A Regional Pilot Weather Information System for Surface Transportation and Incident Management

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Word count
Abstract: 205
Body: 3,820
Figures and Tables: 4 x 250 = 1,000
Total: 5,025

Submission date: November 15, 2005

ABSTRACT

WeatherShare is funded by the California Department of Transportation (Caltrans) and covers a 20-county, Northern California region with approximately 4,000 miles of highways. Caltrans District 2 and adjacent counties have a wide array of data available detailing road and weather conditions in the region, including a growing Roadway Weather Information Systems (RWIS) network and weather stations maintained by other state and federal agencies. There is great potential for the use of such data for purposes ranging from maintenance and traveler safety to emergency medical response and homeland security. The goal of the project is to streamline and integrate currently available road weather data into one single source easily accessible by incident responders and potentially the traveling public, including those from Caltrans RWIS, California Data Exchange Center, National Weather Service, among other providers in the region. This relatively small ITS project follows a customized systems engineering process, and tools such as Project Plan, Concept of Operations, User Requirements Analysis, and Configuration Management Plan are utilized to ensure the success of WeatherShare. The first phase of the project has developed a proof-of-concept system, and the second phase has been planned for expanded geographic coverage, improved functionality, and more extensive evaluation.

KEYWORDS
Surface transportation weather, weather information, integration

BACKGROUND

Weather Information for Surface Transportation

Weather poses significant threats to the surface transportation systems in the U.S. on a nearly continuous basis, as it acts through visibility impairments, precipitation, high winds, temperature extremes, vehicle maneuverability, pavement friction, and roadway infrastructure (1). The safety impacts of road weather are substantial, as weather plays a role in over 1.4 million vehicular crashes in 2001, causing over 615,000 injuries and over 6,900 fatalities (2). The estimated annual economic cost from these weather-related crashes (deaths, injuries, and property) amounts to nearly $42 billion (1). Furthermore, traffic delay due to adverse weather has reached nearly 1 billion hours per year (2).

More timely, accurate, reliable, and user-friendly road and weather information is critical in supporting surface transportation and in ensuring the mobility, safety, efficiency, and productivity of the transportation systems. A study in 2002 indicated that 40% of the potential users of a national 511 system identified weather as the most important information element (3). In addition, weather information for surface transportation will play an increasingly important role in emergency preparedness at all levels of federal, state, and local planning and response (1).

There are a wide spectrum of weather data users who may benefit from the improved quality and accessibility of road and weather information, including: state and municipal departments of transportation (DOTs); public weather forecasting agencies; public weather "consumer" agencies; private weather information providers; electronic & print media; road users (commuters, tourists, truckers, and emergency responders); in-vehicle navigation system providers; general public; mass transit; and rail (4). Therefore, the U.S. DOT has led an intelligent transportation system (ITS) initiative, *Clarus*, "to develop and demonstrate an integrated surface transportation weather observing, forecasting and data management system, and to establish a partnership to create a Nationwide Surface Transportation Weather Observing and Forecasting System". Though still in its early stage, the ultimate goal of this federal-level initiative is to provide information to all transportation managers and users to alleviate the effects of adverse weather (5).

Introduction to the WeatherShare Project

Initiated in 2003, WeatherShare is a component of the Redding Incident Management Enhancement (RIME) program, which consists of a group of technology initiatives designed to improve public safety in the Redding area. RIME organizations include: Caltrans District 2, Caltrans Redding Transportation Management Center (TMC), California Department of Forestry & Fire Protection (CDF), California Highway Patrol (CHP), Shasta Area Safety Communications Agency (SHASCOM), and NorCal Emergency Medical Services (EMS). WeatherShare covers 7 counties in District 2 as well as 13 counties in the adjacent Caltrans Districts.

Caltrans District 2 includes the northeastern counties of California, all the way to the Oregon border. This mostly rural district includes the Cascade Range and the northern portion of the Central Valley. The region features weather extremes (i.e., frequent snow and ice during the winter) and difficult terrain, which make weather information crucial to meet the challenges in highway maintenance and incident management operations.

In addition to the dozens of RWIS stations operated by Caltrans, there are hundreds of weather stations in the region operated by other state and federal agencies. For instance, CDF and

U.S. Bureau of Land Management (BLM) currently operate Remote Automated Weather Stations (RAWS) in the region, which collect meteorological data such as wind speed and direction, precipitation, temperature, relative humidity and fuel moisture to help specialists manage fires. Natural Resources Conservation Service operates a few Snowpack Telemetry (SNOTEL) stations in the region, which automatically collect snowpack and related climatic data. Furthermore, Bay Area Marine Institute, Federal Aviation Administration (FAA), and National Weather Service (NWS) operate weather stations in the region as well.

As a result of site visits, phone interviews and questionnaires, it has been revealed that there is an increasing need for easier accessibility of weather information in the region from the users' perspective. For northern California, there is overlapping and lack of integration in the existing weather data sources, such as weather stations operated by various entities. While there are weather networks designed for the purpose of data aggregation and quality control, such as MesoWest, the Meteorological Assimilation Data Ingest System (MADIS), and the California Data Exchange Center (CDEC), they are neither readily accessible to surface transportation users nor comprehensive enough since they were not specifically designed for this region. MesoWest is one of the largest mesonets in the western United States, operated by the University of Utah and the National Oceanic and Atmospheric Administration (NOAA). In the region, MesoWest provides real-time weather data from more than 200 stations from Caltrans RWIS, APRSWXNET, RAWS, Desert Research Institute (DRI), SNOTEL, NWS, FAA, California Air Resources Board (CARB), California Irrigation Management Information System (CIMIS), California Nevada River Forecast Center (CNRFC), and Mt. Shasta Avalanche Center (SHASAVAL). APRSWXNET is a public service weather network of amateur radio operators and private citizens operating home weather stations. MADIS is dedicated toward making value-added data available from the NOAA Forecast Systems Laboratory (FSL) for the purpose of improving weather forecasting. In addition to hundreds of MesoWest stations, MADIS provides real-time weather data from 39 stations in the region from APRSWXNET, RAWS, FSL Ground-Based GPS, Multi-Agency Profiler Surface Observations, and Weather for You, among others. Operating more than 400 real-time reporting stations in the region, CDEC under the California Department of Water Resources (CDWR) operates an extensive hydrologic data collection network including automatic snow reporting gages for the Cooperative Snow Surveys Program and precipitation and river stage sensors for flood forecasting, as well as some RAWS stations.

The goal of the project is to streamline and integrate currently available road weather data in the region into one single source easily accessible by incident responders and potentially the traveling public. The first phase of the project has developed a proof-of-concept system, and the second phase has been planned for expanded geographic coverage, improved functionality, and more extensive evaluation.

SCOPE

Region of Interest

The Western Transportation Institute at Montana State University (WTI) is under contract to Caltrans Division of Research and Innovation for the development of WeatherShare, of which Caltrans District 2 is the primary technical contact. The project aims to provide integrated, easily accessible road weather information for the RIME region, which includes 11 California counties: Butte, Colusa, Glenn, Sierra, Tehama, Plumas, Trinity, Shasta, Lassen, Siskiyou, and Modoc. The first four counties are covered by Caltrans District 3 while the rest of the RIME Region is covered by District 2. Since the weather events normally begin in the adjacent areas, weather conditions in some District 1 and District 3 counties are of interest to this project as well. FIGURE 1 depicts the region of interest for WeatherShare.

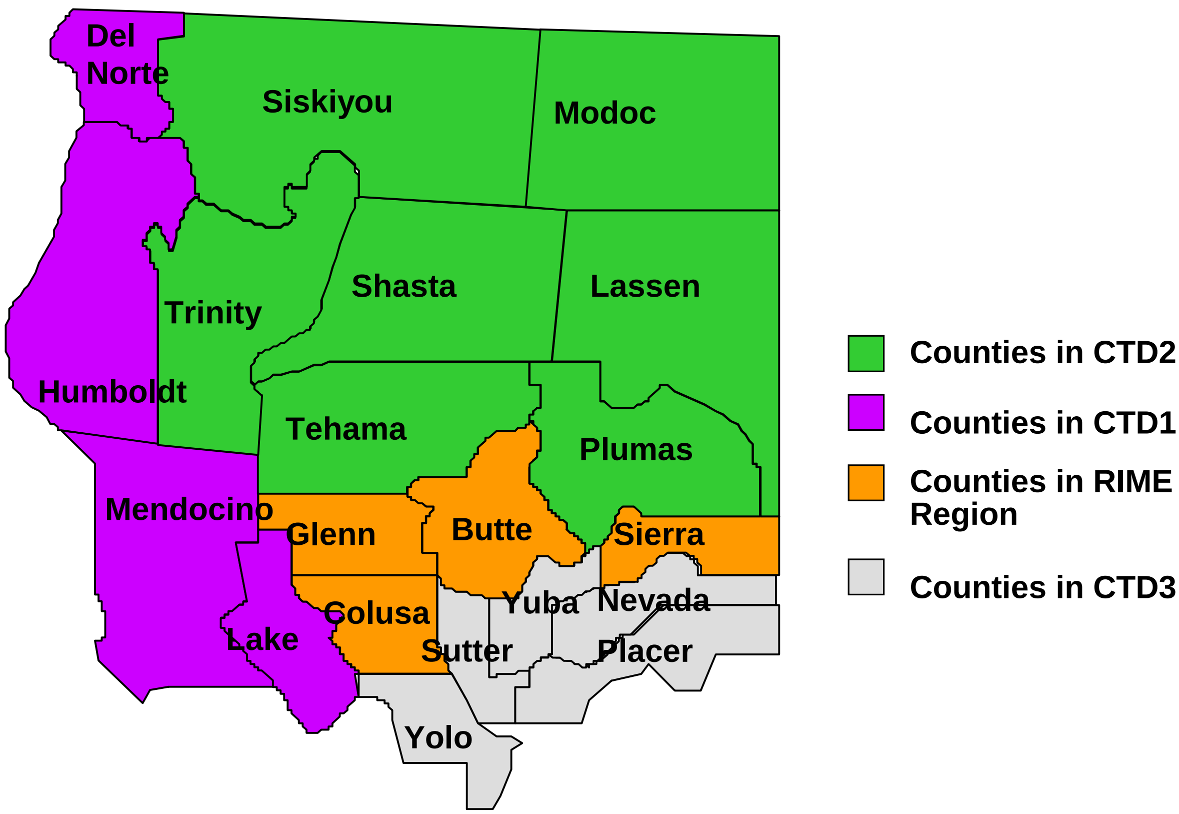

FIGURE 1. Region of Interest for WeatherShare

Management and Methodology

This relatively small ITS project ($200,000/2 years for phase I) follows a customized systems engineering process, and tools such as Project Plan, Concept of Operations, User Requirements Analysis, and Configuration Management Plan are utilized to ensure the success of WeatherShare. A typical systems engineering process is depicted in FIGURE 2.

This project uses a phased approach to minimize potential risks and goes through the V-model in an iterative manner to ensure the quality, cost and timely delivery of the final product. Initially, a prototype application with basic functionality was developed, tested, and deployed to facilitate the gathering of user requirements. While developing the initial system, WTI worked with Caltrans and other RIME stakeholders to identify necessary upgrades to the system. Then WTI implements these upgrades, including utilization of additional data sources, more user-identified functions, as well as improvements to the user interfaces.

The Project Plan was developed to highlight the high-level strategic decisions associated with the design, development, implementation, and evaluation of the WeatherShare system. The Concept of Operations was developed to document the existing system, identify the high-level needs to be addressed, provide a conceptual overview of the WeatherShare system, and define users and operational scenarios of WeatherShare.

In order to deliver a system that meets the users' needs, the research team utilized various tools such as site visits, brainstorming workshops, stakeholder interviews, and an online questionnaire to gather user requirements for the WeatherShare system. The user requirements were then documented, ranked in terms of technical difficulty and user-perceived relevance, finalized and approved by the WeatherShare steering committee consisted of RIME representatives. The requirements specification serves as the guideline for the design and development of the final product.

The Configuration Management Plan identifies the individual components of WeatherShare and procedures/tools to manage the changes to the configuration of these components, in order to systematically trace and therefore control them throughout the product lifecycle.

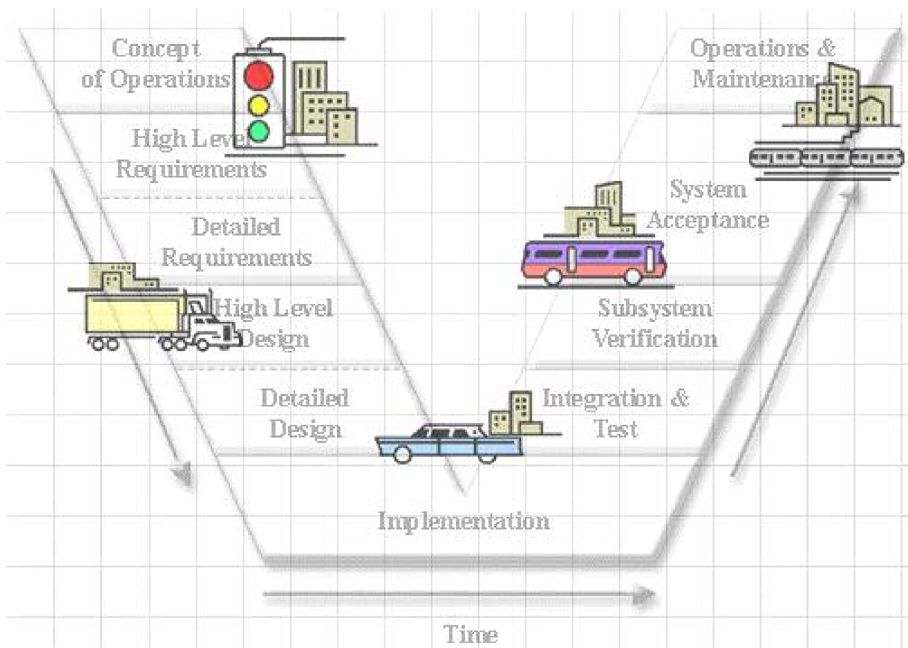

FIGURE 2. V-Model Illustrating the Systems Engineering Process (6)

JUSTIFICATION

Problem Statement

The RIME organizations in Northern California are collectively responsible for maintaining the state highways, responding to incidents on the state highways, and responding to other emergencies. Because of these responsibilities and because these organizations represent people who must travel on the roads in all weather conditions, knowledge of current, forecasted, and historical road and weather conditions assists in the completion of the organizations' missions. Furthermore, Caltrans can use road and weather information to make the roads safer for the traveling public and to inform travelers of potentially dangerous conditions.

In adverse weather events or natural disasters, the call-takers and dispatchers at RIME organizations need detailed road and weather conditions. Currently, tools used include websites and subscription services from NWS and commercial meteorological companies. However, the information must be accessed through separate sources, making it inefficient and time-consuming to assess road and weather conditions. Caltrans District 2 and other RIME members identified a need for access to all of the available road weather data (both pavement data and atmospheric data) from one single source. The existing deficiencies in the current system are listed below.

- Many weather stations exist in the region but access to the information is through various interfaces, some of which are complicated for non-expert users.
- There is overlapping and lack of integration in the existing weather data sources.
- Caltrans RWIS information is available only via the Caltrans website, where relevant road weather information from other sources is not available.
- For Caltrans RWIS, the user can only view the data one station at a time.
- No one outside of Caltrans can view the pavement measurements.
- Caltrans RWIS data, in particular, pavement sensor measurements, are perceived to be inaccurate at times.
- Access to the Caltrans RWIS information is limited to the vendor-provided application and historical data are only available through the vendor.

The use of road and weather data in the area has not yet reached its full potential, leaving room for improvement in integrating existing data from various sources and enabling easier access to the information.

Vision

WeatherShare will provide every RIME agency a better tool to use when responding to roadway incidents under adverse weather conditions or in natural disasters. Furthermore, the traveling public will have a better source when making travel decisions. As a framework to improve the quality and accessibility of road weather information provided to transportation decision-makers, the WeatherShare system would facilitate the use of road and weather data and encourage their applications in new programs.

The desired system will provide reliable access to quality-controlled road and weather information in the region, by integrating all available road and weather data from various sources into one user-friendly interface. The system will greatly increase the efficiency of situation assessments for roadway maintenance, incident management, emergency medical response, traveler safety, fire suppression, flood management, and homeland security applications, among others.

WeatherShare will assist Caltrans District 2 employees, other incident responders, and the general public to make more efficient and better informed assessments of current road and weather conditions in the area. Variations of the user interface will depend on the user's needs. An interactive data-view interface will help the users easily find and understand the information they need.

For Caltrans, WeatherShare will increase the efficiency of their roadway maintenance and snow/ice removal activities. For all incident responders, WeatherShare will shorten the response time to incidents and save lives. In general, this regional system will provide information to all transportation managers and users to alleviate the effects of adverse weather.

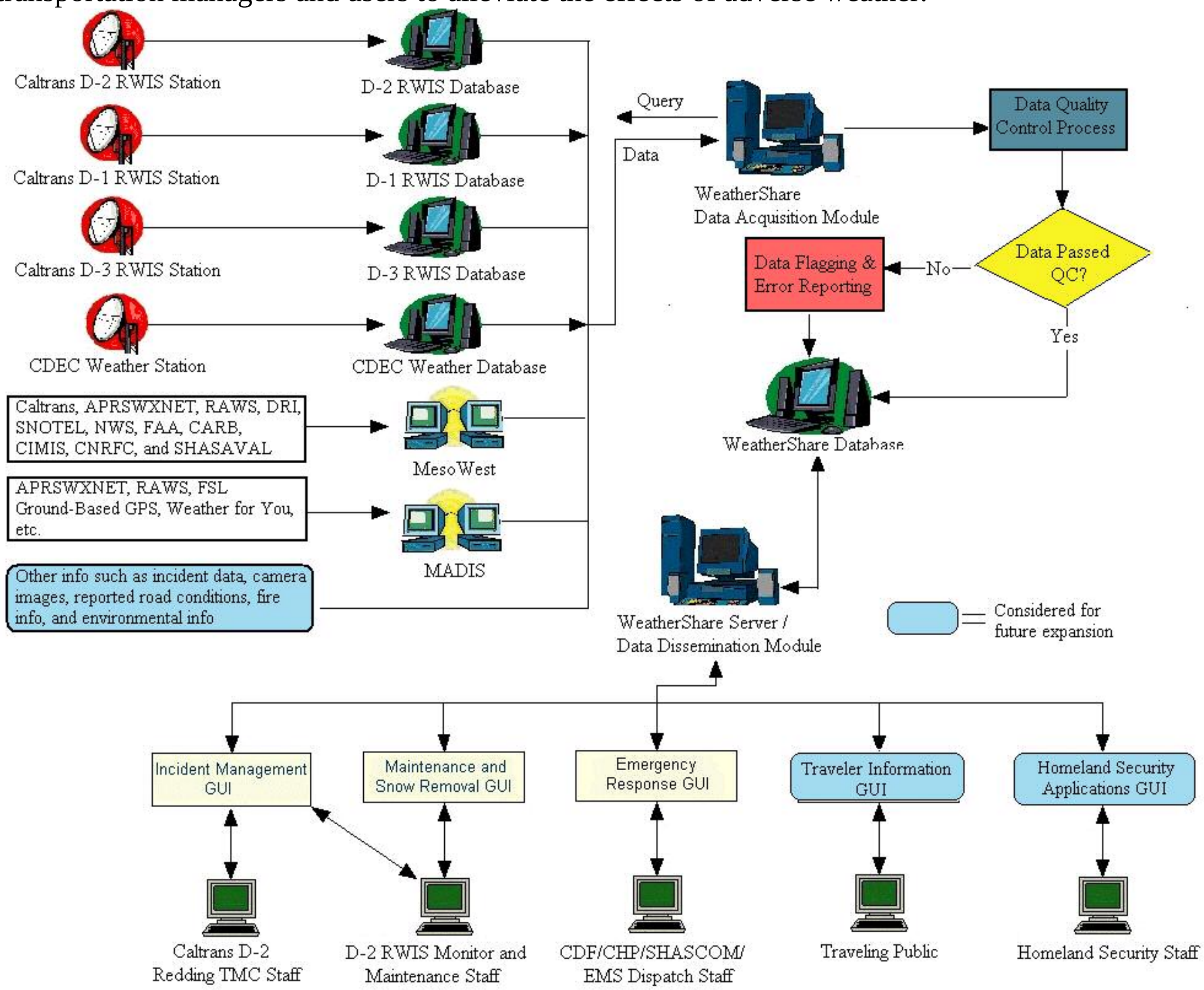

FIGURE 3. WeatherShare Data Flow Diagram

SYSTEM BRIEFING

The Weather system can be illustrated through the data flow diagram shown in FIGURE 3, and the proof-of-concept system is accessible at www.WeatherShare.org. More details of the data flow can be described as follows.

1. Weather stations, including Caltrans District 2, District 1 and District 3 RWIS stations and CDEC weather stations in the area, monitor road and weather conditions at predefined time intervals and send the data back to their central database.
2. MesoWest and MADIS pull weather data from their upstream data providers' databases, at predefined time intervals.
3. WeatherShare accesses the RWIS and CDEC databases as well as MesoWest and MADIS to collect the near-real-time data through the interfaces provided by these upstream data providers. For Caltrans District 1 RWIS and CDEC, the data are pushed to WeatherShare

every 15 minutes. For other data sources, the data are pulled by WeatherShare every 15 minutes.

4. WeatherShare automatically assigns quality control (QC) techniques to the incoming, real-time weather data.
5. WeatherShare integrates the quality controlled data from various sources into one standardized format and stores the data in a central database.
6. Through the graphical user interface (GUI), an interactive map display, client machines (including Caltrans District 2 staff, CDF/CHP/SHASCOM/EMS dispatch staff, general public, etc.) send their requests to the WeatherShare Server. In the proof-of-concept phase of WeatherShare, the default GUI is the same for users from different agencies and the user is allowed to define his or her profile in terms of data layers and alert thresholds.
7. Server identifies the client and his/her privilege level.
8. Server responds to the client's request by searching the database for information needed by its business logic and sends the result back to the client machine. Information is restricted based on the client's privilege level. Only authorized users can access the confidential information such as the Caltrans RWIS pavement temperature data.
9. WeatherShare automatically pushes road weather information to the user every 5 minutes so that the user can monitor the changing conditions without refreshing the webpage.

User-Identified System Features

Based on discussions at the kickoff meeting and stakeholder meetings as well as results from an end user questionnaire, the features identified by users for the ideal WeatherShare system are listed in order of priority as follows.

1. Allow the administrator to add new stations from existing data sources
2. Allow the user to turn on/off various data layers on the interactive map display, such as air temperature and wind speed & direction
3. Automatically push road weather information to the user every 5 minutes
4. Apply quality control procedures for all the real-time reporting stations
5. Ensure that only authorized users can access the confidential information such as the Caltrans RWIS pavement temperature data
6. Remember the authorized user's profile and automatically load the profile once he or she is logged in
7. Allow the user to display a meaningful graphical representation of a particular data value across a selected region, including air temperature and wind
8. Allow the authorized user to define his or her profile, including default data layers
9. Use a map display that permits the user to zoom into, zoom out of, or pan into the area of interest
10. Allow the user to track historical data for a period of up to one year from present
11. Allow the authorized user to enable or disable user-defined alerts
12. *Allow the user to "replay" the graphical representation of a particular data type for a user-defined time period in an accelerated "movie" mode*
13. Allow the authorized user to define thresholds for alerting status change in air temperature, dew point temperature, and wind speed
14. Backup the road weather data on a daily basis and implement a backup mechanism for the server as well

15. Distinguish between authorized and non-authorized users
16. *Provide a filtering function to allow the authorized user to view only stations adjacent to roads, water bodies, or forest, or on the mountaintop*

Due to technical difficulty and cost & schedule implications, the WeatherShare steering committee agreed that the features 12 and 16 should not be implemented in the proof-of-concept phase of WeatherShare, but might be desirable for future phases. The proof-of-concept phase of WeatherShare identified and implemented 44 baseline user requirements, including functional and non-functional requirements.

Unique Characteristics of WeatherShare

The WeatherShare system has the following unique characteristics:

- Leveraging resources (more than 600 weather stations versus 11 Caltrans D-2 RWIS stations);
- Road weather data sharing and integration;
- Weather data standardization and quality control;
- An easy-to-maintain, cost-effective product powered by an open-source web platform (Linux/Apache + Perl + MySQL + PHP);
- Scalable, interactive map displays powered by the SVG technology;
- Customizable, individualized user interfaces powered by the PHP Smarty template system; and
- Database-driven web pages powered by the MySQL technology.

System Architecture

For best performance as a web application, the WeatherShare system adopts a multi-tier architecture. The *business logic* tier includes the Data Parsing, Quality Control, User Privilege Check and SVG Mapping modules. The *data storage* tier involves the MySQL database server and XML/SVG to store the user information, weather station information, geographic information system (GIS) map layers, as well as the road and weather information. The *data presentation* tier serves as an interface between HTML clients and the database server and presents the end user all the information requested.

Three major types of quality control (QC) techniques (validity checks, internal consistency and rate of change checks, and spatial consistency checks) are automatically assigned to the incoming, real-time weather data for all the weather stations used in the WeatherShare system, in spite of the fact that the observation system for some weather stations may have performed QC procedures. The first two levels of weather data QC follows the guidelines established by the National Weather Service in the Technique Specification Package 88-21-R1 (7), while the level 3 of weather data QC is experimental. Only the data that pass all the levels of QC procedures will be displayed to the user, when he or she accesses the weather information from the *recent reports* section.

As a new graphics file format and web development language, Scalable Vector Graphics (SVG) is XML-based and offers advantages over raster static images by providing data-driven, interactive, and animated graphic user interfaces. However, almost all the weather-related Internet websites such as the Washington DOT rWeather and Weather.com currently still use raster images to present road and weather information. The WeatherShare project demonstrates capabilities of the SVG technology and pioneers its implementation in surface transportation weather applications. It is envisioned that SVG would facilitate the weather data sharing between different platforms and applications through XML files.

WeatherShare Interface

The primary means of interface to the WeatherShare system is a W3-standard-compliant web browser. A common user interface will be presented to all the users when they first access the system. Users, except the general public, can log into the WeatherShare system with their user ID and password to set their profile and define what information they prefer to see. A snapshot of the proof-of-concept WeatherShare GUI is shown in FIGURE 4.

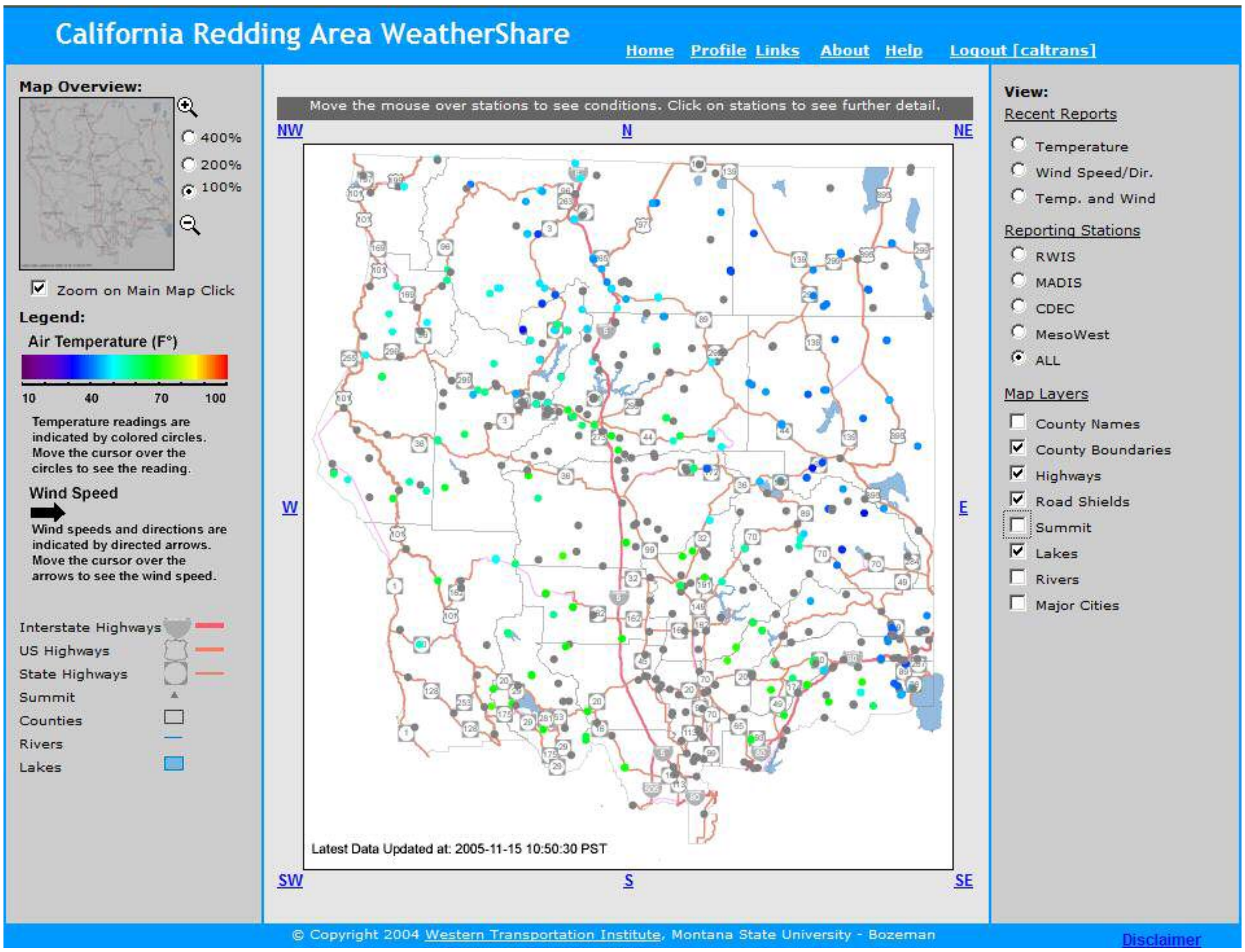

FIGURE 4. A Snapshot of the Proof-of-Concept WeatherShare Interface

CONCLUSIONS

More timely, accurate, reliable, and user-friendly road and weather information is critical in supporting surface transportation and to aid all transportation managers and users in alleviating the effects of adverse weather. WeatherShare has served as a regional showcase and proof-of-concept for this national priority.

The abundance of available road and weather observation data, coupled with the lack of integration of such data, presents great opportunities for leveraging resources and improving the surface transportation weather information systems. Due to the involvement of multiple stakeholders and the complexity of institutional and technical issues, it is important to develop partnerships among organizations in order to promote the successful integration of road and weather data from various sources.

In building a successful ITS system that can meet the users' needs, it is crucial to involve the users and stakeholders since its very early stages of design and development and throughout its lifecycle. Even for a relatively small ITS project, the systems engineering approach is still very valuable in "building the customer voice in the product", and it might be more important to follow the philosophy of systems engineering than to strictly follow its standard documentation. A phased approach should be utilized to minimize potential risks and the management of user expectations is the key to the project's success.

ACKNOWLEDGEMENTS

Caltrans Division of Research and Innovation provided the funding for the research described herein. The authors are also grateful for the support of Caltrans District 2. We appreciate the support and information given by our upstream weather data providers, including CDEC, MADIS, MesoWest and NWS. We would also like to thank many professionals from the RIME organizations (CHP, CDF, SHASCOM, and NorCal EMS) and the WTI IT team for their input. The authors acknowledge Lisa Ballard, P.E. for her valuable contributions at the early stage of this project.

REFERENCES

1. Office of the Federal Coordinator for Meteorological Services and Supporting Research. *Weather Information for Surface Transportation: A National Needs Assessment Report*, 2003. U.S. Department of Commerce, NOAA, FCM-R18-2002.
2. Federal Highway Administration. *Clarus – America's 21st Century Surface Transportation Weather Observing and Forecasting System*, 2004. Road Weather Management Program, Office of Transportation Operations. Publication No. FHWA-HOP-04-037.
3. ITS America. *511's Weather and Road Condition Reports Most Valuable, Survey Shows.* Press release from Intelligent Transportation Society of America, March 13, 2002. Washington, D.C.
4. Murphy, R. *Clarus – Nationwide Surface Transportation Weather Observing & Forecasting System*. ITSA Rural Stakeholder Interest Group. ITS America Conference, Phoenix, AZ, May 3, 2005.
5. Federal Highway Administration. Clarus Initiative, 2005. Available online at www.clarusinitiative.org.
6. Mitretek Systems, Inc. *Building Quality Intelligent Transportation Systems through Systems Engineering*, 2002. Prepared for Intelligent Transportation Systems Joint Program Office, U.S. Department of Transportation.
7. National Weather Service. *Technique Specification Package 88-21-R1 for AWIPS-90 RFP Appendix G Requirements Numbers 2.1 – Quality Control Incoming Data.* April 1, 1993. AWIPS Document Number TSP-032-1992R1.