

Testing the Adverse Visibility Information System Evaluation (ADVISE) – Safer Driving in Fog (02-3140)

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ABSTRACT

There are many advisory systems to warn drivers of fog. However, warning drivers that there is fog ahead does not instruct them on what to do. During the 1995-2000 winter seasons, the Utah Traffic Lab (UTL) has tested a newer technology known as the Adverse Visibility Information System Evaluation (ADVISE). ADVISE uses visibility sensors to determine current sight distance and corresponding safe speed for the prevailing conditions. Variable Message Signs (VMSs) instruct drivers of safe speed. This research measures the effectiveness of the system in reducing the variability between speeds. Prior research through the NCHRP recognizes that reducing variability in speed is more influential in reducing fog-related accidents. Thus, more uniform speeds may help drivers to avoid fog-related overtaking accidents. UTL tested a fog-prone area of I-215 in Salt Lake City, Utah. Phase I represents the control because it did not have VMSs informing drivers of appropriate speeds for roadway conditions. Phase II was an implementation and verification phase for the new technology. Speed limit and road changes also happened during Phase II. Phase III data was collected following VMS installation during the winter of 1999-2000. The data shows that prior to the VMSs, there was a range of driver confusion where drivers did not determine common safe speeds. ADVISE successfully reduced speed variability by an average 22%. The data supports the result that informing drivers of an appropriate speed during adverse visibility is better than requiring each individual driver to determine their own perceived safe speed.

INTRODUCTION

Each decade, fog causes approximately 6,000 deaths nationwide. In 1990-1991, four fog-related accidents involved 240 vehicles and caused 21 fatalities in the United States. The high number of vehicles involved indicates that drivers were likely unaware of the accident until it was too late.

Highways are designed for drivers to have sufficient visibility to safely operate their vehicles. However, due to the variability of fog, adequate warning devices have not been able to tell the driver how fast they should go. Highway advisory radio, individual advisory signs, and fog visibility test signs have been used to caution drivers of visibility restriction. More recently, Variable Message Signs (VMSs), and pavement inset lights have been used to caution drivers that fog is ahead and, possibly, provide improved motorist guidance (1). These fog advisory systems help drivers only to a point; they do not recommend a proper travel speed based on the visibility conditions. Instead, they inform drivers of a variable condition ahead, relying on the drivers' ability to judge the appropriate speed. Since every driver has a different perception of "safe speed", he or she tends to drive too fast for the current sight distance or too slow which can lead to overtaking accidents. While reducing vehicle speeds is the goal, the variation in speeds causes more accidents and increases their severity.

To reduce the risk of accidents during fog, the Utah Department of Transportation (UDOT) installed VMSs in a fog prone area of Interstate 215 in Salt Lake City, Utah, to advise drivers of the appropriate speed for the current conditions. Visibility sensors near the road constantly evaluate the visibility and during reduced visibility, the signs display the recommended safe speed. The system that monitors and sends messages is known as the Adverse Visibility Information System Evaluation (ADVISE). ADVISE provides real-time speed recommendations for drivers during fog in an attempt to decrease the risks of driving through recurring fog zones. This paper provides a statistical evaluation of ADVISE's ability to reduce variability in vehicle speeds during fog, supported by data collected during the 1995-96, 1996-97, 1997-98, and 1999-2000 winter seasons.

REVIEW OF EXISTING RESEARCH AND IMPLEMENTATIONS

Carl Hayden, of the Federal Highways Administration (FHWA) (2), states that ten states have reported identifying one or more locations of recurring fog that has contributed to higher numbers of accidents. Most of those states incorporated static signs to inform the driver of foggy road conditions. Some of the states were reported to have mobile signs that have been placed on the road and move according to where the problem is perceived. Other devices used are raised pavement markers, wider lane lines, wider edge lines, closer spacing of broken lane lines, and flashing beacons mounted on warning signs. Many of these static signs simply inform the drivers of potential fog ahead. The more advanced signs activate flashing lights when fog is present. However, both types of signs fail to provide specific guidance to drivers of the appropriate speed for the conditions. In spite of these warnings, Hayden states that knowing there is fog ahead is often redundant because most motorists can see for themselves. He asks what actions should drivers be encouraged to take when they encounter fog on the road?

District 10 of the California Department of Transportation (Caltrans) has implemented an Automated Warning System to help drivers understand what to do in adverse visibility (3). The California system is on I-5 in a central valley near Stockton, CA. It measures the freeway travel speed at the fog locations. It warns upstream drivers that the freeway travel speeds in the fog ahead are reduced. Signs of 'slow traffic ahead' and 'stopped traffic ahead' are combined with messages of 'reduced visibility', 'low visibility', or 'extremely low visibility' in order to warn entering drivers of upcoming conditions. The literature has not yet provided results on the effectiveness of the system in reducing speeds or accidents.

In 1997, researchers from the University of South Florida (4) evaluated the need for a motorist warning system in the fog prone areas of Tampa Bay, Florida. The study concluded that there was no permanent, specific fog-prone area in Tampa Bay. Instead, they found that the fog rolls randomly around the area. The researchers were able to make several generalizations about fog conditions and the impact on the type of road, the age of the driver, and the time of day. They introduced a four-step process to evaluate advanced fog-detection technologies and suggested strategies to address fog-related incidents in the Tampa Bay area. This information was expanded and published by Turner and Pietrzyk in the February 2000 Institute of Transportation Engineers (ITE) Journal (5). Their findings recommended a "strong educational campaign" to inform motorists of reduced visibility hazards.

Richard Schwab of the FHWA (6) states that the probability of accidents increases in fog as a result of different drivers' versions of a "safe speed". He found that the minimum variance in speed depended upon the density of the fog. Above 122-meter (400 foot) visibility, the minimum variance occurred at the 85% speed. For dense fog below 46 meters (150 feet) of visibility, the 15% speed was a better measure, and that the mean was probably the best overall. Schwab also identified how people react to an incorrect sign message. When told that there was fog ahead when there was none, drivers did not react to the sign recommendation. Once an incorrect message was viewed, drivers required 8 to 10 correct messages before they would again adhere to the sign's recommendations.

Chief John Anderson of the California Highway Patrol (7) stated that the greatest asset in identifying fog locations and reducing speeds was a police presence. Job Klighout, of the Netherlands Department of Transport (8), echoes this sentiment. He states that statistics from the Netherlands indicate that when police are present, there are no accidents.

A NTSB report on the Tennessee I-75 ninety-nine vehicle fog-related collision (9), recommended that, "Countermeasures are needed that ensure drivers proceed through limited-visibility conditions at uniform reduced speeds." According to the criteria given by NCHRP Synthesis 228 (1), an effective tool for reducing restricted visibility accidents provides:

1. Countermeasures that induce drivers to proceed through limited visibility conditions at more uniform speeds.
2. Credible (real-time) information and behavioral guidance signs essential to reducing speed variation.
3. Comprehensive countermeasure systems that include both traffic flow detectors and visibility sensors that automatically alert drivers of hazardous conditions or slow traffic.

While past research shows some alternatives to the static, non-specific fog warning signs (most of which, only warn drivers that fog is present). It also shows how traffic needs to have a more uniform speed in fog. However, it does not mention implementation of a system that uses a more advanced fog warning system that measures visibility and reduces variability in speed.

RESEARCH GOALS AND OBJECTIVES

The purpose of ADVISE is to reduce the variation of road speeds and provide a more uniform traffic flow speed. If drivers are informed of a safe speed based on current visibility, then initial accidents will be reduced. If an accident does happen, then drivers will be more likely able to avoid an incident ahead, thereby reducing multiple vehicle collisions and possible chain-reactions. This research reflects the results of the hypothesis that if driver behavior can be influenced by the recommended speed limit using ADVISE and the variability in speeds is reduced, then there will be reductions in secondary and multiple car accidents during fog-related, reduced visibility.

RESEARCH METHOD

A two-mile, low-lying section of the I-215 freeway that crosses the Jordan River Valley between Redwood Road and I-15 in Salt Lake City, Utah (Figure 1) was tested. Recurring fog on the highway has made this area an ideal test facility for ADVISE.

The HSS Inc. Model PW-600-120 Present Weather Sensors measure road visibility conditions in real-time. The visibility information is communicated to a central computer that uses a weighted average algorithm to determine the visibility condition for the two lowest sensors. The algorithm determines if a reduced speed message is needed. The displayed message is based on a step function whereby threshold limits are placed on the visibility and recommended speed. ADVISE messages, based on measured visibility, are listed below in Table 1. For monitoring the system information, vehicle data from the six detector stations along with the visibility information, and log of the VMS sign messages are stored in a separate database. Figure 2 shows how ADVISE works.

DATA

Speed and classification data was collected by lane, direction and time of day for a two-mile section of I-215 over four winter seasons. This traffic data, when combined with visibility sensor information, has allowed a comprehensive comparison of impacts.

Data was collected in three phases. Phase I (winter 1995-1996) recorded the visibility and traffic data prior to VMS installation. This represented the "before information" or control of the research. Phase I began in

1995 when four fog detectors were placed in the test area. Phases II and III recorded the visibility data, traffic data, and sign messages. They also represent information after the roadside VMSs were operating. Speed loops were installed at six locations (three in each direction) to record vehicle information.

Phase II (1996-1997) occurred as an implementation and calibration of the new system. During this Phase, UDOT installed VMSs, calibrated the communication systems. Data was collected; however, because of the various stages of equipment operations, the data was deemed unreliable and subsequently eliminated from the study. After UDOT completed installation and calibration of the system in Phase II, data collection began in Phase III (winter 1999-2000). Verification of recommended messaging and actual field verification of sign message was completed through Utah Highway Patrol cooperation and the use of video cameras that have been available in the area since the UDOT Transportation Operations Center opened in March of 1999.

Phase I and Phase III are used to compare pre- and post- VMS usage respectively. Phase I represents 38,522 individual vehicles while Phase III has 6,851 vehicles in the sample size. The final comparison data set includes 594 minutes of adverse weather in Phase I and 152 minutes of adverse weather in Phase III.

The visibility measures used to activate the VMSs for Phase III are weighted so the signs erred on the side of caution. Fog can be thick in localized areas, so a weighted average guards against the dangers of dense localized fog. The weighting method is described by the following equation:

$$VMINavg = \frac{1.75v \min 1 + 0.25v \min 2}{2}$$

Note: *VMINavg* is the weighted average of *vmin1* (the lowest visibility measurement) and *vmin2* (the second lowest visibility measurement) from the four available fog sensors.

Table 2 shows the typical densities of the fog that frequents the measured area. The majority of the fog occurs between the 100 and 150-meter visibility range.

ANALYSIS AND RESULTS

The speed, visibility, and sign message were matched by the time and date and displayed so the standard deviation, mean, skew, and other statistical information of the data, could be compared and analyzed. The speeds were compiled into 8 kph (5 mph) bins from 8 kph (5 mph) to 193 kph (120 mph) and the visibility was aggregated into 5-meter bins from 45 meters to 450 meters. Above 450 meter visibility is considered clear.

Throughout the analysis, Phase I represents before VMS installation, meaning drivers made their own decisions about speed. Phase III represents post VMS installation where the message sign notified drivers of fog ahead and recommended a safe speed. The relationship between mean speed and visibility is graphically shown in Figure 3. The standard deviation by visibility is shown in Figure 4.

Figure 3 indicates that the mean speeds for Phase III were higher than the mean speeds for Phase I. They increase from 87 kph (54 mph) to 100 kph (62 mph). This is probably indicative of the general speed increase observed since 1996 on non-fog days and thus the data suggest the signs were ineffective in reducing mean speeds.

Combining the speed information with the standard deviation results, suggests the slower drivers sped up, which contradicts the primary hypothesis that assumes that the faster drivers would slow down. As hypothesized, the standard deviation graph in Figure 4 shows that Phase I has a higher standard deviation of 15.3 kph (9.5 mph) while the use of VMS to inform drivers of visibility conditions in Phase III reduced the speed deviation to 11.9 kph (7.4 mph), a 21.6% reduction.

DISCUSSION

During the study, changes affected driver behavior for this segment of roadway. Some include:

- December 19, 1995, the speed limit was increased from 89KPH (55 MPH) to 105 KPH (65 MPH).

- In 1997, the pavement was re-striped from three lanes to four. The addition of another lane to the road increased the level of service of the road.
- In 1997, construction on I-15 began which resulted in detours due to road and ramp closures resulting in higher ADT volumes on the I-215.

It is possible that, after four years, drivers have adjusted to the increased speed limit and road serviceability and now travel faster in general. This assumption was verified by measuring free flow data on clear days. It used several similar weekdays and times during the day. Both Phase I and Phase III were compared by daytime and nighttime speeds. (shown in Table 3). The results indicate that a 6.8 kph (4.2 mph) mean speed increase and a 2.1 kph (1.3 mph) standard deviation increase has occurred for clear conditions. In nighttime clear conditions (most of the fog events occur at night), the increase in mean speed is 9.0 kph (5.6 mph) with a 3.4 kph (2.1 mph) increase in standard deviation. Therefore, the speeds and standard deviations for clear visibility have increased between 1996 and 1999. Yet the standard deviation in adverse visibility has been reduced.

Figure 3 indicates that, without the VMSs, between 150 and 300-meter visibility, there are substantial differences in the speed. With the VMSs, much of the variability in this visibility range is eliminated. This is what Richard Schwab (6) would categorize as “driver confusion”. If drivers are not recommended a safe speed, each driver relies on his or her judgment in determining a similar safe speed. Between 150 and 300-meter visibility is the range of driver confusion. The mean speed analysis indicated that prior to the VMSs, there were drivers that seemed timid in driving in the fog. These drivers were 20% to 50% slower than the main flow of traffic. This creates a disparity in speed that increases the risk of overtaking accidents. After VMS installation, the number of slower vehicles was reduced, thus reducing the risk of overtaking accidents.

Figure 4 indicates that, in the driver confusion range, the VMSs helped reduce the standard deviation in speeds. This supports that informing drivers as to a safe speed for the visibility condition reduces speed variation in the driver confusion range. The use of VMSs does not reduce standard deviations at all visibility levels but is important in reducing the speed variations in the driver confusion range.

CONCLUSION

ADVISE reduces the average standard deviation of vehicle speed by 22%, based on the collected data. The range of standard deviation reduction is 0% for dense fog and clear conditions and up to 35% for moderate fog conditions. This is attributed to the different drivers' perceptions of “safe speed” as noted by Richard Schwab (6), who asserts that driver confusion is one of the primary causes of variations in speeds. ADVISE defines the safe speeds for drivers and the variation in speed is reduced because drivers no longer have to “guess” an appropriate speed. When consideration is given to the general increase in mean speed and standard deviations of a clear day between 1996 and 1999, then the actual benefits of the ADVISE reduced the standard deviation of speed by 30%. Overall mean speeds increased by 15% as a result of general behavior changes since 1996, indicating no change in relative mean speed during fog as a result of ADVISE.

While traffic still travels above the recommended speed, based on safe stopping distance for the visibility level, the use of a speed advisory reduces variability in speeds. NCHRP 228 identifies speed variation as the primary cause for initial fog related accidents. This reduction in variation reduces the risk of overtaking collisions and multiple vehicle accidents by reducing the probability of the initial accident. Therefore, the impact of the ADVISE may reduce the probability and intensity of accidents.

The findings support the continued use of the Adverse Visibility Information System because it was successful in its purpose of reducing speed variations. Since the system has only recently been implemented and accident data is a multiple year process, future studies will include compilation of accident information to support a statistical comparison on the impact to accidents (number and severity) under fog conditions. Future data will also allow monitoring of drivers' acceptance to the VMSs recommendations and if vehicle speeds begin to decrease to safe levels for the measured visibility condition.

This research represents a logical step in informing drivers of recommended speeds for prevailing conditions. There will be a range of perceived safe conditions by assuming that drivers will be able to make their own decisions on appropriate speeds under reduced conditions. Informing drivers of the expected speed minimizes the differences in speeds between individual vehicles and contributes to a safer driving environment. Therefore, the ADVISE fog warning system installed in Salt Lake City, Utah, failed to reduce mean speed, but it succeeded in reducing the variation between vehicle speeds.

ACKNOWLEDGEMENTS

Funding from the Utah Department of Transportation to the University of Utah Traffic Laboratory supported the research presented in this paper.

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TABLE 1 Highway Visibility Range Criteria for Changeable Message Signs

Highway Visibility Range	Message
> 250 meters	No Message
200 – 250 meters	“Fog Ahead”
200 – 150 meters	“Dense Fog” alternating with “Advise 50 mph”
150 – 100 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”

SOURCE: Rockwell Transportation Systems (10).

TABLE 2 Fog Duration per Visibility Level

<i>Phase</i>			
	<i>I</i>	<i>III</i>	<i>Total</i>
Visibility Range (m)	Minutes	Minutes	Minutes
0 < 60	48	0	48
60 < 100	231	5	236
100 < 150	241	74	315
150 < 250	74	73	145
Total	594	152	746

TABLE 3 1996-1999 Comparisons for Similar Clear Days

Day-Time Comparisons	Mean (KPH)	Standard Deviation (KPH)
1996	105	10.0
1999	111	12.1
Difference	+6.8	+2.1
Night-Time Comparison	Mean (KPH)	Standard Deviation (KPH)
1996	98	12.0
1999	107	15.4
Difference	+9.0	+3.4

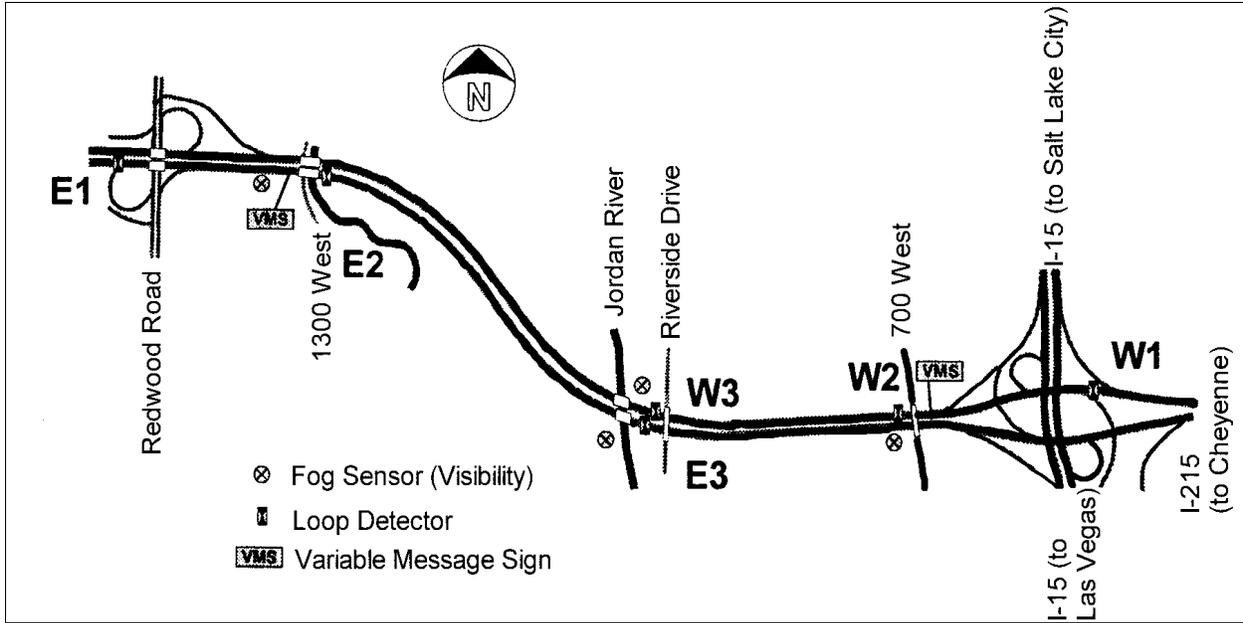


FIGURE 1 Project Test Area

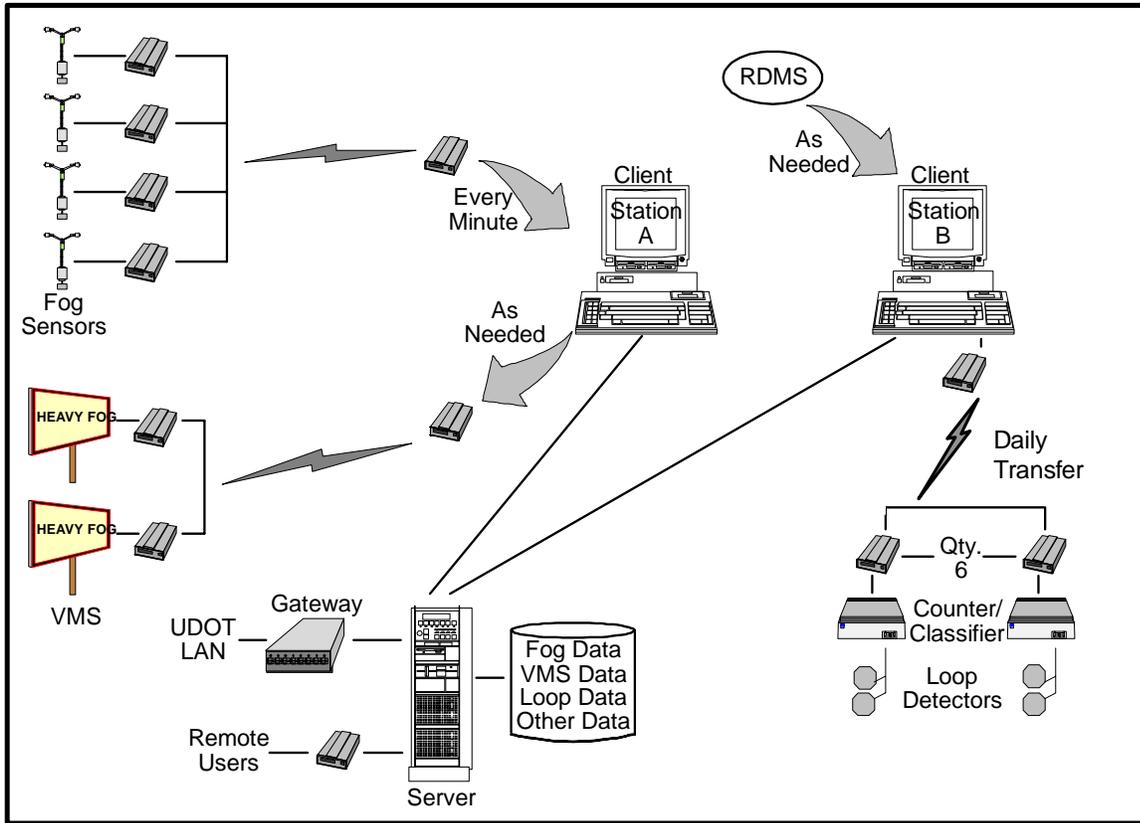


FIGURE 2 ADVISE Flowchart

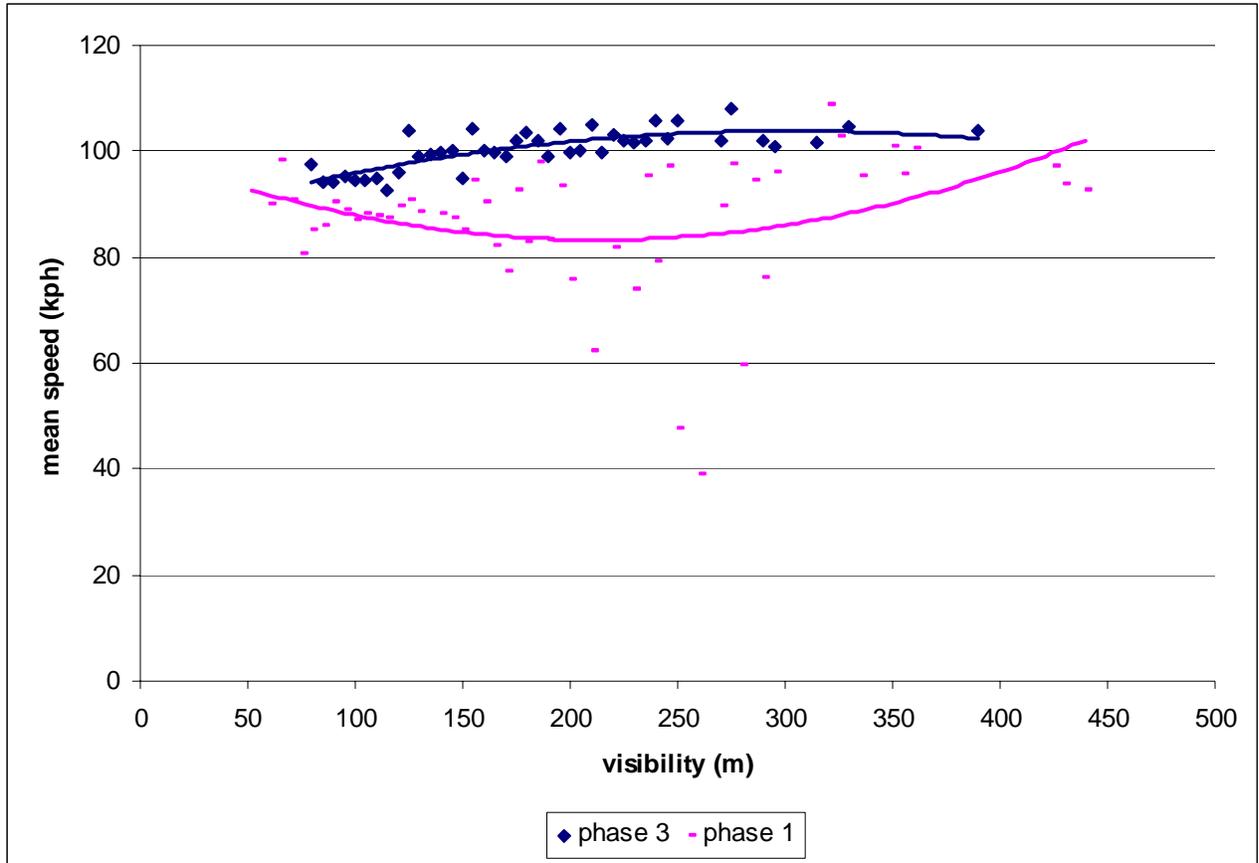


FIGURE 3 Mean Speeds

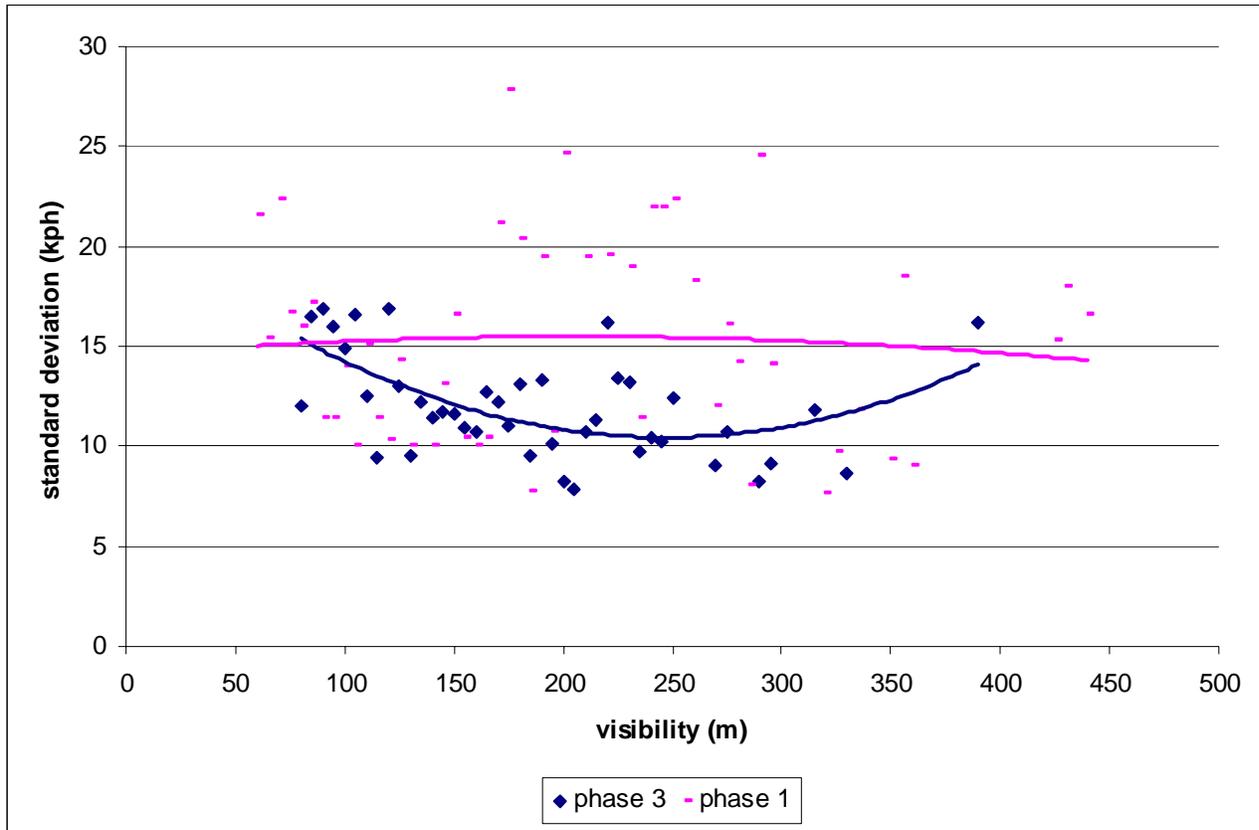


FIGURE 4 Standard Deviation of Speeds