Appendix E

Weather Research and Technology Development Required to Meet WIST User Needs

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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**