that is environmentally and economically sustainable, to be a responsible steward of the nation's nuclear weapons, to clean up its own facilities, and to support continued United States leadership in science and technology.

**DOE Role** (Table F-2): Transportation of nuclear materials, through its National Transportation Program, and repair crew access to electric transmission lines.

A large part of the work performed by the DOE and its partners is the safe management of nuclear materials and permanent disposal of the nation's radioactive wastes. This work includes packaging, ***transporting,*** and storing these hazardous materials.

**Table F-2** Interests of DOE Constituencies in Transportation Sectors

| Department of Energy | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| | Road | Rail | MTS | Pipeline | Transit | Airport Ground Ops |
| National Transportation Program | X | X | X | | | X |
| | | | | | | |
| Power Marketing Administrations | X | | | | | |

DOE's packaging and transportation activities are performed through program offices, which provide policy direction and program oversight. Materials transported in these activities range from weapons components and subassemblies to spent fuel, special nuclear materials, and radioactive or otherwise hazardous waste materials. Field offices are responsible for detailed planning for shipments and for full regulatory compliance. They also serve as focal points for local public and stakeholder interactions.

DOE ships its materials by all modes of transportation, using both commercial and private carriers. In FY 1997 the distribution by sector was 77 percent by air, 22 percent by roadway (motor carrier), and less than 1 percent by rail. In FY 1997, DOE transported 430,000 shipments of non–defense-related materials, consisting of 412,000 (96 percent) nonhazardous shipments and 18,000 shipments (4 percent) of hazardous materials. Of the latter, 5,200 were radioactive. Although shipments of radioactive materials were thus only 1.2 percent of all DOE shipments, DOE ships 75 percent of all curies (a measure of radioactivity) transported in the United States.

## National Transportation Program

The National Transportation Program (NTP), which is DOE's corporate center for packaging and transportation expertise, is located and managed within the Office of Environmental Management. The NTP supports infrastructure and coordinates transportation activities for all nonclassified shipments of hazardous materials, including radioactive materials, mixed wastes, and commodities such as coal, other fuels, maintenance materials, and supplies.

The NTP is responsible for ensuring the availability of safe, secure, and economical transport services; consistency in regulatory implementation; and coordinated outreach and emergency preparedness assistance for DOE programs. The NTP develops and provides training on transportation and packaging management and safety, including domestic and international regulations, guidance, and standards.

## Federal Energy Corporations—The Power Marketing Administrations

The Power Marketing Administrations (PMAs) are power utilities that are agencies of the DOE. Their role is to sell, in the wholesale market, electric power and associated energy produced at federal dams (and some nonfederal power plants). By law, the power is marketed to publicly held entities such as rural electric cooperatives and municipal utilities first, followed by commercial or industrial customers within the region. Any remaining surplus power is sold to customers outside the region. The regions for four of the PMAs are shown in Figure F-1. The fifth PMA is the Alaska Power Administration.

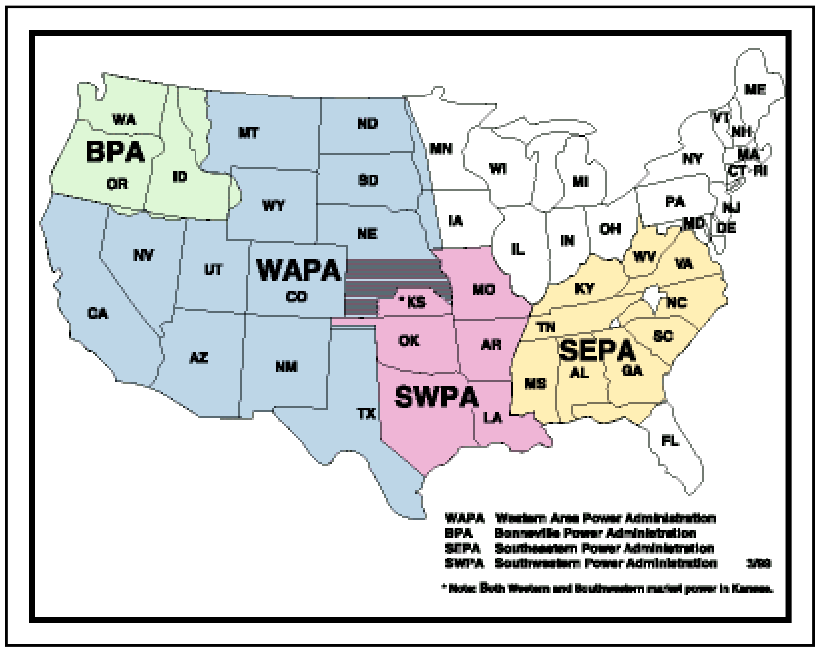
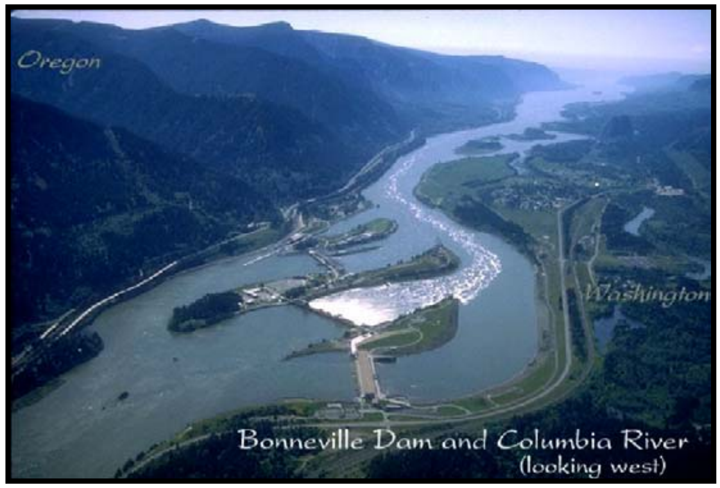



**Figure F-1** PMA Regions.

The PMAs have a significant need for weather information, although most of it is required for managing water resources and long-term planning of power production. Within the scope of the WIST study, the information needed is mostly limited to weather elements that affect the ability of repair crews to service power transmission lines. Consequently, the WIST needs of the PMAs are similar to those of other utilities operating a fleet of repair trucks, such as telephone or cable TV companies. Those needs focus on weather elements such as freezing rain, deep snow, and other precipitation impacts.

The **Bonneville Power Administration**, with headquarters in Portland, Oregon, covers the Pacific Northwest. It markets the wholesale electric power produced at 29 federal dams located in the Columbia–Snake River Basin, as well as the power from one nonfederal nuclear plant. Like all the PMAs, Bonneville does not own or operate any federal dams. It only sells the power produced by these facilities. Two other federal entities, the U.S. Army Corps of Engineers and the Bureau of Reclamation, operate the dams whose electric energy output is sold by this PMA. The nuclear plant is owned by the Washington Public Power Supply System, a consortium of utilities.




Bonneville Dam, one of the sources of power marketed by the Bonneville Power Authority. Photo courtesy Bonneville Power Authority.

Today the Bonneville Power Administration sells about 46 percent of the electric power consumed in the northwestern United States. To deliver that power, it owns and operates one of the largest high-voltage electrical transmission systems in the world, with 15,000 miles of power lines, constituting about three-fourths of the region's high-voltage electric grid.

The **Southeastern Power Administration**, headquartered in Elberton, Georgia, markets the electric power and energy generated at hydroelectric dams operated by the U.S. Army Corps of Engineers in the southeastern portion of the United States. Because this PMA does not own transmission lines, it contracts with other utilities to provide transmission, or "wheeling" services, for its power.

The **Southwestern Power Administration,** which has its headquarters in Tulsa, Oklahoma, is responsible for marketing the hydroelectric power produced at 24 U.S. Army Corps of Engineers multipurpose dams located in Arkansas, Missouri, Oklahoma, and Texas. This PMA operates and maintains 1,380 miles of high-voltage transmission lines, 24 substations, and 46 microwave and VHF radio sites.

The **Western Area Power Administration** has its headquarters in Lakewood, Colorado. It markets and delivers power and related services from 55 hydroelectric plants within a 15-state region of the central and western United States. These plants are operated by the Bureau of Reclamation, U.S. Army Corps of Engineers, or the International Boundary and Water Commission. This PMA operates and maintains a transmission system with more than 16,800 miles of transmission lines, as well as 256 substations and other related facilities.

## DEPARTMENT OF DEFENSE

In addition to being a consumer of transportation weather information, the DoD is also one of the nation's principal producers of weather information. Both the Air Force and the Navy have weather observation and prediction as elements of their mission. The Air Force provides the weather information required by the combat forces of the Air Force and the Army. The Navy provides weather information for Navy and Marines Corps forces.

**DoD Role** (Table F-3): The U.S. Transportation Command (USTRANSCOM), through its Army component Military Traffic Management Command (MTMC), has a major interest in surface transportation (rail, road, and port operations). While the MTMC is responsible for road and rail transportation, the U.S. Army Corps of Engineers is responsible for waterways. The Navy is responsible for open water routes. All of the services have airport ground operations. The Defense Logistics Agency and the Defense Energy Support Center are responsible for pipelines.

**Table F-3** Interests of DoD Constituencies in Transportation Sectors

| | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| **Department of Defense** | **Road** | **Rail** | **MTS** | **Pipeline** | **Transit** | **Airport Ground Ops** |
| U.S. Transportation Command | X | X | X | | X | X |
| Military Traffic Mgmt Command | X | X | X | | X | X |
| | | | | | | |
| U.S. Air Force | X | | | | | X |
| | | | | | | |
| U.S. Navy | X | | X | | | X |
| | | | | | | |
| Defense Logistics Agency | | | | X | | |

### U.S. Transportation Command

The mission of the U.S. Transportation Command (USTRANSCOM) is to provide air, land, and sea transportation for the DoD both in times of peace and in war. It has been designated the single manager of the Defense Transportation System. Strategic mobility is the instrument that allows the United States to act upon the world stage at whatever level is chosen by the national leadership. The potential range of regional threats in the next 20 years is so broad that no single scenario can be identified as an adequate basis for planning. Current U.S. military strategy calls for more military forces to be based in the continental United States, with a reduced forward presence overseas. With fewer U.S. forces stationed overseas, the nation must increase its capability to project military power abroad. USTRANSCOM must continue to strengthen and improve all facets of strategic mobility and must be ready to react on a moment's notice. The ability to project power worldwide rapidly depends on increased airlift capability, additional prepositioning of heavy equipment afloat and ashore, increased surge sealift capacity, and improved readiness and responsiveness of the Ready Reserve Force.

### Military Traffic Management Command

The mission of the MTMC, the Army component of USTRANSCOM, is to support DoD and the mobilization community worldwide during peace and war with responsive planning, crisis response actions, traffic management, terminal operations, integrated transportation systems, and deployability engineering. As USTRANSCOM's overland lift component and primary traffic coordinator, the MTMC has assets and equipment comprising more than 12,000 containers, more than 1,350 rail and tank cars, and 142 miles of government-owned railroad track. The MTMC contracts with commercial transportation resources to provide additional transportation capabilities.

With the help of these commercial industry partners, it accomplishes its mission with 2,355 active duty and reserve military members, as well as Department of the Army civilians, stationed around the world. These professionals come from all branches of the Armed Forces: Army, Navy, Air Force, Marines, Coast Guard, and the Canadian Armed Forces. This personnel strength almost doubles during mobilizations, when Reserve Component units augment the regular service personnel.

### U.S. Air Force

The mission of Air Force Weather is to provide timely, accurate, and relevant mission weather and space environmental information to meet Air Force, Army, Joint, and other defense and intelligence community needs worldwide. These needs include weather support to surface transportation and airfield ground operations worldwide. To accomplish its mission, Air Force Weather executes five core processes: data collection, analysis, forecasting, tailoring, and dissemination. On a global scale, it leverages the numerical weather prediction capabilities of the U.S. Navy and the NWS. It also supports global meteorological satellite applications as the DoD Meteorological Satellite Center of Excellence. For regional scale information down to "mission scales," it exploits meteorological satellites and a suite of models, including the community-developed MM5 mesoscale model, to produce fine-scale weather forecasts for the gamut of aviation and ground activities.

Air Force Weather provides space environmental support for DOD operations. This support is increasingly important within the DOD, as space operations become critical to supporting warfighting operations. Space weather events can affect key military capabilities such as radio communications (HF and UHF), satellite operations, space object tracking, high-altitude flights, radar operations, and the Global Positioning Satellite system.

To meet this spectrum of requirements, Air Force Weather activities are organized across the breadth of military operations, from strategic to operational and tactical levels. The Air Force Weather Agency (AFWA) is the primary strategic center providing global and other large-scale support to strategic customers and Operational Weather Squadrons around the world. As an example, AFWA provides gridded precipitation information to the Army Corps of Engineers to support waterways management. To mitigate the impacts of space weather on DOD and national systems, AFWA also provides space weather observations, forecasts, alerts and warnings, and tailored products. It ensures that information on the space environment is available for warfighters and decision makers at strategic, operational, and tactical levels.

The Air Force Combat Climatology Center, a strategic center under AFWA, provides climatological support including engineering weather data for applications such as road building and simulation support for development and testing of surface transportation systems. The eight Operational Weather Squadrons provide regional forecasting services, warnings, and advisories to protect life and resources and preserve operational capability. These units produce information products tailored for use by Combat Weather Teams, which provide direct support to Air Force and Army operations at the tactical level. Combat Weather Teams provide surface weather decision information for the movement of personnel, equipment, and weapons on and around Air Force and Army installations, as well as for operations en route to and from airports and sea ports. They produce information products that are highly tailored to individual missions and activities. They also provide weather information vital to safe and efficient ground operations on airfields.

### U.S. Navy

The Navy has the military requirement to provide meteorological products and services to support Navy, Marine, and Joint forces. It also provides oceanographic support to all elements of the DoD. The information is used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, as well as to provide tactical or strategic advantage in exploiting the physical environment during military or humanitarian operations.

Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command. Navy meteorology and oceanography organizations collect observations ashore, afloat, and through remote sensors, worldwide. They also are involved in assimilating and processing these observations on a global basis to support analysis and forecasting throughout the world. Environmental data are acquired through links with distribution systems for conventional and remotely sensed data, operated by DoD or NOAA.

The Fleet Numerical Meteorology and Oceanography Center in Monterey, California, provides global, regional, and tactical observations, analysis, and coupled air–ocean forecasts. The Naval Oceanographic Office, located at Stennis Space Center, Mississipi, processes and distributes oceangraphic, hydrographic, and other geophysical data and products. It is the Navy’s primary processing facility for data from NOAA polar-orbiting satellites and the national “core processing center” for sea-surface temperature measurements derived from satellite data.

Worldwide theater and regional support is provided to forces ashore and afloat through six regional centers delivering meteorological and oceanographic services within their broad areas of responsibility. Specific products common to the regional centers include warnings of high winds and seas for the world's oceans, tailored forecast support for Navy, Coast Guard, and NOAA ships at sea, and ship routing services for ocean transits.

The Naval Ice Center, located in Suitland, Maryland, provides tailored ice forecasts and analyses to the DoD. The Navy, through this center, operates the National Ice Center jointly with NOAA and the Coast Guard. The National Ice Center provides ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civilian and military operations.

Facilities of the Naval Meteorology and Oceanography Command—located at Whidbey Island, Washington; Naples, Italy; and Jacksonville and Pensacola, Florida—provide aviation forecast services, as well as Fleet Operating Area and local forecasts and warnings. These services and products are used by aircraft, ships, submarines, and naval bases and staffs. The command also has 31 detachments worldwide. These detachments are primarily situated at naval air stations for aviation safety of flight forecasting, although several are located at naval stations in support of sea-going units. They provide meteorological and oceanographic forecasting and warning services to the DoD and allied units within their local and functional areas of responsibility. Detachments and facilities within the continental United States use numerical weather prediction products from both the Navy and NOAA's National Centers for Environmental Prediction. Overseas detachments and facilities use Navy numerical products, in addition to Air Force and foreign products.

The Navy also has permanent meteorological and oceanographic assets aboard aircraft carriers, major amphibious ships, and command ships. Their primary objectives are safety of ships, aircraft, and embarked personnel; optimum tactical and planning support to onboard warfare commanders; and tailored on-scene products and services for the assigned task force, task group, or allied units in joint, combined, or coalition military and humanitarian operations.

The Navy and Air Force have long cooperated in providing weather support for the DoD. These efforts have led to successes such as the Defense Meteorological Satellite Program and the Joint Typhoon Warning Center, which is operated jointly by the Navy and Air Force and located at Pearl Harbor, Hawaii. Similarly, the Navy and NOAA have a history of cooperative efforts, which increase efficiency and benefit both the Navy and NOAA. All three agencies continue to identify new areas of cooperation

## DEPARTMENT OF COMMERCE AND THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

**DOC Role** (Table F-4): NOAA's National Ocean Service and NOAA Corps are primarily consumers of weather information., although some facilities provide oceanographic and meteorological observations. NOAA's NWS is the principal provider of weather information for the nation.

The role of the Department of Commerce (DOC) is to promote job creation, economic growth, sustainable development and improved living standards for all Americans. The DOC accomplishes these objectives through its various component agencies and by working in partnership with business, universities, and communities. The National Oceanic and Atmospheric Administration (NOAA) is the DOC's primary agency for weather data.

NOAA is dedicated to predicting environmental change and protecting the environment. It uses environmental assessment and prediction to observe and analyze the state of the environment, while protecting public safety and the nation's economic and environmental security through accurate forecasting. Second, it practices environmental stewardship to protect ocean, coastal, and living marine resources and enable sustainable development in the coastal zone.

NOAA provides its services through five major divisions and numerous special program units. The major divisions are NOAA's National Ocean Service, National Marine Fisheries Service, Office of Oceanic and Atmospheric Research, National Weather Service, and National

Environmental Satellite Data and Information Service. NOAA also includes the nation's seventh, and smallest, commissioned service, the NOAA Corps. The commissioned, uniformed officers of the NOAA Corps are scientists and engineers who operate and manage NOAA's fleet of research ships and aircraft.

**Table F-4** Interests of DOC Constituencies in Transportation Sectors

| Department of Commerce, National Oceanic and Atmospheric Administration | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| | Road | Rail | MTS | Pipeline | Transit | Airport Ground Ops |
| NOAA's National Ocean Service | | | X | | | |
| | | | | | | |
| NOAA Corps | | | X | | | |
| | | | | | | |
| NOAA's National Weather Service | X | X | X | X | X | X |

## NOAA's National Ocean Service

As the nation's principal advocate for coastal and ocean stewardship, NOAA's National Ocean Service develops the national foundation for coastal and ocean science, management, response, restoration, and navigation. It provides nautical charting products for safe navigation to the marine community and conducts research on the health of the coastal environment. Both activities contribute to healthy coastal economies. The coastal ocean, which includes the coasts, bays, estuaries, and the Great Lakes, is economically, politically, and socially critical to the nation. Coastal communities are hubs of commerce and home to many major American corporations, ports, and transportation networks. NOAA's National Ocean Service works to find innovative ways to provide information, tools, and techniques that will reduce the vulnerability of these communities to storms, tsunamis, harmful algal blooms, fish kills, marine mammal strandings, and other coastal hazards. It establishes coastal preparedness plans, educates the public about coastal hazards, and develops tools, such as geographic information systems, to help communities plan for and respond to coastal hazards. This agency also provides scientific expertise during operations to clean up oil and hazardous chemical spills and works to restore marine areas harmed by pollution or other damage.

*Support to the Marine Transportation System*

NOAA's National Ocean Service supports the MTS with a variety of navigation and environmental services. NOAA activities authorized by the Coast and Geodetic Survey Act of 1947 and the 1998 Hydrographic Services Improvement Act include programs for Mapping and Charting, Hydrographic Surveys, Geodesy, and Tide and Current Data. These programs are the backbone of the MTS information infrastructure. In addition to promoting safe and efficient maritime commerce with its navigation services, NOAA issues marine weather forecasts, conducts satellite-aided search and rescue tracking with the Coast Guard and other partners, and facilitates sound port development. NOAA also supports an environmentally friendly MTS by conducting waterway risk assessments to aid port planning, organizing spill preparedness and response activities, and promoting fisheries management and habitat restoration. These activities form a comprehensive and effective program supporting the future of the MTS.

Predicting water levels accurately requires forecast models that incorporate weather information. NOAA's National Ocean Service provides real-time observations on water levels, tides, and currents to support the MTS and safe, efficient use of the nation's ports. NOAA merges these oceanographic data with marine meteorological data from the NWS to develop models for nowcasts and forecasts of water levels and conditions important for maritime commerce and safe navigation.

NOAA data on water levels can help move ships in and out of port as quickly as possible, and as fully loaded as safety permits. A few more inches of draft can mean additional thousands to millions of dollars to a shipper. Loading additional cargo can take many hours, and it may take anywhere from two to eight hours for a ship to leave a port and reach the ocean. To maximize cargo loads, mariners need to know what the underkeel clearance will be, from 6 to 24 hours in the future. Ships coming into port use the NOAA sensor data and models to time their arrival for the best underkeel clearance conditions, without wasting fuel by having to wait outside a bay or port entrance for adequate conditions.

### NOAA Corps

The NOAA Corps is the smallest of the seven uniformed services of the United States. The service, consisting of approximately 300 commissioned officers, is an integral part of NOAA. It provides a cadre of professionals trained in engineering, earth sciences, oceanography, meteorology, fisheries science, and other related disciplines. Officers operate research and survey ships, fly "hurricane hunter" research aircraft into nature's most turbulent storms, lead mobile field parties, manage research projects, conduct diving operations, and serve in staff positions throughout NOAA. The ranks within the NOAA Corps are the same as the U.S. Navy, from ensign to rear admiral (upper half).

### NOAA Marine and Aviation Operations

NOAA operates a wide assortment of vessels to conduct hydrographic surveys, oceanographic research, and fisheries research. These vessels, which operate under NOAA Marine and Aviation Operations, are commanded by NOAA Commissioned Officers and crewed by wage marine civilians. The wage marine personnel include licensed masters, mates, and engineers and unlicensed members of the engine, steward, and deck departments. In addition, survey and electronic technicians operate and maintain the ship's mission, communication, and navigation equipment. The ship's officers and crew provide mission support and assistance to embarked scientists from various NOAA laboratories and the academic research community.

### NOAA's National Weather Service

The NWS provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, and adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. The NWS has a national infrastructure in place to gather and process data from the land, sea, and air. These data come from familiar technologies, such as weather radars and satellites, but also from less-familiar technologies, including data buoys for marine observations and surface observing systems for data that help the aviation industry.

The NWS maintains a constant vigil to provide warnings and forecasts of hazardous weather, including thunderstorms, flooding, hurricanes, tornadoes, winter weather, tsunamis, and climate events. It is the sole ***official*** federal voice for issuing warnings during life-threatening weather situations. The NWS broadcasts life-saving information to the public during severe weather events and other hazardous situations through the NOAA Weather Radio network. In addition, the NWS relies on its partners in emergency management and the media to disseminate warnings on severe weather and critical forecasts. With a massive modernization effort just completed (Section 1.3.1), NWS is increasing the accuracy of forecasts and warning times, giving communities more time to prepare for severe weather.

Weather services provided by NWS cost each American about $4 a year. This investment allows the NWS to issue more than 734,000 forecasts (fire weather, public, aviation, and marine) and 850,000 river and flood forecasts annually. Each year, NWS issues between 45,000 and 50,000 potentially life-saving warnings of severe weather.

Every day, millions of economic decisions influenced by the weather are made in agriculture, transportation, power, construction, and other sectors of the economy. Weather and flood conditions affect the entire economy in many direct and indirect ways. Better weather, hydrologic, and climate forecasts and information bring new economic opportunities to almost every sector of the economy. The NWS provides general data and products to private-sector meteorologists, who use this information to provide specialized services and tailored products to clients in the transportation sectors and other industries. NWS forecasts are critical to the commercial and private transportation sector, including airline shipping and trucking industries, nationally and internationally. Airlines rely on short-term forecasts to position their aircraft and adjust flight routes for economic advantage. Long-term climate forecasts help city managers manage more cost-effectively their purchases of resources such as salt and sand for roads and sidewalks. Hydrologic forecasts help communities protect their property by preparing for floods.

The NWS is making great strides in improving weather forecasts and warnings, with its vision of becoming America's "no surprise" weather service. Over the past five years, it has doubled the warning lead time for tornadoes to approximately 12 minutes. This extra warning time saves lives. Today's three-to-four day forecast is as accurate as the two day forecast was 15 years ago. The NWS is working now to make the 6 to 10 day forecast as accurate as the forecast for tomorrow. Products issued around the clock by the NWS affect the lives of every American. Important advances in the science of meteorology and hydrology, coupled with major new technological capabilities for observing and analyzing the atmosphere, will allow the NWS to continue providing unprecedented weather services to the nation, as it works in partnership with other federal entities, state and local governments, and emergency management officials to protect life and property throughout the United States.

## DEPARTMENT OF THE INTERIOR

**DOI Role** (Table F-5): The Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, Fish and Wildlife Service, and National Park Service manage large areas of land with roads and waterways. The U.S. Geological Survey and Bureau of Reclamation provide stream flow data to NWS River Forecast Centers for use in flood forecasting.

As the nation's principal conservation agency, the Department of the Interior (DOI) has responsibility for most of our nationally owned public lands and natural resources. These areas encompass nearly half a billion acres of federal lands, including the entire National Park System and vast tracts of federal lands, mostly in the western regions of the country. Other DOI responsibilities include developing and using resources in an environmentally sound manner.

Within the DOI are a number of bureaus and offices with interests related to WIST. These include the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, Fish and Wildlife Service, U.S. Geological Survey, and the National Park Service.

**Table F-5** Interests of DOI Constituencies in Transportation Sectors

| Department of the Interior | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| | Road | Rail | MTS | Pipeline | Transit | Airport Ground Ops |
| Bureau of Indian Affairs | X | X | X | X | X | X |
| | | | | | | |
| Bureau of Land Management | X | X | X | X | X | X |
| | | | | | | |
| Bureau of Reclamation | X | | X | | | |
| | | | | | | |
| Fish and Wildlife Service | X | | X | | X | |
| | | | | | | |
| National Park Service | X | | X | | | |
| | | | | | | |
| U.S. Geological Survey | | | X | | | |

### Bureau of Indian Affairs

The Bureau of Indian Affairs was established in 1823 to carry out the nation's trust responsibilities for Native Americans. Today there are approximately 50,000 miles of road on Tribal lands. Indian Reservation Roads are public roads that provide access to and within Tribal reservations, trust land, restricted Tribal land, and Alaskan native villages. Approximately 25,000 miles of these roads are under the jurisdiction of the Bureau of Indian Affairs and the Tribal nations. Another 24,000 are owned by state or local governments.

### Bureau of Land Management

The Bureau of Land Management manages 266 million acres of federal land and 570 million acres of subsurface federal mineral resources. These public lands, most of which are in the western continental United States and Alaska, include grasslands, forests, mountains, arctic tundra, and desert lands. The Bureau manages a wide variety of resources and activities on these lands, including energy and minerals, timber, livestock forage, wild horse and burro populations, habitat for fish and wildlife, wilderness areas, and archaeological and historical sites. The mission of the Bureau is to sustain the health, diversity, and productivity of these public lands for the use and enjoyment of present and future generations.

The Bureau of Land Management administers about 85,000 right-of-way authorizations on the public lands, including a variety of transportation-related systems for roads, railroads, and pipelines. It maintains and manages an additional 81,000 miles of roads for public use on the public lands. The Bureau of Land Management also administers 180,000 miles of rivers and streams on the public lands, including more than 2,000 miles of National Wild and Scenic River segments and 5.400 miles of floatable rivers for recreational use.

### Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner, in the interest of the American public. This includes programs, initiatives, and activities that will help the western states, Native American tribal nations, and others meet new water needs and balance the multitude of competing uses for water in the West. The Bureau of Reclamation has constructed more than 350 large dams and reservoirs in the 17 western states, including Hoover Dam on the Colorado River and Grand Coulee Dam on the Columbia River. Today, the Bureau is the largest wholesaler of water in the country and the second largest producer of hydroelectric power in the western United States.

### Fish and Wildlife Service

The Fish and Wildlife Service operates the National Wildlife Refuge System, which comprises more than 93 million acres in more than 570 National Wildlife Refuges and management districts. The refuge system stretches from Florida to Alaska and includes refuges in U.S. insular areas in the Caribbean and the Pacific. Every state and U.S. territory has at least one refuge or management district, and most major American cities are within an hour's drive of one. More than 30 million people visit components of the system each year.

Of the 10,000 miles of roadway in the National Wildlife Refuge System, approximately half is open to the public. The Fish and Wildlife Service also maintains 10,000 miles of dikes and 23,000 water control structures to maintain habitat. This roadway and waterway infrastructure is vulnerable to extremes in precipitation, particularly to tropical storms with extreme winds and storm surge.

### National Park Service

The mission of the National Park Service is to promote and regulate the use of the national parks in such a way as to conserve the scenery, natural and historic objects, and wildlife, leaving them unimpaired for the continued enjoyment, education, and inspiration of current and future generations. The National Park System of the United States comprises 384 areas covering more than 83 million acres in 49 states, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the Virgin Islands. Since 1933 the National Park System has also included national monuments and many historic military sites and battlefields.

## U.S. Geological Survey

The U.S. Geological Survey (USGS) serves the nation as an independent fact-finding agency that collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. It is also the sole science agency for the DOI. USGS scientists pioneered hydrologic gauging techniques for estimating the discharge of water in rivers and streams and modeling the flow of complex ground-water systems.

The USGS has collected water-resources data at approximately 1.5 million sites across the United States, Puerto Rico, and Guam. The types of data collected are varied, but generally fit into the broad categories of surface water and ground water. Surface-water data, such as gauge height (stage) and streamflow (discharge), are collected at major rivers, lakes, and reservoirs. These data, along with data collected by the U.S. Army Corps of Engineers, are used by the NWS River Forecasting Centers to make critical flood forecasts throughout the nation.

# DEPARTMENT OF AGRICULTURE

**USDA Role** (Table F-6): The U.S. Forest Service manages large areas of land with roadways. The Farm Service Agency, through its Commodity Operations, must move agricultural commodities effectively domestically and worldwide.

The mission of the Department of Agriculture (USDA) is to enhance the quality of life for the American people by supporting production of agriculture; ensuring a safe, affordable, nutritious, and accessible food supply; caring for agricultural, forest, and range lands; supporting sound development of rural communities; providing economic opportunities for farm and rural residents; expanding global markets for agricultural and forest products and services; and working to reduce hunger in America and throughout the world.

The U.S. agricultural sector is the largest user of freight transportation, accounting for nearly one-third of all freight transportation services in the Unites States. Because most agricultural production occurs in rural areas, a tremendous volume of transportation services is required to move it to market. As a result, transportation modes vary by commodity and by region.

**Table F-6** Interests of USDA Constituencies in Transportation Sectors

| | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| **Department of Agriculture** | **Road** | **Rail** | **MTS** | **Pipeline** | **Transit** | **Airport Ground Ops** |
| Agricultural Marketing Service | X | X | X | X | X | X |
| | | | | | | |
| Farm Service Agency | X | X | X | X | X | X |
| | | | | | | |
| Forest Service | X | X | X | X | X | X |
| | | | | | | |
| Office of the Chief Economist | X | X | X | X | X | X |

Trucks are the primary movers of agricultural products, accounting for 45 percent of all commodity transport. Trucks are mainly used for short hauls and move virtually all agricultural production from the field and farm to the first consolidation point, which may be a grain elevator, packing shed, or other facility. Among the agricultural commodities moved by truck are field crops, fresh fruits and vegetables, livestock, meats and poultry, dairy products, and canned goods.

Rail is the predominant transportation mode for long hauls in regions far from barge-loading locations. Railways transport 32 percent of agricultural products. They provide the only cost-effective transportation option for many agricultural shippers who are not located close to markets or river transportation. Field crops, grain mill products, fertilizers, and pesticides move by rail.

Barges, which account for 12 percent of agricultural transport, handle large volumes of field crops, fertilizer, and pesticides. They provide a low-cost means of moving fertilizer and other agricultural inputs to production regions, as well as to U.S. ports for export.

The remaining 11 percent of agricultural commodities are transported by pipelines, air freight, and other modes. Pipelines carry just under 30 percent of the movements of fertilizers and pesticides.

Climate and weather conditions affect seasonal demands for transportation of agricultural commodities. Weather affects barge movement more than any other mode of agricultural transportation. Factors such as freezing, flooding, and low water levels adversely affect the use of inland waterways.

### Agricultural Marketing Service

The Transportation and Marketing Program of the Agricultural Marketing Service brings together a unique combination of traffic managers, engineers, rural policy analysts, international trade specialists, and agricultural marketing specialists to help solve problems of U.S. and world agricultural transportation. The program's purpose is to ensure an efficient transportation system for rural America, beginning at the farm gate. This system moves agricultural and other rural products on the nation's highways, railroads, airports, and waterways and into the domestic and international marketplace. The program supplies research and technical information to producers, producer groups, shippers, exporters, rural communities, carriers, government agencies, and universities. The Agricultural Marketing Service publishes *Grain Transportation Prospects* and the *Grain Transportation Report*. The former provides a periodic assessment of the grain transportation situation and prospects for near-term grain transportation demand. This helps railroads, producers, shippers, and receivers anticipate changes in transportation supply and demand. The *Grain Transportation Report* provides information weekly on railcar loadings, rail deliveries to ports, ocean grain freight rates, and numbers of vessels in port, as well as the quantity of grain exported.

### Farm Service Agency

USDA's Farm Service Agency Commodity Operations handles the acquisition, procurement, storage, disposition, and distribution of agricultural commodities. It also administers the U.S. Warehouse Act. These activities help to achieve domestic farm program price support objectives, produce a uniform regulatory system for the storage of agricultural products, and ensure the timely provision of food products for domestic and international food assistance programs and market development programs. The Farm Service Agency arranges for commercial ocean, ground (motor carrier and rail), and air transportation to deliver agricultural commodities domestically and worldwide.

### Forest Service

The Forest Service manages public lands in National Forests and National Grasslands. Its responsibilities include managing national forests for multiple uses and benefits and for the sustained yield of renewable resources such as water, forage, wildlife, wood, and recreation. The Forest Service sustains the health, diversity, and productivity of the 191 million acres of forest and grassland under its care. These areas provide multiple benefits to the country, from traditional commodities such as timber, range, forage, and minerals, to opportunities for recreation. The Forest Service also provides natural resource management guidance and assistance to state and private landowners in both rural and urban environments.

### Office of the Chief Economist

The Office of the Chief Economist advises the Secretary of Agriculture on the economic implications of policies and programs affecting the U.S. food and fiber system and rural areas. This office also oversees the activities of the World Agricultural Outlook Board and the Global Climate Change Office, among other departmental activities. The World Agricultural Outlook Board approves the *Grain Transportation Prospects* report (see description under Agricultural Marketing Service).

## OTHER FEDERAL ENTITIES

The transportation sectors of interests to the constituencies of five additional federal entities are summarized in Table F-7.

**Table F-7** Interests in WIST Transportation Sectors of Constituencies for Other Federal Entities

| | Transportation Sectors of Constituencies | | | | | |
|---|---|---|---|---|---|---|
| **Federal Entity** | **Road** | **Rail** | **MTS** | **Pipeline** | **Transit** | **Airport Ground Ops** |
| Environmental Protection Agency | X | | X | | | |
| Federal Emergency Management Agency | X | X | X | | | |
| National Aeronautics and Space Administration | X | X | X | | | |
| Nuclear Regulatory Commission | X | X | X | | | |
| U.S. Postal Service | X | X | X | | | |

## Environmental Protection Agency

The mission of the U.S. Environmental Protection Agency (EPA) is to protect human health and safeguard the natural environment—air, water, and land—upon which life depends. The EPA ensures that environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade. The EPA also ensures that human health and safeguarding the environment are considered in establishing environmental policy.

Air quality is a major responsibility for the EPA. Coming from many different sources, air pollution threatens health, damages the environment, and causes haze that reduces visibility in urban areas, wilderness areas, and national parks. Under the Clean Air Act, EPA sets limits on how much of a pollutant is allowed in the air anywhere in the United States.

Water is essential for life, and pollution of water has a serious impact on all living creatures. Water pollution can negatively affect the use of water for drinking, household needs, recreation, fishing, transportation, and commerce. The EPA enforces federal clean water and safe drinking water laws, provides support for municipal wastewater treatment plants, and takes part in pollution prevention efforts aimed at protecting watersheds and sources of drinking water. It carries out both regulatory and voluntary programs to fulfill its mission to protect the nation's waters.

An example of EPA's role in establishing environmental policy is the collaborative process for transporting nuclear waste from weapons production facilities to a deep earth disposal site in New Mexico. Initially, the EPA certified that the DOE site in New Mexico meets standards to protect public health and the environment from the harmful effects of radiation exposure and contamination. This EPA decision allows DOE to begin disposing of radioactive waste in the site once all other applicable health and safety standards have been met.

Next, the DOT is responsible for working with individual states to establish the surface routes that will be used to transport waste to the disposal site. Then the NRC regulates the transportation of nuclear waste, including the safety of the containers used to transport waste to the disposal site.

The New Mexico Environment Department is responsible for issuing and enforcing waste disposal permits relating to the type of waste to be disposed of at this site. The New Mexico Radioactive Waste Task Force administers the state's safe transportation program for the site. Finally, the DOE is responsible for developing the site and its day-to-day management.

## Federal Emergency Management Agency

Since its founding in 1979, the mission of the Federal Emergency Management Agency (FEMA) has been to reduce loss of life and property and protect our nation's critical infrastructure from all types of hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response, and recovery. FEMA is an independent agency of the federal government, reporting to the President. Two primary areas of FEMA responsibility with implications for WIST are evacuation management and response to nuclear, biological or chemical (including hazardous materials, or HAZMAT) incidents. Evacuation management includes the movement of people and resources such as emergency equipment and relief supplies in response to major catastrophic events such as earthquakes, flooding, fires, and hurricanes. Response to nuclear, biological, or chemical events includes evacuation of people and care for victims. To respond effectively to these events, FEMA incorporates atmospheric transport and diffusion information into emergency decision-making processes.

## National Aeronautics and Space Administration

The missions of the National Aeronautics and Space Administration (NASA) are to advance and communicate scientific knowledge and understanding of the Earth, the solar system, and the universe; to use the environment of space for research; to explore, use, and enable the development of space for human and robotic endeavors in science and commerce; and to research, develop, verify, and transfer advanced aeronautics, space, and related technologies.

### Goddard Space Flight Center

Goddard Space Flight Center is one of nine field centers operated by NASA. One of this center's many responsibilities is the safe and efficient movement of spacecraft, vehicles, and equipment between Goddard and other facilities, especially the launch facilities. The most prevalent mode of transportation is by truck from the center to either the final destination or an aerial port, such as Andrews Air Force Base, where the cargo can be air shipped. Transportation operations at Goddard are highly dependent on weather conditions, and adverse conditions may delay or cancel an activity (see the Roadway and Marine Transportation System WIST Templates).

### Kennedy Space Center

The John F. Kennedy Space Center is NASA's Spaceport Technology Center and the center for launch and payload processing systems. It is also NASA's lead center for acquisition and management of expendable launch vehicle services and payload carriers. Located at Cape Canaveral Spaceport in Florida, this NASA center manages the checkout, launch, and landing of the Space Shuttles and their payloads. It is also the starting point of all U.S. human space flights.

### Stennis Space Center

The John C. Stennis Space Center is NASA's center for rocket propulsion testing and Earth science applications. It is NASA's primary center for testing and flight-certifying rocket propulsion systems for the Space Shuttle Program and future generations of space vehicles. The Stennis Space Center also provides substantial support in remote sensing, which is valuable for remote observation of weather and related conditions relevant to WIST user needs.

## Nuclear Regulatory Commission

The Nuclear Regulatory Commission (NRC) is an independent agency whose mission is to ensure adequate protection of the public health and safety, the common defense and security, and the environment by regulating the use of nuclear materials. In addition to regulating nuclear energy facilities and radioactive materials in the United States, the NRC regulates the transport, storage, and disposal of nuclear materials and nuclear wastes. It authorizes the use, transportation, and storage of spent nuclear fuel after determining that the proposed activities are consistent with the regulatory framework and level of risk.

From a transportation perspective, the NRC approves the packaging designs for high activity radioactive materials and spent nuclear fuel. It also approves the quality assurance programs for use of these packages. It coordinates and develops guidance with other U.S. government and international agencies on storage and transportation policy and safety issues. When necessary, the NRC provides technical support for incident and emergency response.

## U.S. Postal Service

The mission of the Postal Service is to bind the nation together through the correspondence of the people, provide access in all communities, and offer prompt, reliable postal services at uniform prices. Postal services are an essential government function, one that has been integral to building the nation. The delivery of postal services has supported development of national transportation and communication infrastructures. It has linked urban and rural economies and has led to the creation of the country's physical address system. Transportation responsibilities of the Postal Service range from long-haul interstate movements to local delivery. An observation made at the WIST II Symposium is that the nationwide daily distribution of Postal Service vehicles provides an excellent opportunity to use them as mobile meteorological sensing platforms dispersed throughout the nations highway and road systems.

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