Dynamic Messaging

A Guidance Document Providing Advisory Information on Low-visibility Warning Systems Based on Research and Analysis of Deployed Systems

January 30, 2002

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1.0 INTRODUCTION

The ENTERPRISE program is a multi-state pooled-fund study group with a focus on providing effective solutions for rural transportation applications. ENTERPRISE, in cooperation with the Arizona Department of Transportation (ADOT), is researching solutions for problems motorists face in limited visibility situations. The ability to *detect* low-visibility incidents has been the focus of previous ENTERPRISE projects; however, the approaches used to effectively warn motorists of either localized or wide-area low-visibility events have been less rigorously evaluated. This project seeks to identify components of low-visibility warning systems and the techniques deployed by various states that best address improving safety by detecting low-visibility events and disseminating advanced information to motorists as well further evaluating low-visibility detection technologies during these conditions.

1.1 Low Visibility Related Incidents

Low-visibility highway warning systems have been recognized as a means for giving motorists advanced notice of prevailing adverse conditions. With such systems motorists can avoid tragic accidents caused by dense fog, blowing snow, rain and dust, which are often fatal. According to the National Transportation Safety Board (NTBS) most fog-related crashes occur because motorist fail to maintain uniform reduced speeds[1]. Often drivers may slow to low speeds and even stop while others increase speeds. Motorist lack basic knowledge about driving in low-visibility condition, and as a result, several fatal events have occurred as noted in the Table 1 below.

Table 1. Low-visibility related incidents

Date	Place	Deaths	Injuries	Vehicles
12/90	Calhoun, TN	12	44	99
1/91	Salt Lake City, UT	4	25	69
12/94	Tejon Pass, CA	2	27	40
4/94	Bowie, AZ	12	23	16
1/95	Menifee, AR	5	-	>9
3/95	Mobile, AL	1	74	100
11/95	Monroe, MI	-	9	54
12/96	Tampa Bay, FL	1	24	54

[2]

Remedial actions were taken immediately after the incidents listed above, and all of the sites are now equipped with automated or more effective manually operating low-visibility warning systems. Each location is, however, comprised of different system components, varying degrees of geographic and weather conditions and a tailored criterion for detecting low-visibility events and providing motorist with appropriate warning messages. Three locations noted in the table and their systems are described in greater detail below as well as in the subsequent deployed systems section located in the Appendix A of this document.

This document will recommend specific building blocks for low-visibility systems based on research of geographic and climatic characteristics of localized or wide-area low-visibility events. Furthermore, it will highlight the effectiveness of several deployed systems and recommend guidelines for operation based of the success of researched systems.

2.0 OVERVIEW

There are several critical measures that will determine the success of a low-visibility warning system, including:

- The initial site selection and placement of the reduced visibility warning system;
- The detection method(s) used to assess conditions and trigger response;
- The strategies used to warn or advise travelers; and
- The technologies and equipment used to communicate to the travelers and warning messages.

2.1 Objectives

The objectives of this document are to take the information gathered on several low-visibility warning systems and present background information and recommendations on each of the critical measures identified above. A methodology for addressing low-visibility events and applying detection methods and information dissemination techniques based on deployed system will provide a rough functional sketch of an ideal visibility warning system.

3.0 IDENTIFYING AND SELECTING SITES FOR LOW-VISIBILITY WARNING SYSTEMS

Low-visibility warning systems serve as useful mechanisms to warn travelers of visibility limitations in order to help prevent accidents. The sites that have most often been equipped with low-visibility monitoring and warning systems are those that:

- Experience recurring low-visibility conditions;
- Have a proven record for accidents caused by low-visibility conditions; and
- Support alternate routes that vehicles may divert upon to avoid conditions.

3.1 Types of low-visibility conditions

The deployments reviewed within this project addressed different types/causes of low-visibility. Each type is defined below, together with examples of real-world deployments:

3.2 Fog

Fog poses serious threats to travelers, especially given the fact that fog can readily occur even under clear weather conditions, and is often unexpected by motorists. Fog forms because temperature and moisture vary sharply in short periods of time; air cools to its saturation point and mixes with air parcels with different temperatures and humidity levels. Fog seldom tends to form when the dew point temperature differs from the air temperature by more than 4 degrees Fahrenheit.

Five types of fog exist depending upon the geographic location, as described below:

- *Radiation*

Radiation fog occurs when cool temperatures contrast with warm and moist ground. These conditions usually occur on calm, clear nights after a period of rainfall. As the cool air moves over the warm and moist ground, it condenses to form fog. If the temperature contrast between the warm ground and the cool air above is especially significant, the fog can become extremely dense. Interstate 5 and State routes 205 and 120 in San Joaquin County, California, a major arterial that serves Stockton-Manteca and the San Francisco Bay area, experiences seasonal radiation fog from October through April due to a low lying delta which creates heavy ground fog.

- *Advection*

The second type of fog, advection, or precipitation-induced fog is caused by falling precipitation, like rain or drizzle, and then is pushed into other areas by the wind. Unlike radiation fog, this type of fog can occur even with strong winds, and usually occurs when warmer air moves over colder ground. This is especially true during the winter when warm air moves over frozen or snow-covered ground. Advection fog tends to be more widespread than radiation fog, but can be just as dense.

- *Up-Slope Fog*

Up-slope fog forms exclusively in areas of sharp up-slopes, such as valleys in the area around I-75 on the Hiwassee Bridge in Tennessee, or the eastern slope of the Rockies. This type of fog requires a fairly brisk wind, with warm and humid conditions at the surface. As the wind is forced up the slope, it is cooled beyond the dew point and therefore produces fog. This fog will disappear when the wind dies out, because radiation cooling takes effect.

- *Evaporation Fog*

Evaporation fog occurs when warm land air blowing over a large and cold body of water will become foggy if the dew point of the land air is higher than the water temperature. The cold-water chills the land air to below the dew point, condensing shallow but dense fog. Such fog conditions occur along I-275 in Tampa Bay, Florida, as well as along I-10 in Mobile, Alabama, where both locations' close proximity to water cause sea fog conditions. Similar fog conditions can occur in areas surrounding large bodies of water such as in the Great Lakes region.

- *Fog Due to Industrial Activity*

Although studies have not been conducted to conclude precise levels of fog, which industries such as cooling ponds from a paper mills may add, evidence suggests that industries should be recognized as a contributing factor. Subsequent to the tragic fog related incident involving 99 vehicles on I-75 along the Hiwassee bridge in Tennessee, as noted in (Table 1),the operators of the nearby paper mill voluntarily suspended operation of the paper mill.

3.3 Blowing Dust and Blowing Snow

Blowing dust most often occurs when the weather is dry and windy and travelers are most likely not anticipating any visibility reductions. Blowing dust can occur throughout the winter and late spring months in the high southern plains where agricultural fields lie dormant with little vegetation. As is the case in areas such as Lubbock, TX, where the semi-arid landscape is vulnerable to such conditions and winds can gust in excess of 60 to 70 m.p.h. Dust conditions however, are most likely to occur in the Northern Rockies and the Southwestern United States during the summer months. Arid and sparsely vegetated areas, where dust storms quickly move across wide valleys and dust plumes can greatly reduce visibility, characterize an 80-mile stretch of I-84 in Idaho. Similar seasonal conditions occur along stretches of I-10 in southern Arizona where winds of 25 to 35 M.P.H. can cause reduced visibility conditions.

Blowing snow conditions occur over widespread areas in valleys and mountain passes of the Rocky Mountains and into the Great Plains, but only when winter conditions are suitable. Blowing snow can come about during snowstorms, and also may occur as a result of the wind blowing surface snow during clear weather conditions. A number of accidents due to blowing snow also occurred along I-84 in Idaho. Such events occur over a wide spread area however, and make advanced warning of precise locations of low-visibility pockets difficult to predict and disseminate to motorists.[3]

In summary, a variety of naturally occurring and man-made objects can cause frequent events of very localized fog conditions. Often, such conditions are understood by locals; however, they can pose serious threats to travelers passing through the area.

3.4 Recommendations for selecting locations for visibility warning systems

In all of the above examples, locations were selected that experienced recurring situations of low-visibility, and where the cause of these conditions was understood. The following suggestions are intended to guide transportation agencies through the selection process of identifying sites for visibility monitoring and warning systems:

Step One: Based upon accident statistics and user feedback, identify the extent of the area prone to visibility restrictions. This will help identify if this is a localized area or a wide stretch.

Step Two: Determine the most prominent cause of the low-visibility conditions. This may be geographic conditions such as nearby water, low-lying topography, or man made objects, such as factory cooling ponds. Understanding the cause of the conditions will help define if the events can be expected year-round or seasonally, which may help determine if permanent or mobile equipment is used.

Step Three: Determine all the possible types of weather conditions that the specified area is prone to (e.g. fog, dust, smoke, heavy rain, and snow). Assessing the climatic and environmental causes of low-visibility events will help determine the appropriate sensor.

Step Four: Determine if any planned developments or changes in the area will impact the low-visibility situations.

Step Five: Define the proposed area for monitoring and disseminating information on low-visibility and share this information with associated agencies in and around the area.

4.0 DETERMINING THE MOST EFFECTIVE LOW-VISIBILITY DETECTION METHOD

Mapping a criterion of possible weather and environmental conditions that will cause low-visibility events will help determine the variables (i.e., fog, dust, and snow) that need to be detected. Low-visibility events such as fog are constantly changing and create a set of challenges when detecting. Likewise, dust storms can form and dissipate in short periods of time also making detection difficult. The following is a list of visibility detection equipment that has been deployed as part of operating low-visibility warning systems.

4.1.1 Selecting visibility and incident detection equipment

A. Visibility Sensors

Several sensors are available for real-time visibility detection purposes and can range from $2,000 to $12,000[1]. The U.S. Department of Transportation Small Business Innovative Research Program solicited proposals for low cost visibility detection sensors, which would have allowed sensors to encompass a wider area and subsequently a greater degree of accuracy when detecting visibility over widespread areas prone to low-visibility. Funding issues, however, have delayed such work for now.

The storm warning system along I-84 in Idaho is equipped with three visibility forward scatter optical sensors systems (Handar-Belfort, SSI-Belfort, and SSI-WIVIS) to measure visibility, wind speed and direction, precipitation type and rate, air temperature, relative humidity, and pavement condition.

Likewise the ADVISE visibility warning system along I-215 and I-15 in Salt Lake City, Utah is equipped with HSS sensors which employs both forward and back scatter sensing technology which detects in snow, fog and rain events.

B. Traffic Sensors

Automated traffic counters record the lane number, time, speed, vehicle type (passenger car or truck), and length of each vehicle passing the sensor site, for incident detection purposes. Traffic sensors can serve as a means of reporting incidents back to the control center and appropriate warning can be sent to DMS. Project ADVISE in Utah is equipped with six traffic counters, while the Tennessee fog warning system along 1-75 between Knoxville and Chattanoga is equipped with 44 vehicle speed detectors.

C. Road and Weather Information Stations (RWIS)

A combination on visibility sensors, along with road and weather sensing equipment, can help optimize real-time data as well as serve as a useful highway specific low-visibility forecasting tool. An RWIS is made up of three main elements and include the following:

- Environmental sensors to collect weather data such as, air temperature, amount and type of precipitation, visibility, dew point, relative humidity, and wind speed and direction. Additionally environmental sensors collect surface data such as pavement and sub-surface temperature and surface conditions (wet, dry or freezing);
- Road and weather models to develop forecasting techniques; and
- Dissemination platforms on which to disseminate forecasted information.

Due to the varying weather conditions, which surround the I-84 in Idaho, plans to deploy and integrate RWIS data into the visibility warning system are currently being developed.

D. Closed-Circuit Television (CCTV)

Closed-circuit television (CCTV) cameras serve as an effective tool for monitoring visibility levels from a remote location. CCTV cameras in the Idaho storm warning system were aimed at series of fixed signs with flashing beacons and were spaced at distances of (25, 500, 850 and 1500 feet) to further aid in visibility assessments. Furthermore, states have used CCTV archived data to view time lapse videos of fog or dust events to further assess the timing and synthesis of low-visibility events.

E. Manual Detection

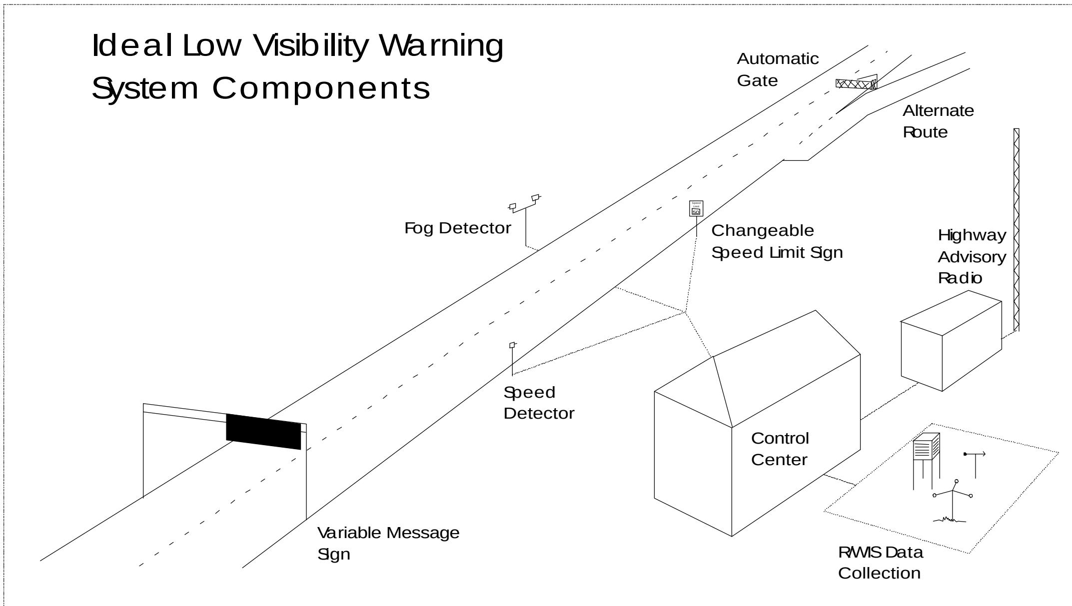
Manual monitoring can be an effective low-cost means of detecting seasonal low-visibility conditions. I-10 in southern Arizona experiences high winds, which create dust storms. The Arizona DOT monitors wind speeds from the National Weather Service and when the RWIS data inform the maintenance personnel that winds reach speeds greater then 25 m.p.h. advanced warning messages are disseminated to travelers via dynamic message signs.

4.1.2 Joining low visibility system components with central or on-site operations center

Dedicated on-site centralized operations centers allow for effective and timely data transfer to and from system infrastructure (e.g., sensors, VMS, RWIS). However, the nearly deployed visibility warning system along 1-10 near Mobile Alabama has been integrated with an existing traffic operations center, eliminating the cost of an on-site center. Due to often-remote geographic locations of visibility warning systems, communications infrastructure may not support data exchange and on-site operation centers have been found to be more effective with the following components:

- Uninterruptible Power Supply (UPS) will allow system to operate during power shortages;
- Dedicated Communication Lines to and from the onsite or central operations center; and
- NTCIP Compliant Hardware.

The graphic below provides a rough sketch of the system components described above and the layout of a typical low-visibility warning system.



5.0 DEFINING A STRATEGY FOR WARNING TRAVELERS

Several guidelines need to be addressed when developing strategies to warn travelers of low-visibility events. As noted earlier, according to the National Transportation Safety Board (NTBS), most fog-related crashes occur because motorists fail to maintain uniform reduced speeds. Failure to maintain uniform speeds could be inferred as a common problem for all low-visibility situations. Obstacles, such as variations in motorists' speeds and the lack of knowledge of prevailing low-visibility events, provide challenges when developing counter-measures, which will increase safety in low-visibility prone areas. The following objectives cover the initial steps taken in developing guidelines, which provide a framework of goals visibility-warning systems seek to accomplish.

5.1 High-Level Strategies

- Determine precisely what information motorists perceive as valuable;
- Develop exactly what messages convey effective warnings which will ultimately attain slower and more uniform speeds or reroute traffic to alternate roads; and
- Determine when motorists must receive messages for maximum effectiveness.

Project ADVISE along I-215 and I –15 developed objectives, which seek to reduce mean speeds as well as variations in speeds through disseminating messages to motorists via Dynamic Message Signs (DMS). Although mean speeds were not reduced, variations in speeds were reduced via messages such as “Dense Fog Advise 30 mph”. [5]

The Hiawassee Bridge along I-75 in Tennessee greatly increased safety in the localized area prone to fog, by disseminating speed reduction warnings to travelers via DMS, changeable speed limit signs and highway advisory radio.

The Idaho Storm Warning System along I-85 developed objectives to warn drivers of low-visibility events by disseminating advanced warning of fog events and speed reduction messages via DMS.

6.0 SELECTING COMMUNICATIONS TECHNOLOGIES, PLACEMENT AND DEFINING MESSAGES TO BROADCAST

Visibility-warning systems demand a range of technologies to disseminate warning messages to motorists. Furthermore, effective placement of communication technology poses a challenge as low-visibility pockets can shift and dissipate quickly, making advanced warning of the precise location motorists should expect to encounter difficult. Providing accurate real-time warnings to motorist in wide spread areas is particularly challenging, as conditions frequently change. The following components, however, have been found to provide motorists with an effective means of conveying advanced warning with the intent of reducing and maintaining uniform speeds.

6.1 Communication Technologies

- *Dynamic Message Signs (DMS)*

Dynamic message signs have been recognized as an effective means for disseminating information to motorist in order to improve operations, reduce accidents, and inform travelers of changing weather conditions. The following real world examples portray a brief overview of DMS placement and message sets, which have effectively increased safety.

A total of ten DMSs, five on each side, provide a series of warnings to motorists based on current visibility levels along a 10-mile stretch of I-75 approaching the Hiawassee Bridge in Tennessee. Based on recorded crash data due to fog and a well-defined area where localized fog occurs, DMSs were placed in roughly 1- to 3-mile intervals with the first sign roughly six miles prior to the fog-prone area to support alternate routes if the bridge is closed. It should be noted that since the deployment of the fog warning system, zero low-visibility accidents were recorded. The following messages are display in Tables 2 through 5 based on a set conditions determined by visibility levels:

Case 1 – Speed Reduction Warning

Case 1 message set is based on light fog conditions with visibility level less then three-quarters of a mile, although enough to slow motorist down and create variations in speeds of traffic.

Table 2

Sign #1	Sign #2	Sign #3	Sign #4	Sign #5
Blank	**Blank**	**Caution Slow Traffic Ahead**	**Caution Slow Traffic Ahead**	**Caution Slow Traffic Ahead**
		Flash Top Line	**Flash Top Line**	**Flash Top Line**

Case 2 – Fog Ahead – Speed Limit 50 mph, Northbound and Southbound

Case 2 message sets are based on visibility conditions less than one half mile and motorists are alerted to reduced speeds and tune to highway advisory radio for additional information.

Table 3

Sign #1	Sign #2	Sign #3	Sign #4	Sign #5
Blank	**Blank**	**Fog Ahead Advisory Radio Tune To ____AM**	**Fog Ahead Reduce Speed Turn on Low Beams**	**Fog Speed Limit 50 mph**
		Flash Top Line	**Flash Top Line**	**Flash Top Line**

Case 3 – Fog Ahead – Speed Limit 35 mph, Northbound and Southbound

Case 3 message sets are based on visibility conditions less then one-quarter mile where fog conditions are considered "heavy". Motorists are alerted to reduce speeds to 35 mph via changeable speed limit signs and tune to highway advisory radio for further information.

Table 4

Sign #1	Sign #2	Sign #3	Sign #4	Sign #5
Blank	**Blank**	**Fog Ahead Advisory Radio Tune To ____AM**	**Fog Ahead Reduce Speed Turn on Low Beams**	**Fog Speed Limit 35 mph**
		Flash Top Line	**Flash Top Line**	**Flash Top Line**

Case 4 – Road Closed/Detour, Northbound and Southbound

Case 4 messages sets address the most severe fog conditions where all five signs are activated to alert motorist of road closure, detour and to tune to highway advisory radio for further information.

Table 5

Sign #1	Sign #2	Sign #3	Sign #4	Sign #5
Detour Ahead	**I-75 Closed Detour**	**Fog Ahead Advisory Radio Tune To ____AM**	**Detour Ahead Reduce Speed Merge Right**	**I-75 Closed Detour**
Flash Top Line	**Flash Top Line**	**Flash Top Line**	**Flash Top Line**	**Flash Top Line**

The Idaho storm-warning system is equipped with four DMSs, which again, disseminate warning messages to motorist based on visibility conditions. Unlike localized fog events, which occur along I-75 in Tennessee, the Idaho storm warning system covers 80 miles of highway with only four DMSs. The following message sets in Tables 6 through 9 alert motorist of blowing snow, dusts, reduced speeds, detours and road closures:

Possible message scenarios for four DMS in Idaho/Utah SWS.

Tables 6 through 9 show the possible messages that are displayed on each of the three-line DMS that encompass the Idaho storm warning system.

DMS No. 1: Eastbound I-84 at I-86 Junction

The DMS located at the I-84 and I-86 junction, disseminates advanced warning to motorists of poor visibility conditions or I-84 road closures.

Table 6

Line 1	Line 2	Line 3
Strong Winds	**I-84 Open**	**Slow to 45**
Strong Winds Ahead	**I-84 Closed**	**Use I-86**
Poor Visibility	**On I-84**	**Slow to 35**

DMS No. 2: Westbound I-84 at Sublet Interchange

The DMS located at the Sublet interchange, where blowing snow or dust frequently occur, disseminates the following possible messages.

Table 7

Line 1	Line 2	Line 3
Strong Winds	**Ahead**	**N/A**
Poor Visibility	**Slow to 35**	**N/A**

DMS No. 3: Westbound I-84 at Snoville, Utah

The DMS located at Snoville, Utah is primarily used to assist maintenance crews with providing motorists with advanced road closures during poor weather conditions.

Table 8

Line 1	Line 2	Line 3
Idaho I-84 Closed	**15 Miles Ahead**	**Utah SR-30 Closed**

Strong Winds	**Ahead**	**Ahead**
Poor Visibility	**Road Work**	**Blank**

DMS No. 4: Northbound I-15 at I-84 Junction Tremonton, Utah

The DMS located at I-15 and I-84 is also used primarily to assist maintenance crews with alerting motorists of poor road and weather conditions.

Table 9

Line 1	Line 2	Line 3
I-15 Closed	**I-84 Open**	**Slow to 55**
I-15 Open	**I-84 Closed**	**Slow to 45**
Strong Winds	**Ahead**	**Slow to 35**
Strong Winds Ahead	**On I-15**	**Use I-84**
Fog	**On I-84**	**Use I-15 & I-86**
Poor Visibility	**Mobile Homes**	**Ahead**

An evaluation report revealed DMSs do not impact driver speeds due to the distance between signs and pockets of low-visibility. The DMSs are manually operated by the Idaho DOT, who determine which messages to display; however, the signs can be activated by the visibility sensors if visibility levels are less then 0.23 miles.[4]

- *Changeable Speed Limit Signs*

Changeable speed limit signs serve as additional tools for making motorists aware of the reductions in speed limit. Furthermore, changeable speed limit signs can be interoperable with visibility sensors and can display speeds based on pre-determined visibility levels.

- *Highway Advisory Radio (HAR)*

Highway advisory radio may provide an effective means of disseminating visibility warnings to drivers in both localized and widespread low-visibility areas. As noted in the Tennessee example above motorists are advised to tune to HAR for further advanced warning information. Furthermore, HAR can provide an effective method for warning motorists of advanced real time locations of low-visibility pockets in wide spread areas.

- *Fixed Signs with Flashing Beacons*

Finally fixed signs, which display “fog ahead”, equipped with flashing beacons, serve as a low-cost tool for fog or blowing dust or snow events.

7. CONCLUSION

Warning signs can become enveloped in fog and unreadable. Dusts and blowing snow can quickly move across an area, making it difficult to effectively inform travelers of their locations and severity. Likewise fog can frequently encompass a localized area, such as a bridge spanning a river valley, making boundaries slightly easier to delineate and therefore easier to provide solutions for warning motorists. This third sentence about the bridge is not easy to understand and follow. What is it trying to say? However, pinpointing fog, dust or blowing snow in a widespread area where minor changes in geographic and weather conditions frequently occur, make identifying specific placement for both low-visibility detection equipment and information dissemination media difficult

The need for low-visibility warning systems has been highly recognized with the increasing number of fatal accidents due to fog, dust and blowing snow. Within this document several examples of deployed low-visibility systems were highlighted, and likewise various solutions for both localized and wide area visibility events were summarized. The guidelines developed from this project seek to assists agencies that are assessing areas prone to low-visibility within their jurisdictions and are considering appropriate counter-measures to detect low-visibility events, disseminate warning information to motorist and reduce accidents and increase safety in low-visibility conditions

APPENDIX A

Deployed Systems

The following table summarizes the systems discussed in this Guidance Document. They cover both systems designed specifically for dust, fog and snow and those that operate for any visibility limitations.

System	State	Conditions	Sensor Technology	Message Media
Alabama I-10	Alabama	Fog	Fog detectors, CCTV	Three fixed VMS One portable VMS
Caltrans Automated Fog Warning System	California	Fog/dust	Weather sensors, speed detectors, CCTV	Nine DMS
Idaho SWS	Idaho and Utah	Blowing snow/dust	LIDAR, RADAR and SCAN	Four DMS
North Carolina I-40	North Carolina	Fog	Visibility Sensors, Remote processor signal	Two VMS
Project Advise	Utah	Fog	Highway Visibility Sensors, Traffic Detectors	Two DMS
Tennessee Fog Warning	Tennessee	Fog	Fog detectors, vehicle flow detectors, two weather sensors	Ten DMS, ten variable speed limit signs and six fixed signs with flashing beacons

LOW-VISIBILITY SYSTEM SUMMARIES

Alabama

Location(s):	The system is located on I-10 outside of Mobile.
State:	Alabama
Contact:	Vince Calametti Alabama DOT (334) 470-8220
Type of condition:	Frequent fog conditions cover this section of I-10, due to its close proximity to Mobile Bay.
Coverage area:	The system encompasses a 6.2-mile area of I-10, which includes the Cochrane Bridge.
Objective:	To detect fog events that may cause low-visibility conditions and alert motorist with the appropriate advanced warning information.

<table>
<tr><td>Type of monitoring equipment:</td><td>The system is comprised of the following components for monitoring visibility and traffic conditions:

• 6 forward scatter Scientific Technology brand fog detectors spaced ¾ of a mile apart;
• 11 pan/tilt/zoom closed circuit cameras;
• 14 fixed closed circuit cameras;
• 3 Mark 4 dot matrix VMS with strobes that intensify the message;
• 1 portable VMS;
• Streetlights; and
• Fiber optic connections.</td></tr>
<tr><td>Type of warning:</td><td>An advanced warning of low-visibility conditions is automatically disseminated to drivers via VMS and changeable speed limit signs. The pan/tilt/zoom cameras are activated to identify problems if the average speed drops below 45 mph.</td></tr>
<tr><td>Message:</td><td>The following are possible message scenarios capable of being displayed.

Visibility < 900 feet
• VMS display “fog ahead”
• Speed limit remains 65 mph

Visibility < 600 feet
• VMS display “fog, slow, use low beams, trucks keep right”
• Speed limit is reduced to 55 mph

Visibility < 450 feet
• VMS display “fog, slow use low beams, truck keep right”
• Speed limit is reduced to 45 mph

Visibility < 280 feet
• VMS display “dense fog, slow, use low beams, trucks keep right”
• Speed limit is reduced to 35 mph

Visibility < 175 feet
• Road is closed and the VMS divert traffic off the highway.</td></tr>
<tr><td>Advance Warning:</td><td>The pan/tilt/zoom cameras are automatically activated to identify problems if traffic flows drop below 45 mph.</td></tr>
</table>

Cost:	The total system cost came to $6.2 million. Funding was split 80/20 between FHWA and the Alabama DOT.
Measured Effectiveness:	The system began operation in September/October 2000 and the Alabama DOT will need two years to perform tests and gather data before performance measures will be conducted and evaluation documents made available. An error rate up to 25% has been recorded, due to problems, which lie with sensors determining visibility distances.
Perceived Effectiveness:	The system has encountered problems with the sensors, which were originally designed for airports and only require a determination of visibility of 2,400 feet. The sensors were not designed to distinguish between finer gradations of fog, which creates a large margin of error. Additional interference problems with sensors that distort readings are attributed to strong sun angles and reflections from the water surface.
Future Plans:	Due to the high degree of error with the sensors, Alabama DOT plans to install additional forward scatter sensors, which should minimize the margin of error. Furthermore Alabama DOT plans to experiment with moving the thresholds for fog detection up to 1500 feet from 900 feet.

Caltrans Automated Fog Warning System (CAWS)

Location(s):	The system covers Interstate-5 and State Routes 205 and 120 in San Joaquin County, a major arterial that serves the Stockton-Manteca areas to the east and the San Francisco Bay area to the west.
State:	California
Contact:	Clint Gregory, California Department of Transportation New Technology and Research Program (209) 948-7449
Type of condition:	The geography of the area consists of a low-lying delta, which is prone to seasonal ground fog from October through April, outside of the Stockton-Manteca area. Blowing dust is also a problem throughout the year during periods of high wind.
Coverage area:	Interstate 5, State Route 120, State Route 205, all of which are in a close proximity to the Stockton-Manteca metropolitan area.
Objective:	The project seeks to accomplish the following objectives: • Reduce traffic incidents resulting from fog and dust events by June 30, 2003; • To compare incident data before and after the system's activation in 1997, referencing base year data from 1996, the last year prior to system activation by June, 30 2002; and • To assess the technical soundness, quality and integration of the system components to assure that the system is capable of performing as specified under all required conditions by September 30, 2002.

Type of monitoring and functionality of equipment:	The system comprises the following components for monitoring visibility and traffic conditions: • Meteorological Monitoring System - Nine remote weather stations deployed on Interstates 5 and State Route 120. Each are equipped with dual axis atmospheric visibility sensor, an anemometer, barometer, thermometer, dew point sensor, precipitation gauge and a telemetry system for encoding all instrument data and transmitting to a central facility for display and recording on a PC. Data is carried via leased phone lines to the TMC in District 10 located in Stockton. • Traffic Monitoring System - Duplex loop-pair speed detection traps are installed at 36 sites at approximately ½ mile intervals on I-5, SR-99 and SR-120. Six sites are designated as communication hubs, which all other detection sites are connected to and traffic flow and speed data is sent to the TMC. • Closed Circuit Television Cameras - A network of CCTV cameras was installed for incident verification, remote monitoring capabilities and the option for selective dissemination of information to the public via a state Web Site. The Fog Warning System automatically detects reduced visibility and speeds. The system automatically advises travelers, via the DMS, of speeds that would be safe for conditions ahead. In the event of an accident during foggy conditions the speed messages will override the fog messages. The system can be manually overridden by the operators in the Caltrans Traffic Management Center (TMC) as necessary for highway emergencies, advisories, construction, and maintenance work.
Type of warning:	Caltrans Model 500 changeable message signs were installed in nine locations. A total of six messages are capable of being displayed based on traffic speeds, visibility and wind speed.

Message:	The following are possible message scenarios capable of being displayed: Two Traffic Speed Warnings “Slow Traffic Ahead” “Stopped Traffic Ahead” Three Visibility Warnings “Reduced Visibility Ahead” “Low-visibility Ahead” “Extremely Low-visibility Ahead” One Wind Warning “High Winds Ahead”
Advance Warning:	The first advanced warning on I-5 is disseminated to drivers via DMS located approximately six miles from the fog prone areas and the four additional DMS on I-5 are located in 2-mile intervals leading up to the areas prone to low-visibility. Similarly, the DMS on SR-120 are located in 2-mile intervals with the first DMS located approximately four miles due to lower traffic flows, from areas of low-visibility.
Cost:	Phase I deployment was estimated at $2.5 million.
Measured Effectiveness:	Evaluation measures are currently underway which will assess the systems effectiveness on the following levels. • Technical Assessment - An evaluation of the system design and integration of the systems sub-components will test how well the system communicates and the status of field instruments and computational hardware. • Operational Assessment - Accuracy and reliability levels will be observed on visibility and traffic sensing components, and the selection and display of the systems warning messages. • Assessment of impact on driver behavior during limited visibility. An evaluation will be conducted to determine whether drivers reduce their speed before viewing the DMS or immediately after viewing CMD warning messages. Assessment of long-term impact of system accident rates and losses. Tests will compare accident rates several years prior to the systems activation and will determine if the system is having a positive effect on accident rates. Furthermore the test will attempt to infer if warning drivers ahead of time may have eliminated or reduced the severity of accidents.

Perceived Effectiveness:	Although evaluation measures are still in progress, a significant reduction in the number and severity of accidents since the system's activation has been evident.
Future Plans:	Future efforts include evaluating the system on a yearly basis in order to meet the outlined goals of reducing the number of accidents caused by low-visibility levels and developing an autonomous system by June 2003.

I-84 Idaho/Utah Storm Warning System (SWS)

Location(s):	I-84 between Boise and Salt Lake City
State:	Idaho and Northern Utah
Contact:	Brian Breen, Idaho Department of Transportation, (208) 332-7893.
Type of condition:	Blowing snow during the winter and dust storms during the summer due to dry and windy valley atmospheric conditions.
Coverage area:	The test area covers a 100-mile corridor of I-84 that is well known for a history of frequent and severe accidents.
Objective:	The project was conducted in two phases. The first objective was to determine if the visibility sensors provide accurate visibility measurements, determine which sensor is the most effective and establish a baseline driver behavior for vehicles in the test areas. The second objective was to assess whether DMS would reduce vehicle speeds during periods of low visibility, determine if visibility sensors provide valuable data and assess relationship between weather factors such as high winds, snow and poor visibility.
Type of monitoring and functionality of equipment:	The system tested four types of visibility and weather sensors provided by Surface Systems Inc. (SSI), Handar Corporation and Santa Fe Technologies referred to as WIVIS (Weather Identifier and Visibility Sensor), SSI-Belfort, Handar-Belfort and Lidar (Light Direction and Ranging). The Lidar sensor however was not operational during any of the low visibility events and subsequently no data was used in the final evaluation. The sensors measure visibility and weather data using forward scatter detection technology. The data collected by the sensors is then transmitted to a master computer via dedicated landlines to the central data collection center in Cortterell, ID. The data is then automatically transmitted from the central operations center and the appropriate low-visibility warning message is then automatically displayed on the dynamic message signs. Additionally closed circuit television cameras were installed at the test site as monitoring equipment. The cameras were aimed at a series of five target signs that were equipped with flashing lights to enhance their visibility. The target signs were placed at distances of 250, 500, 850, 1200 and 1500 feet to aid in the assessment of visibility.
Type of warning:	Warning messages are disseminated via four DMS located throughout the test area.

Message:	The system is equipped with three fiber-optic lines that are capable of disseminating up to ten different message sets to the four VMS. See appendix A for message sets.
Advance Warning:	Warning messages are disseminated to drivers upon their approach approximately 1 mile prior to I-84 at the junction of I-15 and approximately 1 mile prior to I-84 at the junction of I-86.
Cost:	Approximately $2 million.
Measured Effectiveness:	Several effectiveness measures were performed on the sensors as well as the dynamic message signs to evaluate their performance and the changes in driver behavior. Measured effectiveness of the Handar-Belfort and the SSI-Belfort sensors revealed that reasonable estimates of true visibility were calculated and a direct correlation between the sensor low-visibility readings and reduction of driver's speeds was found. The SSI-WIVIS sensor was not as accurate as the Handar-Belfort or the SSI-Belfort sensor in measuring visibility. The Handar-Belfort and SSI-Belfort sensors consistently identify measurements that are below 0.23 miles or above 0.23 miles and were considered effective in identifying low visibility events. Due to the limited number of low-visibility events during the test phase the data available on the impact the dynamic message signs had on drivers speeds was limited. Thus the dynamic message signs did not appear to have an apparent effect on driver speeds. Although during extreme weather conditions such as high winds the dynamic messages signs did have an apparent effect as lower speeds were recorded.
Perceived Effectiveness:	The results from phase I indicate that the system components have the potential to provide accurate information to en-route travelers. Phase II will determine the most effective sensors to integrate into the overall system.
Future Plans:	Plans to incorporate and develop an interoperable visibility warning system with the Idaho RWIS system are currently being undertaken. Due to upgrades in system components, the DMS will be replaced to be compatible with new technology.

North Carolina

Location(s):	I-40 in Haywood County North Carolina
State:	North Carolina
Contact:	Greg Fuller (919) 733-8021
Type of condition:	Fog conditions are heavily localized on a five-mile stretch of I-40 due to temperature inversions created by the low-lying section and a paper mill, which creates additional water vapor.
Coverage area:	The system encompasses a 5-mile section of I-40 in Haywood County.
Objective:	To detect fog events that may cause low-visibility conditions and alert motorist with the appropriate advanced warning information.
Type of monitoring and functionality of equipment :	The system is comprised of the following components for monitoring visibility and traffic conditions: • Fiber optic connections. • 5 Belfort sensors; • 7 DMS; • 6 video cameras; • 1 RWIS • Remote processor signals; and • Onsite systems connected via fiber optics. The system sends information from a weather station, and data from five fog detection devices, to a Main Control Center (MCC) hub. The enhanced communications network also had to control the flow of information to seven, strategically located variable message signs and six video cameras to the Bridge Control Center (BCC). The BBC then processes the data from the sensors, monitors video images for sensor confirmation and the appropriate message is then automatically sent to DMS.
Type of warning:	Drivers are warned via two DMS.

Message:	The DMS are capable of disseminating different scenarios, which handle different thresholds of visibility. The DMS will display: • "Low-visibility, slow speed" Although the DOT maintains the system the State Highway Patrol has full autonomy over the system and decided which message scenarios to disseminate from their central office.
Advance Warning:	The DMS are located one mile before the localized areas of fog in either direction of traffic.
Cost:	Total cost for the system amounted to $1.1 million. The cost for the sensors came to $30,000 each and cost for each of the VMS came to $125,000. Funding came from FHWA, which were specifically STP funds.
Measured Effectiveness:	Only three multi-car fog related accidents have been recorded in the last fifteen years. Therefore due to such low-recorded data levels accident reduction studies have not been conducted.
Perceived Effectiveness:	Although low levels of accidents have been recorded, North Carolina installed a fog warning system as a preventative measure for potentially eliminating accidents due to fog events.
Future Plans:	Future plans include installing three CCTV cameras for surveillance and verification of low-visibility events.

Project ADVISE

Location(s):	Greater Salt Lake City metropolitan area.
State:	Utah
Contact:	Sam Sherman, Utah Department of Transportation Research (801) 965-4196, ssherman@dot.state.ut.us
Type of condition:	The geography of the area comprises a low-lying stretch of the valley and the Jordan River, which creates temperature inversions resulting in localized foggy conditions.
Coverage area:	The system covers the entire section of I-215 in the greater Salt Lake Metropolitan area where fog conditions are highly localized.
Objective:	To reduce speeds of traffic flows and the number and severity of accidents during fog events through the use of fog detection sensors and real-time information systems such as DMS.

Type of monitoring and functionality of the equipment:	The system comprises four Highway Visibility Sensors (HVS), and two Automatic Traffic Counter (ATC) Sites. The HVS use
Type of warning:	Warning messages are disseminated via two DMS.
Message:	Warning messages differ depending upon the level of visibility: >250 meters No Message 200-250 meters “Fog Ahead” 150-200 meters “Dense Fog” alternating with “Advise 50 mph” 100-150 meters “Dense Fog” alternating with “Advise 40 mph” 60-100 meters “Dense Fog” alternating with “Advise 30 mph” <60 meters “Dense Fog” alternating with “Advise 25 mph”
Advance Warning:	Advanced warning is disseminated to drivers approximately five miles on either side of the fog prone areas
Cost:	No estimate provided.
Measured Effectiveness:	Although the warning systems decreased the standard deviation of speeds by 22% from 9.5 mph to 7.4 mph, the mean speeds increased by 15%, 8 mph (6 mph of this increase attributed to general increase in speeds).
Perceived Effectiveness:	Project ADVISE improved traffic safety on I-215 by reducing the variations of speed under foggy conditions; however mean speeds were not reduced to recommended levels.
Future Plans:	Project ADVISE will continue as it provides accurate and reliable information to drivers. Additional information will be collected and added to ongoing evaluations. System improvements include updating of sign controller (to Mark IV), replacement of RF communications with fiber optic, incorporate speed loop information into a feedback process for message delivery, TOC operator notification/involvement, and verify message display.
Other notes:	Additional deployment options were noted and include: • Integrating ADVISE into TOC; • Identify statewide areas where fog related accidents are high and prioritize for deployment based on cost-benefit analysis; and • Expand to include TOC region as a whole utilizing video detection and operator intervention.

Tennessee Fog Warning

Location(s):	I-75 on the Hiwassee Bridge.
State:	Tennessee
Contact:	Don Dahlinger, Tennessee Department of Transportation (615) 741-3033
Type of condition:	The area consists of a river valley prone to foggy conditions due to high temperature inversions and cooling ponds from a paper mill, which creates additional water vapor in the valley.
Coverage area:	The warning system covers a nineteen-mile stretch of I-75, with the river valley, the area most likely prone to fog, being six miles long.
Objective:	To detect fog events that may cause low-visibility conditions and provide motorists with the appropriate warning information.
Type of monitoring and functionality of equipment:	The system comprises eight fog detectors and two RWIS stations. Additional components include a series of forty-four radar vehicle flow detectors, which monitor vehicle speeds. Data gathered from the fog detectors, RWIS stations and radar detectors is processed at a central operations center on a PC and by both automated and manual monitoring of data the computer detects and predicts conditions which may lead to low-visibility events. The highway patrol is also on site visually confirming conditions. A set of pre-determined messages are sent automatically or manually to the DMS to warn drivers of foggy conditions, which they will encounter.
Type of warning:	Warning messages are disseminated to motorists via ten DMS, ten variable speed limit signs, and six fixed signs with flashing beacons. It'd be nice to know how these components work. For example, how does variable speed limit signs operate?
Message:	See tables 2 through 5.
Advance Warning:	Five DMS precede the bridge on either side and are spaced approximately 1.5 to 3 miles apart. Drivers receive the first warning roughly three miles prior to the fog prone areas. If I-75 is closed, however, due to extremely low-visibility, then drivers are warned six miles prior to the bridge and are instructed to detour and exit I-75.
Cost:	$4.5 million, with maintenance cost averaging $200,000 per year.
Measured Effectiveness:	Between 1993 and 1995, the system was activated for a total of 122 reduced visibility events and no accidents were reported for this period.
Perceived Effectiveness:	The system has been highly effective in warning drivers of low-visibility levels and reducing speeds and accident rates.
Future Plans:	Future evaluations have been planned.

APPENIX B

Model System Components

As part of the project development, ADOT hosted a focus group to discuss low-visibility warning systems. The focus group convened individuals from various states that have deployed or are considering deploying fog/dust storm warning systems. The purpose was to discuss the successes of deployed systems and the lessons learned through deployment and evaluation. Focus group participants revealed that since deployment of low-visibility warning systems in their jurisdictions the number of incidents have drastically been reduced and in some cases none have been reported.

Members of the focus group discussed their agencies' approach to developing mechanisms for classifying low-visibility prone areas, which ultimately lead to identifying the appropriate building blocks for deployment of a warning system.

The following table is a list of possible components for low-visibility warning systems for both localized and wide area systems.

**The Enterprise Program does not promote any of the specified vendors listed in the following table. The manufactures listed below are provided to give agencies a rough idea of various components that may be included in a low-visibility system.*

LOW-VISIBILITY SYSTEM COMPONENTS

Component	Manufacturer	Web Site
Dynamic Message Sign	Addco	http://www.addcoinc.com/index.html
	3M Dynamic Messaging Systems	http://www.3m.com/us/safety/tcm/
	Data Display Group	http://www.data-display.com/
	Altaroute Limited	//www.altaroute.com/
Changeable Speed Limit Signs	The Flash	http://www.the-flash.com/
	Precision Solar Controls	http://www.precisionsolarcontrols.com/index.html
	Addco	http://www.addcoinc.com/index.html
	American Electronic Sign	http://www.americanelectronicsign.com
Ramps Gates	Engineered Parking Systems, Inc.	http://www.epsinfo.com/prod01.htm
	Federal ADP	http://www.federalapd.com/PRODUCTS/INDUST/inbarr.htm
	Computer Recognition Systems	http://www.crs-its.com/
	National ITS	http://www.nationalits.com/index2.html
Highway Advisory	National ITS	http://www.nationalits.com/ind

Radio (HAR)		ex2.html
	Highway Information Systems	http://www.highwayinfo.com/
	Soundsoft	http://216.149.241.9/
	Cue Network Corporation	http://www.cue.com/
Closed Circuit Television Cameras (CCTV)	COHU	www.cohu-cameras.com/index.html
	Institute for Microelectronics, Stuttgart	www.ims-chips.de/index_flash.htm
	Iteris	http://www.iteris.com/
	Image Sensing Systems	http://imagesensing.com/index.html
Fixed Sign With Flashing Lights	Precision Solar Controls	http://www.precisionsolarcontrols.com/index.html
	Ultra Ltd	http://www.ultraltd.com/english/security.htm
	Forest City Signs	http://www.forestcitysigns.com/page1.html
	Varitext	http://www.varitext.co.uk/home.html
Site Control Center	Computer Recognition Systems	http://www.crs-its.com/
	Siemens	www.adt.siemens.de/traffic/
	National ITS	http://www.nationalits.com/index2.html
	Econolite Control Products	http://www.econolite.com/INDEXz2.htm
Road and Weather Information Station	SSI	ssiweather.com
	Vaisala	www.vaisala.com
	Boschung	www.boschung.com
	Nu-Metrics	www.nu-metrics.com
Visibility Sensors	Qualmetrics	www.qualimetrics.com
	United Security Products, Inc	www.unitedsecurity.com
	Belfort Instruments	JROlenick@aol.com
	Siemens	www.adt.siemens.de/traffic/
	Optical Scientific Inc.	http://www.scti.com/prod04.htm
Video Surveillance	LVW Electronics	http://www.lvw.com/video_security.htm
	Ultra Ltd	http://www.ultraltd.com/english/security.htm
	Econolite Control Products, Inc	http://www.econolite.com/
	Siemens	www.adt.siemens.de/traffic/
Traffic Detectors	Precision Solar Controls	http://www.precisionsolarcontrols.com/index.html
	Nu-Metrics	www.nu-metrics.com
	Siemens	www.adt.siemens.de/traffic/
	Computer Recognition Systems	http://www.crs-its.com/

WORKS CITED

[1] "New Road Way Visibility Sensors" Research, Development, and Technology Turner-Fairbank Highway Research, McLean, VA February 1996. Online Internet

[2] "Getting Clear on Fog-Related Crashes in Tampa Bay" ITE Journal, February, 2000. Online Internet

[3] "Highway Fog Warning System," Turner Fairbank Highway Research Center, McLean, VA, 1999. Online Internet

[4] "Idaho Storm Warning System Operational Test," Final Report. University of Idaho, Boise State et. al December 2000. Online Internet