Connected Vehicle Pilot Deployment Program Phase 2

Final System Performance Report, Baseline Conditions – WYDOT CV Pilot

www.its.dot.gov/index.htm

Final Report – July 30, 2018

Publication Number: FHWA-JPO-17-474

U.S. Department of Transportation

Produced by DTFH6116RA00007

U.S. Department of Transportation

Intelligent Transportation Systems (ITS) Joint Program Office

Version History

#	Date	Author	Comment
1	09/29//2017	WYDOT	First draft of the Initial System Performance Report
2	11/15/2017	WYDOT	Second draft, updated based on comments received from USDOT
3	12/11/17	WYDOT	Final *Initial System Performance Report* with edits to respond to additional USDOT comments
4	03/30/2018	WYDOT	Final System Performance Report for Phase 2.
5	06/19/2018	WYDOT	Final version incorporating responses to USDOT comments.
6	07/30/2018	WYDOT	Final Document

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-17-474		

4. Title and Subtitle Connected Vehicle Pilot Deployment Program Phase 2, Final System Performance Report, Baseline Conditions – WYDOT CV Pilot	**5. Report Date** 03/30/2018 Updated 07/09/2018 **6. Performing Organization Code**
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9. Performing Organization Name and Address Wyoming DOT, 5300 Bishop Boulevard, Cheyenne, WY 82009 McFarland Management, 202 N 9th Street, Ste. 302, Boise, ID 83702 ICF International, 1725 Eye St NW, Washington DC, 20006 Trihydro Corporation, 1252 Commerce Drive, Laramie, WY 82070 Vital Assurance, 175 S. Third St., Suite 200, Columbus, OH 43215	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH6116RA00007
12. Sponsoring Agency Name and Address ITS-Joint Program Office 1200 New Jersey Avenue, S.E., Washington, DC 20590	**13. Type of Report and Period Covered** Final System Performance Report 10/2017 to 03/2018 **14. Sponsoring Agency Code**

15. Supplementary Notes
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16. Abstract
The Wyoming Department of Transportation's (WYDOT) Connected Vehicle (CV) Pilot Deployment Program is intended to develop a suite of applications that utilize vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication technology to reduce the impact of adverse weather on truck travel in the I-80 corridor. These applications support a flexible range of services from advisories, roadside alerts, parking notifications and dynamic travel guidance. Information from these applications are made available directly to the equipped fleets or through data connections to fleet management centers (who will then communicate it to their trucks using their own systems). The pilot is being conducted in three Phases. Phase I, already completed, included the planning for the CV pilot including the concept of operations development. Phase II is the design, development, and testing phase. Phase III includes a real-world demonstration of the applications developed as part of this pilot.

This Phase II document presents the Final System Performance Report of the WYDOT CV Pilot. The purpose of this report is to provide USDOT, TTI and Volpe with a final status of Wyoming's performance measurement activities at the end of Phase II. The primary focus will be on documenting the data collected and analysis performed to support the establishment of the pre-deployment conditions, based on data collected through summer 2017 and winter 2017-18.

17. Key Words	18. Distribution Statement
Connected Vehicle Technology, I-80 Corridor, Road Weather, Truck Safety, System Architecture	This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	196	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgements

We acknowledge the timely and high-quality support offered by USDOT, and the support contractor Noblis throughout Phase 2.

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1 Introduction

1.1 Project Scope

Wyoming is one of the first wave of CV Pilot sites selected to showcase the value of and spur the adoption of CV technology in the United States. CV technology is a broad term to describe the applications and the systems that leverage dedicated short-range communications (DSRC) for vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle (I2V) communication to improve safety, mobility and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOT is focusing on improving safety and mobility by creating new ways to communicate road and travel information to commercial truck drivers and fleet managers along the 402 miles of Interstate 80 (I-80 henceforth) in the State. I-80 is a major corridor for east/west freight in the northwest part of the country, supporting the movement of over 32 million tons of freight per year (at 16 tons per truck). Truck volume ranges from 30 to 55% of the total traffic stream on an annual basis, with seasonal rises that can make up as much as 70% of the traffic stream. Furthermore, its elevation is all above 6,000 feet, with the highest point reaching 8,640 feet (2,633 m) above sea level at Sherman Summit.

For the pilot project, WYDOT concluded Phase 1 (planning) in September 2016 and then initiated Phase 2 (deployment) which is scheduled to conclude in August 2018. This will be followed by an 18-month demonstration period (Phase 3).

Systems and applications developed in the pilot will enable drivers of connected vehicles to have improved awareness of potential hazards and of situations they cannot see. At a very high level, the pilot scope includes the following implementation elements:

- **Deploy about 75 roadside units (RSU)** that can receive and broadcast messages using DSRC along various sections on I-80.
- **Equip around 400 vehicles, a combination of fleet vehicles and commercial trucks, with on-board units (OBU).** Of the 400 vehicles, at least 150 are planned to be heavy trucks. All vehicles are expected to be regular users of I-80. Several types of OBUs are being procured as part of the pilot and differ based on their communication capabilities, ability to integrate with the in-vehicle network, and connectivity to ancillary devices and sensors. All OBUs will have the functionality to broadcast Basic Safety Messages (BSM) and will include a human-machine interface (HMI) to share alerts and advisories to drivers of these vehicles.
- **Develop several V2V and I2V applications** that will enable communication to drivers of alerts and advisories regarding various road conditions. These applications include support for in-vehicle dissemination of advisories for collision avoidance, speed management, detours, parking, and presence of work zones and maintenance and emergency vehicles downstream of their current location.

- **Enable overall improvements in WYDOT's traffic management and traveler information practices** by using data collected from connected vehicles. Targeted improvements include ingesting more location specific mobile road weather information system (RWIS) data, using Pikalert®[1] to provide for more accurate and road segment specific conditions to define better variable speed limits (VSLs), and improving road condition dissemination via 511, Dynamic Message Signs (DMS) and other WYDOT sources.

1.2 Purpose of this Final System Performance Report of Baseline Conditions

The purpose of this report is to provide USDOT, TTI and Volpe with Wyoming's system performance data and analysis at the conclusion of Phase 2. The primary focus is on documenting the data collected and analysis performed to support the establishment of the pre-deployment (baseline) conditions. Please note, pre-deployment data collection focuses on the period beginning in December 2016 through November 2017, including work zone data in the summer of 2017. Crash data before December 2016 is also included in the report given the natural variations inherent in these data.

1.3 Document Overview

This document provides our final report of the data collected, analytical methods developed, analyses performed, and final performance measure values generated to substantiate our baseline conditions. Specifically, this document contains:

- Data, analyses and final results for the PMs that require pre-deployment conditions be established.
- Analytical methods related to post-CV-deployment PMs are not presented in this report, however are documented in our Performance Measurement and Evaluation Support Plan Update.
- An overview of the winter conditions on I-80 and the corresponding impacts to travel during the baseline period. This is offered as a backdrop to understanding the data collected and analysis results.
- Current results of our safety analysis and simulation/modeling efforts. Our future plans to utilize the simulation and modeling capabilities are documented in our Performance Measurement and Evaluation Support Plan Update.
- A status report of efforts to ensure end-to-end data collection, testing, processing, and storage.
- Also included herein are a set of conclusions based on analyses of pre-deployment (baseline) data collected.

[1] Pikalert is a trademark of the University Corporation for Atmospheric Research.

1.4 Summary of Findings and the Potential of Connected Vehicle Technologies

The information documented in this Final System Performance Report describes the data collection approaches and analytical methods that have been established for just over half of the performance measures. Analyses were conducted on data collected during the baseline period and pre-deployment conditions were established for eleven performance measures. Additionally, statistical data was collected and presented on the impacts of this past winter on the transportation system and travelers.

The baseline data collection period was one of the most severe on record, especially the number and intensity of strong wind events in the corridor. Fifty-six (56) separate significant winter weather events were documented between December 2016 and November 2017. These weather events resulted in extensive use of variable speed limit systems and dynamic message signs, constant updates of the Wyoming traveler information system and the commercial vehicle operator portal, and numerous road closures. Of the crashes in this period, over 17% were blown over trucks due to extreme strong winds. Additionally, there were 7 fatalities. Indeed, this was a very impactful baseline winter season on the traveling public and commercial vehicle operators.

The primary focus of the Wyoming Connected Vehicle Pilot is to improve safety in the I-80 corridor. The analysis of historical and current speed adherence and crash data presented herein provides some early insight into how connected vehicle technology may achieve this goal of improved safety. For instance:

- During this baseline data collection period for all weather conditions, about 14.2% of vehicles are currently traveling 5 mph or more above the post speed (speed adherence is good) and a 29.6% of the vehicles are traveling outside a +/- 10 mph buffer (speed variation is moderate). For certain severe storm conditions, like ice and high winds (storm category 6), the compliance rate drops to 53.4% and the speed buffer to 45%. These conditions can translate or contribute to the number of crashes and crash severity. We anticipate an improvement in these values through CV-technologies to improve Situational Awareness (TIM messages) regarding posted speeds, especially in variable speed limit (VSL) areas. Additionally, the VSL systems and dynamic message signs (DMS) will have more accurate and timely information based on improved and expanded data collection and enhanced analysis from Pikalert.
- 1,310 crashes were recorded from October 2016 through May 2017. Weather conditions existing during the crashes included clear (48%) and snowing (21%). Road conditions existing during the crashes included ice/frost (39%), dry (36%) and snow (15%). It is important to note that after April 14 are classified as "non-winter" crashes but aren't necessarily non-weather given the high altitude of the corridor and the occurrence of frequent heavy thunderstorms and other turbulent weather conditions that occur outside of the "winter" season. The use of the two six-month periods was used to illustrate the broad safety differences in crash occurrence between these two periods but not to imply that no weather events occur outside of the winter months. We believe CV-enabled technologies can help

to reduce the number of crashes during all conditions. Forward Collision Warning can help avoid a crash in any condition. Spot Weather Impact Warnings can alert a driver to poor weather or road conditions resulting in an avoided crash. Improved driver Situational Awareness through TIM messages can also result in an avoided crash, especially during inclement weather and hazardous road conditions.

- Historically, about 30% of crashes on I-80 are multi-vehicle crashes, which include some events with tens of vehicles involved. Our goal is to reduce the number of secondary crashes by using CV technologies to alert drivers of a crash ahead so they can stop earlier or otherwise avoid becoming a crash victim. Further, these crashes can be the reason a section of I-80 need to be closed. During the data collection period from October 2016 through May 2017, a cumulative total of 3,632 hours of closures on 52 road closure segments were issued. We anticipate that implementation of CV applications such as Forward Collision Warning, Distress Notification, Work Zone Warnings, and in-vehicle TIM messages have the potential to reduce the number of vehicles in a crash by warning the driver of a crash just ahead.
- Finally, since 2010, 553 critical injury crashes have resulted from crashes on I-80. Of those, 132 fatal crashes occurred. Through implementation of CV technologies mentioned above, we believe we have the potential to significantly reduce these numbers either by drivers avoiding a crash all together or speeds being reduced during a crash.

1.5 Document Organization

The following report sections include:

- **Section 2: References** that support the information contained in this report.
- **Section 3: Performance Measurement Overview** to remind the readers of our Performance Measures (PM) and related analysis approach.
- **Section 4: Pre-Deployment Data Collected** describes the pre-deployment related data collected that support the analyses and results
- **Section 5: I-80 Baseline Winter Conditions** provides the context to understand the data and analyses.
- **Section 6: Pre-Deployment Data Analyses** and final PM results for the measures that require pre-deployment conditions be established.
- **Section 7: Safety Analysis and Simulation Modeling** including a description of results of the safety analysis and calibration of the simulation model.
- **Section 8: Data Collection and Processing Status** describes our ongoing efforts to ensure accurate and timely end-to-end data collection, processing, and storage.
- **Section 9: Conclusions** summarizes accomplishments and provides insight into how connected vehicle technology may achieve our improved safety goals.
- **Appendices A through H** provides supportive information needed to full explain the results of the baseline conditions analyses.

2 References

The following table lists the standards documents and other resources used and referenced to develop the concepts in this document.

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3 Performance Measurement Overview

The Wyoming Performance Measurement and Evaluation Support Plan, PMESP identifies twenty-one separate performance measures (PMs) in an effort to evaluate system performance and project impacts. The PMs are assembled into eight evaluation-focused groupings.

Table 3-1 provides a listing of the PMs by group. Of the twenty-one PMs, twelve require the establishment of pre-deployment conditions (indicated in the Table). These twelve PMs are the focus of this report.

PMs 1-3, Road Weather Conditions Reports, will measure the quantity, coverage and latency of road weather condition reports from WYDOT field maintenance forces. It is anticipated that improved data flow to and from maintenance vehicles will support increased numbers of reports and decreased refresh times. Pre-deployment data was collected and these PMs were calculated. The details of these preliminary analyses are discussed in subsequent report sections.

PMs 8-10, Improved Information to Commercial Vehicle Fleets, will measure the CVO fleet manager's satisfaction with TMC information and actions taken due to receipt of that information. They will also document drivers' expressed benefits. With improved information being provided post-CV-deployment, it is anticipated that satisfaction levels will rise and resulting actions will be adjusted accordingly. A pre-deployment survey was executed to document current satisfaction levels and actions taken. The details of these survey results are discussed in subsequent report sections. Additionally, a pre-deployment survey was provided to drivers to learn of their current experience driving I-80 and familiarization with various levels of technology.

PMs 14-15, Improved Speed Adherence and Reduced Speed Variation, will measure the vehicle (car and truck separately) speeds versus posted speed. It is anticipated that post-CV-deployment vehicles will travel closer to the posted speeds and within closer speed variations between vehicles. Pre-deployment individual speeds were collected at certain I-80 locations and the PMs calculated. The details of these preliminary analyses are discussed in subsequent report sections.

PMs 18-21, Reduced Vehicle Crashes, will measure the reduction in vehicle (all vehicles and trucks separately) crashes and crash rates pre- and post-CV-deployment. A 8-year history of vehicle crashes (2010 – 2017) were collected and analyzed to generate the pre-deployment PM values. Work zone related crashes were isolated for analysis. The details of these preliminary analyses are discussed in subsequent report sections.

Table 3-1. Performance Measure Summary and Pre-Deployment Conditions Required Indicator

Wyoming CV Pilot Performance Measures		Pre-Deployment Conditions Required?
Improved Road Weather Condition Reports Received into the TMC		
1	Number of road weather condition reports per road section/day pre and post CV Pilot (quantity)	YES
2	Number of road sections with at least one reported road condition per hour pre and post CV Pilot (coverage)	YES
3	Average refresh time of road condition reports in each section pre and post CV Pilot (latency)	YES
Improved Ability of the TMC to Generate Alerts and Advisories		
4	Pikalert™ generated motorist alert warnings (MAWs) that were rejected by TMC operators as inaccurate	NO
Effectively Disseminate and Receive I2V and V2I Messages		
5	Number of messages sent from the TMC that are received by the RSU	NO
6	Number of messages sent and received between the RSU and WYDOT fleet vehicle's OBU (when vehicles are in the vicinity of a RSU)	NO
7	Connected vehicles that likely took action following receipt of an alert Parked Reduced speed Came to a stop safely Exited	NO
Improved Information to Commercial Vehicle Fleets		
8	Commercial vehicle managers are satisfied with information provided by the TMC (compare before and after CV Pilot) Road conditions Road weather forecasts Parking information	YES
9	Number of operational changes made by fleet managers due to information from TMC (compare before and after CV Pilot) Routing Timing Parking availability Cancelled trips	YES
10	Commercial vehicle drivers' benefits experienced due to CV technology during major incidents and events on I-80	YES
Effectively Transmitted V2V Messages		
11	Number of V2V messages properly received in surrounding vehicles from sending vehicle (WYDOT fleet vehicles in vicinity of each other)	NO
12	Connected vehicles that likely took action following receipt of a V2V alert Parked Reduced speed Came to a stop safely Exited	NO

Wyoming CV Pilot Performance Measures		Pre-Deployment Conditions Required?
Automated Emergency Notification of a Crash		
13	Number of emergency notifications that are first received in the TMC from connected vehicles (compared to alternate traditional methods, such as 911 caller)	NO
Improved Speed Adherence and Reduced Speed Variation		
14	Total vehicles traveling at no more than 5 mph over the posted speed (compare before and after CV Pilot)	YES
15	Total vehicles traveling within +/- 10 mph of the Posted Speed (compare before and after CV Pilot)	YES
16	Speed of applicable connected vehicles are closer to posted speed when compared to non-connected vehicles	NO
Reduced Vehicle Crashes		
17	Number of connected vehicles involved in a crash Initial crashes Secondary crashes	NO
18	Reduction of the number of vehicles involved in a crash (compare a multi-year average before and after CV Pilot)	YES
19	Reduction of total and truck crash rates within a work zone area (compare a multi-year average before and after CV Pilot)	YES
20	Reduction of total and truck crash rates along the corridor (compare a multi-year average before and after CV Pilot)	YES
21	Reduction of critical (fatal or incapacitating) total and truck crash rates in the corridor (compare a multi-year average before and after CV Pilot)	YES

4 Pre-Deployment Data Collected

Descriptions of the pre-deployment data collected to support performance measurement analyses are provided below by major grouping.

4.1 Road Condition Reports

Data collected in this category supports the calculation of the following performance measures:

1. Number of road condition reports per road section/day (quantity)
2. Number of road section with at least one reported road condition per hour (coverage)
3. Average refresh time of road condition reported in each section (latency)

The WYDOT TMC collects and stores all field maintenance reported road conditions by day/time and location. Special software was written to extract the data required during weather events. WYDOT rates the overall impact (low, moderate, high) to the traveler by various road conditions, weather conditions, advisories, and restrictions. A table of these ratings is provided in *Appendix A. Road Condition Ratings*. We defined a "weather event" as anything other than a low rating. Therefore, the data provided by the WYDOT TMC for analysis was only during weather events as defined in this way. The "Non-low number of road conditions" is the number of road reports that have a rating of anything other than "low." Table 4-1 defines the data collected (December 2016 through May 2017, and October and November 2017). This completes a database that represents a full winter of weather events (fall, winter, and spring). Data was not available in the fall of 2016 (and therefore was not included in our initial report), but data for the fall of 2017 (October and November) was collected and included in this report to round out a complete winter season. Crash data was available and is included prior to December 2016.

Table 4-1. Road Condition Reports Data Collected

Data Element	Data Description/Units
Road Condition Reports Per Road Section Per Day	
Event start	Date and time (when rating moved from L to M or H)
Event end	Date and time (when rating moved from M or H to L)
Road section code	Maintenance road section abbreviation
Total number of condition reports	Number of reports by road section
Non-low number of condition reports	Number of reports by road section
Condition reported	Condition by road section
Road Sections Reported Per Hour	
Event start	Date and time same as above
Event end	Date and time same as above
Report hour	Hour value, within event start/end
Total number of condition reports	Number of reports within each hour
Non-low number of condition reports	Number of reports within each hour

Average Refresh Time Per Section	
Event start	Date and time same as above
Event end	Date and time same as above
Road section code	Maintenance road section abbreviation
Total average refresh time	Minutes, time between reports by section
Road open average refresh time	Minutes, time between reports by section
Other Supportive Data	
Road closed time	Day/time, by event and road section code
Road open time	Day/time, by event and road section code
Road section code beginning point	Mile post and landmark
Road section code end point	Mile post and landmark

4.2 Commercial Vehicle Operator Surveys

Data collected in this category supports the calculation of the following performance measures:

8. Commercial vehicle managers are satisfied with the information provided by the TMC
9. Number of operational changes made by fleet managers due to information from TMC

The data collected to support the establishment of the pre-deployment conditions in this category was from a survey executed by WYDOT. The survey was sent to all subscribers of the Commercial Vehicle Operator Portal (CVOP). The portal provides specific weather forecast information that helps commercial vehicle operators make decisions or preparations for upcoming truck trips. The survey was attached to the CVOP site (this is common practice for WYDOT to obtain feedback). Reminder emails were distributed to the same group following major weather events. A total of 129 responses were received (out of 279 unique users since October 2016).

The following questions were included in the survey (questions 1-5 are relevant to the pre-deployment data collection; questions 6-10 informed WYDOT regarding planned CVOP enhancements):

1. What is your role with your company?
    a. Dispatcher
    b. Driver
    c. Owner/Operator
    d. Management
    e. Other

2. Please rate your overall satisfaction with WYDOT Commercial Vehicle Operator Portal (CVOP).
    a. Very satisfied
    b. Somewhat satisfied
    c. Neither satisfied or dissatisfied
    d. Somewhat dissatisfied
    e. Very dissatisfied

3. Please indicate your level of satisfaction with the following Interstate information types provided.

Information Type	Very Satisfied	Somewhat Satisfied	Neither Satisfied or Dissatisfied	Somewhat Dissatisfied	Very Dissatisfied
Road Weather Forecasts					
Travel Wind Advisories					
Travel Advisories - Other					

4. Based on the Commercial Vehicle Operator Portal (CVOP) information provided, what type of decisions do you normally make? Please complete table below.

	Frequency of decision made				
Operational Changes Made to Trips	Never	Rarely	Sometimes	Often	Always
Change Routing					
Advance or delay a trip					
Notify Driver					
Cancel the trip					

5. Referring to the most recent weather event that impacted your operations, did you change routing, advance or delay a trip, notify driver or cancel a trip? If so, please provide the details below:

What information caused you to make an operational change? What action did you take? Other details that would help us understand the circumstances?

6. What additional features would you like to see on the CVOP? Please complete the table below.

	Level of Usefulness			
Possible CVOP Features	Not Useful	Somewhat Useful	Useful	Very Useful
Real-time road conditions				
Real-time atmospheric conditions				
Real-time weather radar graphics				
Real-time NWS watches and warnings				
More granular forecast periods (currently every 12 hours for up to 72 hours)				
Weather station data				

Webcams				
Truck parking availability				
Additional routes				
Mobile friendly format (smartphone/tablet accessible)				
Other, please specify.				

7. WYDOT has been sending video forecasts to all CVOP subscribers. Do you want to continue receiving this information?
   a. Yes
   b. No

Please explain your response.

8. Would you be willing to provide, or ask your drivers to provide, truck parking availability information with a crowd-sourced mobile app?
   a. Yes
   b. No

9. Are you familiar with the text-based version of the CVOP information?
   a. Yes
   b. No

If yes, when and how do you use it?

10. Are you familiar with the map-based version of the CVOP information?
    a. Yes
    b. No

If yes, when and how do you use it?

4.3 Commercial Vehicle Baseline Driver Surveys

Data collected in this category supports the establishment of a baseline for PM 10:

10. Commercial vehicle drivers' benefits experienced due to CV technology during major incidents and events on I-80

As part of the training program, commercial vehicle drivers were asked a set of questions to establish baseline conditions. The questions were grouped into the following categories:

- Experience driving a commercial vehicle on I-80
- Familiarization and understanding of technological tools to support safe driving within the I-80 corridor, including connected vehicle technologies

- How traveler information is acquired and used to ensure safe and efficient driving within the I-80 corridor
- Impressions of safety and use of technology
- Responses to various severe weather conditions when driving within the I-80 corridor

The training and execution of the surveys is currently underway. Upon completion of Phase 2, the details of the surveying and results will be made available upon request.

4.4 Speed

Individual speed data comes from 74 of the 88 Wavetronix speed radar devices listed in the WYDOT device inventory installed along I-80 prior to the CV Pilot project. The density of sensors is greatest in the four variable speed limit corridors with a lesser amount installed in the non-VSL areas. Table 4-2 shows the density in average number of miles per sensor for the four VSL corridors and the five non-VSL corridors, which highlights the large difference in sensor densities between the VSL and non-VSL corridors.

These sensors are described by a three- or four-digit device ID number. Secondary descriptors include a device name, route milepost, and the location of the speed sensor installation, which is necessary for matching lane numbers to direction of travel. The sensor IDs listed in the inventory for which there is no data are likely older sensors that have been replaced prior to the CV Pilot project but their sensor IDs have been retained for purposes of archived data.

Table 4-2. Density of the speed sensors in VSL and non-VSL corridors.

Corridor Type	Corridor ID	Corridor Range East to West (milepost)	Length (miles)	Number of Sensors	Density (miles/sensor)
Non-VSL	N1	0-8.45	8.45	0	--
VSL	V1	8.45-27.6	19.15	12	1.60
Non-VSL	N2	27.6-90.45	62.85	2	31.43
VSL	V2	90.45-110.36	19.91	12	1.66
Non-VSL	N3	110.36-238.8	128.44	8	16.06
VSL	V3	238.8-289.5	50.7	22	2.30
Non-VSL	N4	289.5-317.68	28.18	1	28.18
VSL	V4	317.68-353.0	35.32	28	1.25
Non-VSL	N5	353.0-402.0	49.0	3	16.33

Speed sensor data including sensor ID, description, and milepost can be found in *Appendix B. Corridor Devices*. The speed sensor table in the appendix has been merged with other data sources so that it indicates the nearest road weather stations, the 2015 Annual Daily Traffic, a VSL corridor ID number to indicate if it's in a VSL corridor (IDs beginning with V) or not (IDs beginning with N), the speed limit sign for speed data in the eastbound and westbound directions, a Horizontal Curve category in either the increasing and decreasing milepost direction (see comment on column heading) and a vertical grade in both the increasing and decreasing direction. Figure 4-1 provides a map of showing the location of the speed sensors, weather stations, and variable speed limit corridors.

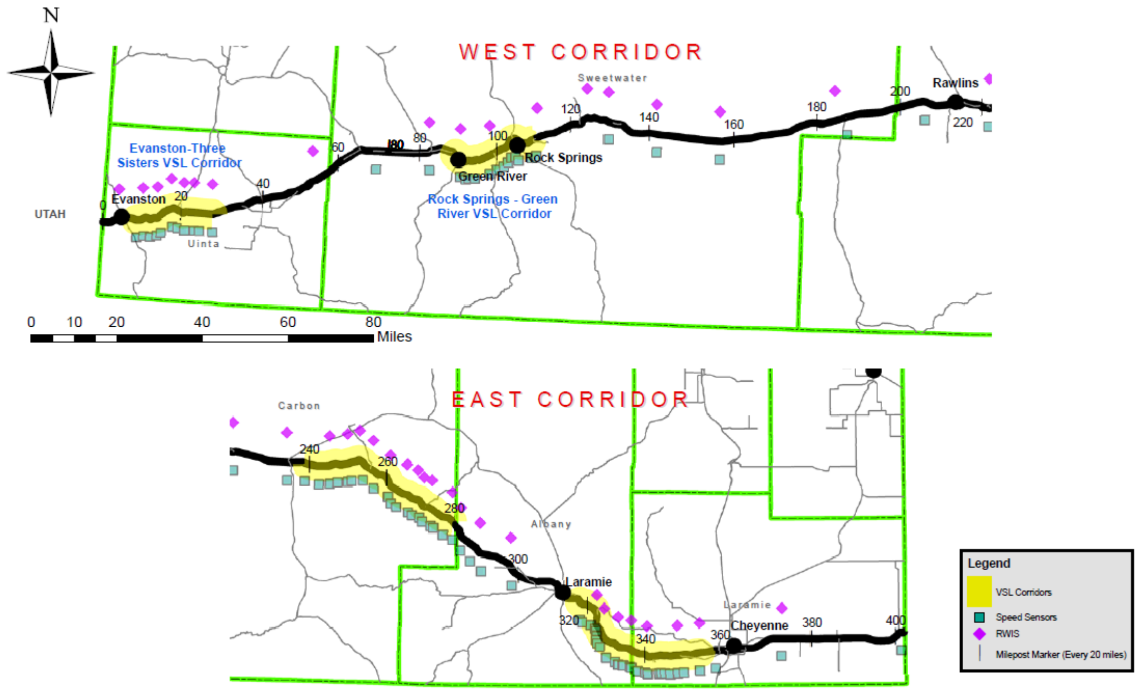


Figure 4-1. Location of Speed Sensor, RWIS, and VSL Corridors on Wyoming I-80 (Source: WYDOT)

Prior to the CV Pilot project, WYDOT collected aggregate speed data from the radar speed sensors, providing average speeds and vehicle counts in 30 second bins. In order to calculate speed performance measures related to speed compliance and speed variation, the sensors had to be changed to log individual speeds as opposed to binned speeds. Discussions for making this change began in the summer of 2016. It was discovered that when the speed sensors were switched from aggregate to individual speed modes the speed sensor data became unavailable to the TMC operators so reprogramming of the TMC's Advanced Traffic Management System, Intelligent Roadway Information System (IRIS) software was required. Work on reconfiguration began in October 2016 and became a more complicated process than originally estimated.

In late December 2016, individual speed data became available for some speed sensors but the issue with these sensors being offline for the TMC operators remained. In order to maintain safe operations of the corridor, a subset of priority sensors was created to provide coverage of the corridor for the CV Pilot data collection purposes while ensuring there was adequate coverage for the operators. Data for the remaining sensors did not come online until May 2017. Archived individual speed data is received monthly from WYDOT as a single csv file. Availability of data by month for each of the sensors currently collecting data can be found in Table 4-3. Delays in data available prevented fall and early winter storms from 2016 to be included in the original baseline analysis so speed data from October and November of 2017 were added to the baseline analysis to account for these conditions.

Table 4-3. Speed Records Availability by Sensor and Month

Sensor	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Oct 17	Nov 17
382					32,843	151,325	132,094	208,740
384					81,796	78,005	417,091	360,450
385					81,542	456,402	414,521	357,461
386					86,178	458,591	410,353	362,648
387					88,991	458,059	428,563	369,195
388					88,784	456,361	415,212	358,304
389					86,362	460,699	423,200	364,387
390					82,014	396,126	381,249	331,175
391					96,596	479,717	433,105	376,134
396					95,423	500,887	448,435	384,940
398					41,039	234,467	346,965	298,239
400					86,635	411,578	347,722	298,350
405					82,893	423,534	362,765	292,653
407		109,239	165,411	173,251	58,532	1,537	199,357	170,749
408		124,055	177,563	185,813	203,487	238,990	208,020	177,632
411		80,224	174,677	179,449	207,656	58,119	206,044	178,898
482					87,034	419,850	344,027	303,842
1075	114,834				55,638	246,319	217,063	192,209
1100		138,764	190,557	197,471	226,066	247,449	216,455	190,732
1134					101,925	486,787	426,863	374,911
1219	176,716	244,277	336,631	334,463	371,774	419,583	355,601	308,274
1231					40,756	201,264	173,491	147,752
1241					88,744	424,343	358,953	309,947
1251					52,264	252,041	219,468	190,756
1258					46,196	214,450	180,809	155,550
1269	178,812	210,420	302,862	317,255	362,001	420,024	356,788	305,725
1327					84,724	419,373		
1342					84,480	2,902		
1837		98,828	153,310	162,667	180,122	199,960	171,717	146,436
1839					82,563	249,165	433,005	376,409
2032	7,860	432,495	613,950	619,899	690,773	733,736	667,744	598,259
2049	6,480	387,558	549,486	560,958	629,136	688,629	623,398	554,177
2070	3,950	419,577	600,153	606,559	672,236	757,841	689,106	622,525
2079		321,203	460,822	470,884	532,788	597,742	525,464	463,059
2090		159,594	230,997	240,731	274,127	313,259	269,906	238,057
2146	176,370	224,344	301,909	309,320	352,118	404,837	362,153	309,717
2147					55,013	286,597	258,629	223,835
2178	217,669	258,744	352,319	360,991	401,201	456,125	414,479	358,462
2191					46,085	231,175	211,304	183,644

Sensor	Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Oct 17	Nov 17
2202					41,731	228,508	208,386	178,870
2213					43,935	228,876	207,801	180,035
2246					91,750	467,313	422,973	366,408
2263					90,870	477,894	431,154	373,638
2274					95,673	475,844	429,485	372,147
2289					97,545	484,350	436,198	378,020
2298					91,679	478,753	430,628	372,707
2310					63,568	320,050	285,843	247,347
2319					95,338	470,387	423,255	367,214
2334	14,342	255,319	378,768	391,929	446,405	501,534		
2346	14,462				113,638	504,089	440,989	380,125
2359	208,613	260,159	378,969	393,284	446,909	502,522	440,001	379,386
2372	169,742	202,409	306,536	314,949	364,230	412,805	356,860	203,274
2383	11,099	199,308	297,375	307,143	354,004	267,808	344,889	298,873
2395	14,057	255,990	378,857	392,365	446,070	501,173	433,064	377,125
2409	8,099	140,899	215,154	226,580	256,956	295,455	250,540	215,794
2421	7,454	147,603	219,902	226,035	262,693	297,162	257,335	219,718
2433	8,123	137,725	210,669	219,359	250,273	291,698	231,441	202,413
2445	12,879	236,041	350,670	363,091	411,552	462,706	403,998	349,284
2578		281,900	399,698	415,383	466,754	515,362	451,924	400,428
2607	13,705	237,067	351,602	364,144	412,367	438,515	397,985	346,158
2609	10,278	189,585	283,381	293,112	336,033	380,257	326,100	282,426
2916	223,837	261,105	372,860	388,418	433,517	434,604	431,294	378,697
3236	6,155	269,490	393,463	405,677	452,659	498,285	447,754	395,849
3249	4,113	234,488	324,679	321,754	365,351	384,627	353,327	317,361
3296	240,049	366,020	526,144	532,002	593,913	638,072	575,823	519,485
3402		117,798	187,375	196,478	227,981	263,306	224,408	191,080
3482					84,386	399,530	306,609	322,729
3654						39,834	226,162	194,656
3897		186,278	3,966	3,378	4,182	351,093	353,510	302,164
3899		100,923	150,823	153,920				
3901		194,215	301,560	316,871	362,810	415,930	356,507	305,670
3903		189,004	285,878	294,254	336,280	382,332		
3905					86,630	414,835	352,844	302,152
3907					87,591	422,018	361,335	306,998
3909					68,404	347,559	286,467	246,788

In its unprocessed state, the speed records contain six variables including data/time, sensor ID, individual speed (MPH), vehicle length (feet), a length-based vehicle classification, and lane number. These variables are described in greater depth in the Speed Data Description section within *Appendix C. Data Descriptions.*

The individual speed data contains records with null speed values, which can occur when a vehicle is detected but shielded by a vehicle in an adjacent lane such that a speed cannot be determined. There are also cases where the speed is null and the length of vehicle is recorded as 6 (feet). These observations are believed to be erroneous values and at times can far exceed the number of expected observations based on historic traffic volumes. Speed sensor #3899 is particularly prone to this issue. In May 2017, sensor 3899 had 9,745,295 records, of which 9,698,898 (99.5%) had null values for speed and a vehicle length of 6 feet. It is recommended that all observations with null speeds tagged for data quality (i.e. set to 0) and that sensor 3899 not be used in any of the analyses. A check for percentage of null speeds is run for each month of sensor data to make sure that sensors with poor data quality are not used in development of the baseline.

Additional fields are appended to each speed observation to aid in the calculation of performance measures to create processed data sets (see Table 4-4). No data is removed during processing, so all records and fields remain unchanged, only additional fields are added. For more details on the methodology behind the calculations used to determine values for these fields, please refer to Section 7 of this report.

The processing of speed data appends applicable weather (from RWIS data) and posted speed variables to the original data. See the listing of speed sensors in Appendix B. Corridor Devices to see which RWIS and VSL signs (eastbound and westbound) are associated with each speed sensor.

Data quality for the speed sensors in terms of the number of non-zero speed observations and the availability of data from the sensors over time will be addressed in the final baseline report by looking at the distribution of the monthly records by time and comparing the number of records to the traffic volume data collected from inductive loop detectors by the traffic program.

Table 4-4. Variables in Processed Speed Data

Data field	Description	Units	Notes
Date_Time, Sensor, Speed, Length, Class, and Lane fields remain same as unprocessed data. See Appendix C for details			
PostedSpd	Posted Speed at time of observation from either static speed signs or variable speed signs	MPH	Posted speed is dependent on the roadway direction so varies by lane designation and time and date.
RWIS	Station ID for Road Weather Information System associated with speed observation	Unique alphanumeric identifier to each RWIS	See sensor description spreadsheet to link RWIS ID to information of the location

Data field	Description	Units	Notes
WB_VSL	Sign ID for closest upstream speed sign for westbound observations		Sign ID of 1 is for static speed limit sign of 75, Sign ID of 2 is for static speed limit sign of 80
EB_VSL	Sign ID of closest upstream speed sign for westbound observations		
Sensor_Loc	Location of speed sensor relative to closest lane (EB or WB)		Since lanes are numbered 1 to 4 based on closest lane, lane direction is dependent on what side of the road the sensor is installed on.
MILEPOST	Milepost of speed sensor		
LaneDir	Direction of travel for speed observation	Assigns 1 for WB observations and 2 for EB observations	Assigning direction to lane numbers is depending on sensor location variable
StationID	Station ID for Road Weather Information System associated with speed observation	Unique alphanumeric identifier to each RWIS	See sensor description spreadsheet to link RWIS ID to information of the location
PostedSpd_VSLTime	Time that Posted Speed was set by VSL system.	Time in MST/MTD. NaN for static speed limit signs.	
RoadCond	Road Condition Rating of 1-4	1 = dry pavement, 2=wet pavement, 3= snow, 4= ice	Road condition surface conditions from RWIS converted to rating system
Vis	Visibility rating of 1 – 3	1 = >0.95 miles, 2 = between 0.57 and 0.95 miles, 3 = <0.57 miles	Visibility readings from RWIS sensors converted to rating system
RH	Relative Humidity rating of 1 -2	1 = <92%, 2 = > 92%	Relative Humidity readings from RWIS sensors converted to rating system
SurfTemp	Surface Temperature rating of 1 – 3	1 = >32°F, 2 = between 25 and 32°F, 3 = <25°F	Surface Temp readings from RWIS sensors converted to rating system
WdSpd	Wind Speed Rating of 1 - 3	1 = <30 mph, 2 = between 30 and 45 mph, 3=>45 mph	Wind Speed readings from RWIS sensors converted to rating system

Data field	Description	Units	Notes
StormNum	Storm number between 1 and 216	Unique storm number between 1 and 216 based on ratings of 5 weather variables	Storm numbers will be compressed down to 10 – 15 storm types after additional analyses of speed data
PostedSpd	Posted speed associated with observed speed	Miles per hour (MPH)	Posted speed from either static or VSL sign
PostedSpd_VSLTime	Time associated with posted speed	Time of most current speed change for speeds in VSL corridors	Static speed signs given null or "Not a Time (NaT) value
SpeedCompliant5	Binary variable for whether speed observation is at or below the posted speed plus 5 mph	1 = speed observation is compliant, 0 = speed observation is not compliant	Definition of speed compliance as posted speed plus 5 mph comes from definition of PM #14
SpeedBuffer10	Binary variable for whether speed observation is within 10 mph +/- of the posted speed	1= speed observation is within buffer, 0 = speed observation is not within buffer	Definition of speed buffer of +/- 10 mph of posted speed comes from definition of PM #15
DataQuality	Binary variable for whether speed observation is flagged for data quality parameters	1 = acceptable per data quality standards, 0 = unacceptable per data quality standards	At this point all records flagged as 1 but additional analysis will likely lead to adoption of data quality rules
StormCat	Storm Category number of 0 to 11	StormCat = 0 is for uncategorized storm numbers. StormCat =1 associated with ideal or low speed impact storms. StormCat 2 - 11 have varying levels of speed impacts	Based on cluster analysis of 216 storm numbers

Generally, the closest priority RWIS by milepost was associated with each speed sensor. Two potential exceptions to this rule is 1) when that sensor was found to be located in an area where it was too protected from weather conditions and was found not to adequately represent the conditions at the sensor, and 2) when the RWIS sensor was located in close proximity to another RWIS. See the data description for RWIS for more details on how the original RWIS data were processed.

Speed sensors are installed closest to either the inside eastbound (EB) or westbound (WB) lanes. Lane numbers are assigned so that the closest lane is given lane ID 1 and are numbered sequentially outward. In order to determine if a particular lane is in the eastbound or westbound direction, you must first know what side of the road the sensor is located. Because lane direction is dependent on the sensor location, the speed observations for EB sensors are processed separately from those for WB sensors. Note that WB processed data includes vehicles traveling in both the westbound and eastbound direction since a westbound sensor can typically read across all four lanes of traffic. The WB and EB designation is only necessary for assigning lane direction to a particular observation so that the appropriate static or variable speed limit sign can be associated with that observation.

The next fields are related to weather conditions and include the identification code for the Road Weather Information System (RWIS ID) that is associated with that speed observation based on proximity of that RWIS and the rating of five primary weather variables associated from previous research with changes in observed speeds. These weather variable ratings lead to 216 unique combinations, which are assigned a storm number code (StormNum).

The two processed data fields (SpeedCompliant5 and SpeedBuffer10) are based on the definitions for Performance Measures 14 and 15. The DataQuality variable is set to 1 if the observation should be included in the performance measure calculations. The variable is set to 0 if either the observed or posted speed is 0. The last variable is the StormCat is set to a value between 0 and 11. Category 0 are uncategorized storms that were storm numbers with too few observations to be included in the storm categorization cluster analysis. See Section 4.6.1 for more information on weather categorization.

A total of 64.3 million speed observations were processed and 56.4 million were included in the performance measures after data quality screening. The largest number of observations (53.4 million) were in storm category 1, which is for ideal or low impact storms, which is to be expected given the large number of good weather days the corridor experiences. Figure 4-2 shows the breakdown of Category 1 speed observations (83%) versus all other categories (17%). The chart on the right breaks down the other storm categories including storm category 0, which is for uncategorized storm numbers. From this, it can be seen that storm categories 2, 3, and 11 all have over 2 million observations. Some storm numbers (4, 5 and 6) have less than 100, with the remaining storm numbers varying between 4,000 to 340,000 observations. *Appendix D. Storm Categories* has a table with more details on the breakdown of speed observations by storm category.

Speed performance measures will be reported both in aggregate form and by individual sensor for a select subset of sensors for each storm category. Aggregate results ensure adequate representation of all storm categories but also have considerable variation present in the data due to differences in traffic volumes and geometric features. Reporting by individual sensors may result in some storm categories having too few observations for meaningful statistical testing but have the advantage of limiting the impacts of some of the other confounding factors. From the 37 speed sensors included in the baseline analysis, 20 sensors had more than 1.5 million observations. Figure 4-3 shows the breakdown of observations by sensor ID. The orange sensors were ones that were identified in earlier analysis to be preferred sensors because of their location with “ideal” geometry (low grade and horizontal curvature).

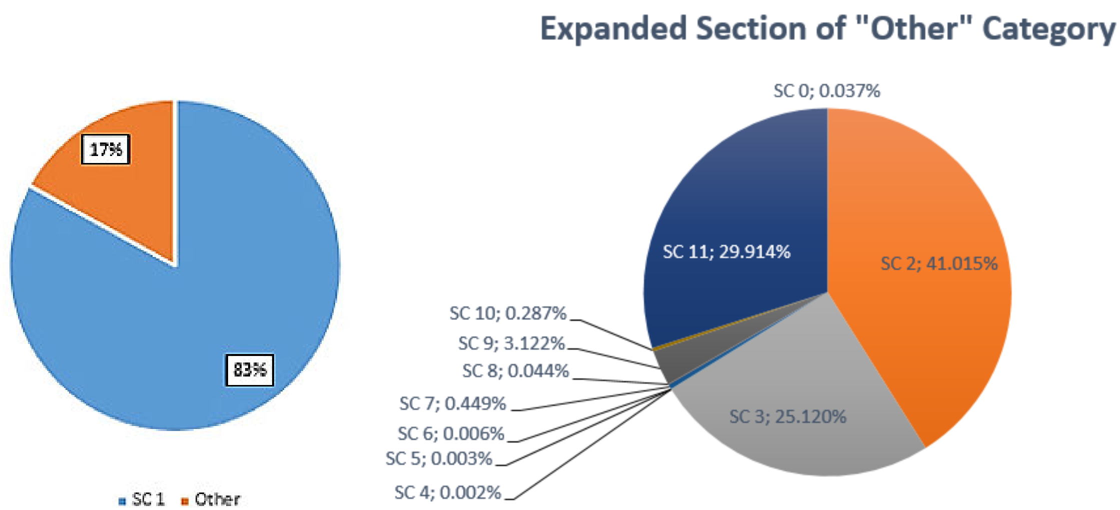


Figure 4-2 . Breakdown of Baseline Speed Observations by Storm Category (Source: WYDOT)

Speed Observations from 37 sensors during the months of January through May as well as October and November of 2017 totaled approximately 64 million observations. These observations were categorized by sensor and broken down by storm category. MatLab code then processed the total speed observations into total number of quality observations, speed compliant observations and speed buffer observations. To increase data quality, sensors totaling more than 1.5 million observations across the months of October, November and January through May of 2017 were selected as high data quality sensors. Of the 37 sensors speed data was collected from, only 20 sensors met the total speed observation threshold of 1.5 million as shown in Figure 4-3. The highlighted “orange” sensors are previously selected priority speed sensors based on their location, differing ADT’s, and low vertical and horizontal curvature. All sensors included in the baseline were considered acceptable from a geometric design viewpoint.

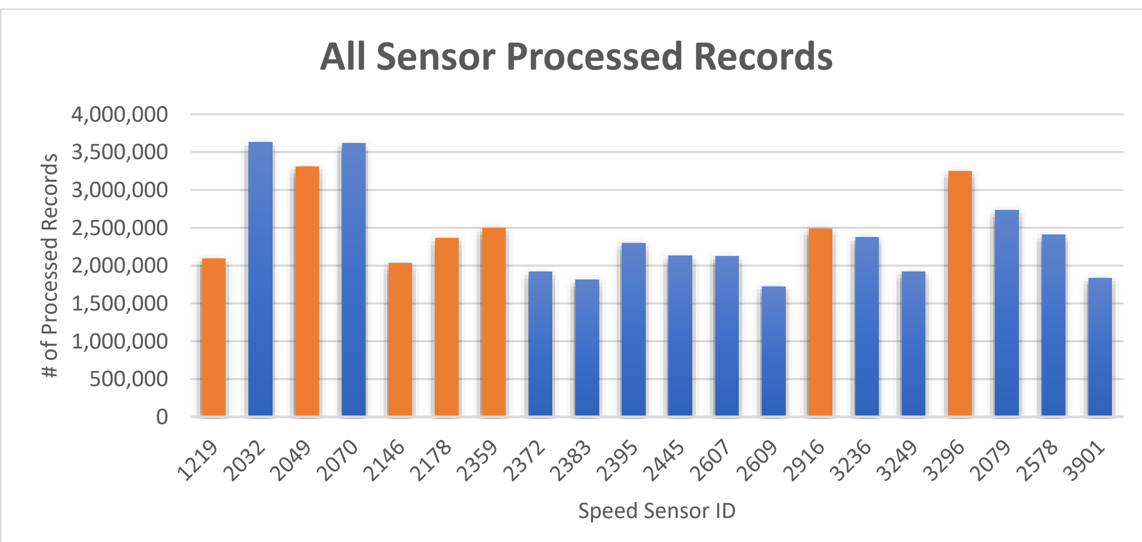


Figure 4-3. Number of Speed Observations for Priority Sensors (Source: WYDOT)

4.5 Crash

Crash records for the state of Wyoming are maintained by the Wyoming Department of Transportation's Highway Safety Program. All reported crashes in the state, regardless of roadway jurisdiction, are contained in this crash database. WYDOT adopted a Model Minimum Uniform Crash Criteria (MMUCC) compliant electronic crash form on January 1, 2008. Details on crash reporting in Wyoming can be found in the *Wyoming's Investigators Traffic Crash Reporting Manual*, which was revised in July 2016 (WYDOT, 2016).

For the CV Pilot project, periodic queries are run by the Highway Safety Program and updated crash data provided. The crash data for the baseline safety performance measures covers the time period from January 1, 2010, to December, 2017. Table 4-5 summarizes the crashes per year on the project corridor from 2010 – 2017.

Table 4-5. Summary of crashes per year on I-80 in Wyoming

Year	Total
2010	1,659
2011	1,678
2012	1,406
2013	1,544
2014	1,592
2015	1,409
2016	1,641
2017	1,706
Total	**12,635**

In its unprocessed state, there are three separate worksheets in the crash data spreadsheet. The *BulkBase* worksheet is the summary crash data, with each row representing a crash event. Each crash record in the *BulkBase* includes data fields providing information on the location of each crash, the number of people and vehicles involved, road/weather conditions, and much more. See *Appendix C. Data Descriptions* for a complete list of the data fields included for each crash record. The *Involved* worksheet contains additional information that may be available about the people involved in the crashes (drivers, passengers, pedestrians, bicyclists). The *Vehicle* worksheet contains additional information that may be available about the vehicles involved in the crashes. For the most part, only the *BulkBase* worksheet is used for analysis of Performance Measures other than the use of Vehicle data for the identification of truck-related crashes.

The baseline bulk crash data on the I-80 corridor through Wyoming includes 24 columns and 12,643 records. The columns include data such as report number, crash date/time, milepost, first harmful event and location, manner of collision, severity, weather, and road conditions. The data also includes work sheets for a summary of data, involved (persons) information, and vehicle information. There were concerns with duplicate data reports in the information received from WYDOT because the bulk data has instances where multiple rows were found with the same crash record, which is supposed to be a unique number for each crash. Further investigation found that multiple records for individual crashes occurred when more than one weather or road condition was reported. Since the methodology developed for the safety performance intended to link the crashes to other weather sources, it was determined acceptable to remove duplicate crash records, thus maintaining only the first reported weather and first reported road condition. The original crash records, before duplicate removals, were also retained on a separate worksheet in case this decision was revisited later in the project. All the discussion of crash record data in this report refers to the data where the duplicates were removed.

Additional fields are appended to each crash record in the *BulkBase* worksheet to aid in the calculation of performance measures and to create processed data sets. No data is removed during processing, so all records and fields remain unchanged, only additional fields are added. The additional fields link the crash records to specific types of crashes identified by project performance measures such as truck-related, work zone, secondary and serious crashes. See *Appendix C. Data Descriptions* for a complete list of the data fields included for each processed crash record, the approach implemented to determine the values of the data fields, and for a complete list of the data fields included for each processed crash record. For more details on the methodology and calculations used to determine the baseline PM values, see Section 6.4 of this report.

The *Vehicle* worksheet contains supplemental information on the vehicles involved in crashes including vehicle type, year, make and model. For the purposes of the performance measurement analysis, the vehicle type was used to identify truck crashes. Crashes involving at least one truck are given a value of “1” for the TruckPM variable and “0” if no vehicle involved is a truck. Vehicle Types identified as trucks include Cargo Vans, Heavy Truck >26,000, Light Truck, Medium Truck, and Motor Home.

4.5.1 Descriptive Statistics for Crash Data

The following section provides general descriptive statistics for the baseline crash data. Additional analyses of the crash data are described in Section 6.4 for crash related performance measures and in Chapter 7 for the more detailed safety analysis. This section is intended to provide a broad overview of the corridor’s crash history so that the results in future chapters can be better understood. These descriptive statistics are not intended to be a full crash analysis of the corridor.

For the purposes of this project, all crashes occurring between October 15 and April 14 each year are considered to have occurred during the Winter Season and all other crashes are considered a part of the Summer Season. These dates reflect WYDOT’s past practice of implementing seasonal speed limits along I-80 where static speed limits were reduced from 75 to 65 for high hazard corridors. A breakdown of the number of crashes by year and season can be found in Figure 4-4, which shows that the six months of the winter season consistently has higher frequency of crashes than the six months of summer season. Figure 4-5 shows the same thing for truck crashes only. The average number of crashes from 2010 through 2017 was 1,011 for winter and 569 for summer per year. The crashes shown are for all reported crashes during that season regardless of the reported road or weather condition at the time of the crash.

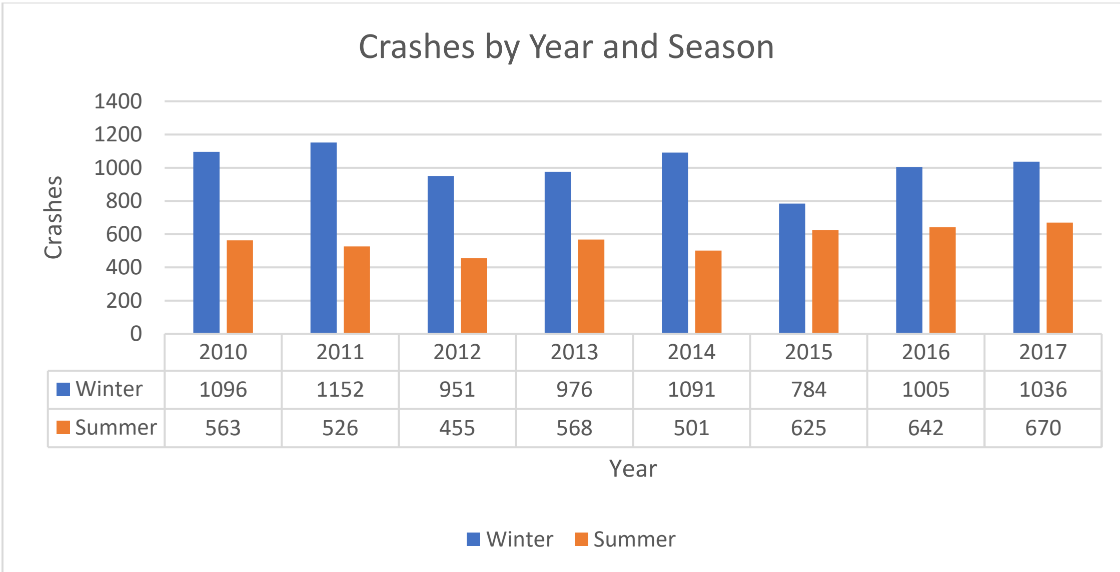


Figure 4-4. Crashes by Year and Season (Source: WYDOT)

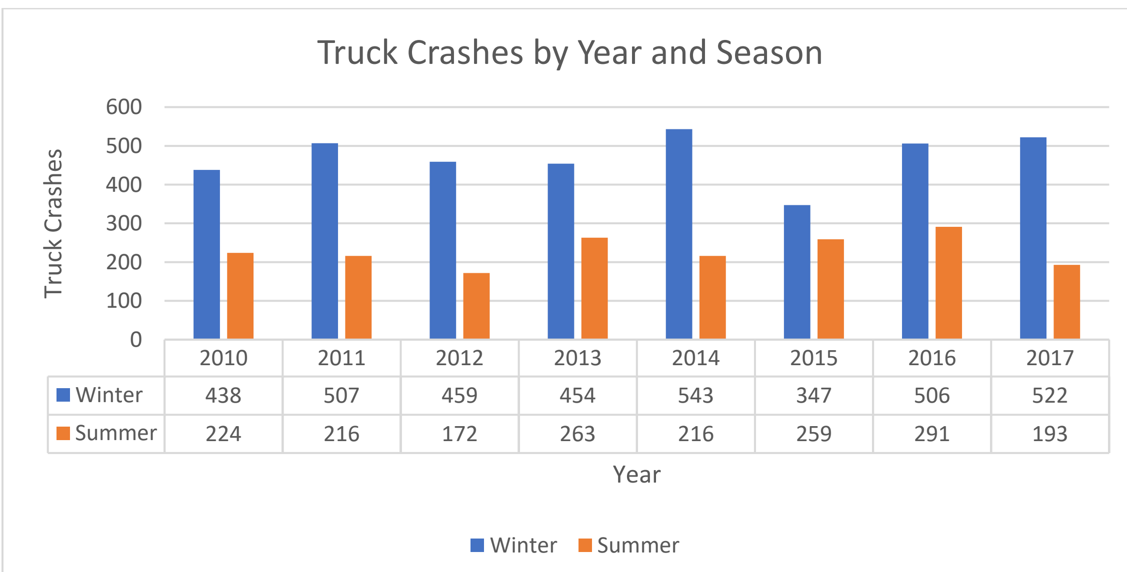


Figure 4-5. Truck Crashes by Year and Season (Source: WYDOT)

It is important to note that three of the four variable speed limit corridors were installed during 2011 with Green River-Rock Springs being activated in February of that year and the Laramie-Cheyenne and Evanston-Lyman corridors activated in October. The first VSL at Elk Mountain was installed in February of 2009. The safety analysis described in Chapter 8 of this report includes the use of variable speed limits as an explanatory variable to account for these conditions but Figure 4-4 and Figure 4-5 do not.

The traffic volumes associated with the years shown in Figure 4-4 are reported in a later section but for comparison purposes the winter season ADT is generally 86% of the annual average and the summer season is 114% of the annual average.

Since the project's main goal is to improve safety through implementation of CV technology, the baseline statistics must adequately describe the current levels of safety on the corridor. The corridor is frequently impacted by severe weather conditions so crash occurrences vary greatly depending on the weather in any given season, requiring that safety statistics be normalized based on the weather conditions that the road was subjected to. Figure 4-6 shows the number of crashes that occurred during each recorded weather type. and Figure 4-7 shows this information for truck crashes. Note that this figure was created using only the first reported weather condition. More detailed analysis of weather impacts on safety using RWIS data will be discussed later in the report but this figure gives a general idea of the main types of weather conditions associated with crashes in the dataset. Similarly, Figure 4-8 shows the first reported road condition for crashes in the dataset, which shows that the road conditions during these crashes were usually dry, ice/frost, or mud/dirt/gravel.

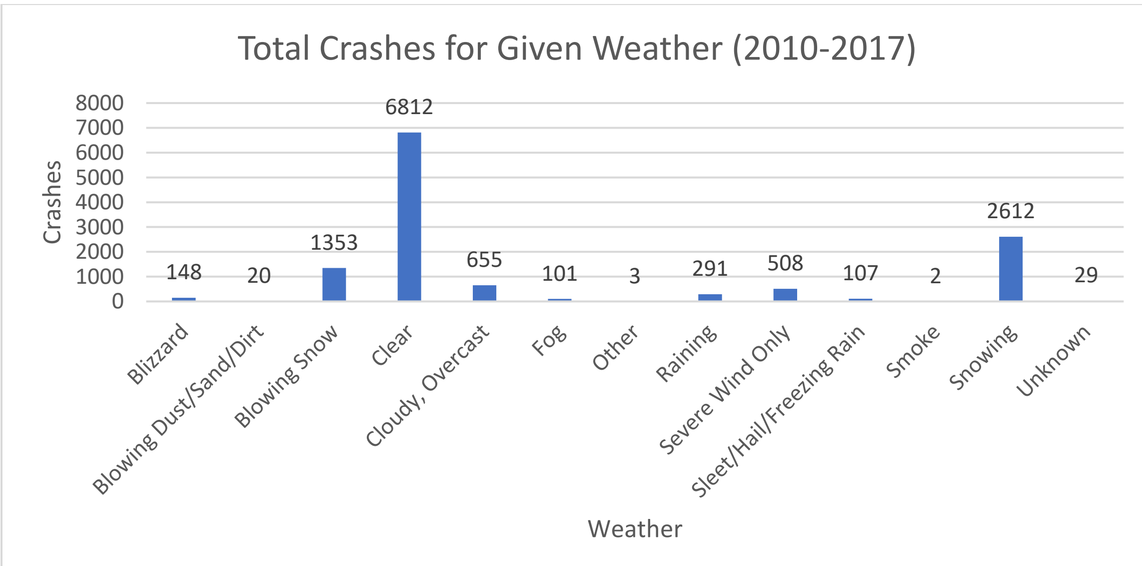


Figure 4-6. First Reported Weather Condition (Source: WYDOT)

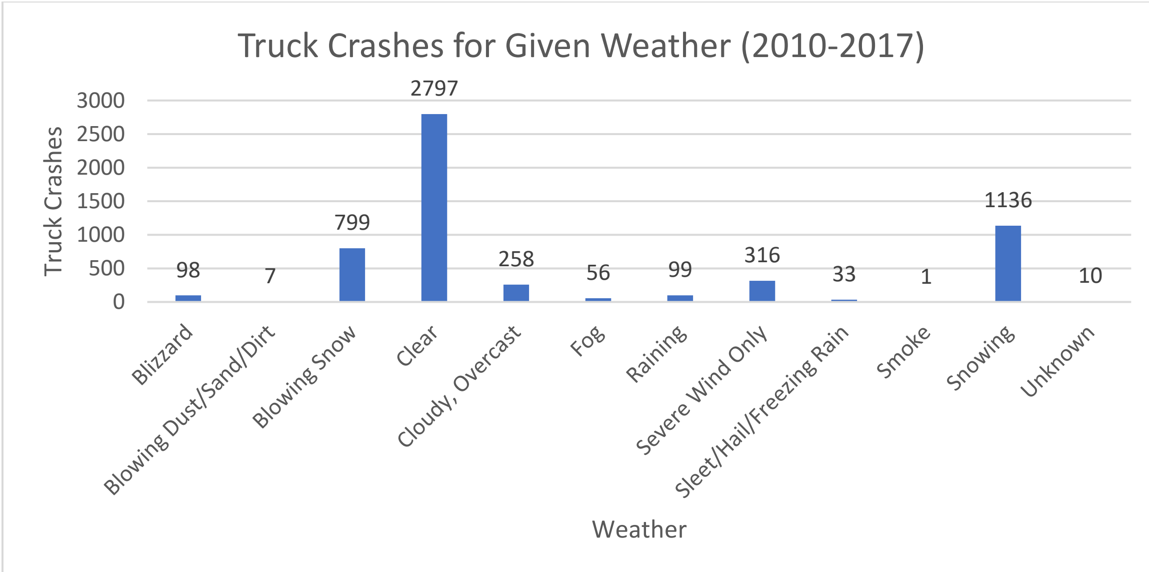


Figure 4-7. First Reported Weather Condition for Truck Crashes (Source: WYDOT)

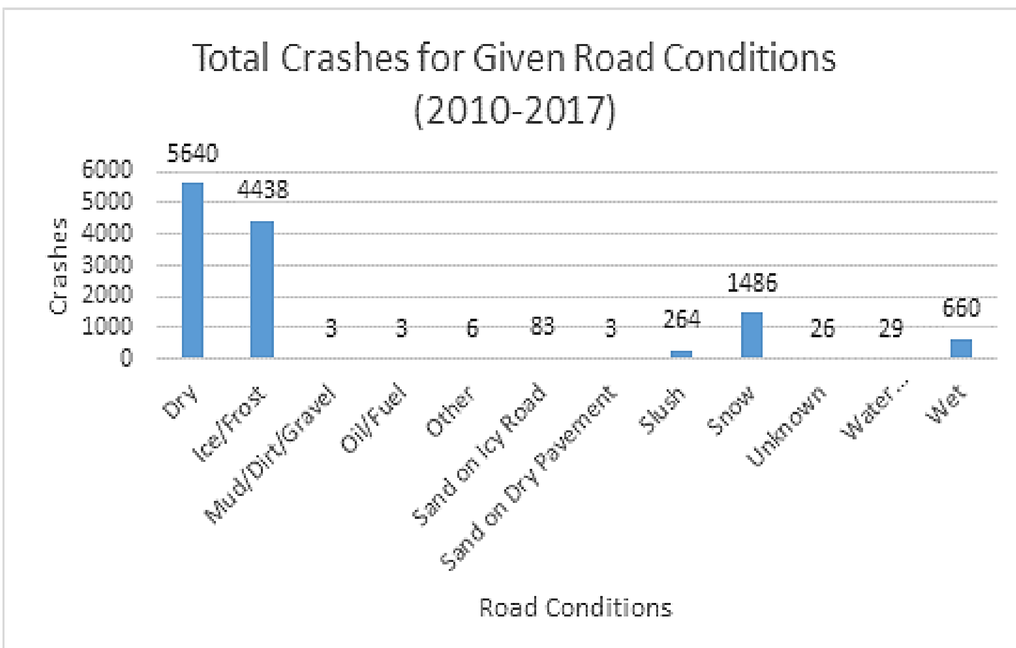


Figure 4-8. First Reported Road Condition (Source: WYDOT)

There are too many combinations of weather and road conditions to report here but it is interesting to note that dry road conditions and clear weather accounted for 40% of the crashes with the remaining crashes having either a reported road condition, weather condition, or both.

Figure 4-9 shows this information for truck crashes. Identified truck crashes for each year are shown in Table 4-6.

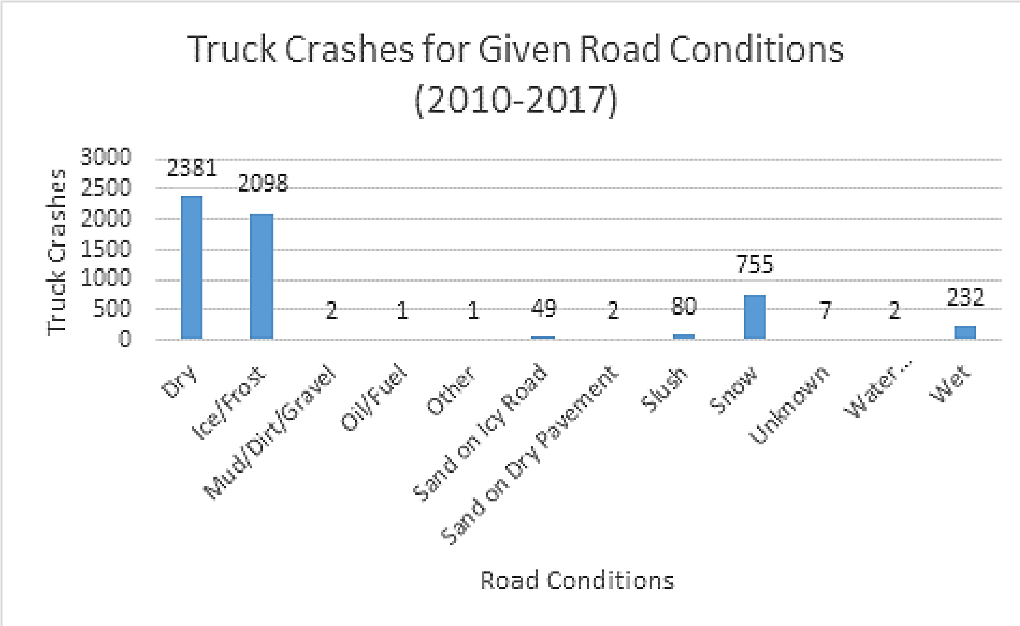


Figure 4-9. First Reported Road Condition for Truck Crashes (Source: WYDOT)

Table 4-6. Truck Crashes

Year	Truck Crashes	Percentage
2010	662	39.9%
2011	723	43.1%
2012	631	44.9%
2013	717	46.4%
2014	759	47.7%
2015	606	43.0%
2016	794	48.4%
2017	718	41.9%
Total	5,610	44.4%

4.6 Other Supportive Data

Other supportive data sources such as weather, road closures, work zones, traffic volumes, and dynamic messages were found to be important to the performance measure analyses. In some cases, this supportive data was necessary to incorporate with the primary data sources to verify the performance of developed methodologies. Each of these supportive data sources are described in the following subsections.

4.6.1 RWIS Sensor Data

RWIS sensor data is collected from ten priority stations of the 50 total stations installed along I-80—see Figure 4-1 in Section 4.4. RWIS data are currently used to account for weather in the speed-related performance measures. Other PMs utilize different approaches to account for weather such as road condition reporting (see Section 4.1) and NOAA data (see Chapter 7).

RWIS data from the WYDOT stations are archived in several publicly available locations. Originally, the plan was to access the RWIS data from the Federal Highway supported Weather Data Environment (WxDE) (FHWA, 2017), [YR1] since this data source would be used in the deployment of the Pikalert system being developed for this project (UCAR, 2017). When data was pulled from the WxDE a discrepancy between the station description and the spatial data information was found for the majority of the corridor RWIS leading to uncertainty in the historic data. This issue has since been resolved, but in order to avoid delays the MesoWest archive out of University of Utah was used for the baseline development activities (Utah, 2017). WxDE is currently being incorporated into the project's Pikalert system and the decision on whether to move back to this source for future performance measurement activities will be revisited during Phase 3. Since both systems pull from the same original RWIS data feed from Wyoming, the data provided by both systems is the same.

These sensors can be described in one of two ways: a seven-character WYDOT ID or a three/four-character MesoWest Station. Each of the stations are also characterized by a route milepost. Additional information of all 50 RWIS stations can be found in Appendix B. Corridor Devices of this report**.** This spreadsheet provides the four-character MesoWest Station, latitude, longitude, and elevation.

Early on in the project, it was deemed necessary to balance the large amount of weather data generated by 50 weather stations with the need to characterize the weather along a 400-mile corridor. An analysis was done on the proximity of the RWIS to the speed sensor locations to determine the closest RWIS. In addition to finding the closest RWIS, all RWIS within 5 miles of the speed sensor were also identified. It was found that a subset of 10 priority sensors provided data coverage for all speed sensors. These priority sensors are listed in Table 4-7 below.

Table 4-7. Priority RWIS

MesoWest	WYDOT	Name	Elev	Milepost
WY31	R003348	Painter	6,939	10.16
KFIR	R000362	First Divide	7,500	13.86
KCMS	R000363	Peru Hill	6,387	82.31
KPER	R000366	Green River Tunnel East	6,315	90.5
WY9	R001078	Rock Springs West	6,238	97.9
WY10	R001093	Baxter Road	6,369	111.5
WY19	R001220	Elk Mountain	7,304	256.17
WY28	R001270	Arlington East	7,781	273.85
WY28	R001354	Summit East	8,589	325.8
KVDW	R000360	Vedauwoo	8,365	329.4

Previous research was done along the project corridor that analyzed observed speed and RWIS weather variables (Promothes & Young, 2014; Vijay & Young, 2012; Buddemeyer, Young, & Dorsey-Spitz, 2010). This research found that changes in speeds were correlated with five weather variables: Relative Humidity, Visibility, Wind Speed, Road Surface Condition, and Surface Temperature. For this research, these five weather variables serve as the primary indicators of weather conditions at the time of a speed observation.

The data from each RWIS station consists of Station ID, Date & Time, and five variables available for each station: Relative Humidity, Visibility, Wind Speed, Road Condition, and Surface Temperature. The format of Date & Time is provided in UTC (Coordinated Universal Time). In order to process the data, the Date & Time format needs to be converted into MST (Mountain Standard Time). Since UTC does not account for daylight savings time, when converting to MST, daylight savings time will need to be accounted for.[2] Table 4-8 is a sample of the unprocessed RWIS data.

Table 4-8. Sample RWIS Data

Station_ ID	Date_Time_ Mountain	Relative_ Humidity_ set_1	Wind_ speed_set _1	road_ temp_set _1	Road_surface_ condition_set_ 1	Visibility_ set_1
KCMS	11 30 2016 16:02	79	12.44	33.08	1	
KCMS	11 30 2016 16:07	79	13.04	32.9	1	
KCMS	11 30 2016 16:12	79	12.44	32.54	1	
KCMS	11 30 2016 16:17	80	14.29	32.36	1	
KCMS	11 30 2016 16:22	80	13.04	31.82	1	
KCMS	11 30 2016 16:27	80	10.56	31.82	1	
KCMS	11 30 2016 16:32	80	10.56	31.46	1	
KCMS	11 30 2016 16:37	81	9.33	31.1	1	
KCMS	11 30 2016 16:42	81	11.81	31.1	1	
KCMS	11 30 2016 16:47	81	10.56	30.74	1	
KCMS	11 30 2016 16:52	81	11.81	30.56	1	
KCMS	11 30 2016 16:57	82	10.56	30.2	1	
KCMS	11 30 2016 17:02	83	8.7	29.48	1	

In its processed state, the RWIS output consists of the five weather variable data fields and a category of storm number. To obtain the processed data, the unprocessed data is input into a Matlab code to convert continuous weather data into categorical data**.** All data fields are coded based upon the thresholds of each data field. Each data field's threshold (except for storm number) and its respective code can be seen in Table 4-9. Generally ideal conditions are assigned a value of "1" with values increases as the weather conditions worsen.

Given the thresholds and categories for the five weather variables, there are 216 unique combinations of variables. Currently these are linked to storm numbers 1 to 216. Storm number 1 indicates all five weather condition variables are set to 1. The definitions of each storm number can be found in the *Appendix D. Storm Categories.*

Table 4-9. Processed RWIS Data Description

Data field	Description	Units	Notes
Station_ID	3- or 4-character MesoWest station		
DateTime	Date and Time in MST/MDT	MST/MDT Format: mm/dd/yyyy h:mm AM/PM	Original data converted to MST/MDT from UTC
RelativeHumidity	Low or high humidity based on weather conditions.	1 = <92%, 2 = > 92%	Relative Humidity readings from RWIS sensors converted to rating system

[2] Daylight savings time for 2017 begins on March 12 at 2:00 am.

WindSpeed	Wind speed based on current weather conditions.	1 = <30 mph, 2 = between 30 and 45 mph, 3=>45 mph	Wind Speed readings from RWIS sensors converted to rating system
SurfaceTemp	Temperature of road surface based on current weather conditions. Rating of 1 – 3	1 = >32°F, 2 = between 25 and 32°F, 3 = <25°F	Surface Temp readings from RWIS sensors converted to rating system
RoadCondition	Condition of road surface based on current weather conditions. Rating of 1 – 4	1 = dry pavement, 2 = wet pavement, 3 = snow, 4 = ice	Road surface condition is given on a scale of 0-10. Code 1 is ideal, dry conditions. Code 0,9,10 are defaulted to ideal conditions. Code 2 through Code 8 ranges from damp to black ice conditions.
Visibility	Forward length visible to the driver	1 = >0.95 miles, 2 = between 0.57 and 0.95 miles, 3 = <0.57 miles	Visibility readings from RWIS sensors converted to rating system
StormNumber	Number given to storm based on combination of above five variables	Unique storm number between 1 and 216 based on ratings of 5 weather variables	Storm numbers tied to 11 storm categories in the processed speed data.

For the baseline analysis terminology, storm numbers refer to the 216 unique combinations of the five storm variables and storm categories is a clustering of multiple storm numbers that are found to have similar speed behavior.

For analyses of the speed-related performance measures, the 216 storm numbers were reduced to 11 storms categories using a data mining analysis technique. It was determined that many storm conditions likely lead to similar speed behaviors and that aggregating speed observations into fewer storm categories would provide more meaningful performance measure results and would help to ensure an adequate number of observations in order to statistically test differences between baseline and post-deployment conditions. The original 216 storm numbers are retained in the data if it becomes desirable to keep results disaggregated or to remap storm numbers to storm categories. Once storm categories have been determined and assigned to the speed data, speed observations from each storm category can be analyzed together to create the baseline values and speed distributions.

Using a data-mining program called *processing.org*, the 216 storm numbers were pooled into categories using a technique called hierarchical clustering. Clustering is a process that creates clusters such that data points within a cluster are close to each other but also far apart from data points within other clusters (Salvador & Chan, 2014). The process of hierarchical clustering has two approaches: agglomerative or divisive. The agglomerative algorithm repeatedly merges two clusters until the desired number of clusters is achieved.

The divisive algorithm repeatedly splits two clusters. The process of condensing 216 storm numbers down to 10-15 categories was done using the agglomerative clustering algorithm. The process starts with storm number 1 where all conditions are ideal. This singular storm is then compared to all other storm numbers in order to find another similar storm. These similar storms are now a pair. This process is repeated until the desired number of categories is achieved.

The 216 storm numbers were originally divided into five clusters. However, it was determined that five clusters were not enough to break up certain characteristics of some storm types. For example, a weather event of high wind and ideal pavement conditions and a weather event with reduced visibility and moderate wind were placed into the same category as ideal conditions. From this, seven clusters and nine clusters were tested. The final test of 25 clusters was done to see if the cluster containing ideal conditions could be broken down even more. However, that cluster remained stable even with this large number of desired clusters setting. The final categorization used the results nine-cluster analysis, which then manually divided cluster 1 into three clusters, resulting in 11 final categories. This placed the wind events and poor surface conditions into separate categories from the ideal cluster since we know those are often of particular concern on the corridor.

In the *processing.org* script, the speed observations from the 216 storm numbers were arranged into an 18x12 table. Moving down the rows will vary the road condition and the visibility codes. Moving across the columns will vary the relative humidity, surface temperature, and wind speed codes. Figure 4-10 below shows a visual of the speed distributions for all storm numbers organized in an 18x12 grid. The codes for each variable can be seen to the left and above each storm.

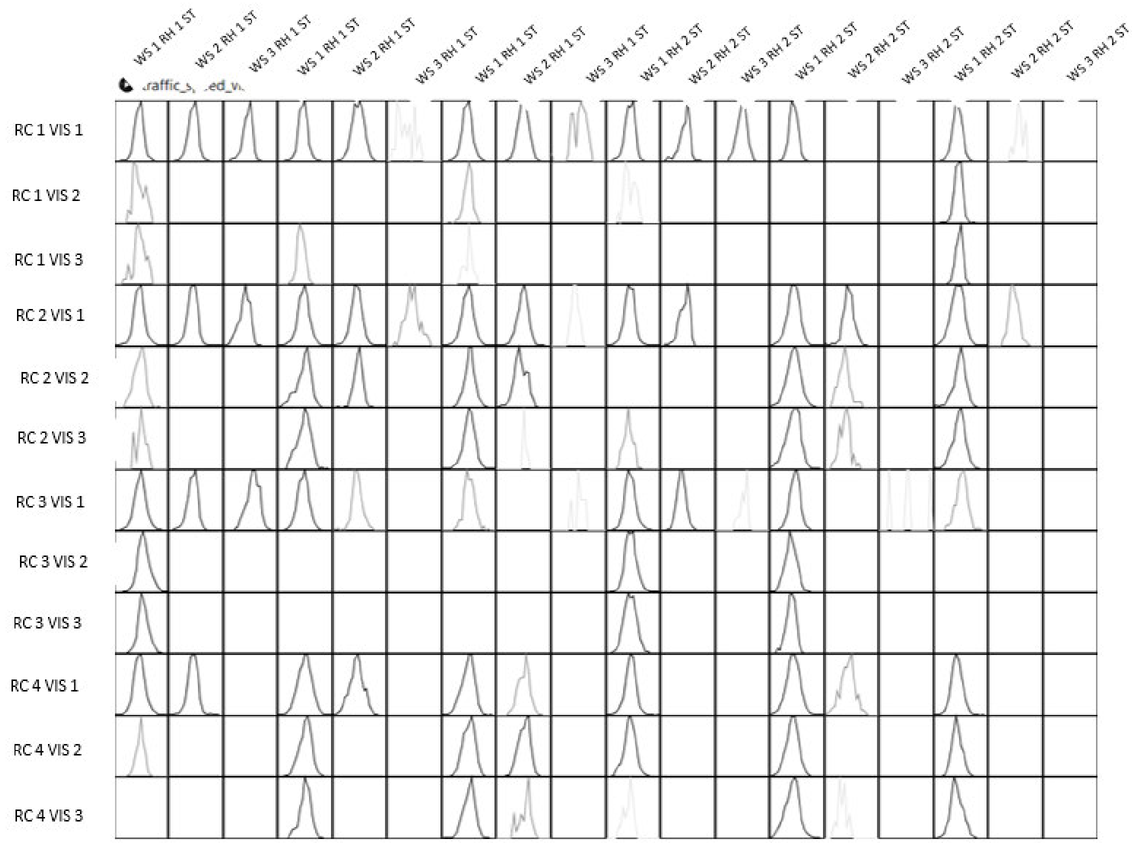


Figure 4-10. Storm number speed distributions & variable codes (Source: WYDOT).

The curve in each storm number represents the speed distribution during a weather event of those conditions. Between January and May 2017, approximately 37 million speed observations were collected. The storm numbers that have a black lined distribution in the figure have 100 or more observations. The storm numbers that have a grey lined distribution have between 1 and 100 observations. Any storm numbers that have zero speed observations are shown in the figure as blank white square. Storm numbers without observations are likely storms that are meteorologically unlikely since the 216 storm numbers were based only on unique combinations without consideration of whether conditions could occur at the same time. For example, it is not likely for there to be low visibility with low relative humidity.

These storm numbers were assigned a storm category zero in case they were to occur in later months of the baseline analysis or in the post-deployment analysis. The storm numbers are retained in the analysis in case it is later desired to extract these observations to be analyzed in another storm category. The number of speed observations for each storm number can be seen in Table 4-10. While 106 of the 216 storm numbers have no speed observations, the remaining storm numbers range from 4 to 27 million observations. A storm category containing ideal conditions (storm number 1) had the most observations at 27,044,919.

Table 4-10. Speed observations by storm number

Storm #	# Obs	Storm #	# Obs	Storm #	# Obs	Storm #	# Obs
1	27,044,919	55	1,389,643	109	961,919	163	113,684
2	457,804	56	28,711	110	41,182	164	4,931
3	281,987	57	1,044	111	1,060	165	-
4	1,038,497	58	697,260	112	23,833	166	50,648
5	18,409	59	35,235	113	1,210	167	1,759
6	221	60	307	114	-	168	-
7	848,363	61	646,656	115	209	169	7,875
8	13,451	62	31,517	116	-	170	436
9	120	63	557	117	6	171	-
10	666,671	64	503,066	118	633,543	172	86,072
11	953	65	855	119	892	173	-
12	1,847	66	-	120	36	174	-
13	111,171	67	243,313	121	18,697	175	47,068
14	-	68	922	122	-	176	367
15	-	69	-	123	4	177	-
16	292,125	70	227,009	124	373	178	8,367
17	31	71	1,444	125	-	179	-
18	-	72	-	126	-	180	-
19	76	73	242	127	14,530	181	502
20	-	74	30	128	96	182	-
21	-	75	-	129	-	183	-
22	-	76	4,354	130	-	184	2,582
23	-	77	2,604	131	-	185	3,372
24	-	78	-	132	-	186	-
25	410	79	6,541	133	-	187	3,524
26	-	80	3,493	134	-	188	2,466
27	-	81	-	135	-	189	-
28	5,239	82	5,498	136	42,741	190	15,260
29	-	83	-	137	-	191	-
30	-	84	-	138	-	192	-
31	29	85	6,852	139	5,233	193	21,214
32	-	86	57	140	-	194	-
33	-	87	-	141	-	195	-
34	1,447	88	1,307	142	-	196	1,903
35	-	89	-	143	-	197	-
36	-	90	-	144	-	198	-
37	212	91	57	145	4,187	199	-
38	-	92	-	146	26	200	70

Storm #	# Obs	Storm #	# Obs	Storm #	# Obs	Storm #	# Obs
39	-	93	-	147	-	201	-
40	1,165	94	2,329	148	-	202	550
41	-	95	3,155	149	-	203	5,471
42	-	96	-	150	-	204	-
43	113	97	9,809	151	-	205	5,224
44	-	98	1,351	152	-	206	1,897
45	-	99	-	153	-	207	-
46	10,205	100	15,488	154	42,495	208	16,212
47	-	101	-	155	-	209	-
48	-	102	-	156	-	210	-
49	439	103	7,721	157	3,301	211	17,857
50	-	104	166	158	-	212	1,227
51	-	105	-	159	-	213	-
52	3,191	106	5,275	160	-	214	2,653
53	-	107	180	161	-	215	19
54	-	108	-	162	-	216	-

The *processing.org* file allows the user to visualize the similarity of the observed speed distributions for the storm number they have chosen to the rest of the grid. Each square represents a storm number and the background color indicates similarity between that storm number and the storm number the cursor currently has selected. Figure 4-11 displays nine clusters (or colors) from the original cluster analysis. Storm number 1 of ideal conditions is outlined in the far upper left corner of Figure 4-11. The other storm numbers with a teal background also show similarities to a storm of ideal conditions. The colors used to represent the storm numbers are arbitrary and do not represent an increasing storm severity.

The teal colored cluster was then manually broken down into three different categories (category 1-3) since several storm types known to be of concern (high winds and poor surface condition) were contained in this cluster. The final breakdown of storm categories can be seen below in Table 4-11.

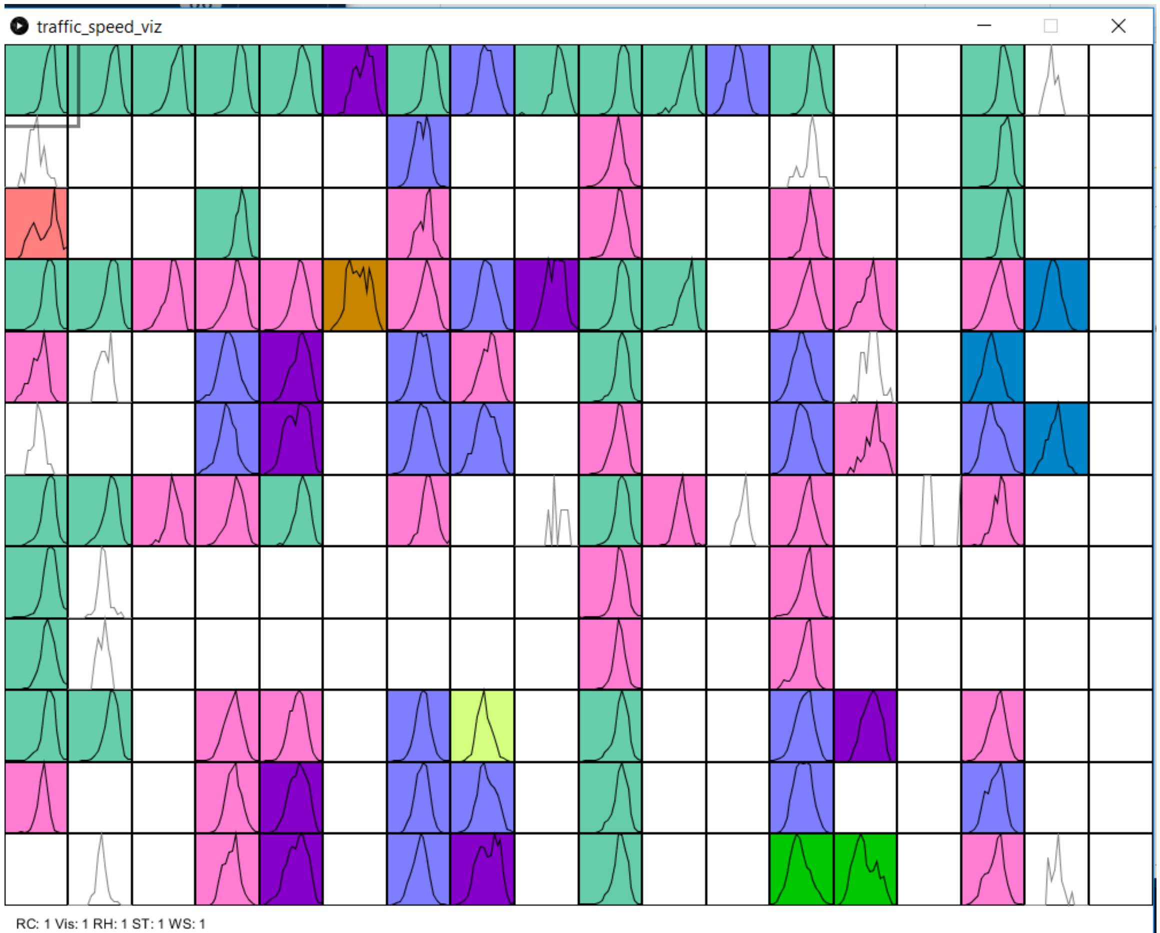


Figure 4-11. Storm categories of 9 clusters (Source: WYDOT)

Table 4-11. Final 11 Storm Categories

Storm Category	Description	Storm Numbers Assigned to Category
0	No category assigned	
1	Ideal	1, 2, 3, 10, 11, 55, 56, 64, 65, 82
2	Wind Event	4, 5, 7, 9, 13, 16, 34, 40, 52
3	Snow or Ice Surface Condition	109, 110, 113, 118, 127, 145, 163, 164, 172, 190, 208
4	Low Visibility	37
5	Wet pavement, moderate wind	60
6	Ice, high wind	170
7	Ice, low visibility or moderate wind	211, 212
8	High wind, high RH, wet roads	71, 88, 107
9	Mixed Conditions	8, 12, 25, 62, 76, 79, 85, 94, 97, 98, 103, 106, 169, 175, 187, 188, 193, 196, 205
10	Wind Events with Cold Surface Temps	6, 63, 77, 95, 176, 185, 203, 206
11	Mixed Conditions 2	28, 43 46, 49, 57, 58 59, 61, , 67, 68, 70, 73, 80, 100,111, 112, 115, 119, 121, 124, 136, 139, 154, 157, 166, 167, 178, 181, 184, 202, 214

4.6.2 Variable Speed Limit Data

Posted data comes from 66 Variable Speed Limit signs located along the I-80 corridor. These devices are integrated into four separate sections along I-80. The four VSL corridors are located between Evanston and Three Sisters, Rock Springs and Green River, along Elk Mountain, and from Cheyenne to Laramie. Latitude and longitude as well as mileposts are used to describe the approximate location of each VSL sign. More information on the variable speed limit signs can be found in *Appendix B. Corridor Devices.*

The VSL dataset are organized by month and offer information regarding device ID, milepost range, location, default speed setting and current posted speed in 5-minute intervals**.** A sample of the VSL data is shown in Table 4-12 with the latitude and longitude columns from this table removed in order to better display the other variables. Data from October 2016 to June 2017 and for October and November 2017 has been compiled.

Table 4-12. Sample VSL Data

DEVICE ID	ROUTE	FROM_RM	TO_RM	DISPLAY_NAME	DIRECTION	DEFAULT_SPEED	VSL_MPH	UPDATED	MILEPOST
2336	I-80	10.16	6.26	I-80 WB 10.16 (Painter Interchange)	D	75	55	3/1/2017 0:02	10.16
2336	I-80	10.16	6.26	I-80 WB 10.16 (Painter Interchange)	D	75	55	3/1/2017 0:07	10.16
2336	I-80	10.16	6.26	I-80 WB 10.16 (Painter Interchange)	D	75	55	3/1/2017 0:12	10.16
2336	I-80	10.16	6.26	I-80 WB 10.16 (Painter Interchange)	D	75	55	3/1/2017 0:22	10.16

When the speed data is combined with the VSL data, speed sensors associated with 75 mph static speed limit zones are given a speed sensor ID of 1 and those associated with 80 MPH static speed limit zones are given a speed sensor ID of 2. During processing of the speed sensor data, the posted speeds static zones were associated with their static speed limits. Figure 4-12 shows the distribution of posted speeds in January 2017 associated with the observed speeds to provide a visual on the typical speed limits for a winter month. The lowest speed limit set was 35 mph, for which there were 2,250 occurrences. Note that there are no 65 mph static speed limit zones associated with any speed sensors and that all variable speed limit zones have a maximum speed limit of 75 mph. Therefore, the data shown in the figure for 75 mph contains both static and VSL instances of this posted speed and the 80 mph bar comes only from static speed limit zone observations.

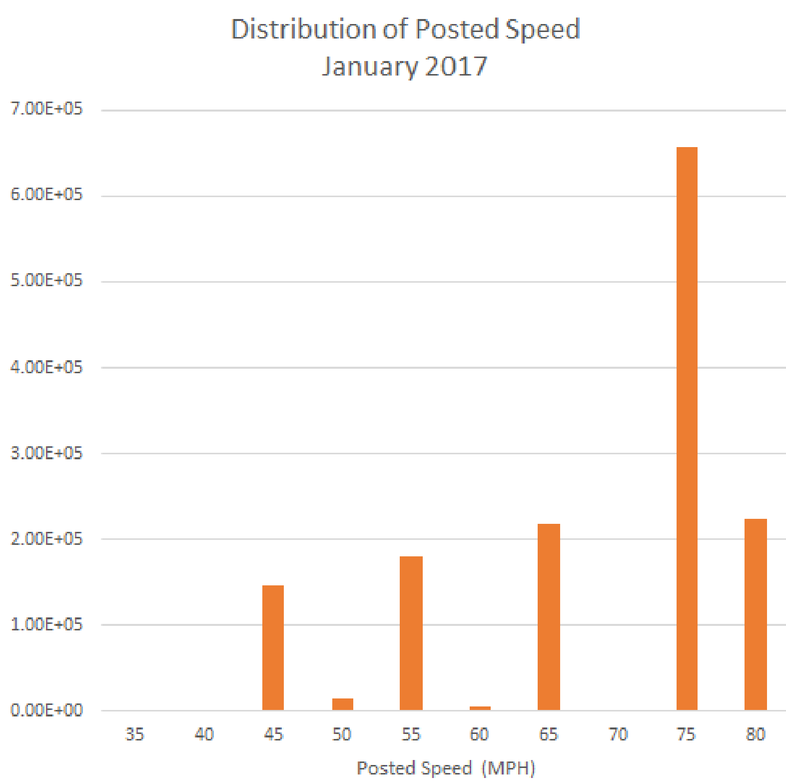


Figure 4-12. Distribution of Posted Speeds for January 2017 (Source: WYDOT)

4.6.3 Road Closure Data

In severe or potentially harmful weather conditions along the I-80 corridor, there are road closure gates put in place as a safety measure for drivers. Roadway closures along the project corridor are relatively common occurrences due to weather and crash events. Closures are controlled by road closure gates at the edges of urban areas so a closure affects a range of mileposts for a given direction of travel. The Wyoming Transportation Management Center (TMC) is able to monitor the weather conditions and remotely close the gates as needed. Figure 4-13 shows the signs with flashing beacon proceeding the road closure gates (left) and a picture of the gates (right). Table 4-13 lists 26 milepost ranges where road closure events can occur starting from near the Utah-Wyoming border in the west (MP 6.26) to the Nebraska-Wyoming border in the east (MP 402.78). Since road closures can occur in both directions for each of these segments, there are a total of 52 locations where road closure events can occur at any point in time.

Figure 4-13. Road Closure Gate (Source: WYDOT)

Table 4-13. Road Closure Segments

#	MP Begin	MP End	#	MP Begin	MP End
1	6.26	18.29	14	187.2	209.5
2	18.29	30.4	15	221.2	235.23
3	30.4	39.9	16	235.23	255.6
4	39.9	53.31	17	255.6	267.19
5	53.31	66.17	18	267.19	272.06
6	66.17	83.01	19	272.06	280.9
7	83.01	104.83	20	280.9	309.91
8	104.83	111.16	21	317.45	323.05
9	111.16	130.84	22	323.05	335.11
10	130.84	142.17	23	348.36	358.5
11	142.17	158.55	24	370.1	377.35
12	158.55	173.41	25	377.35	401.3
13	173.41	187.2	26	401.3	402.78

A road closure database is maintained by the WYDOT TMC. For the baseline analysis period, road closure data from October 2016 to May 2017 plus October and November of 2017 were analyzed. For descriptive data purposes only the single winter season from October 2016 – May 2017 are shown below but the data behind these graphs contain the additional month of October and November since the speed analyses in the report are based on a time period from January 2016 – May 2016 plus October and November and detailed closure information for this time period is helpful when analyzing this data. The graphs and tables in this section are provided to give a picture of how closure frequency and duration changes throughout the winter season.

A closure event is described by date and time a closure was added, removed or updated, the direction of the closure, and closure reason. For this analysis, a single closure event is defined as a closure of one of the segments (in Table 4-13) in a single direction of travel, so a closure that shut down both directions of travel would be considered two events. Unprocessed closure data includes "update" events where a direction of travel was added or removed. In order to treat each direction as independent event, all road closures were separated by direction and the update field converted into a closure start or closure end time.

An abstract of the data in its raw form, as given by WYDOT, is presented in Table 4-14 below.

Table 4-14. Unprocessed Road Closure Data Sample

Road Segment	Reporting Section	Milepost Range	Date/Time	Closure Status	Closure Direction	Closure Reason
I80 between the Utah State Line and Rock Springs	Between Evanston and Exit 18, US 189	6.26 – 18.29	10/17/16 06:18	Added	Eastbound	Winter Conditions
			10/17/16 09:26	Removed		
			11/23/16 19:20	Added	Eastbound	Winter Conditions
			11/23/16 19:52	Updated	Both	Winter Conditions
			11/24/16 02:49	Updated	Eastbound	Winter Conditions
			11/24/16 10:02	Removed		
			12/05/16 05:07	Added	Both	Winter Conditions
			12/05/16 07:49	Removed		
			12/10/16 19:34	Added	Eastbound	Crash
			12/10/16 19:38	Updated	Both	Crash
			12/11/16 03:46	Removed		
			12/11/16 05:02	Added	Eastbound	Winter Conditions
			12/11/16 08:45	Removed		
			01/04/17 21:16	Added	Both	Winter Conditions
			01/05/17 05:18	Updated	Eastbound	Winter Conditions
			01/05/17 05:39	Removed		
			01/08/17 17:53	Added	Westbound	Winter Conditions
			01/08/17 20:06	Removed		
			01/09/17 07:48	Added	Eastbound	Crash

			01/09/17 09:41	Removed		
			01/09/17 16:33	Added	Both	Winter Conditions
			01/09/17 20:39	Updated	Westbound	Winter Conditions
			01/09/17 21:22	Removed		

To analyze the data, each closure needs to be defined by a "Date/Time Start" and a "Date/Time End". Any events that have a Closure Direction as 'Both' need to be changed into two events with the same Date/Time Start and Date/Time End but with Eastbound as the direction of one and Westbound as the direction of the other. Other information used to describe closure events include range of milepost, reason for closure, and total duration (hrs:min). Table 4-15 provides an example of this processed data.

Table 4-15. Processed Road Closure Data Sample

MP Begin	MP End	Date/ Time Closure Added	Data/ Time Closure Removed	Closure Status	Closure Direction	Closure Reason	Duration (hrs:min)
6.26	18.29	10/17/16 06:18	10/17/16 09:26	Added	Eastbound	Winter Conditions	03:08
6.26	18.29	11/23/16 19:20	11/24/16 10:02	Added	Eastbound	Winter Conditions	14:42
6.26	18.29	11/23/16 19:52	11/24/16 02:49	Updated	Westbound	Winter Conditions	06:57
6.26	18.29	12/05/16 05:07	12/05/16 07:49	Added	Eastbound	Winter Conditions	02:42
6.26	18.29	12/05/16 05:07	12/05/16 07:49	Added	Westbound	Winter Conditions	02:42
6.26	18.29	12/10/16 19:34	12/11/16 03:46	Added	Eastbound	Crash	08:12
6.26	18.29	12/10/16 19:38	12/11/16 03:46	Updated	Westbound	Crash	08:08

For the time period analyzed (Oct –May of last winter), 459 road closure events occurred, for a total duration of 3,632 hours of road closure. Figure 4-14 shows a breakdown of these closures by month including the closure code that was used at the time of the closure event. Figure 4-15 shows the average duration by month. Figure 4-16 shows the variation in closure duration using a box plot. The pattern shown in these figures, with higher road closure frequency during winter months (Jan. and Feb.) but significantly higher duration of closures during the spring (May) is typical for the winter seasons in this region.

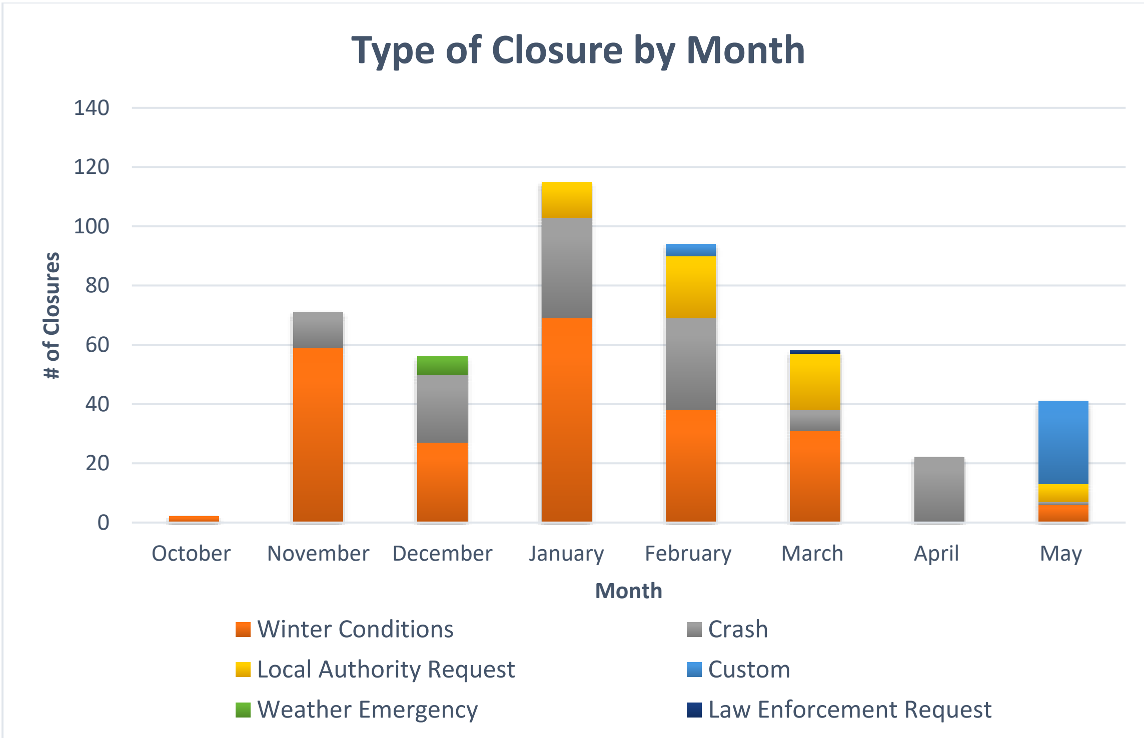


Figure 4-14. Reason of Road Closure Event by Month, Oct. 2016 – May 2017 (Source: WYDOT)

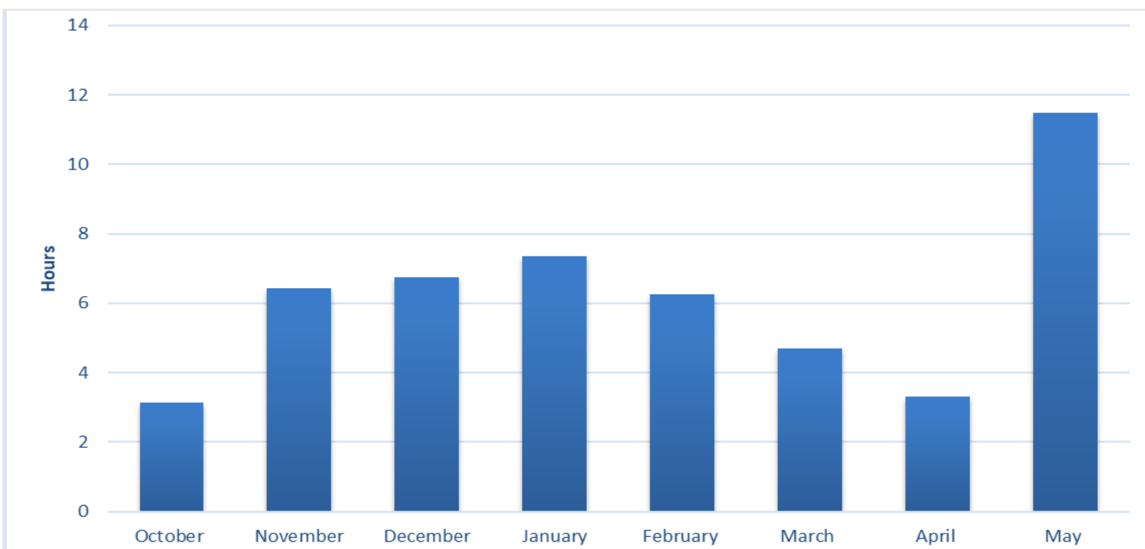


Figure 4-15. Road Closure Event Average Duration by Month, Oct. 2016 – May 2017 (Source: WYDOT)

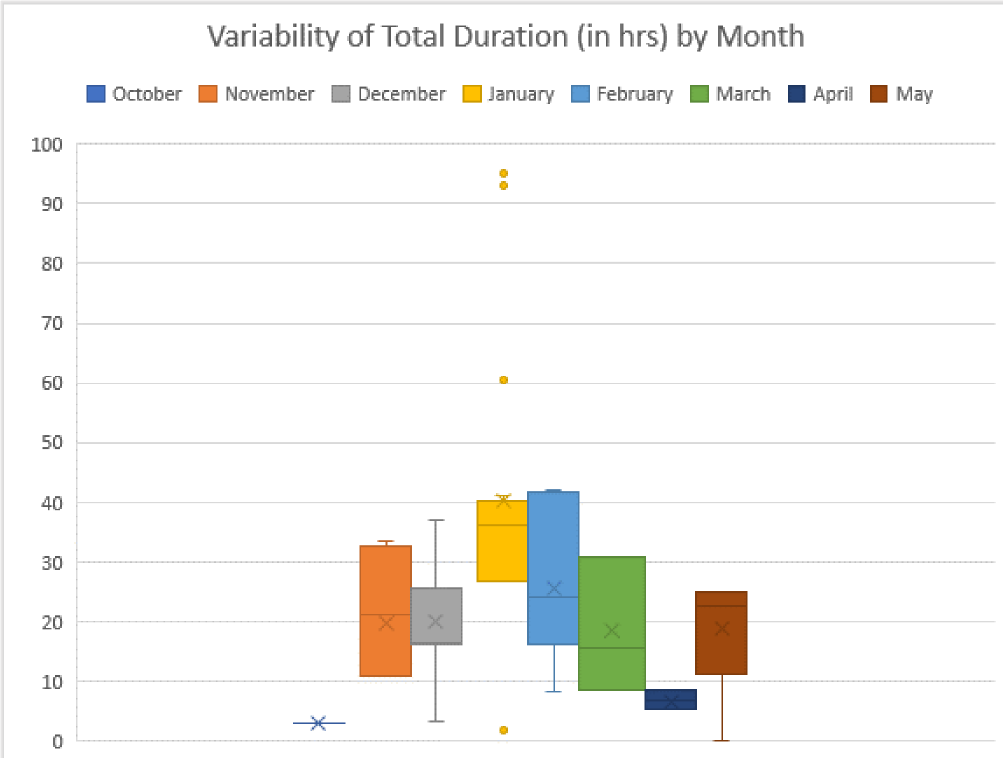


Figure 4-16. Road Closure Duration Variability by Month, Oct. 2016 – May 2017 (Source: WYDOT).

Table 4-16 shows the frequency of road closures by roadway segment to illustrate which mileposts were subject to more closures from October 2016 to May 2017.

Table 4-16. Frequency of Road Closure by Closure Segment

#	Milepost Range	Closures
1	6.26 to 18.29	34
2	18.29 to 30.4	33
3	30.4 to 39.9	30
4	39.9 to 53.31	30
5	53.31 to 66.17	5
6	66.17 to 83.01	5
7	83.01 to 104.83	6
8	104.83 to 111.16	6
9	111.16 to 130.84	16
10	130.84 to 142.17	16
11	142.17 to 158.55	17
12	158.55 to 173.41	16
13	173.41 to 187.2	16
14	187.2 to 209.5	18
15	221.2 to 235.23	22

#	Milepost Range	Closures
16	235.23 to 255.6	28
17	255.6 to 267.19	28
18	267.19 to 272.06	26
18	272.06 to 280.9	26
20	280.9 to 309.91	27
21	317.45 to 323.05	24
22	323.05 to 335.11	28
23	348.36 to 358.5	22
24	370.1 to 377.35	2
25	377.35 to 401.3	4
26	401.3 to 402.78	3

4.6.4 Work Zone Data

WYDOT maintains active construction project information in a database called the Construction Console. Two tables in this database are important to the CV Pilot in the identification of active work zones. The first is the *Projects* tables, which has information about the project number, location, and start and end dates. The *Console* was not fully implemented until 2012, so a begin date of January 1, 2013 was used for incorporating this data into the safety performance measure analyses. The Project_Key variable is the unique identifier for active construction projects. Other important variables in the Console data are the Start_TS, End_TS, Route, From_RM, and To_RM. All Route values should have “ML80B,” indicating the project was on I-80. The Start_TS and End_TS are the start and end timestamp dates for the project. The From_RM and To_RM are the mile markers affected by the project.

See Section 6.4.2 for discussion on how the work zone data is used to identify work zone crashes.

Processed speed data contains a “WorkZone” variable that identifies observations occurring within active work zones. Construction Console data beginning in 2017 is used to determine this variable. Table 4-17 contains a list of projects for the 2017 construction season along with the project’s anticipated start and end dates, beginning and ending mileposts, and the sensor IDs impacted. Currently this variable has not been analyzed in the processed data.

Table 4-17. 2017 Construction Projects on Wyoming I-80

Proj ID	Description	Beg RM	End RM	Reason	Let Dt	Comp Dt	Speed Sensor(s)
B171 008	VARIOUS LOCATIONS	0	3.91	CONTRACT PATCHING	1/12/20 17	10/31/ 2017	N/A
I8011 85	VARIABLE SPEED LIMIT SIGNS DYNAMIC MESSAGE SIGN	1.4	1.4	VSL & DMS	2/9/201 7		N/A

Proj ID	Description	Beg RM	End RM	Reason	Let Dt	Comp Dt	Speed Sensor(s)
B171 007	VARIOUS LOCATIONS	2.572	22.16	CRACK SEAL	10/13/2 016	4/30/2 017	2334, 2346, 2359, 2372, 2383, 2395, 2409, 2421, 2433
TRFS N17	VARIOUS LOCATIONS ALONG I-80 & ASSOCIATED INTERCHANGES	5.3	5.3	UPGRADE & REPAIR LOGO SIGNS	4/13/20 17		N/A
I1800 22	US 85 & I-80 RAMPS	8.5	8.5	LEFT TURN SIGNAL/ STRIPING	7/13/20 17		2334
B163 028	MOVE OVER SIGNS	17.2	17.2	MOVE OVER SIGNS	8/11/20 16	10/31/ 2017	2395
B151 035	VARIOUS LOCATIONS	19.8	19.8	GUARDRAIL UPGRADE	7/14/20 16	10/31/ 2017	2409
I8011 81	LYMAN EAST	39.2	49.1	MILL & OVERLAY/BR REHAB	11/10/2 016	11/30/ 2018	N/A
B173 002	VARIOUS LOCATIONS	72.9	96.9	CHIP SEAL	3/16/20 17		1075, 3236, 3296, 3243, 3249
B173 011	VARIOUS LOCATIONS	92.14	99.4	CRACK SEAL	10/13/2 016	4/30/ 2017	3243, 3249, 1084
N531 019	ROCK SPRINGS STREETS/DEWAR DRIVE	102.9	103.8	MILL 2"/FDR/ OVERLAY 2"/ADA	5/11/20 17		2049
B179 037	VARIOUS LOCATIONS EPOXY STRIPING	141.3	145.0	EPOXY STRIPING	2/9/ 2017		1145
I8031 45	COUNTY LINE WEST/WESTBOUND LANE	186.6	199.1	MILL/ OVERLAY/ SEAL COAT	11/10/2 016	10/31/ 2017	411
I8042 56	WALCOTT SECTION/EASTBOUN D LANE	233.8	240.0	MILL/PLANT MIX/SEAL COAT	7/14/20 16	10/15/ 2017	407, 3897
I8042 62	QUEALY DOME INTERCHANGE TO PETERSON INTERCHANGE	238.8	238.8	UPGRADE POSTS/LED SIGNS	3/16/20 17		3897
I8031 49	I-80	281.0	281.0	SIGNS; UPGRADE AND NEW	7/14/20 16	6/30/2 017	1280
I8062 02	ALBANY COUNTY LINE	336.5	341.2	MILL/OVERLAY/ SEAL COAT	9/8/201 6	10/31/ 2017	388, 389, 2246, 390
I8062 10	I-80 SIGNS	339.3	339.3	SIGN AND POST UPGRADES	7/13/20 17		2246
I8062 06	COUNTY LINE EAST	341.2	348.4	MILL/OVERLAY/ SEAL COAT	1/12/20 17	10/31/ 2018	390, 2263, 391, 2274, 2298

Proj ID	Description	Beg RM	End RM	Reason	Let Dt	Comp Dt	Speed Sensor(s)
B161 026	MOVE OVER SIGNS	356.2	356.2	MOVE OVER SIGNS	8/11/20 16	10/31/ 2017	1839
B171 009	VARIOUS LOCATIONS	357.7	361.8	SLAB REPAIR	1/12/20 17	10/31/ 2017	1839
B171 010	STR NO. AYV & AYU	358.6	359.3	BRIDGE REHAB	1/12/20 17	10/31/ 2017	1839
I8062 05	CENTRAL AVENUE-ARCHER INTERCHANGE/EAST BOUND LANE	362	372.4	MILL/OVERLAY/ SEAL COAT	9/8/ 2016	6/30/ 2018	3482
I8061 99	PINEBLUFFS MARGINAL/EASTBOU ND LANE	400.6	402.8	MILL & OVERLAY/BR REPLACEMENT S	5/12/20 16	8/31/ 2018	382

Figure 4-17 and Figure 4-18 break down the work zone crashes by weather and road conditions.

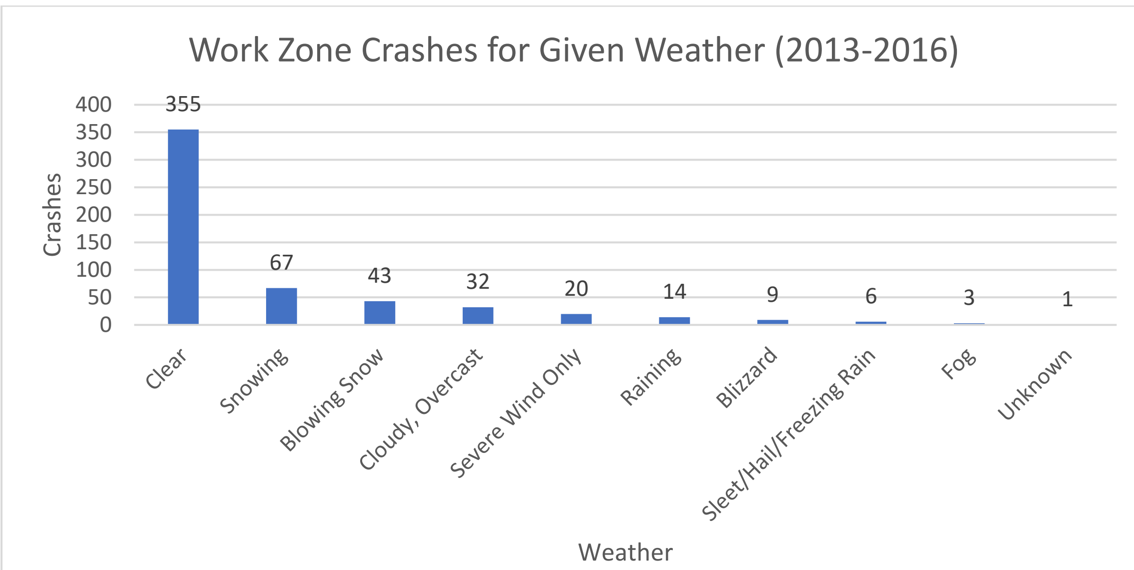


Figure 4-17. Work Zone Crashes for Given Weather 2013-2016 (Source: WYDOT).

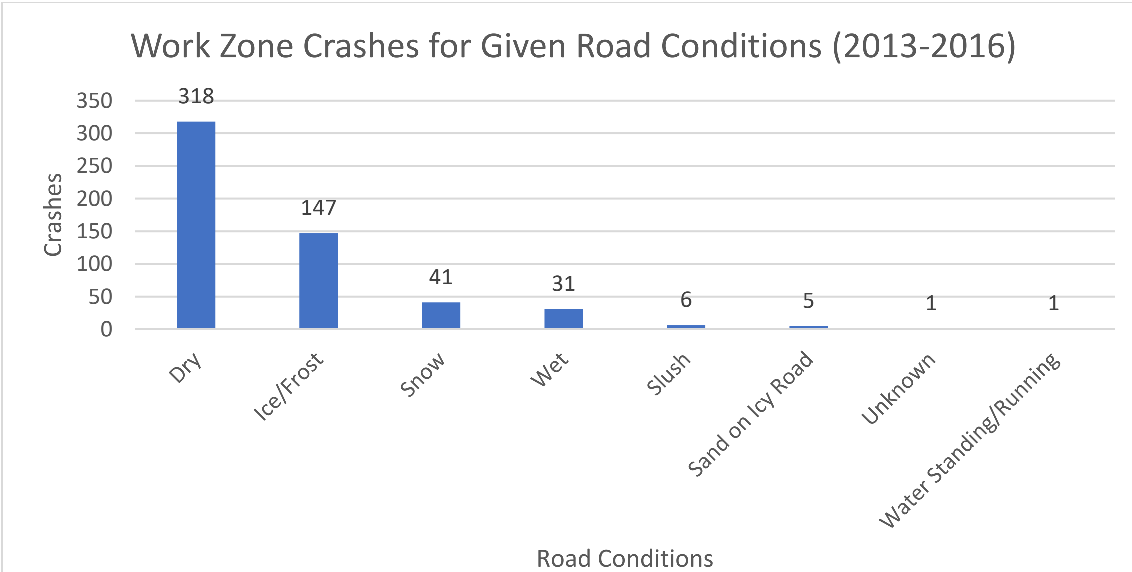


Figure 4-18. Work Zone Crashes for Given Road Conditions 2013-2016 (Source: WYDOT).

As part of the baseline activities, the speed data was also analyzed to see if work zone activities involving lane closures could be seen in the existing speed data. To begin this, the work zone information from the construction console was reviewed to see if any of the proposed work zones overlapped with existing speed sensors. From this process, 27 speed sensors with potential work zone impacts were identified. Speed data for these sensors were queried to provide daily traffic volumes for each lane. This data was graphed to see if there were sudden changes in traffic volumes that would represent single or multiple lane closures.

For example, Sensor 388 at milepost 336.5 (Buford East) was within the limits of a Mill/Overlay/Seal coat project is shown in Figure 4-19. Lane numbers are based on distance from the speed sensor. Since sensor 388 is installed on the westbound side so lane 1 is the westbound, right-hand lane and lane 4 is the eastbound, right-hand lane. From this it can be seen that the construction impacts were in July, August and September. Figure 4-20 focuses on this time period and it can be seen that in late July that lane 4 was closed for several periods with the volume moved over to lane 3. Similarly, we can see periods where lane 3 is closed with volume all moved to lane 4.

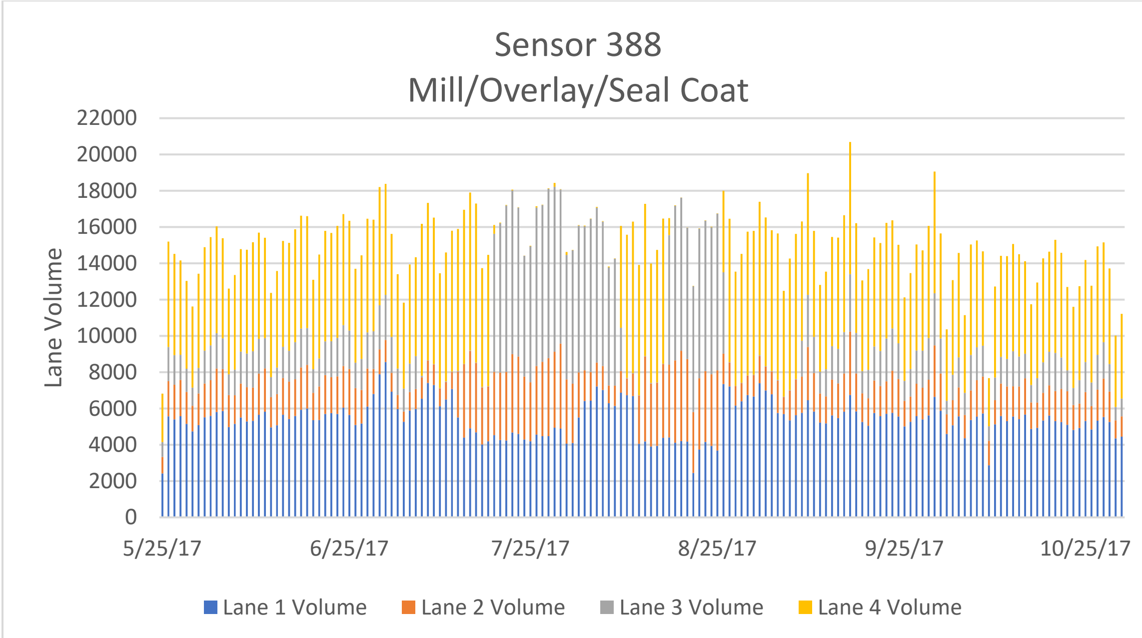


Figure 4-19. Example Work Zone Speed Observations for Entire Construction Season (Source: WYDOT)

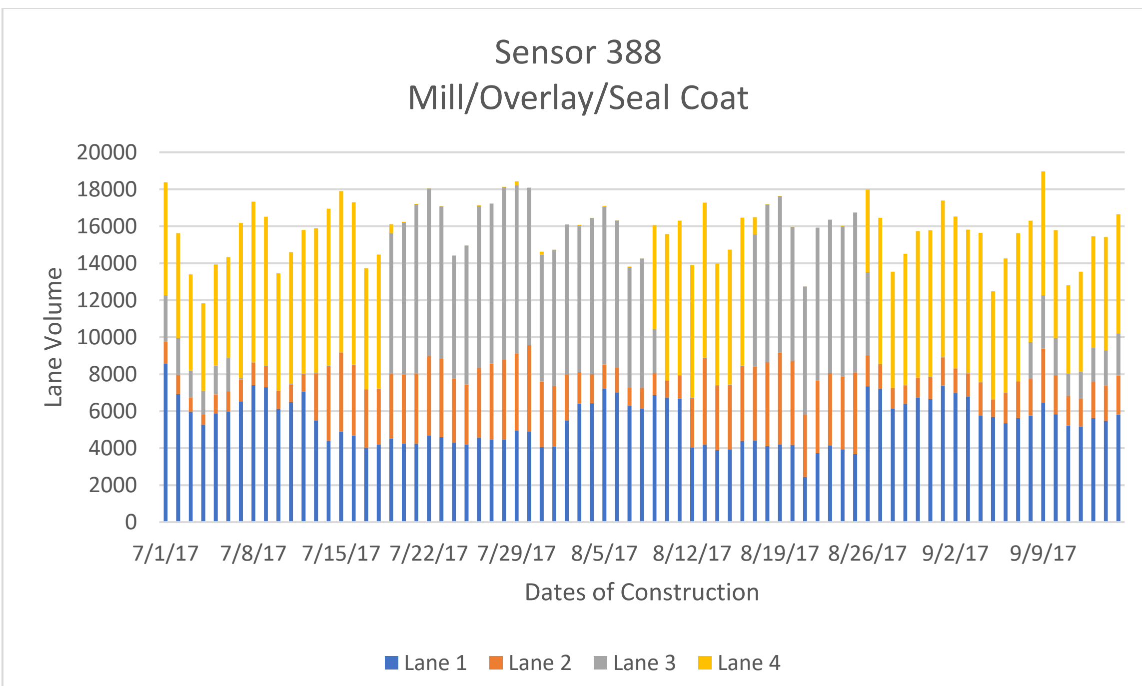


Figure 4-20. Example Work Zone Speed Observations for July – September (Source: WYDOT)

Using this analysis process, the 27 sensors were reviewed and six sensors shown to have obvious work zone related impacts due to lane closures. Graphs of these six sensors are shown in Appendix H. From these graphs, speed observations from specific sensors and time periods could be queried and analyzed as work zone speeds.

4.6.5 Traffic Volume Data

In order to determine the effects of traffic volumes on various performance measures and to calculate the crash rates for different corridor segments, the traffic volumes for the 402-mile project corridor had to be determined. Information on traffic volumes on WYDOT facilities can be obtained from the WYDOT Traffic Data website (WYDOT, WYDOT Traffic Data Website, 2017) and the annual *WYDOT Vehicle Miles Book*. This traffic data comes from inductive loops along the corridor and WYDOT splits the corridor into 98 sections based on the location of these loops. At the time of this report, the 2017 Vehicle Miles Book was not yet available.

Since Wyoming I-80 corridor has very few interchanges causing significant changes in traffic volumes, it was determined that the corridor could be aggregated into larger sections for traffic volume purposes. The entire corridor was analyzed and if a segment AADT changed by more than 10% then a new segment was defined. This led to the corridor being split into 19 traffic volume sections. The AADTs for these segments were calculated as weighted averages of each of its traffic subsections. Table 4-18 shows the AADT values for the 19 segments and includes the beginning and ending mileposts for each segment. Table 4-19 shows the Annual Average Daily Truck Traffic (AADTT) for the same segments.

Table 4-18. Annual Average Daily Traffic (AADT), 2010-2016

Section ID	Begin MP	End MP	2016	2015	2014	2013	2012	2011	2010
1	0	5	15,616	15,288	14,653	14,484	14,444	14,361	13,673
2	5	33	12,510	12,584	12,435	12,301	12,270	12,090	12,445
3	33	62	10,575	11,066	10,891	10,792	10,751	10,623	10,928
4	62	89	13,404	13,687	13,167	13,020	13,019	12,987	13,184
5	89	92	12,120	14,988	14,752	14,620	14,562	14,390	14,729
6	92	99	12,263	25,508	25,108	24,883	24,784	24,491	25,068
7	99	105	19,736	18,997	18,598	18,314	18,390	18,201	18,049
8	105	122	15,496	14,701	14,346	14,103	14,014	13,825	13,981
9	122	212	11,733	12,175	11,976	11,856	11,822	11,664	12,004
10	212	216	12,692	13,834	13,616	13,388	13,164	13,021	12,945
11	216	228	13,386	13,317	13,108	12,990	12,939	12,785	13,127
12	228	310	10,342	10,706	10,503	10,485	10,350	10,229	10,526
13	310	311	11,858	7,639	7,320	7,394	7,271	7,192	7,150
14	311	312	11,858	12,408	12,212	12,008	11,807	11,678	11,610
15	312	359	14,105	14,203	13,887	13,813	13,276	13,144	13,365
16	359	362	18,597	15,820	15,568	15,362	15,187	15,016	15,114
17	362	364	15,197	15,046	14,809	14,561	14,318	14,162	14,079
18	364	386	10,313	10,193	9,991	9,694	9,504	9,508	9,518
19	386	402	9,547	8,526	8,512	8,379	8,153	8,255	8,462

Table 4-19. Annual Average Daily Truck Traffic (AADTT), 2010-2016

Section ID	Begin MP	End MP	2016	2015	2014	2013	2012	2011	2010
1	0	5	4,606	6,298	6,234	6,013	5,944	5,973	5,397
2	5	33	4,822	5,606	5,578	5,498	5,493	5,513	5,362
3	33	62	5,237	4,916	4,925	4,932	4,894	4,943	5,220
4	62	89	5,548	6,547	6,400	6,023	6,009	6,173	6,257
5	89	92	7,041	6,783	6,526	6,685	6,629	6,295	6,362
6	92	99	7,034	6,774	6,678	6,694	6,454	6,838	6,838
7	99	105	7,067	7,246	7,263	6,398	6,255	6,543	6,850
8	105	122	6,945	6,734	6,740	6,394	6,410	6,448	6,460
9	122	212	5,348	5,879	5,916	5,430	5,381	6,323	6,526
10	212	216	4,705	7,222	7,290	4,309	4,261	6,000	6,566
11	216	228	5,103	6,958	7,017	5,921	5,890	6,109	5,924
12	228	310	4,255	5,831	5,835	4,857	5,540	5,625	5,685
13	310	311	2,652	2,333	2,324	2,409	2,354	3,959	3,887
14	311	312	2,652	4,035	4,018	3,911	3,822	5,864	5,864
15	312	359	5,656	6,022	5,928	5,797	5,708	5,739	5,864
16	359	362	6,002	7,479	7,324	5,807	5,761	5,724	5,752
17	362	364	6,008	7,017	6,862	5,070	5,012	5,109	5,084
18	364	386	5,086	4,696	4,557	4,351	4,207	4,304	4,357
19	386	402	3,673	4,539	4,376	4,083	3,946	4,110	4,232

Using segment lengths as the weighting criteria, corridor averages for AADT and AADTT were calculated to provide insight into general trends in the data. The results are shown in Table 4-20.

Table 4-20. Length-Based Weighted Corridor Averages for AADT and AADTT, 2010-2016

	2016	2015	2014	2013	2012	2011	2010
Average Annual Daily Traffic	12,112	12,491	12,248	12,130	11,996	11,874	12,123
Average Annual Daily Truck Traffic	5,156	5,858	5,828	5,339	5,430	5,734	5,827

The corridor can be divided into the four variable speed limit corridors and the non-VSL corridors that separate them, resulting in nine different segments. Using a length based weighting method, the ADT values for these nine segments can be seen in Table 4-21. The segment weight column provides the weighting and segment numbers used for all the ADT segments used to derive the aggregated ADT values. Table 4-22 provides similar values for the daily truck travel.

Table 4-21. Length-Based Weighted VSL/Non-VSL Segment Averages for AADT, 2010-2015

Sect ID	MP Beg	MP End	AADT Segment Weights	2016	2015	2014	2013	2012	2011	2010
N1	0	8.5	60% 1 ; 40% 2	14,374	14,206	13,766	13,611	13,574	13,453	13,182
V1	8.5	27.6	100% 2	12,510	12,584	12,435	12,301	12,270	12,090	12,445
N2	27.6	88.9	10% 2 ; 50% 3 ; 40% 4	11,900	12,266	11,956	11,834	11,810	11,715	11,982
V2	88.9	107.9	18% 5 ; 35% 6 ; 30% 7 ; 17% 8	15,029	19,824	19,461	19,232	19,195	18,973	19,216
N3	107.9	238.8	11% 8 ; 69% 9 ; 3% 10 ; 9% 11 ; 8% 12	12,213	12,488	12,270	12,142	12,086	11,929	12,233
V3	238.8	289.5	100% 12	10,342	10,706	10,503	10,485	10,350	10,229	10,526
N4	289.5	317.7	74% 12 ; 3% 13 ; 3% 14 ;20% 15	11,186	11,364	11,136	11,104	10,887	10,764	11,025
V4	317.7	353	100% 15	18,597	15,820	15,568	15,362	15,187	15,016	15,114
N5	353	402	12% 15 ; 6% 16 ; 4% 17 ; 45% 18 ; 33% 19	11,208	10,656	10,498	10,289	10,044	10,047	10,149

Table 4-22. Length-Based Weighted VSL/Non-VSL Segment Averages for Truck AADTT, 2010-2016

Sect ID	MP Beg	MP End	AADTT Segment Weights	2016	2015	2014	2013	2012	2011	2010
N1	0	8.5	60% 1 ; 40% 2	4,692	6,021	5,972	5,807	5,764	5,789	5,383
V1	8.5	27.6	100% 2	4,822	5,606	5,578	5,498	5,493	5,513	5,362
N2	27.6	88.9	10% 2 ; 50% 3 ; 40% 4	5,320	5,637	5,580	5,425	5,400	5,492	5,649
V2	88.9	107.9	1% 4 ; 17% 5 ; 35% 6 ; 30% 7 ; 17% 8	7,030	6,910	6,837	6,553	6,418	6,585	6,692
N3	107.9	238.8	11% 8 ; 69% 9 ; 3% 10 ; 9% 11 ; 8% 12	5,395	6,107	6,140	5,501	5,519	6,252	6,398
V3	238.8	289.5	100% 12	4,255	5,831	5,835	4,857	5,540	5,625	5,685
N4	289.5	317.7	74% 12 ; 3% 13 ; 3% 14 ; 20% 15	4,439	5,710	5,694	4,943	5,426	5,605	5,672
V4	317.7	353	100% 15	6,002	7,479	7,324	5,807	5,761	5,724	5,752
N5	353	402	12% 15 ; 6% 16 ; 4% 17 ; 45% 18 ; 33% 19	4,780	5,063	4,920	4,552	4,426	4,530	4,609

Given that average daily traffic values can vary from month to month, an average annual daily traffic value may not be representative of the amount of cars the roadway sees during a specific month. Crash rates typically increase with traffic volume, so this variance could cause our crash rates to artificially inflate if the roadway is experiencing a higher traffic volume than is represented by the annual average. To better represent the crash rates that the corridor is experiencing for a given month, the AADT in the crash rate equation can be multiplied by an adjustment factor which will modify the traffic volume to be representative of the month that is being evaluated.

To create these adjustment factors, the monthly average daily traffic volumes (MADT) contained within the *2015 Wyoming Automatic Traffic Recorder Report Book* were divided by the annual AADT for the same year. The MADT's described within the traffic report book are recorded at a specific milepost for both eastbound and westbound traffic for 2015, 2014, and 2005. It was determined from these three years of data that the monthly factors were stable over time and did not need to be calculated for each individual year.

The average of the MADTs for both directions (AVG. MADT) for a specific milepost was calculated and used as the input for the numerator. These were analyzed for each of the 19 segments and review of these values found minimal variations by segment so that overall monthly factors for the corridor could be used. These factors are shown in Table 4-23. As the table shows, traffic volumes are higher in summer months than in winter. Using the monthly factors, the season factors were calculated to be 0.86 for the winter (October 15-April 14) and 1.14 for the summer (April 15 – October 14). Truck percentages at the monthly level are not available so the same monthly factors would have to be used but applied to AADTT values as opposed to AADT values to get monthly truck traffic volumes.

Table 4-23. Monthly Traffic Volume Factors

Month	Factor	Month	Factor
Jan	0.81	Jul	1.26
Feb	0.82	Aug	1.22
Mar	0.90	Sep	1.13
Apr	0.93	Oct	1.05
May	1.01	Nov	0.88
Jun	1.20	Dec	0.78

4.6.6 Dynamic Message Sign Data

Dynamic Message Sign (DMS) data comes from 40 DMS located along the corridor. DMS on the corridor are either overhead or roadside mounted signs. At this time, the DMS sign data are only used to verify conditions on the roadway and are not formally part of any performance measure analyses. The DMS data contains ten data fields--see *Appendix C. Data Descriptions* for full data description. Table 4-24 provides a sample of the DMS data.

Table 4-24. Example of Dynamic Message Sign Data

DEVICEID	DISPLAY_NAME	LAT_DECIMAL	LONG_DECIMAL	DIRECTION	BLANK	SIGN_TEXT	UPDATED	MILEPOST
10	I-80 WB 7.5 (Evanston)	41.265643	-110.915148	D	F	FOG USE CAUTION	02-OCT-16 04.19.10.294000000 AM	7.5
10	I-80 WB 7.5 (Evanston)	41.265643	-110.915148	D	F	FOG USE CAUTION	02-OCT-16 04.22.48.265000000 AM	7.5
10	I-80 WB 7.5 (Evanston)	41.265643	-110.915148	D	T		02-OCT-16 07.27.43.208000000 AM	7.5
10	I-80 WB 7.5 (Evanston)	41.265643	-110.915148	D	T		02-OCT-16 07.32.49.557000000 AM	7.5
10	I-80 WB 7.5 (Evanston)	41.265643	-110.915148	D	F	SEVERE THUNDERSTORM WARNING IN EFFECT UNTIL 930 PM WIND GUSTS TO 70 MPH POSSIBLE	02-OCT-16 08.55.28.367000000 PM	7.5

5 I-80 Baseline Winter Conditions

The baseline winter season was very active on the I-80 corridor (December 2016 through May 2017; and, October through November 2017). Numerous winter storms were recorded with higher than average occurrences of strong winds. These weather events resulted in numerous road closures, activations of Wyoming's variable speed limits, crashes, vehicle blow-overs, and fatalities. It is important to understand these events and their impacts as background to the pre-deployment data analysis. Section 4.5 describes our preliminary efforts to establish a weather index that we can use to compare data from different years.

5.1 Defining a Weather Event

It was necessary to define what determines a weather event. Fortunately, WYDOT already collects data that provides the foundation for defining weather events, through the road and weather conditions reports from field maintenance personnel. WYDOT uses these reports to rate the overall impact to travelers (low, moderate, high) by various road conditions, weather conditions, advisories, and restrictions. A table of what conditions dictate the low, moderate, and high ratings is provided in *Appendix A. Road Condition Ratings.*

Recall that "weather event" is defined as anything other than a low rating anywhere in the corridor. This means that an event starts when a reported road or weather condition signifies something other than a low rating. And, the event doesn't end until the entire corridor is back to a low rating. This definition was used to analyze PMs 1-3 and to report on the baseline winter conditions described below.

5.2 Baseline Weather Events

Using the definition above, we identified 56 separate weather events from December 2016 through May 2017, and including October and November 2017. These events varied in duration, type, and location in the I-80 corridor. Some events were corridor-wide, while others were focused on just certain areas.

Table 5-1 provides a summary of the 56 weather events and their general characteristics. The number of spring events are higher than those in the heart of winter, but tend to be shorter in duration and more focused in location (still very strong and impactful storms). The winter events tend to last longer and impact a larger portion of the corridor. Event duration ranged from as low as 2 hours to as long as 20 days. The average duration over the six months was approximately 52 hours. The description of the event type came directly from the WYDOT field maintenance reports. The location was determined through a careful review of each storm and field reports (by maintenance section).

Table 5-1. Baseline I-80 Weather Event Summary

Month	Number	Avg. Duration (hours)	Duration Range (hours)	Type	Location
Oct '17	10	32	17-64	Strong winds (4); slick, fog, reduced visibility (3); slick, strong winds, black ice (3)	Entire corridor (8); specific areas between Rawlins and Cheyenne (2)
Nov '17	5	65	19-105	Strong winds (3); slick, slick, strong winds, drifted snow, reduced visibility, black ice (2)	Entire corridor (4); Arlington, Laramie area (1)
Dec '16	5	42	5-153	Strong winds (2); Snow, blowing snow, slick, strong winds (3)	Entire corridor (2); Specific areas (3)
Jan '17	3	212	10-486	Strong winds (1); Snow, blowing snow, slick, strong winds, ice (2)	Entire corridor (2); Specific areas (1)
Feb '17	4	73	1-247	Strong winds (1); Fog (2); Snow, blowing snow, slick, strong winds, ice (1)	Entire corridor (1); Specific areas (3)
Mar '17	9	42	7-108	Strong winds (3); Snow, blowing snow, slick, strong winds, ice (5)	Entire corridor (1); Specific areas (8)
Apr '17	12	29	10-61	Strong winds (5); Snow, blowing snow, slick, strong winds, ice (7)	Entire corridor (3); Specific areas (9)
May '17	8	19	5-60	Strong winds (2); Fog (2); Blowing snow, slick, strong winds (4)	Entire corridor (1); Specific areas (7)
Total	**56**	**52**			

5.3 Weather Event Impacts

These 56 weather events resulted in one of the most impactful and busiest seasons for the WYDOT TMC operators in a long time. Number of closures, VSL activations, crashes, vehicle blow-overs, and fatalities were used to illustrate the level of impact. Table 5-2 provides these data by month.

There were 479 individual road closures in our baseline period. This includes 26 closure segments in each direction along the 402 mile I-80 corridor. This value reflects when each segment is closed. (Note that this is different than the value reported in Section 4.5.3, which also included closures during October and November of 2016)

The value of 13,430 VSL activations represents every time a VSL segment displayed a speed less than maximum (67 segments within 4 VSL corridors).

Crashes were also significant, including 1,173 individually documented crashes for the entire period (some including multiple vehicles involved). Of the 1,173, 207 were vehicle blow-overs (almost all commercial trucks) – this was the result of a very high frequency of strong wind events. These crashes resulted in 7 fatalities for the baseline time period.

Table 5-2. Weather Event Impacts, December 2016 – May 2017; and October and November 2017

Month	Number	Closures	VSL Activations	Crashes	Vehicle Blow-overs	Fatalities
Oct	10	32	1,270	77	11	1
Nov	5	44	1,698	177	30	0
Dec	5	59	2,156	186	25	2
Jan	3	118	2,924	284	38	1
Feb	4	97	1,859	188	51	1
Mar	9	61	1,403	138	25	1
Apr	12	24	1,428	115	27	0
May	8	44	692	95	0	1
Total	**56**	**479**	**13,430**	**1,173**	**207**	**7**

5.4 Crash Data

This section provides a summary of the crash statistics for 1,310 reported crashes from October 1, 2016 – May 31, 2017. Using the winter season definition of October 15 through April 14, a total of 1,067 crashes occurred, which is very similar to the average winter crashes of 1,010 for the seven previous winters. Figure 5-1 provides the crashes per month, which shows the most crashes occurring in the month of January. Figure 5-2 provides the crashes by number of involved vehicles, showing that most crashes were single-vehicle crashes. The most number of vehicles involved in a crash that winter was 19, which was a crash that occurred on January 11th at milepost 19.75, which is located in the Evanston VSL corridor, during a snow and ice event. This section of the corridor from milepost 18.29 to milepost 30.4 was closed until 12:25:00 due to weather conditions. When the section reopened, the above mentioned crash occurred 13:30:00. Following the crash, the road closed again at 13:43:00 and remained closed for almost 24 hours.

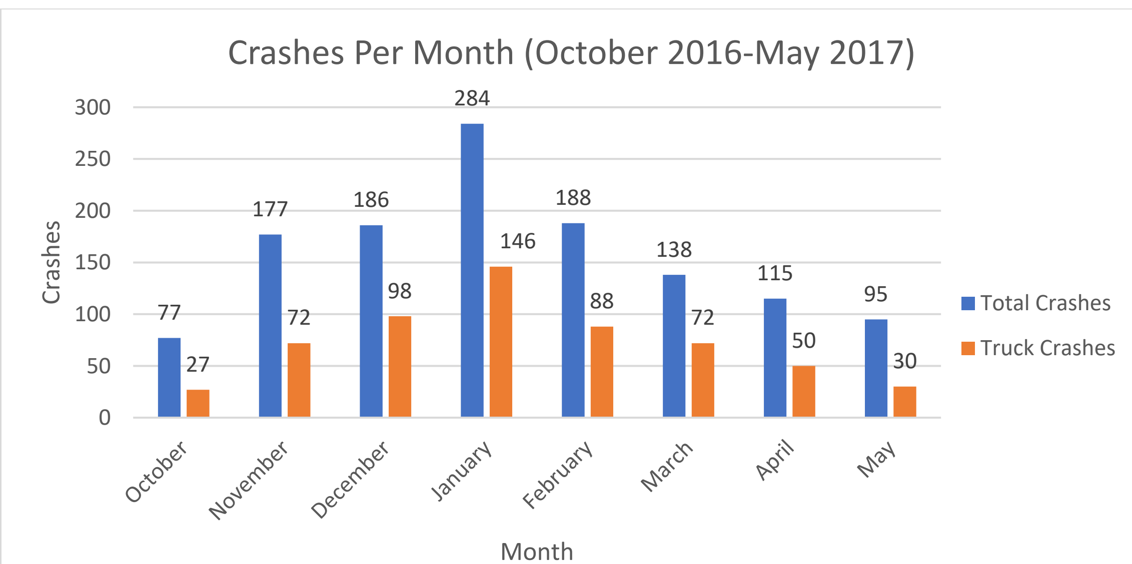


Figure 5-1. Crashes per Month for Winter 2016-17 (Source: WYDOT).

Of the 1,310 crashes, 8 crashes were fatal with a total of 9 fatalities.[3] For injuries, there were 33 incapacitating injuries, 92 non-incapacitating, and 68 injury crashes and a total of 274 injured persons for last winter.

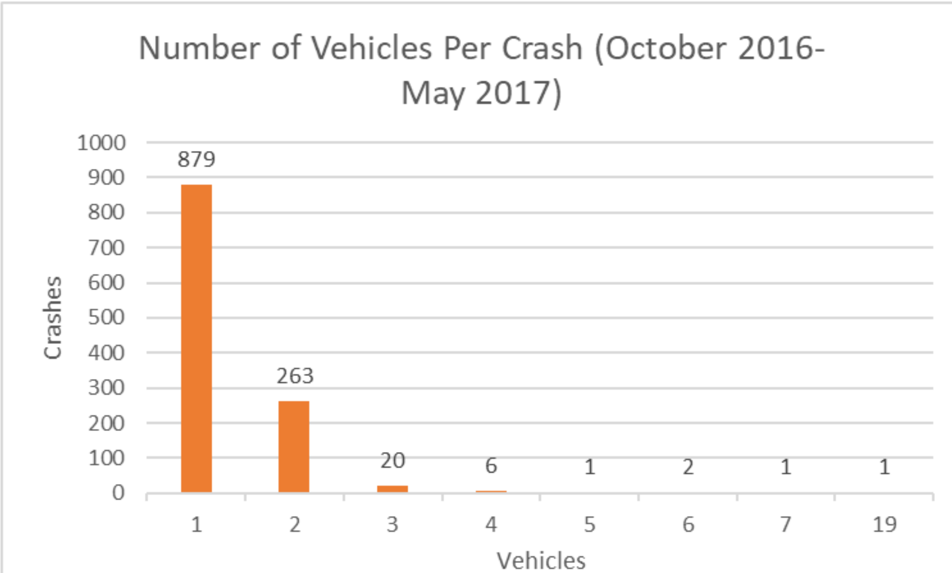


Figure 5-2. Crashes by Number of Involved Vehicles for Winter 2016-17 (Source: WYDOT).

Figure 5-3 and Figure 5-4 show the crashes for winter 2016-2017 by reported weather and road conditions respectively. Most crashes occurred during clear weather conditions (48%), with snowing weather (21%) being the next highest. For road conditions, ice/frost conditions (39%) were reported the most, closely followed by dry road conditions (36%).

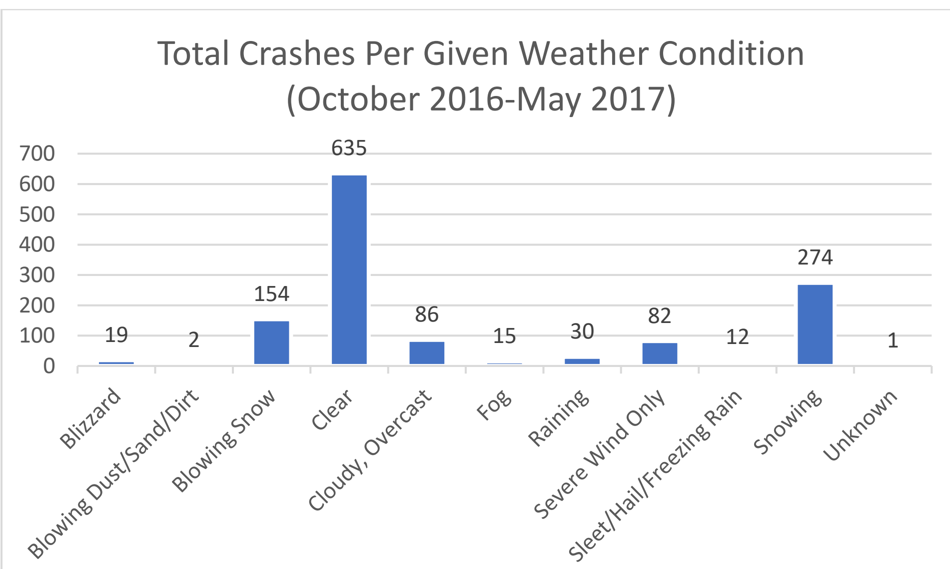


Figure 5-3. Crashes by Reported Weather for Winter 2016-17 (Source: WYDOT)

[3] Note this is for a slightly longer time period than the weather events discussed in the previous section.

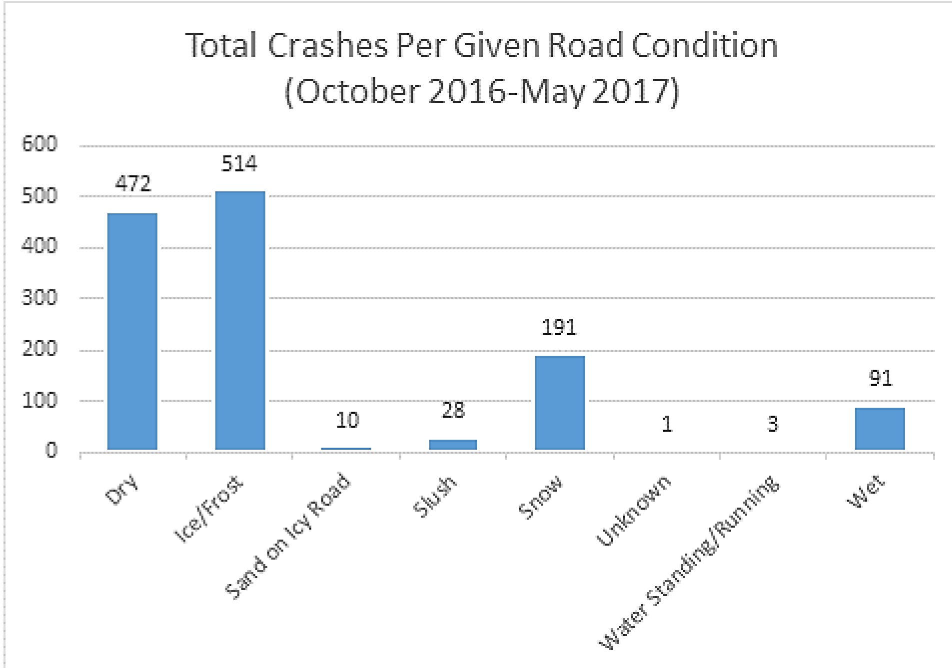


Figure 5-4. Crashes by Reported Road Condition for Winter 2016-17 (Source: WYDOT)

The last summary statistics is the crash type. Figure 5-5 shows the breakdown of the 1,310 crashes for the winter season, which shows that single vehicle crashes are by far the most common accounting for almost 68%. Rear end crashes are the next most common crash type at 11%.

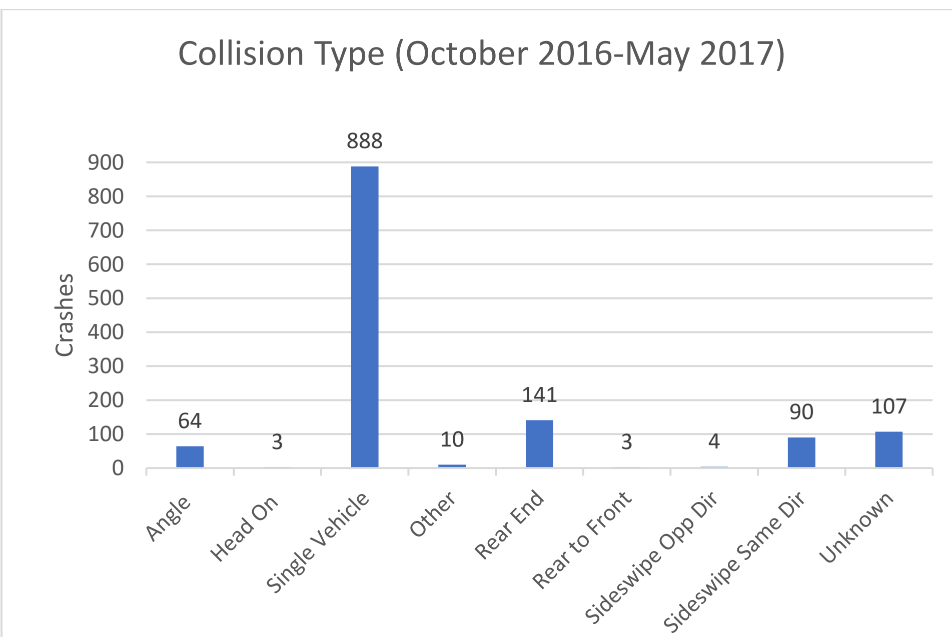


Figure 5-5. Crashes by Crash Type for Winter 2016-17 (Source: WYDOT).

Overturning crashes are of particular interest to this corridor as frequent high wind events are common. Previous research has shown that crashes reported as overturn crashes are a measure of these high wind crashes (Young & Liesman, 2007). For last winter, 225 overturning crashes were reported as the “First Harmful Event” in the crash data from October 2016 through May 2017, as seen in Figure 5-6.

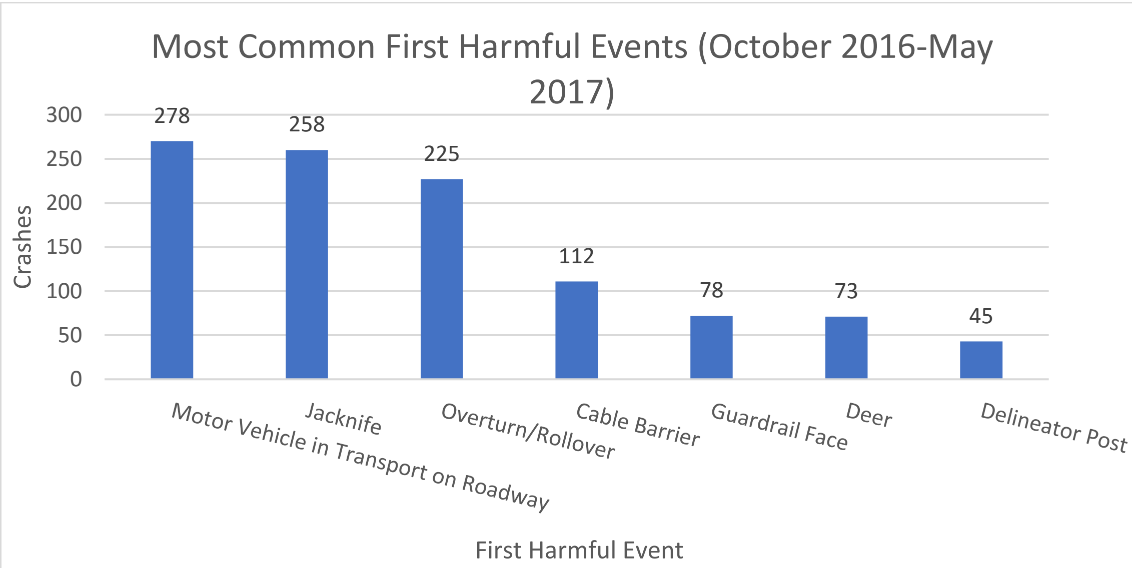


Figure 5-6. First Harmful Events for Winter 2016-17 (Source: WYDOT).

The Connected Vehicle Pilot is expected to improve safety during winter events along the corridor through improved in-vehicle information and through on-board alerts for connected vehicles and an improvement of the traveler information system for all vehicles. Considering the predominate types of crash and conditions for the corridor, it is anticipated that there would be a reduction in crashes during winter weather and adverse road conditions. While the predominant weather condition for crashes is clear, the predominant road condition is icy. One thought is that visibly adverse conditions like falling or blowing snow are a more obvious hazard than clear conditions with poor road surfaces. The CV Pilots provision of more timely and accurate road condition information is likely to have an impact by providing quality information for hazards that may not be readily apparent. The top two crash types are single vehicle and rear-end crashes, for which the CV Pilot project is also likely to impact since both of these can be caused by driver’s being not fully aware of the hazardous nature of the road conditions.

5.5 Analysis of Two Weather Events

Before finalizing the tools to process large amounts of speed data for the analysis of PM-14 and PM-15, an analysis of two storm events was performed. For this preliminary analysis, more visualization of the storm events spatially and temporally was performed than what will be done for the full baseline analysis.

The two storm events being analyzed are March 5th-11th and April 27th – 29th, both taking place in 2017. These events were defined as winter storm events where snow and ice were the main cause of crashes along the I-80 corridor. The two storm events were considered major events that impacted the entire corridor. To represent both the temporal and spatial variations in the storm event, weather and speed data from four locations were analyzed for each event. This report provides the visual representation of data for only the March 5th – 11th storm event since similar results were seen for both events. The full presentation of the two events can be found in Appendix D. Storm Categories.

Figure 5-7 shows the weather conditions at the four weather stations during the March storm event. The weather data shown in the figure are the processed road condition, visibility, relative humidity, surface temperature and wind speed data. For all these categorical variables, values of 1 represent ideal conditions and higher values represent worsening conditions, but the number of categories vary by variable. (See Section 4.6.1 for more details). As this graph shows, the weather conditions experienced at each sensor differed in type, severity, and time.

Figure 5-8 shows the 85th percentile speed for a storm event on March 5-11, 2017 for four speed sensors along the I-80 corridor. This graph gives a visualization of the speed compliance within variable speed limit zones (VSL) in terms of four weather variables. The graph also shows the crashes and road closures that occurred on the road segment associated with sensor. The location of the crashes on the figure associates the time of the crash with the x-axis but does not associate the crash with the speed y-axis.

Lastly, Figure 5-9 shows the speed compliance for both a strict definition, a posted speed plus 5 MPH, and a posted speed limit plus 10 MPH. The value for speed compliant indicates the percentage of travelers at or below the speed compliance level (such as posted speed plus 10 MPH). This figure shows how greatly the speed performance measure can vary for a single storm event and by time and location. *Appendix E. Analysis of Two Storm Events*

contains additional graphs including the standard deviation of speed and hourly traffic volumes for both storm events.

The analysis of these storm events showed that the analysis approach using priority weather stations and speed sensors was necessary given the differences in performance measures by time and location. The storm event analysis also showed that classification of weather events by location, as opposed to classifying a weather event once for the entire corridor, was also necessary.

Another key finding of this analysis was in determining the impact of weather on speed behavior, which was evident in the graphs. While the observed traffic volumes are generally quite low along the corridor, it was known from experience with the corridor that periods of higher volumes could be found after significant road closures occurred. The graphs shown in Appendix E contain bar graphs of vehicle volumes expressed in vehicles/hour for all lanes of traffic, which are typically four-lanes, with two lanes in each direction. The *Highway Capacity Manual* suggests observations of free flow speed can be field measured for basic freeway segments when volumes are below 1,000 passenger cars per hour per lane.

The results from milepost 91.99 in the East Green River locations were the highest volumes seen in the analysis given the location of this sensor between the towns of Green River and Rock Springs were higher ADTs are seen because of significant commuting and shopping trip behavior between the two communities. The graphed volumes are for four lanes of interstate traffic and at its peak we see volumes below 1,400 vehicles/hour for four lanes. Several of the graphed weather events involved road closures with higher volumes experienced after the road reopens but even these cases had volumes well below the HCM threshold as seen in the March 5th storm event for sensor 256 where the post closure volumes peaked at 2,500 passenger cars per hour for all four lanes of traffic.

The analysis of these two weather events leads us to believe that weather is the primary reason for speed behavior differences to that clustering speed observations based on weather categories was a reasonable approach for performance measurement and the additional clustering based on demand (using measured volumes) was not necessary.

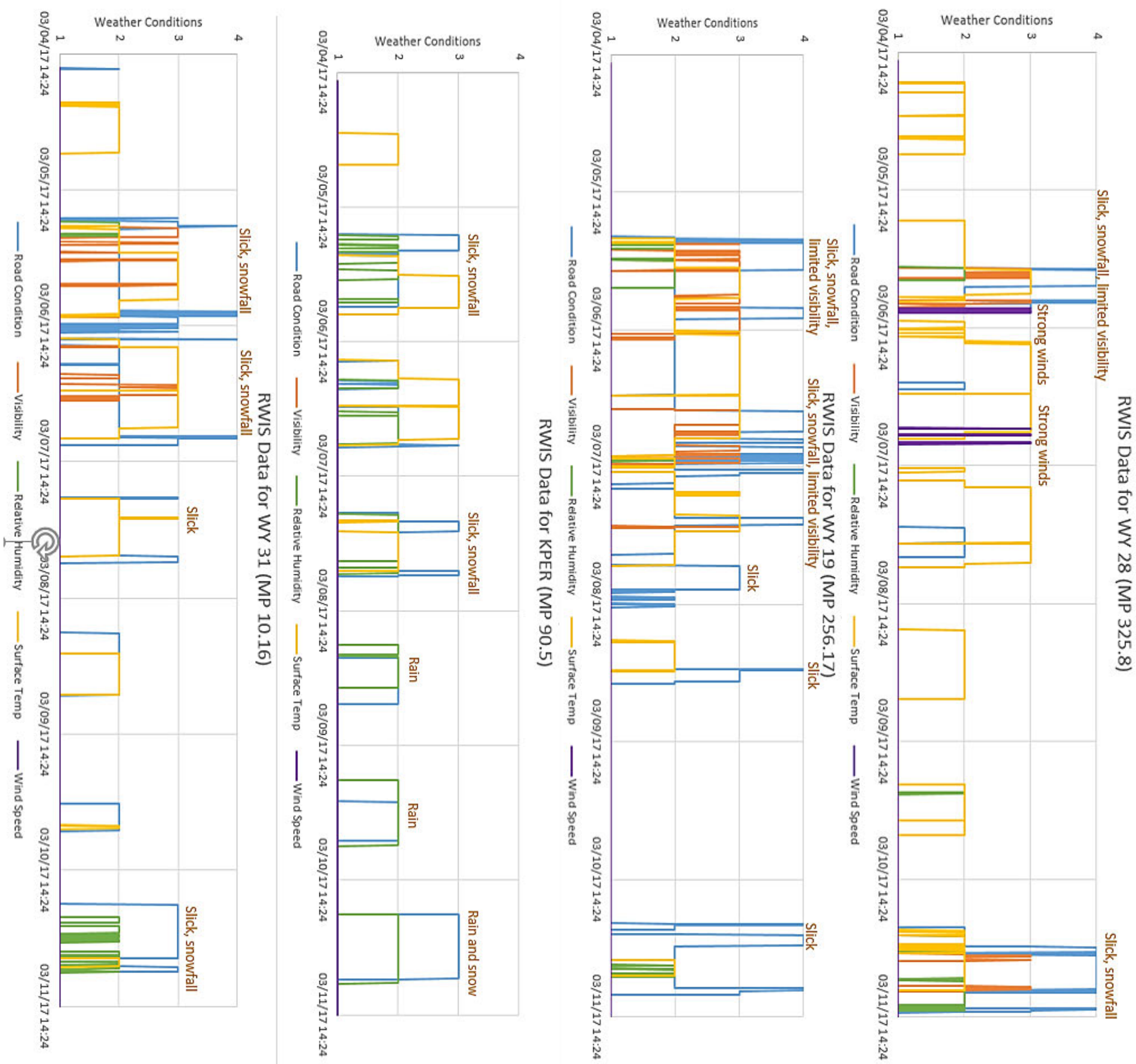


Figure 5-7. Weather Conditions for March 5 – 11th Storm Event (Source: WYDOT)

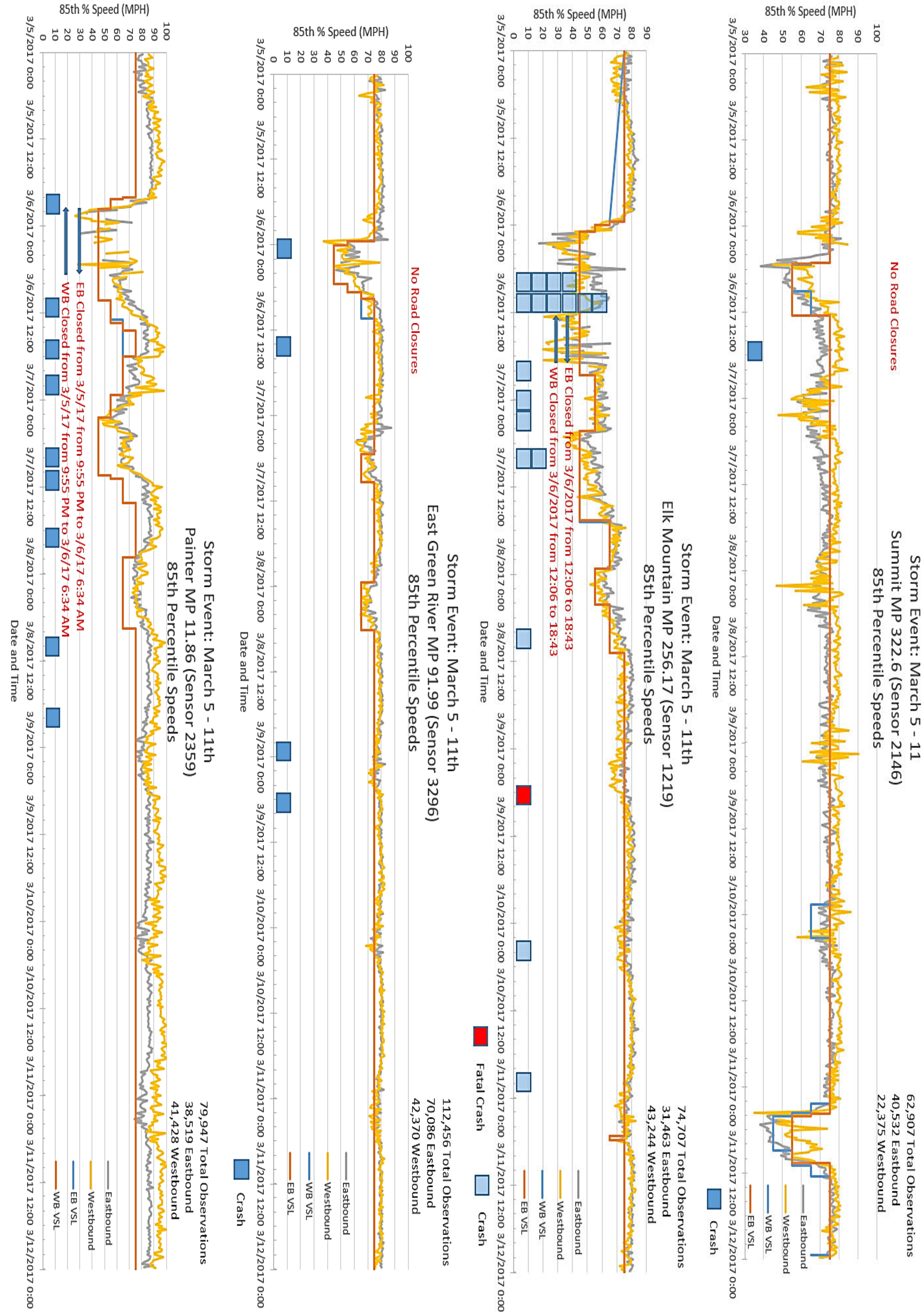


Figure 5-8. 85th % Speed, Crashes, and Closures for March 5 – 11th Storm Event (Source: WYDOT)

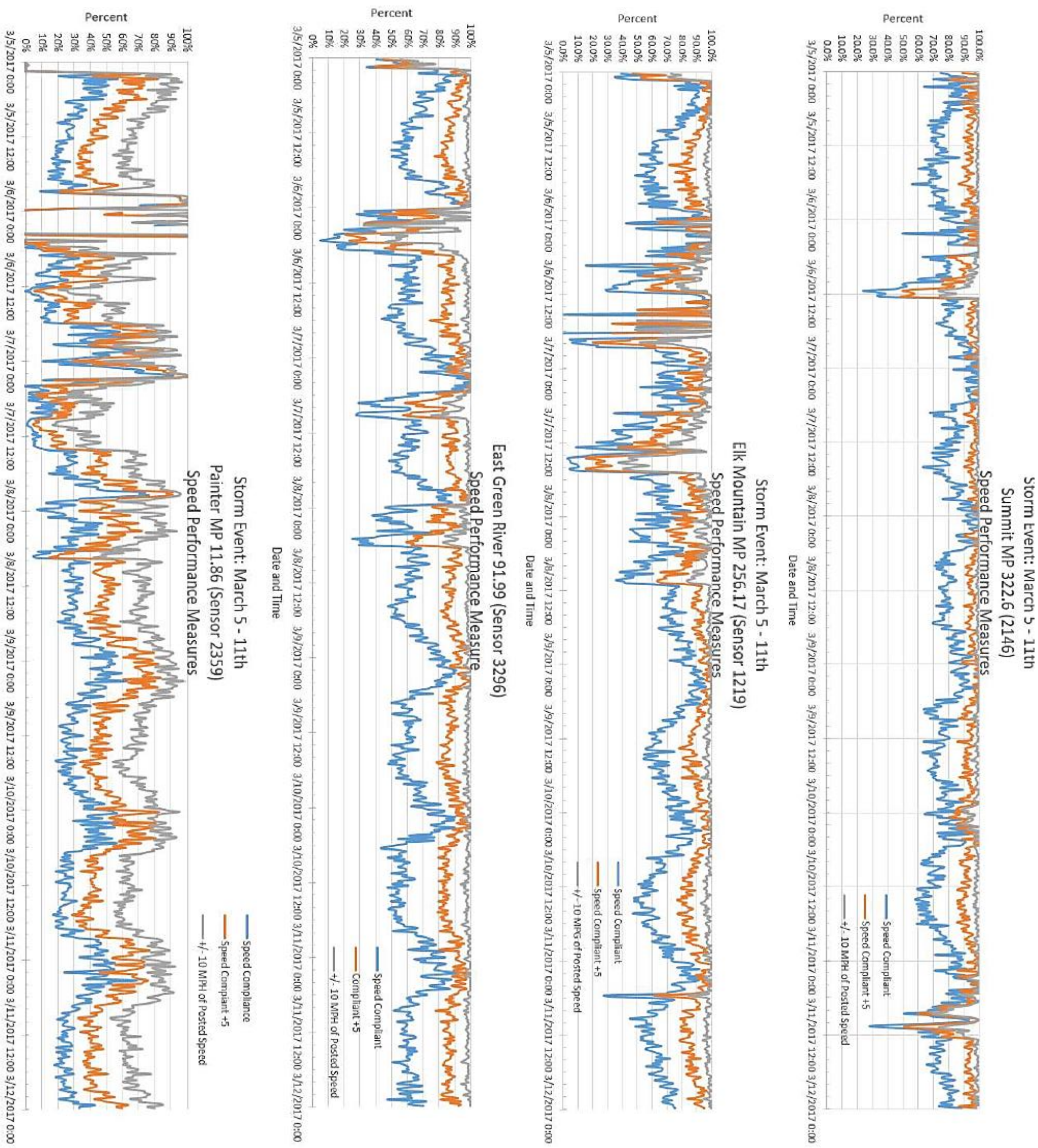


Figure 5-9. Speed Compliance for March 5 - 11th Storm Event (Source: WYDOT)

6 Pre-Deployment Data Analysis

6.1 Road Condition Reports

The road condition reporting measures focus on the quantity of reports (number of road condition reports), the coverage of the reports (number of road sections with at least one report), and the latency of the reports (average refresh rate of reports). We expect that the quantity of road reports and the coverage will increase during the CV Pilot deployment. Conversely, we expect the latency of reports will decrease. This section describes the final pre-deployment (baseline) conditions from which a comparison can be made with deployment data in Phase 3.

In order to make these calculations from the data collected (see Section 4.1), two important values were needed for each of the defined 56 weather events, those were:

- Number of unique reporting sections – There are a total of 56 reporting sections along the 402 mile I-80 corridor (28 reporting sections in each direction of travel). The number of reporting sections for each weather event were extracted from the raw data and used in some of the calculations below. The values ranged from a low of 4 sections for a fog event to a high of all 56 sections for several corridor-wide events.
- Hours of each weather event – The raw data contains the total number of hours for which at least one report was made for each weather event. These values were logged for each event and used in some of the calculations below. It is important to note that the hours per weather event logged are when a report was made, not the total number of hours the event took place (start and end dates/times) – these were not always the same. The values ranged from 2 hours for that same fog event to 486 hours for a major winter storm in January 2017.

It is expected during Phase 3 CV Pilot Deployment that the number and frequency of reports will increase with the use of the road condition reporting system (RCRS) onboard the snowplows (full deployment on I-80 as part of the CV Pilot). This system allows drivers to more easily make road reports and other issues encountered while operational during winter weather events. The data is also used to enhance the broad area traveler information disseminated from the TMC.

A summary of the calculated performance measures by weather event is provided in *Appendix F. Results of PMs 1-3.*

6.1.1 PM-1: Number of Road Condition Reports

Performance Measure: Number of road condition reports per section per day.

The average number of road condition reports per section per day during weather events was 4.3 reports. This is our final pre-deployment condition value. The value ranged from

1.4 to 12.0 with a median of 3.6. The larger the value results in more benefit to the WYDOT TMC by having more information about road conditions. The calculation was made by first dividing the total number of reports during a given weather event by the number of unique road reporting sections. Then, dividing that value by the fractional number of days (hours of the weather event divided by 24).

Maintenance personnel that are reporting the road condition reports are instructed to make a report by section every 2 hours, or when conditions change. The value of 4.3 reports per section per day is most likely lower than their instructions would indicate because they do not always feel a new report is necessary if conditions haven't changed in the past 2 hours.

The wide range in value per weather event (1.4 to 12.0) reflects the varying level of impact and changing conditions over the entire corridor. It is interesting to note that the average value for strong wind events which don't typically change often during the event was only 2.7 reports, while the average value for a fog event was 7.9 reports, which are more likely to change frequently during this type of event.

6.1.2 PM-2: Number of Road Sections With At Least One Report

Performance Measure: Number of road sections with at least one road condition report per hour.

The average number of road sections with at least one road condition report per hour during weather events was 5.0 sections. This is our final pre-deployment condition value. The value ranged from 1.4 to 10.5 with a median of 4.5 sections. The larger the value results in more benefit to the WYDOT TMC by having more information about road conditions. The total value per weather event was calculated by averaging the total number of road sections reported per hour within a given weather event.

The magnitude of the value for each weather event is highly dependent on the total number of road sections impacted by that event. Therefore, values tended to be higher for weather events that impact a larger portion of the corridor. For instance, the average number of road sections with at least one road condition report per hour during weather events that affect the entire corridor (all 56 sections rated at a moderate or high impact) was 8.0 sections. These weather events also tend to be longer duration events.

6.1.3 PM-3: Average Refresh Time of Road Reports

Performance Measure: Average refresh time of road conditions reported per section.

The average refresh time (in hours) of road conditions reported per section was 3.9 hours during weather events. This is our final pre-deployment condition value. The value ranged from 0.7 to 7.8 with median of 3.7 hours. In this case, the lower the value result in more benefit to the WYDOT TMC by having a higher frequency of road conditions reports. The value was calculated by taking an average of all the individual weather event values.

Review of the data does not indicate any definable trends as to why the refresh time varies with storms. It is possibly an indicator of intensity of the weather events or the magnitude of changing conditions within a weather event that results in a higher frequency of road condition reports being generated and sent to the TMC.

6.1.4 Analysis by Weather Category

The Wyoming Performance Measurement team analyzed the road condition data by weather category to determine if differences occurred for each PM 1-3 during different weather event types. Careful review of the data resulted in the following weather event types.

- Strong winds only
- Fog, low visibility
- Poor pavement conditions, no strong winds reported
- Poor pavement conditions with strong winds
- Extreme weather conditions with numerous high impact conditions

Table 6-1 summarizes the results of this analysis. The values represent averages of each storm included in each particular weather event type.

Table 6-1. Averages of Each Storm Included in Each Weather Event Type

Weather Event Type (Number of events)	Unique Sections	Storm hours	Number road condition reports	Number road sections	Average refresh time (hours)
Strong Winds Only (18)	34.2	26.3	2.7	3.5	4.3
Fog, Low Visibility (5)	15.2	9.4	7.9	3.0	2.9
Poor Pavement, no Winds (5)	29.2	26.8	5.5	5.4	3.7
Poor Pavement, Strong Winds (10)	24.1	15.4	5.5	3.9	3.3
Extreme Conditions (18)	51.2	117.1	3.8	7.2	4.4
Total Averages (56)	**35.7**	**52.1**	**4.3**	**4.9**	**3.9**

Some notable observations:

- Strong winds only events tend to have fewer reports and are less frequent than the average. This may be because drivers might not report when conditions aren't changing.
- Fog, low visibility events tend to have more reports reported more frequently due to the ever-changing conditions associated with fog events.
- Extreme weather conditions with numerous high impact conditions typically cover larger portions of the I-80 corridor and have much longer durations. However, the number and frequency of road reports tend to be about average.

These values will be used to compare like conditions during the post CV deployment during Phase 3 Pilot activities.

6.2 Commercial Vehicle Operator Surveys Results

The survey questions presented to the CVOP subscribers (commercial vehicle operators) focused on their level of satisfaction with specific information provided to them in the CVOP and their response to the information demonstrated by operational changes their managers make regarding commercial trips during weather events. As mentioned in Section 4.2, we received 129 responses to the survey. The distribution of the roles of the respondents is shown in Figure 6-1. Over 60% were drivers, about 25% were owner/operators, and just under 9% identified themselves as management. Drivers are typically supported by company dispatchers, but in some cases make travel decisions based on the conditions they are confronted with. Wyoming has numerous smaller trucking companies with small fleets that consider themselves owner/operators – they would likely not have a dispatch function and operate independently.

The following paragraphs describe the survey results for performance measures 8 and 9.

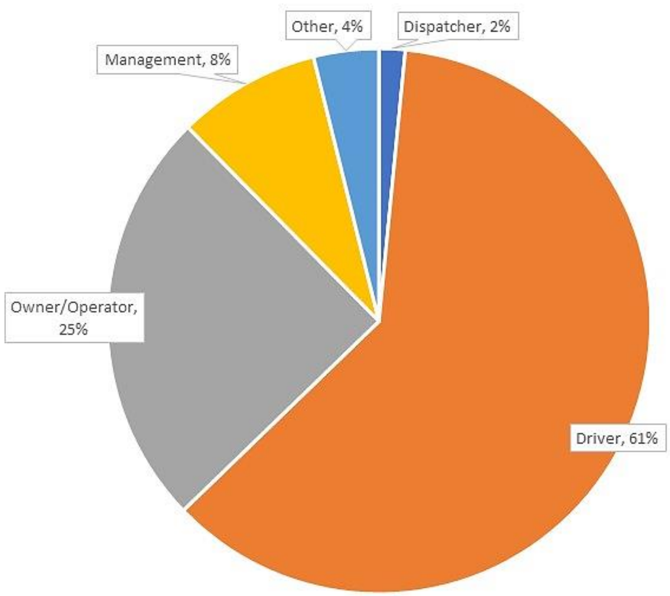


Figure 6-1. Survey Respondents Roles (Source: WYDOT)

6.2.1 PM-8: Commercial Vehicle Managers are satisfied with the information provided by the TMC

The overall satisfaction of respondents with the information provided on the CVOP was very high – 96.1% indicated that they were either very satisfied (75.2%) or somewhat satisfied (20.9%). The remaining 3.9% said they were neither satisfied nor dissatisfied. No respondent said they were dissatisfied with the information.

When asked about specific information provided (road weather forecasts, travel wind advisories, or other travel advisories), the responses were also very positive. Figure 6-2 illustrates the level of satisfaction with each of these specific information types. Again, the vast majority of respondents indicated that they either are very satisfied or somewhat satisfied with the CVOP information.

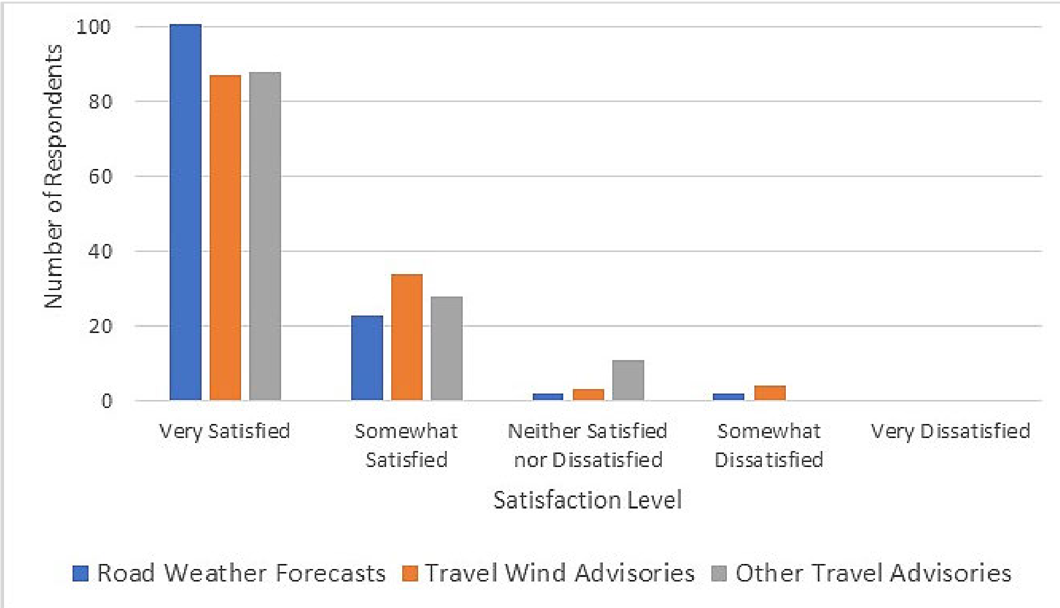


Figure 6-2. Respondents Level of Satisfaction with Three Specific CVOP Information Elements (Source: WYDOT)

6.2.2 PM-9: Number of operational changes made by fleet managers due to information from the TMC

Probably the most important survey question was related to how they use the information. Knowing that commercial trips are typically made regardless of weather and road conditions, it was interesting to learn in several cases operational changes were made during weather events. Table 6-2 indicates the relative frequency of operational changes respondents made when CVOP provided forecasted weather events.

Table 6-2. Frequency of Operational Changes

Operational Change	Always	Often	Sometimes	Rarely	Never	Totals
Change Routing	18 (14%)	30 (23%)	57 (45%)	17 (13%)	6 (5%)	**128**
Advance or Delay a Trip	20 (16%)	27 (21%)	60 (47%)	18 (14%)	4 (3%)	**129**
Notify Driver	49 (40%)	38 (31%)	20 (16%)	2 (2%)	14 (11%)	**123**
Cancel Trip	4 (3%)	7 (5%)	30 (23%)	39 (30%)	48 (38%)	**128**

Fleet managers and drivers do make operational changes when alerted to weather events that may affect their trip. Anecdotal input from trucking company representatives during early project stakeholder meetings indicated that they don't cancel a trip unless the road is closed, and that the weather events that impacted their operations the most were strong winds and icy conditions. However, more often than not they will make a route change or change the timing of their trip. Additionally, almost always the driver will be notified which helps them be more aware and prepared for the conditions. This data is strong indicator that the information provided through their subscription to CVOP is very important to their decisions regarding upcoming trips and maintaining a safe and profitable business.

6.3 Speed

The following sections provide the methodology and preliminary analysis results for the two of the three speed related performance measures (see Table 6-3). PM-16 relates to connected vehicle speed compliance and therefore is not included in the baseline activities.

Table 6-3. Speed Related Performance Measures

No.	Performance Measure	Target
Improved Speed Adherence and Reduced Speed Variation		
14	Total vehicles traveling at no more than 5 mph over the posted speed (compare before and after CV Pilot)	20% improvement over baseline of total vehicles traveling no more than 5 mph over posted speed during CV Pilot. Baseline will determine what percentage is traveling no more than 5 mph over posted speed prior to CV Pilot.
15	Total vehicles traveling within +/- 10 mph of the posted speed (compare before and after CV Pilot)	20% improvement over baseline of total vehicles traveling within +/- 10 mph of the posted speed during CV Pilot. Baseline will determine what percent is traveling within +/- 10 mph of the posted speed prior to CV Pilot
16	Speed of applicable connected vehicles are closer to posted speed when compared to non-connected vehicles	Connected vehicles are 20% closer to posted speed

6.3.1 PM-14: Speed Compliance

PM-14 focuses on speed compliance as defined by the number of vehicles traveling no more than 5 mph over the posted speed. Analysis of this performance measure requires use of the processed speed data where individual vehicle speeds can be compared to the posted speed. As described in Section 4, the direction of travel for each speed observation must first be determined. The raw speed data contains information about the lane number for each speed observation, but this is dependent on which side of the road the sensor is installed on. Sensors can be installed adjacent to the inside lane of the westbound or eastbound travel lanes. The Wavetronix speed sensors define lane 1 as the lane closest to the sensor. During the speed sensor data processing (see Section 4.4) the speed observations are divided into sensors with eastbound and westbound sensor installations so that the lane numbers can be attributed to either eastbound or westbound travel. Once this is accomplished, the speed observation can be associated with either the eastbound or westbound speed limit signs.

Speed limit signs can be either static or variable. The maximum speed for most of the I-80 corridor is 75 mph with some sections of 80 mph added in the last few years. There are a few short sections of 65 mph near the Green River tunnel and through a westbound section of Telephone Canyon just east of Laramie. Speed observations for static sections were assigned a speed sensor ID of 1 for 75 mph and a 2 for 80 mph. There are no 65 mph static speed limit areas associated with a speed sensor.

Once the posted speed for each observation was determined, PM 14 was calculated simply by adding 5 mph to the posted speed and determining if the observed speed was below that value. The variable “SpeedCompliant5” was assigned a value of 1 if the observation was compliant and a 0 otherwise.

Figure 6-3 shows the speed compliance results for the 56.4 million speed observations that passed data quality screening by storm category. Results show speed compliance percentages exceeding 80% for the majority of the storm categories. The highest compliant storm category was category 1, which is for ideal and low impact storm conditions. The lowest compliance (53.4%) was found with storm category 5, which is for storms with wet pavement and moderate wind conditions. Storm category 4 (low visibility) and 6 (ice with high winds) also had lower compliance rates. See Section 4.6.1 for more information on storm categories.

Implementation of the CV Pilot program is expected to improve speed compliance by providing connected vehicles with in-vehicle warnings and posted speed information. All vehicles are also expected to be impacted by the CV Pilot since the variable speed limit and dynamic message sign systems will be improved through more timely and accurate road condition information. This leads to better informed drivers and to more appropriate setting of variable speed limits, both of which are expected to improve compliance.

Low compliance can occur due to drivers generally speeding in static roadway segments or in areas where the maximum variable speed limit is set. Noncompliant drivers can also be feeling that the reduced speed of variable speed limits at that time is too low for current conditions.

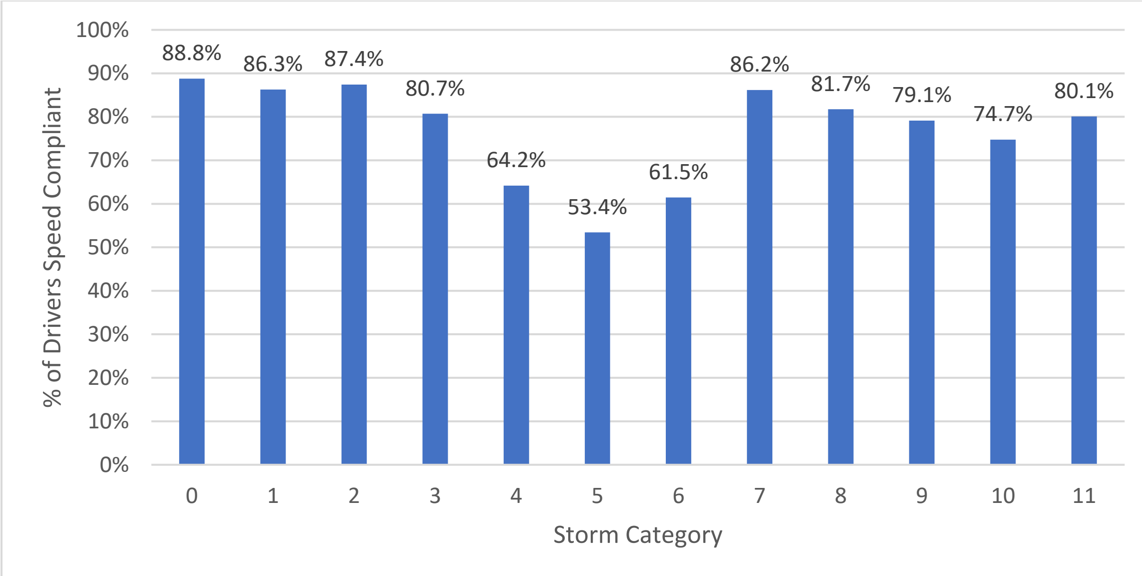


Figure 6-3. Baseline Speed Compliance Percentages by Storm Category (Source: WYDOT)

For 20 of the sensors included in the baseline data, the speed compliance percentages were determined at the individual sensor level. Figure 6-4 illustrates the results for Sensor 2359, which is located in a variable speed limit zone at milepost 11.86, east of the town of Evanston. For this sensor, no data for storm categories 6, 8 or 10 was recorded. Speed compliance at this sensor is relatively low compared to the aggregate results, with values ranging from 43.6% to 74.1%. Speed compliance results for all individual speed sensors can be found in Appendix G.

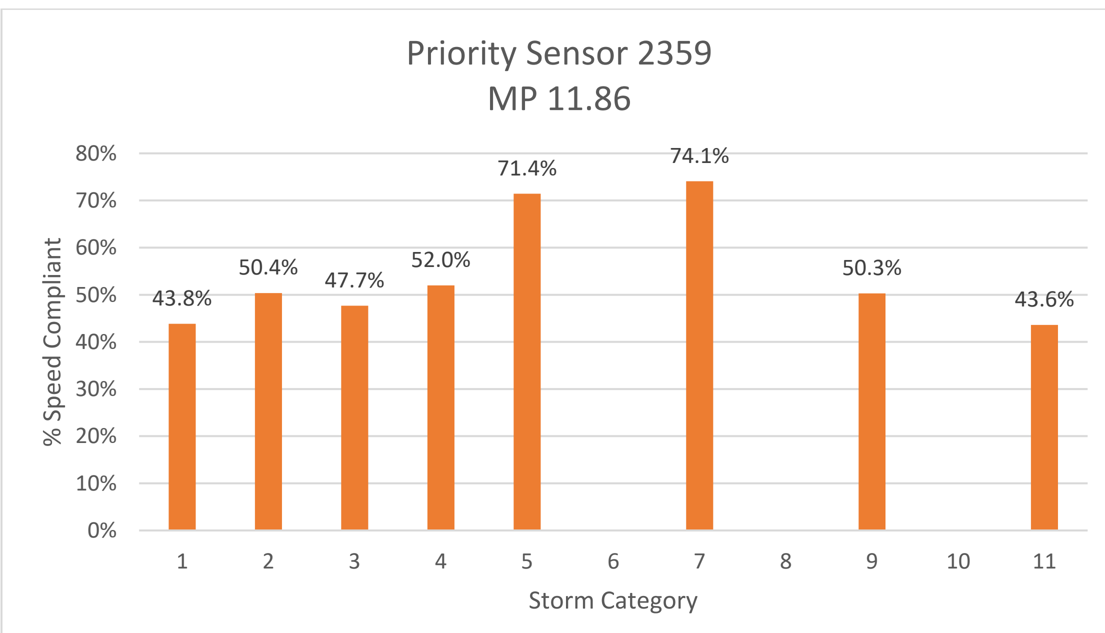


Figure 6-4. Baseline Speed Compliance Percentages by Storm Category for Sensor 2359 - MP 11.86 (Source: WYDOT)

Implementation of the CV Pilot program is expected to improve speed compliance by providing connected vehicles with in-vehicle warnings and posted speed information. All vehicles are also expected to be impacted by the CV Pilot since the variable speed limit and dynamic message sign systems will be improved through more timely and accurate road condition information. This leads to better informed drivers and to more appropriate setting of variable speed limits, both of which are expected to improve compliance.

Note that many of the speed sensors are located along with the variable speed limit signs because of limited power and communication along the rural corridor. It is generally recognized that speed compliance would be higher near the sign as opposed to locations away from the sign. Our performance measure analysis approach is to compare before and after CV deployment values at the same location and it is understood that both the before and after values may be different if measured at a location away from the speed limit sign. Only the relative change in values will be captured by the analysis.

6.3.2 PM-15: Speed Variation

PM-15 is a measure of speed variation by determining the number of vehicles that are within 10 mph above and below the posted speed. Using the same processed speed data as PM-14, the speed variation measure compares the difference between the posted and observed speed. If this absolute value of this difference is less than 10 then the observation is considered within the buffer. The variable “SpeedBuffer10” was assigned a 1 if the observation was within the buffer and a 0 otherwise.

Figure 6-5 shows the speed buffer results for the 56.4 million speed observations that passed data quality screening by storm category. Results show speed buffer percentages exceeding 60% for the half of the storm categories. The highest percent of observations within the buffer at 71.6% was for storm category was category 1, which is for ideal and low impact storm conditions. The lowest compliance (45.0%) was found with storm category 5, which is for storms with wet pavement and moderate wind conditions. Storm categories 7 through 10 all had percentages below 60% with these categories representing a wide range of conditions. See Section 4.6.1 for more information on storm categories.

Compared to the speed compliance rates, these percentages are much lower suggesting that drivers are selecting speeds well below the posted speeds since speeds more than 10 mph above the speed limits would be listed as non-compliant in PM 14.

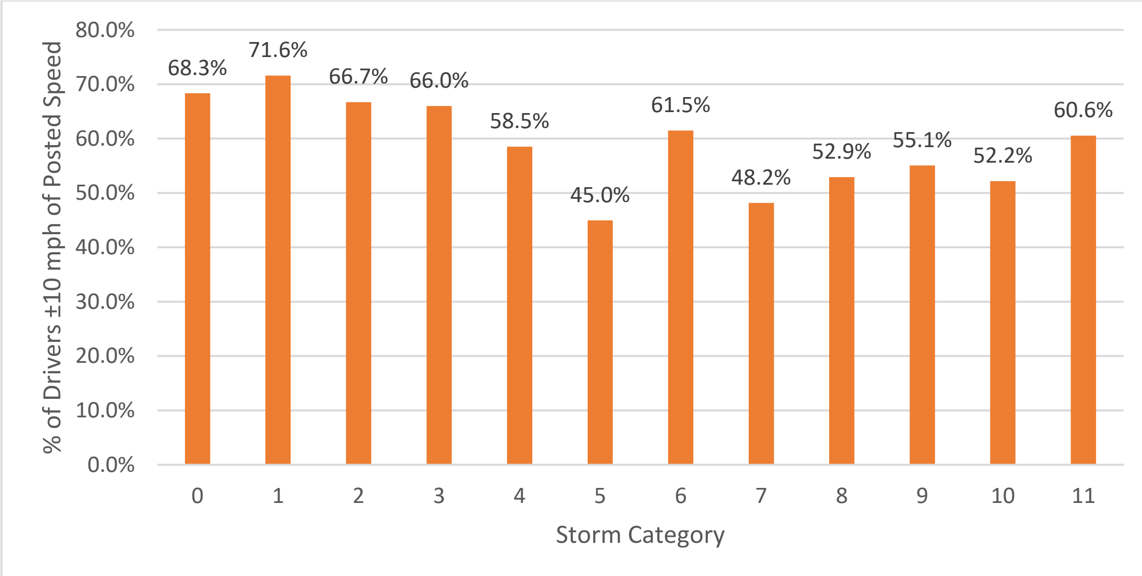


Figure 6-5. Baseline Speed Buffer Results by Storm Category (Source: WYDOT)

For 20 of the sensors included in the baseline data, the speed buffer percentages were determined at the individual sensor level. Figure 6-6 illustrates the results for Sensor 2359, which is located in a variable speed limit zone at milepost 11.86, east of the town of Evanston. For this sensor, no data for storm categories 6, 8 or 10. Speed buffer percentages at this sensor are higher than those for the aggregate results, with values ranging from 55.2% to 69.1%, which could be attributed the ability of the corridor to set variable speed limits based on conditions, although the majority of the speed observations in the baseline were collected in VSL zones. Speed buffer results for all individual speed sensors can be found in Appendix G.

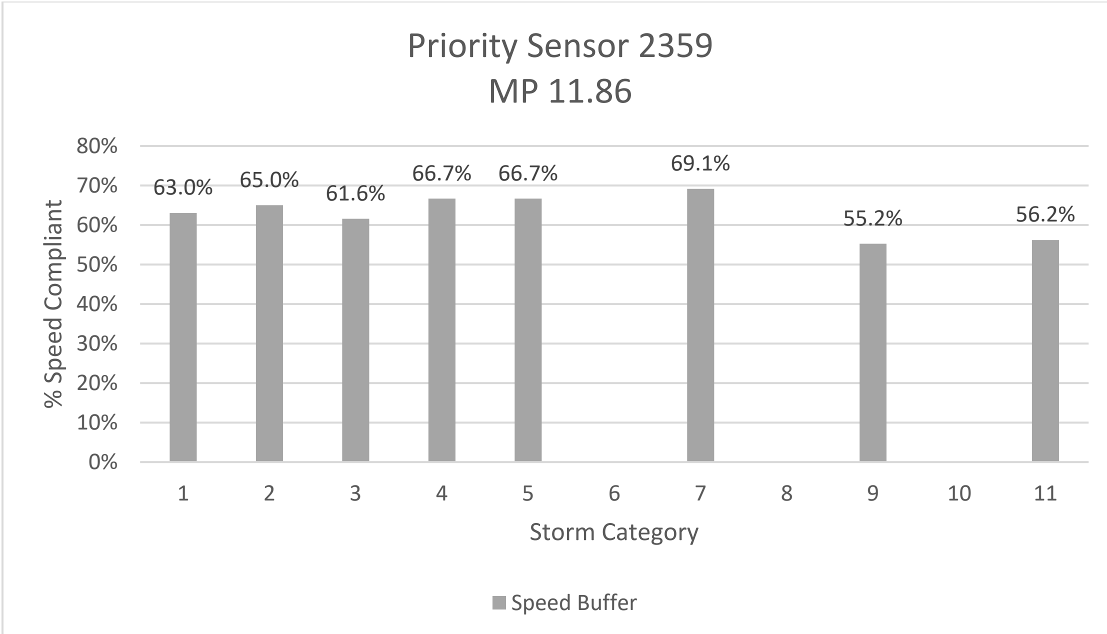


Figure 6-6. Speed Buffer Percentages for Sensor 2359 (Source WYDOT).

Implementation of the CV Pilot program is expected to improve speed variance as measured by the speed buffer by providing connected vehicles with in-vehicle warnings and posted speed information. All vehicles are also expected to be impacted by the CV Pilot since the variable speed limit and dynamic message sign systems will be improved through more timely and accurate road condition information. This leads to better informed drivers and to more appropriate setting of variable speed limits, both of which are expected to increase the number of vehicles driving within the speed buffer. Reduction in speed variation is important since there is a relationship between increased speed variation and increased crashes. Given the limited duration of Phase 3 of the project for monitoring the CV Pilot, it is believed that the observation of speeds will be a critical early indicator of changes in the corridor safety.

6.4 Safety

The following sections describe the methodology and preliminary analysis results for four of the five crash-related performance measures, see Table 6-4. PM-17 relates to connected vehicle crashes and therefor is not included in the baseline activities. For the post-deployment data, connected and non-connected vehicles in each of the safety performance measures will be identified in the data.

Post-deployment crash data will be analyzed using the same methodology and assumptions as described above for the baseline data.

Table 6-4. Safety Performance Measures

No.	Performance Measure	Target
Reduced Vehicle Crashes		
17	Number of connected vehicles involved in a crash • Initial crashes • Secondary crashes[1] (total and specifically rear-end crashes	N/A
18	Reduction of the number of vehicles involved in a crash (compare a 5-year average before Pilot to CV Pilot data) • Track connected versus non-connected vehicles	25% reduction in the number of vehicles involved in a crash
19	Reduction of total and truck crash rates within a work zone area (compare a 5-year average before Pilot to CV Pilot data) • Track connected versus non-connected vehicles	10% reduction in total and truck crash rate within work zones
20	Reduction of total and rates of truck crash along the corridor (compare a 5-year average before Pilot to CV Pilot data) • Track connected versus non-connected vehicles	10% reduction in total and truck crash rates
21	Reduction of critical (fatal or incapacitating) total and truck crash rates in the corridor (compare a 5-year average before Pilot to CV Pilot data) • Track connected versus non-connected vehicles	10% reduction in total and truck critical crash rates

6.4.1 PM-18: Number of Vehicles Involved in a Crash

This performance measure focuses on the number of vehicles (trucks and non-trucks) involved in each crash, which is reported by the responding officer at the scene of the crash. A car that hits an animal would be a single vehicle collision, while a rear-end collision would have at least two vehicles involved in the crash. Each crash report includes data on the number of vehicles involved.

This PM will be useful at gauging how effective the CV technology is in reducing the number of vehicles involved in crash events. Vehicles implemented with CV technology will alert drivers of hazardous road conditions or crashes ahead. The project hopes that this alert will give drivers more time to react and to prepare for the conditions. Prepared drivers will crash less and collisions will involve fewer vehicles; large pileups and secondary crashes should be lowered with the implementation of CV technology. The I-80 corridor is prone to vehicle pile-ups with the number of vehicles involved in these crashes often above 10. The use of CV technology holds promise for reducing these types of crashes.

PM 18 considers the crash history from 2010 through June of 2017 for baseline conditions. Because this PM does not rely on traffic information necessary for determining crash rates, it was easy to sum the crashes from 2010-2017 by number of vehicles involved and create a histogram (as shown in Figure 6-7). This figure shows that the majority of crashes involve a single vehicle. The largest number of vehicles involved in a crash in the dataset is 28 vehicles. Figure 6-8displays this information for truck crashes, which are defined when at least one vehicle involved in the crash is a truck.

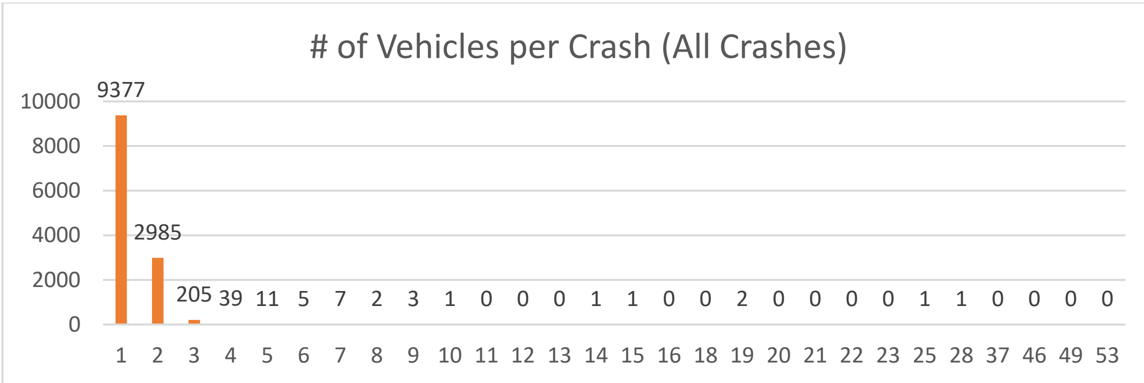


Figure 6-7. Number of Vehicles Involved in Crash without Secondary Crashes (Source: WYDOT)

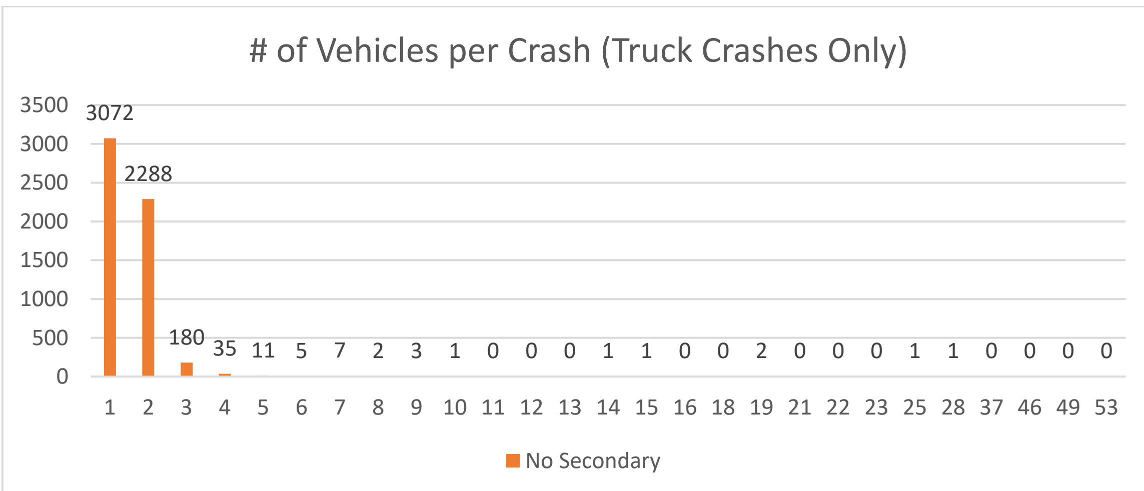


Figure 6-8. Number of Vehicles Involved in Crash for Trucks without Secondary Crashes (Source: WYDOT)

However, this data point does not consider secondary crashes. A secondary crash is typically defined as a crash that occurs after the initial incident and is caused by the initial crash. Examples of this include but are not limited to: a car swerving and hitting the median to avoid the initial crash and a vehicle going in the opposite direction crashing because the driver was looking at the initial incident. Judging whether a crash is a secondary crash is not exact, and is most easily identifiable by first responders. However, there is no way of recording it with the current reporting methods. Considering secondary crashes when considering the impact of CV technology in reducing the number of vehicles involved in a crash. Consideration of secondary crashes is particularly important for capturing the large, multi-vehicle crashes that occur on the project corridor. When a large pileup occurs, multiple responders are sent to the scene, resulting in separate crash reports.

Because there is no method for recording secondary crashes, data analysis must be performed to determine whether a crash is considered a secondary crash or not. There have been previous studies and academic articles that utilize different methodologies to identify secondary crashes and they have two common elements: length and time

(Kristoff, 2017; Pigman, Green, & Walton, 2011). Length regards to the distance (in miles) from the initial crash in either direction and time refers to a time period directly after the initial crash. Crashes occurring within a certain time period and distance from the initial crash get classified as a secondary crash.

For the purposes of this project it has been decided that a crash will be a secondary crash if it happens within one mile in either direction and within an hour and fifteen minutes of an initial crash. Because this corridor experiences low levels of traffic congestion, any crash occurring more than a mile away would be highly unlikely to be a result of an initial collision. The time period was chosen to increase the likelihood of capturing the large pile-ups crashes that occur.

It should be noted that this definition is considerably different than what is found in the literature. When considering the impacts of CV technology on the corridor, the focus is on operations during weather events. Traditional secondary crash definitions focus more on the impacts of backward forming shockwaves, rubber necking at crash locations, and temporary lane reductions and lane maneuvering. Given the rural nature of this corridor, these types of impacts are relatively low due to low traffic density. Much more likely are drivers entering a roadway segment where road and weather conditions are increasing the risk to all drivers causing a series of crashes near in time and location to each other. These are the types of crashes the CV Pilot technology is being designed to address, therefore the definition of secondary crashes for this Pilot was developed to best capture these effects.

A function was created for each crash in the data set to search the entire database for a crash that was within 75 minutes and with 1 mile. Crashes that occurred 75 minutes apart or exactly 1 mile apart were included as secondary crashes. Once all of these crashes were isolated, each secondary crash was given the same crash report record as the initial one under the secondary crash field, which allows the secondary crashes to be combined with its initial crash to create a single crash report. After these filters had been applied to all crashes, if it met both criteria the collision was deemed a secondary crash. For the time period analyzed, 1,109 crashes of the 11,668 crashes were classified as a secondary crash. Once these secondary crashes were identified, they were reassigned the initial crash's report number and using a pivot table the number of vehicles involved in each crash were recalculated and the following histogram was the result—see Figure 6-9 and Figure 6-10. When the two histograms are compared, the differences become obvious due to the effects of the secondary crash definition on the number of vehicles involved in a crash—see Figure 6-11, which only shows crash number for crashes involving 5 or fewer vehicles.

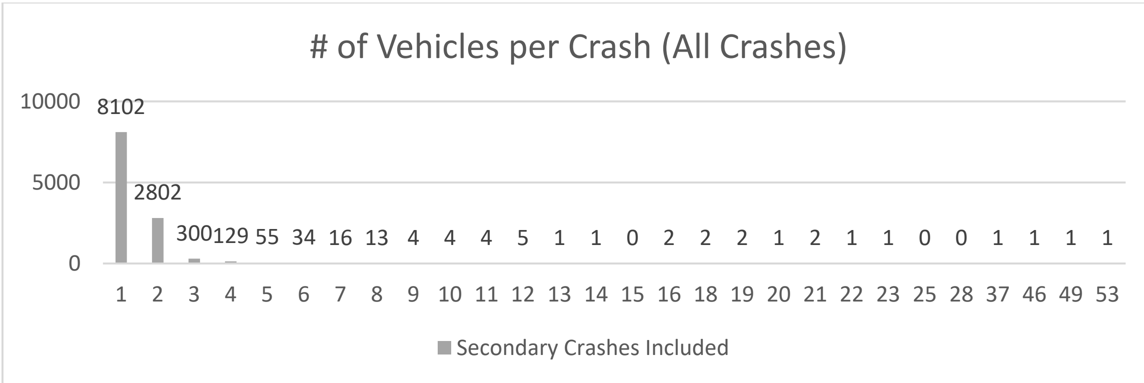


Figure 6-9. Number of Vehicles Involved in Crash with Secondary Crashes (Source: WYDOT)

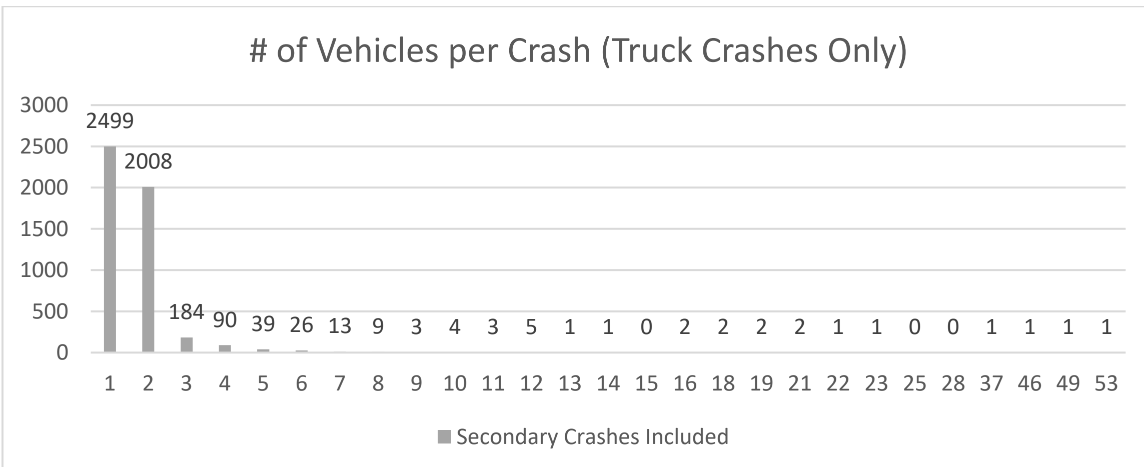
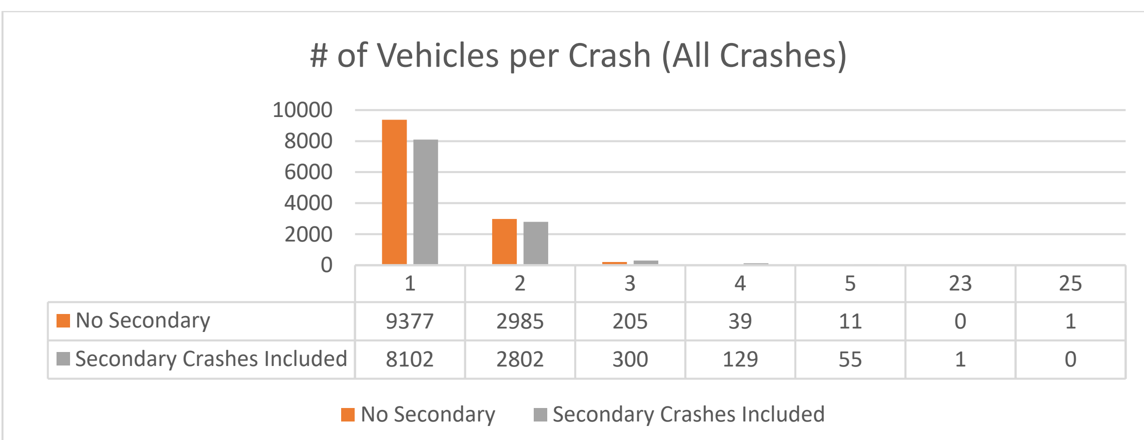


Figure 6-10. Number of Vehicles Involved in Crash with Secondary Crashes (Truck Crashes) (Source: WYDOT)



	1	2	3	4	5	23	25
No Secondary	9377	2985	205	39	11	0	1
Secondary Crashes Included	8102	2802	300	129	55	1	0

Figure 6-11. Comparison with and without Secondary Crashes (Source: WYDOT)

As discussed earlier, deciding the time and length interval for classifying secondary crashes was an important aspect of the analysis. There was a high profile 90-vehicle pileup on I-80 in April 2015 and these graphs show the largest crash at 28 cars. Ideally there would be a data point with a crash showing the number of vehicles at 90. But in order to make that happen, the length and time intervals had to be expanded so much that the secondary crash numbers became unreasonably large. There are multiple reasons for this happening, with a crash as large as the 90 vehicle pileup, the first responders are more worried with checking on safety and clearing the road than the crash reports. Reports are recorded much later and, with that time delay the multiple reports submitted had different times and the crash was so long that some reports had different mileposts markings. That crash did end up being the largest recorded at 53 with some additional smaller ones that fell out of the time or outside of the mileage.

This data will be evaluated again once CV technology has been implemented. The same method for identifying secondary crashes will be used and the calculation of the number of vehicles involved in each crash will be reapplied. Hopefully vehicles that have CV technology will avoid secondary crashes and will have smaller crashes because of the extra information available to the driver.

If the crash is considered a secondary crash, then the variable “SecondaryCrash” is assigned the crash report number of the primary crash. If the crash record is not linked to another crash, then this variable is set to 0.

6.4.2 PM-19: Work Zones

Tracking crashes within work zones is an important measure of traffic safety. Generally, highways and interstates are void of pedestrians. In work zones, however, workers are out and exposed to the hazards of driver errors. Also, the presence of additional signs and work zone equipment creates additional potential hazards that drivers must avoid. By establishing a baseline of crashes in work zones, implementations of the Connected Vehicle capabilities can be monitored for effectiveness and work zone safety can be improved.

Performance Measure 19 measures the crashes that occur within work zones on the Wyoming Interstate 80 corridor. The overall goal of this performance measure is a 10% reduction in total crashes and truck crashes within work zones on the corridor. This will be measured by establishing a baseline crash rates for work zones prior to the implementation of the CV Pilot technology, and comparing the baseline to crash rates measured after the CV Pilot technology is implemented. This portion of the report provides the crash data measured in work zones, defines the parameters set for work zones, and explains the methodology used for analyzing the data and compiling it into work zone crash rates.

The Model Minimum Uniform Crash Criteria (MMUCC) defines a work zone as “an area of a traffic way where construction, maintenance, or utility work activities are identified by warning signs/signals/indicators, including those on transport devices (e.g., signs, flashing lights, channelizing devices, barriers, pavement markings, flagmen, warning signs and arrow boards mounted on the vehicles in a mobile maintenance activity) that mark the beginning and end of a construction, maintenance or utility work activity.” Currently, the Wyoming Department of Transportation does not track if a crash occurred inside a work zone. In addition, there is no data that provides the exact placement of the work zone traffic control devices. This posed some difficulty in defining the parameters of a work zone, as well as trying to determine whether a crash occurred within a work zone.

In order to provide consistent data for this project, a work zone is defined as the roadway from beginning mile marker to end mile marker as defined in the construction console, from beginning project date to end project date, twenty-four hours a day, seven days a week, in both directions of travel. While a construction project often occurs only on one side of the Interstate, the data provided from the construction console (see Section 0) did not specify the direction of travel for the construction projects. In addition, the crash data did not indicate the direction of travel a crash occurred. Very few of the construction projects in the database indicated specific hours or days of the week for operations; therefore, these restrictions were removed from all projects.

A work zone crash is any crash that occurs within the parameters defined by the work zone. The first step in identifying work zone related crashes was to analyze the bulk crash data provided by the State of Wyoming. Upon inspection of the bulk crash data, it is apparent that “work zone” is not a parameter that the State of Wyoming tracks in this data. The only indication that a crash occurred in a work zone is found under the column heading “First Harmful Event”. Under this heading, crashes where vehicles struck a work zone channeling device or work zone maintenance equipment are identified. There is no indication of any other type of collision, such as a rollover or rear-end, that may have occurred inside a work zone. Table 6-5 shows a total of 51 crashes that were identified from 2013 to 2016 using only the bulk crash data, which accounts for approximately 9% of the total work zone crashes that were later identified using the methodology outlined below.

Table 6-5. Work Zone Crashes, 2013-2016.

First Harmful Event	2013	2014	2015	2016	Total
Work Zone Channeling Device	6	7	11	20	44
Work Zone/Maintenance Equipment		2	4	1	7
Total	**6**	**9**	**15**	**21**	**51**

Identifying crashes that occurred in work zones required additional information. WYDOT provided their Construction Console for this information. The WYDOT Construction Console is an internal database that tracks their construction and maintenance projects across the state of Wyoming. It provides valuable information such as start and end dates of projects, and beginning and ending mile markers of projects. Using this information in conjunction with the bulk crash data provided a consistent method for identifying work zone crashes.

The WYDOT Construction Console was not implemented until 2012, so a begin date of January 1, 2013 was chosen for the beginning of data analysis for work zone crashes. To identify work zone crashes in the bulk base data, the WYDOT Construction Console was referenced. If a crash occurred within the start and end times and the beginning and ending mile markers for a project in the Construction Console, then the crash was identified as a work zone crash.

Table 6-6 shows the total crashes and total work zone crashes that occurred in the I-80 corridor from 2013 through 2017. There was a total of 7,898 crashes in the corridor, and 934 of these crashes occurred within work zones accounting for almost 12% of all crashes. The 632 work zone crashes from 2013-2016 are considerably higher than the 51 crashes identified by using bulk base data indicators alone and should be viewed as more representative of the work zone crash history in the corridor. Table 6-8 contains work zone crash information for truck crashes where at least one vehicle involved in the crash was identified as a truck.

Table 6-6. Work Zone Total Crashes using Construction Console Data, 2013 - 2017

Crash Type	2013	2014	2015	2016	2017
Non-WZ Crash	1,462	1,539	1,195	1,358	1,410
Work Zone Crash	82	53	214	283	302
Total	1,544	1,592	1,409	1,641	1,712
Percent in Work Zone	5.31%	3.33%	15.19%	17.25%	17.64%

Table 6-7. Work Zone Truck Crashes using Construction Console Data, 2013 - 2017

Crash Type	2013	2014	2015	2016	2017
Non-WZ Crash	684	737	495	642	607
Work Zone Crash	33	22	111	152	111
Total	717	759	606	794	718
Percent in Work Zone	4.60%	2.90%	18.32%	19.14%	15.46%

If the crash is considered work zone related, then the variable "WorkZone" in the processed crash data is assigned the project ID from the construction console dataset. If the crash record is not linked to a work zone, then this variable is set to 0. Crash records prior to 2013 have "N/A" for the "WorkZone" Variable and crashes.

Using the average daily vehicle travel and average daily truck travel values for each year from section 4.6.5, work zone and work zone truck crash rates were calculated using the work zone crashes and truck work zone crashes reported in Tables 6-6 and 6-7 and are shown in Table 6-8. Since construction console data is only available from 2013 and 2017 AADT and AADTT values were not yet published, only the years 2013 to 2016 are reported. More detailed information on the calculation of crash rates for all safety performance measures can be found in section 6.4.3.

Table 6-8. Work Zone and Work Zone Truck Crashes Rates, 2013 - 2017

Crash Type	2013	2014	2015	2016	Avg
Work Zone Crash	0.159	0.117	0.029	0.046	0.088
Work Zone Truck Crash	0.147	0.129	0.026	0.042	0.086

6.4.3 PM-20: Crash Rates

Crash rates can provide useful information about how safe a roadway or section of roadway is. This performance measure deals with crash rates for both passenger vehicles and trucks along the corridor. The objective is to establish a historical baseline of crash rates and statistics that will be compared against the post CV deployment data. Creating these baseline crash rates and normalizing the data for variables such as weather and traffic volume will allow our team to measure the performance of CV technology with regards to safety along I-80.

For determination of crash rates, the *BulkBase* crash dataset that includes all crash reports along the corridor from 2010 through December 2016 was used (see Section 4.5). The traffic volume data discussed in Section 4.6.5 was used for calculating rates. ADT values for 2017 are not yet available from the WYDOT traffic program so 2017 crash rates cannot be calculated at this time.

To quantify our crash rates, a crash Rate per Million Vehicles Miles Travelled method (RMVMT) was used using crashes for each year. This equation, see Equation 1, is a function of the number of crashes during a given year, the length of the roadway over which the crashes occurred, and the traffic volume expressed as an average, annual daily traffic volume (AADT). If the rate is for a time period less than a year then the number of days is adjusted down from 365 and a Monthly Factor (MF) is used to adjust the AADT values.

Equation 1. Crash Rate per Million Vehicle Miles Traveled (RMVMT)

$$RMVMT = \frac{(A)(10^6)}{(L)(AADT)(MF)(365)}$$

A = # of crashes
L = Length of section
MF = Monthly factor (when applicable)
AADT = Annual average daily traffic (both directions)

Crash rates can be calculated for different subsections of the corridor. For the initial analysis, rates were calculated for the entire corridor and by traffic volume segments and variable and non-variable speed limit segments. Table 6-8 provides the overall corridor rates for total and truck crash rates. Length-based AADT and AADTT weighted averages were used for calculation of these rates.

Table 6-8. Total Corridor Crash and Truck Crash Rates, 2010-2016

Year	Crash Rate	Truck Crash Rate
2010	1.448	0.658
2011	1.413	0.763
2012	1.114	0.714
2013	1.361	0.807
2014	1.396	0.807
2015	1.126	0.646
2016	1.353	0.944

Table 6-9 shows the calculated RMVMT values for the VSL and non-VSL segments—see *Appendix B. Corridor Devices* for information on the roadway segment definitions for the variables speed limit and non-VSL (i.e. static) corridors. These values are fairly consistent, although there are a couple of outliers in the data, specifically, sections N1 and N3 for total crash rates. Sections V1, V3 and V4 have large truck crash rates for 2016. This table will act as our baseline and will be compared to the post CV technology deployment data.

Table 6-9. VSL and non-VSL Roadway Segment Crash Rates, 2010-2017

Crash Rate per Million Vehicle Miles Traveled (RMVMT)								
Section ID	2010	2011	2012	2013	2014	2015	2016	Avg
N1	1.08	1.13	0.83	0.83	0.89	0.98	1.28	1.00
V1	1.60	1.09	0.87	1.00	1.26	0.87	1.12	1.12
N2	0.63	0.64	0.63	0.45	0.48	0.67	0.74	0.61
V2	1.20	1.08	0.99	1.22	0.97	0.97	1.55	1.14
N3	0.72	0.83	0.59	0.76	0.78	0.59	0.76	0.72
V3	1.12	1.62	1.26	1.26	1.35	0.95	1.11	1.24
N4	1.07	0.86	0.94	0.93	0.88	1.02	0.76	0.92
V4	1.29	1.28	0.92	1.00	1.09	0.98	0.95	1.07
N5	0.73	0.61	0.72	0.84	0.78	0.61	0.77	0.72
Crash Rate per Million Vehicle Miles Truck Traveled (RMVMTT) (Trucks)								
Section ID	2010	2011	2012	2013	2014	2015	2016	Avg
N1	0.84	0.84	0.56	0.56	0.70	0.86	1.37	0.82
V1	1.50	0.83	0.76	0.83	1.13	0.67	1.46	1.03
N2	0.49	0.55	0.62	0.41	0.44	0.61	0.80	0.56
V2	0.88	0.96	0.40	1.06	0.86	0.73	0.94	0.83
N3	0.64	0.72	0.61	0.84	0.75	0.54	0.90	0.71
V3	1.00	1.79	1.49	1.50	1.53	0.94	1.69	1.42
N4	0.62	0.69	1.18	1.16	0.90	1.04	0.81	0.91
V4	1.44	1.36	0.97	1.39	1.11	0.97	1.55	1.26
N5	0.53	0.31	0.58	0.72	0.70	0.42	0.71	0.57

To account for other confounding factors such as weather and implementation of countermeasures along the corridor (such as median barriers) a full safety analysis of the crash data is being performed. See Section 7.1 for information on this modeling effort.

6.4.4 PM-21: Critical Crashes

Tracking the different types of crashes within the entire corridor is important in reaching our main goal of reducing the amount of secondary crashes. The crash data our team received includes a column for injury classification, KABCO. KABCO classifications include fatal (K), incapacitating (A), non-incapacitating (B), possible injury (C), no injury (O), and unknown. While these crashes are important, we are mainly concerned with the fatal and incapacitating crashes. By establishing a baseline of crashes on the corridor, implementation of Connected Vehicle technology can be monitored for effectiveness and corridor safety can be improved.

PM- 21 tracks and measures the crashes that occur within the entire corridor and different VSL sections of the corridor on the Interstate 80 corridor through the State of Wyoming. The overall goal of this performance measure is a 10% reduction in total and truck critical crash rates. This will be measured by establishing baseline crash rates for the fatal and incapacitating prior to the implementation of the CV Pilot technology, and comparing the baseline to crash rates measured afterward. This portion of the report provides the crash data measured for the different injury classifications on the corridor and explains the methodology used for analyzing the data and compiling it into K and A crash rates. Table 6-9 shows all the injury classifications using the KABCO-scale that occurred in the I-80 corridor from 2010 through 2016.

Using the ADT values discussed in Section 4.5, the crash frequencies in the previous table were used to calculate the crash rates in Table 6-11. Underneath each of the categories is the baseline crash rates for fatal and incapacitating crashes of total traffic. Table 6-11 contains the truck crash frequency by severity for the same time period.

Table 6-12 shows the serious (fatal and incapacitating injury) crash rates on each of the VSL and non-VSL segments within the I-80 corridor using total crashes. Crash rates by segment for truck crashes by road segment were also be calculated.

Table 6-9. Crash Frequency by Severity, 2010-2017

Year	Unknown	No Injury (O)	Possible Injury (C)	Non-Incapacitating Injury (B)	Incapacitating Injury (A)	Fatal (K)	Total	Total Critical (K+A)
2010	12	1992	242	205	102	22	2575	124
2011	14	1946	210	180	91	21	2462	112
2012	20	1564	119	187	54	16	1960	70
2013	14	1919	156	221	93	20	2423	113
2014	9	2001	176	220	74	29	2509	103
2015	15	1610	173	193	59	14	2064	73
2016	18	2008	139	157	56	26	2404	82
2017	8	1397	91	148	51	17	1712	68
TOTAL	91	10087	868	1042	421	132	12641	553

Table 6-10. Truck Crash Frequency by Severity, 2010-2017

Year	Unknown	No Injury (O)	Possible Injury (C)	Non-Incapacitating Injury (B)	Incapacitating Injury (A)	Fatal (K)	Total	Total Critical (K+A)
2010	3	512	60	50	26	11	662	37
2011	3	577	58	51	23	11	723	34
2012	0	514	34	63	13	7	631	20
2013	5	576	37	62	31	6	717	37
2014	2	617	47	59	25	9	759	34
2015	4	477	44	54	17	10	606	27
2016	5	663	47	50	19	10	794	29
2017	1	586	39	60	26	6	718	32
TOTAL	23	4522	366	449	180	70	5610	250

Table 6-11. Crash Rates, 2010-2016

Year	Total Crash Rate	Critical (K + A) Crash Rate	Truck Crash Rate	Critical (K+A) Truck Crash Rate
2010	2.780	0.0697	0.658	0.0434
2011	2.707	0.0643	0.763	0.0405
2012	2.132	0.0398	0.714	0.0251
2013	2.605	0.0635	0.807	0.0473
2014	2.715	0.0573	0.807	0.0390
2015	2.156	0.0398	0.646	0.0308
2016	2.591	0.0461	0.944	0.0381

Table 6-12. Serious Crashes by Road Segment for 2010-2016

Road Segment	Corridor Crash Rates (K+A) Total	Corridor Truck Crash Rates (K+A) Total
N1	0.066	0.057
N2	0.038	0.049
N3	0.030	0.038
N4	0.042	0.028
N5	0.034	0.031
V1	0.043	0.063
V2	0.068	0.054
V3	0.069	0.062
V4	0.076	0.043

7 Safety and Simulation Modeling

Previous sections illustrated clearly the significant variations of factors contributing to crashes; these factors included weather and traffic conditions, work zones, closures, VSL, DMS, and maintenance along the 402-mile I-80 corridor. While preliminary analyses of crashes and individual snowstorms are an essential step, other factors such as driver behavior, roadway geometry, safety countermeasures, and the interrelationships between these factors might not be accounted for. Therefore, classical safety modeling of crashes as well as microsimulation of Surrogate Measures of Safety (SMoS) will be utilized to aid in evaluating the safety benefits of the CV applications.

7.1 Safety Modeling

Safety modeling is an important step to calibrate jurisdiction-specific Safety Performance Functions that are accurate to predict number of crashes over a time period while accounting for various confounding factors. In general, safety models serve three main purposes; 1) estimating how safe or unsafe certain roadway segments are, thereby interventions and design treatments can be implemented, 2) quantifying the safety effectiveness of an intervention or a design change, and 3) investigating the safety effects of different confounding factors. Because of the random and stochastic nature of crashes, safety of a roadway facility is defined by the number of crashes or crash consequences by type and severity expected to occur on the entity during a specific period. It is worth noting that the expected safety is not the observed safety of a roadway facility; the expected safety is the unobserved underlying true safety of the facility, whereas the observed safety is subject to random fluctuations known as the regression to the mean bias (RTM). This concept is very important in observational before-after studies.

7.1.1 Roadway Segmentation and Data Preparation

A first but essential step in data preparation is road segmentation. Given the variation of I-80 geometry and the mountainous nature, homogeneity of the segmented roadway sections was used as a major criterion for segmenting the east and west bounds of the 402-mile study corridor. Horizontal and vertical alignments as well as cross-sectional elements and traffic volumes were scrutinized. A minimum-length criterion of 0.1 mile was used to avoid the low exposure problem and the large statistical uncertainty of the crash rates per short segment (Miaou, 1994). Segments shorter than 0.1 mile were combined with adjacent segment with similar geometrical characteristics as much as possible. Equivalent grades were calculated and considered in the segmentation process (Ahmed, Huang, Abdel-Aty, & Guevara, 2011). Average and composite grades methods, provided in the Highway Capacity Manual (HCM) 2016, were followed to determine the equivalent grades (Transportation Research Board, 2016).

For safety modeling, seven years of crash data and various data were collected from several sources from 2010 to 2016 provided mostly from WYDOT. Crashes were extracted from the Crash Analysis Reporting Environment (CARE) database. The CARE database includes detailed information about crashes occurred in Wyoming starting from 1994. Roadway geometric characteristics, cross-section elements, pavement type, and traffic data were extracted from the WYDOT Roadway Data Portal (RDP). Although the RDP provides comprehensive information about roadways in Wyoming, other important roadway information, such as locations and types of shoulder rumble strips, locations of interchanges, climbing lanes locations, and snow fences information were not available. Due to this aggregation level, lack of detailed information occurs with CARE and RDP data, which might disregard the temporal effects within the aggregated time period. Unobserved heterogeneity could also be introduced, which might present errors in model estimation (Lord & Mannering, 2010). To mitigate these issues, other non-traditional data sources were used to gather further information on potential predictors of crashes as described below.

An extensive manual data extraction process was performed in this study using other non-traditional data sources. Pathway video logs, Google Earth Pro®, and Google Maps® were utilized to complete the dataset. Several hours were spent inspecting yearly Pathway Video Logs®, frame by frame, of the whole 402-mile I-80 corridor for both directions to extract roadway information on an annual basis. In addition, Google Earth Pro® and Google Maps® were used to check, confirm, and obtain missing data that could not be obtained from the Pathway Video Logs®.

Information about snow fences location, types, and height was requested from WYDOT. Google KMZ files for snow fences were obtained, containing detailed information of each snow fence. An additional effort was exerted to combine snow fences information with the investigated dataset. Weather stations with complete datasets close to the I-80 corridor were used to extract the weather data information used in this study. In addition, weather data were extracted from the National Oceanic and Atmospheric Administration (NOAA) website. It is to be noted that RWIS do not cover the whole corridor.

The segmented dataset was subdivided into two facility types, roadway segments, and interchange segments. Due to the rural nature of the corridor and the low traffic volumes, junctions with interstate roads, principal arterials, and minor arterial were only considered in subdividing the dataset. Twenty-six interchanges were identified for the increasing direction and 27 interchanges for the decreasing direction. A 0.3 miles buffer zone was constructed to identify the interchange influence area. The 0.3 miles buffer was measured from the painted nose of the ramps in the gore area. Total Interchange segment lengths were nearly 30 miles, which represents 7.5% of the total corridor length, with a total number of crashes of 12.3% of the total corridor crashes. Table 7-1 shows the descriptive statistics for the variables used in this analysis.

Table 7-1. Descriptive statistics of the investigated variables

Dataset: 1,638 roadway segments on 402-mile I-80 between 2010-2016					
Dependent Variables		**Mean**	**St. Dev.**	**Min.**	**Max.**
Total crashes/ segment		6.63	7.66	0	78
Property Damage Only (PDO) Crashes/ segment		5.32	6.36	0	67
Fatal and Injury (F+I) Crashes/ segment		1.31	1.78	0	14
Truck Crashes		2.72	4.09	0	42
Continuous Response Variables					
Variable type	**Variable Name (Abbreviation)**	**Mean**	**St. Dev.**	**Min.**	**Max.**
Traffic Data	Average Annual Daily Traffic (AADT)	6289.13	1264.83	3989	11842.68
	Vehicle Miles Travelled (VMT)	3006.96	3086.29	345.31	34821.72
	Average Annual Daily Truck Traffic (AADTT)	2966.58	317.73	1962.03	3638.65
	Truck Percentage (TPER)	48%	5%	3.1%	56%
Vertical & Horizontal Characteristics	Segment Length (L) - miles	0.49	0.53	0.1	5.84
	Grade (GRADE)	0.10%	1.93%	-6.21%	5.57%
	Delta (DELTA)	10.44	17.31	0	102.47
	Radius (RAD)	2856.17	5512.80	0	85852.14
	Degree of Curvature (DOC)	0.61	1.82	0	44.33
Cross-Sectional Elements	Median Width (MDWDTH) - feet	93.47	70.55	18	956
	Total Width (WTOT) - feet	38.29	3.73	28	80
	Width of Left Shoulder (WLSH) - feet	3.79	0.61	2	4
	Width of Right Shoulder (WRSH) - feet	9.42	1.32	2	16
	Number of Lanes (NLANE)	2.08	0.3	2	5
Countermeasure	Height of Snow Fences (SFH) - feet	1.91	3.79	0	14
	Bridge Count (BRGCOUNT)	0.20	0.43	0	3
Weather Conditions	Number of Snow Days (SNWDAY)	34	14.18	14	69
	Number of Rainy Days (RNDAY)	82.05	18.01	51	114
	Number of Windy Days (WINDAY)	25.04	5.13	9	44
Percentage of Winter Season Crashes/ segment	Total (PTWC)	0.69	0.34	0	1
	PDO (PPDOWC)	0.66	0.36	0	1
	F+I (PFIWC)	0.44	0.46	0	1
Categorical Response Variables					
Variable Name (Abbreviation)	**Level (Code Value)**	**Percentage in each category**			
Median Type (MEDTYP)	Depressed (1)*	71.25			
	Raised (2)	28.75			
Left Shoulder Type (LSHTYP)	Asphalt (1)*	71.49			
	Concrete (2)	28.51			
Right Shoulder Type (RSHTYP)	Asphalt (1)*	71.49			
	Concrete (2)	28.51			
Lane Type (LANTYP)	Asphalt (1)*	46.89			
	Concrete (2)	48.60			

	Combined (3)	4.52
Facility Type (FACTYP)	Roadway (1)* Interchange (2)	89.19 10.81
Variable Speed Limit (VSL)	Present (1) Not Present (0)*	36.45 63.55
Climbing Lane (CLIMLANE)	Present (1) Not Present (0)*	2.63 97.37
Snow Fences (SF)	Present (1) Not Present (0)*	26.98 73.02
Snow Fence Type (SFTYP)	No Fence (0)* Living Fences (1) Inclined Fences (2) Vertical Fences (3)	72.34 0.67 5.43 21.55

*Reference category for variable

7.1.2 Preliminary Analysis

The 402-mile corridor is characterized by mountainous terrain of steep vertical grades, challenging horizontal alignment, and adverse weather conditions. These three main factors were investigated in the preliminary analysis.

Part (a) in Figure 7-1 shows a plan view of I-80 corridor with the four VSL sections marked in green. The first implemented VSL section was the Elk Mountain in February 2009 with a length of 52 miles, followed by 25 miles section in Green River in February 2011. The last two sections were shortly implemented after the Green River section in October 2011, with a length of 23 miles for the Evanston section and 47 miles for the Laramie-Cheyenne section (Saha, Ahmed, & Young, 2015).

Parts b in Figure 7-1 for the increasing and decreasing directions show the projection of total, PDO and F+I crashes segmented into 5 miles sections over all the 402-mile corridor. VSL sections are marked with a gray shade. For both directions, a significant increase in total and PDO crashes is observed in the VSL sections, in addition to a slight increase in F+I crashes. This increase in crashes might be a result of the challenging roadway geometry and adverse weather conditions within the four VSL sections, as shown in part (c) and (d) in Figure 7-1. Parts (c) in Figure 7-1 shows higher number of horizontal curves per mile within the VSL sections for both directions. A high variation in vertical grades per mile is also observed within the VSL sections.

Weather condition is one of the most significant factors affecting crashes on I-80 (Buddemeyer J. , Young, Sabawat, & Layton, 2010; Saha, Ahmed, & Young, 2015). Parts (d) in Figure 7-1, shows the average number of snowy days, rainy days, and windy days encountered on I-80 corridor from 2010 to 2016. It shows that the Elk Mountain and Laramie-Cheyenne sections have relatively more severe weather conditions compared to other sections on the I-80 study corridor. The preliminary analysis will be extended to include total and truck crashes within work zones, truck crashes, and truck critical crashes along the corridor. It is worth mentioning that pavement conditions and visibility levels were not included in calibrating SPFs due to lack of data. The minimum visibility data provided by NOAA is one mile. It was assumed that a visibility of one mile is significantly more than the required visibility for a safe stopping sight distance at the maximum speed limit on the corridor, thus was excluded. Roadway surface condition data were available only for VSL sections within the recent few years. Hence, they were not included.

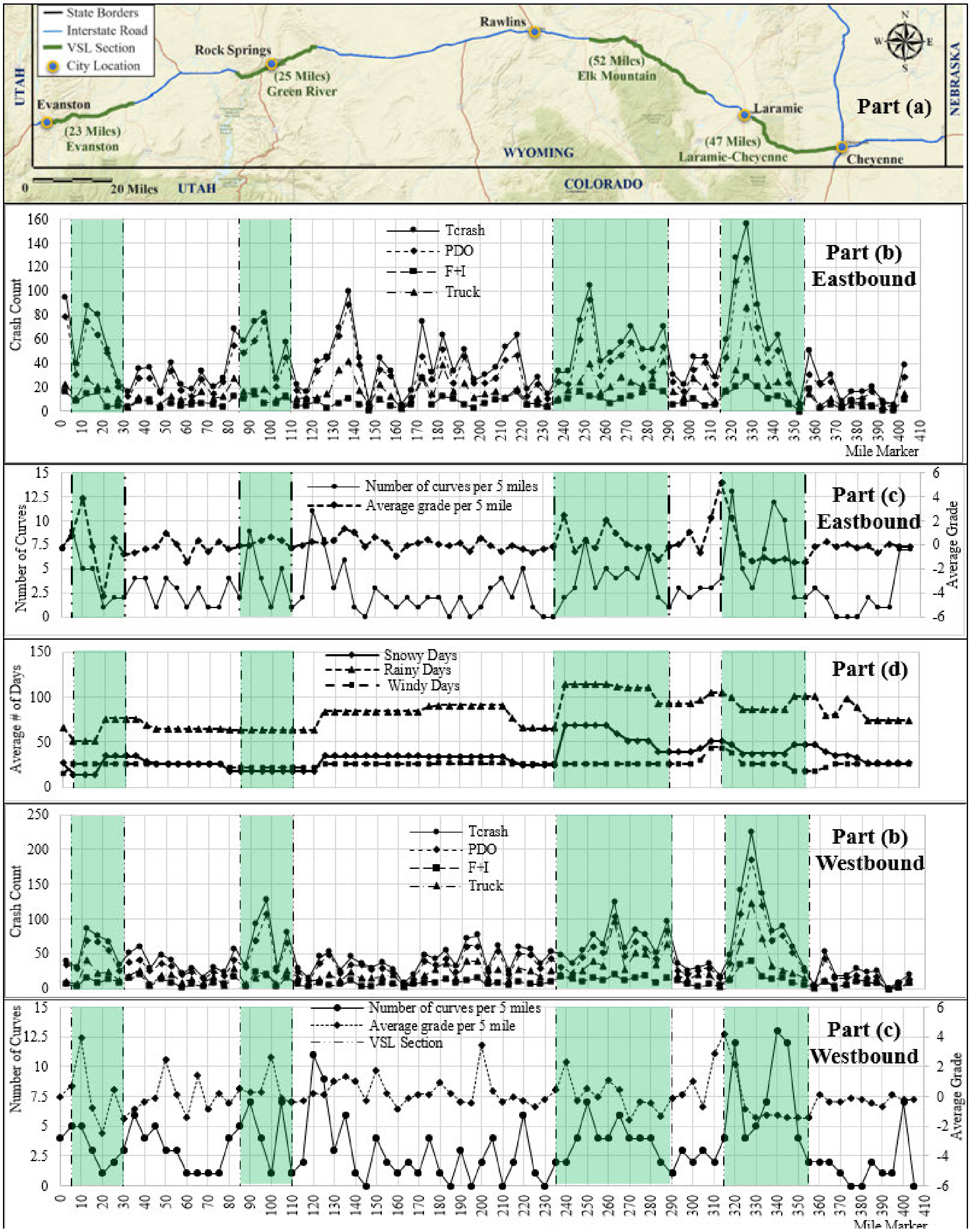


Figure 7-1. Observed crash counts, geometric characteristics, and weather conditions on I-80 and VSL sections from 2010 to 2016 (Source: WYDOT)

7.1.3 Safety Performance Functions (SPF)

As mentioned earlier, many factors contribute to crash occurrence, including driver behavior, vehicle performance, traffic and geometric characteristics, weather conditions, implemented countermeasures, and interactions between these factors. Unfortunately, driver behavior factors are usually unavailable. Therefore, available roadway, traffic and weather conditions factors will be used to calibrate full SPFs for the 402-mile corridor. Previous studies applied a vast variety of statistical models to develop safety performance functions (Lord & Mannering, 2010); these methods ranged from classical frequentist to other more advanced models. It is worth mentioning that each statistical technique has its strengths and weaknesses in estimating crash frequencies.

Negative binomial (NB), a traditional frequentist technique, is one of the most common used to develop crash prediction models (Miaou & Lum, 1993; Miaou, 1994; Donnell & Mason, 2006; Farid, Abdel-Aty, Lee, Eluru, & Wang, 2016). Negative binomial models account for the over dispersion for crash data, however, it can be affected by the low sample mean and small sample size (Lord & Mannering, 2010). To achieve more reliable estimations, Bayesian statistics with updating approach to update beliefs about the behavior of the parameter with prior knowledge are adopted in the literature (Ahmed, Huang, Abdel-Aty, & Guevara, 2011; Ahmed, Abdel-Aty, & Yu, 2012; Ahmed & Abdel-Aty, 2013). Moreover, recent Machine Learning (ML) techniques such as Multivariate Adaptive Regression Splines (MARS), Generalized Nonlinear Model (GNM), Stochastic Gradient Boosting, and Neural Network have shown superior prediction accuracy compared to traditional modeling techniques (Park & Abdel-Aty, 2015; Haleem, Gan, & Lu, 2013; Ahmed & Abdel-Aty, 2013; Chang, 2005).

Furthermore, non-parametric techniques can handle the nonlinearity found in crash data. Most commonly, the influence of traffic and roadway elements on crash frequency and severity are the most considered in the literature. Roadway elements include segment length, vertical grade, degree of curvature, horizontal curve radius, curve deflection angle, shoulder widths, median width and type, and number of lanes; traffic elements such as AADT, access points and truck percentage; and environmental conditions are among the common significant variables that were found to influence crash frequency (Carson & Mannering, 2010; Milton & Mannering, 1998; Chang, 2005; Cafiso, Di Graziano, Di Silvestro, La Cava, & Persaud, 2010; Malyshkina & Mannering, 2010; Ahmed, Abdel-Aty, & Yu, 2012). For the CV project, all of these factors in addition to countermeasures such as VSL, DMS, snow fences, climbing lanes, land use, etc. will be considered.

SPFs were mainly calibrated for crashes as per the Highway Safety Manual. The performance measures in here are referring to the types and severity of crashes. SPFs were calibrated for total crashes, Fatal+ Injury crashes, PDO crashes, and truck crashes. Eventually, the predicted crashes from the SPFs will be compared with the observed crashes during post-deployment period to determine whether or not there are reductions in crashes due to CV deployment program. It is worth mentioning that using SPFs will also account for confounding factors such as changes in weather as well as the interactions between weather, traffic, and geometric characteristics.

Safety performance functions (SPF) for the three severity levels in addition to truck crashes were developed using Negative Binomial (NB) model. The estimates obtained for the set of variables influencing the different crash severities were significant at a 5% significance level. The results of the four developed models, i.e., variable estimates, probability, odds ratios, and percentage of effect of each variable on the response, are provided in Table 7-2. Akaike information criterion (AIC) was used to assess the goodness of fit of the models.

The natural logarithm of vehicle miles travelled (VMT) was found to be the most significant factor affecting crashes, as probability of crashes would increase nearly 7 times for each one unit increase in log (VMT). The natural log of AADTT was found to be significant for PDO crashes. According the models estimates, having a major interchange with I-80 would increase the likelihood of having a crash by nearly 17%, for total and PDO crashes. Horizontal geometry was found to affect all the investigated crash types. One degree increase in deflection angle would increase the probability of having a crash by nearly 0.4% for total, PDO, and Truck crashes. For F+I crashes, an increase of 0.7% was obtained. Other roadway features as median type and number of bridges affect the occurrence of crashes with a range of 20% to 36%.

Severe weather was also among the factor that significantly affected crashes on I-80. It was found that for each day increase in rainy days, the probability of having a crash would increase by nearly 1% for total, PDO, and F+I crashes. For truck crashes, the probability would increase to nearly 2%. Wind was found to be the most significant weather factor that increases crashes. The increase in crash probability was found to increase by nearly 1.35% for total crashes, 2.07% for F+I crashes, 1.17% for PDO crashes, and 1.61% for Truck crashes. On the other hand, snowy days was not found to be significant in crash occurrence except for the truck crashes. Surprisingly, it was found to reduce truck crashes by 1.62% for each day increase in snowy days. This might be due to the relatively low traffic during snowy weather, in addition to the more cautious the motorists are when driving in adverse conditions. It is worth mentioning that during severe winter conditions, I-80 would be closed. This also may explain the effect of the increase of snowy days on crashes.

The developed models showed that countermeasures as shoulder rumble strips helped in reducing crashes. A reduction ranges between 21% to 25% was found for the total, F+I, and PDO crashes. However, it was not significant in reducing truck crashes. Variable speed limit as a main effect seemed to be ineffective in reducing crashes. Nevertheless, VSL interaction terms with weather and horizontal geometry were found to be significant in reducing crashes. Controlling for number of rainy days, VSL would reduce total and PDO crashes by nearly 1%. Additionally, the interaction between VSL and existence of horizontal curves would reduce F+I crashes by nearly 1.24%.

Table 7-2. Negative Binomial (NB) Model Estimates

Predictors	Total Crashes			Fatal and Injury (F+I)			Property Damage Only (PDO)			Truck Crashes		
	Estimates	(SE)	P-value	Estimates	(SE)	P-value	Estimates	(SE)	P-value	Estimates	(SE)	P-value
Intercept	-6.1664	0.271	<.0001	-7.7565	0.354	<.0001	-9.2369	1.676	<.0001	-7.9656	0.362	<.0001
Log(VMT)	1.9476	0.063	<.0001	1.9436	0.084	<.0001	1.9237	0.067	<.0001	2.0634	0.080	<.0001
Log(AADTT)	--	--	Not Sig.	--	--	Not Sig.	0.3726	0.207	0.0500	--	--	Not Sig.
FACTYP(2)	0.1546	0.068	0.0230	--	--	Not Sig.	0.1588	0.072	0.0270	--	--	Not Sig.
Delta	0.0041	0.001	<.0001	0.0070	0.002	<.0001	0.0040	0.001	0.0020	0.0037	0.002	0.015
LANTYP (2)	--	--	Not Sig.	-0.1226	0.062	0.047	--	--	Not Sig.	-0.1209	0.057	0.034
LANTYP (3)	--	--	Not Sig.	-0.2736	0.144	0.057	--	--	Not Sig.	0.2913	0.139	0.036
MDWDTH	--	--	Not Sig.	--	--	Not Sig.	--	--	Not Sig.	0.0007	0.001	0.0233
MEDTYP	0.2906	0.052	<.0001	0.1799	0.067	0.007	0.3098	0.056	<.0001	0.2591	0.064	<.0001
BRGCOUNT	0.2761	0.045	<.0001	0.2961	0.055	<.0001	0.2654	0.047	<.0001	0.2537	0.055	<.0001
RNDAY	0.0089	0.002	<.0001	0.0078	0.002	<.0001	0.0088	0.002	<.0001	0.0191	0.004	<.0001
WINDAY	0.0134	0.004	0.0020	0.0205	0.005	<.0001	0.0116	0.005	0.0110	0.0160	0.006	0.004
SNWDAY	--	--	Not Sig.	--	--	Not Sig.	--	--	Not Sig.	-0.0163	0.006	0.007
VSL	1.5070	0.446	<.0001	0.8550	0.137	<.0001	1.4868	0.476	0.0020	0.6628	0.129	<.0001
SFTYP(1)	-0.2740	0.238	0.2490	--	--	Not Sig.	-0.1456	0.258	0.5730	-0.3292	0.314	0.294
SFTYP(2)	0.2477	0.093	0.0080	--	--	Not Sig.	0.2496	0.099	0.0120	0.4373	0.124	0.001
SFTYP(3)	0.0203	0.053	0.7040	--	--	Not Sig.	0.0191	0.057	0.7390	0.0587	0.067	0.382
SRS	-0.2346	0.070	<.0001	-0.2810	0.097	0.004	-0.2327	0.075	0.0020	--	--	Not Sig.
RNDAY * VSL	-0.0096	0.005	0.0470	--	--	Not Sig.	-0.0094	0.005	0.0490	--	--	Not Sig.
Delta * VSL	--	--	Not Sig.	-0.0125	0.006	0.037	--	--	Not Sig.	--	--	Not Sig.
Dispersion factor (K)	0.4189	0.024		0.2711	0.040		0.4484	0.027		0.5180	0.038	
AIC	8712.94			4552.31			8139.25			6282.18		

7.2 Simulation Modeling

In response to the WYDOT CV Pilot Deployment Program "*Performance Measurement and Evaluation Support Plan*", traffic simulation modeling using VISSIM software is conducted for the analysis of traffic safety performance measures. The use of microscopic traffic simulation modeling allows for the analysis of conflict-event safety surrogates such as time-to-collision, distribution of speeds, speed variation, number of lane changes, etc. It is anticipated that the CV deployment will result in changes to speed selection, lane changing and car following behavior for CV-equipped drivers that can be modeled in a microsimulation environment. Therefore, by using microsimulation, researchers can gain insightful understanding of the impacts of the safety effectiveness of CV technology. In this regard, this system performance report proposes a VISSIM simulation framework for a segment of the Cheyenne-Laramie (mileposts 317 to 340) Variable Speed Limit corridor to determine the suitability of adopting a microscopic simulation approach for providing insight into the safety effectiveness of CV technology under various scenarios. The selected corridor represents the most challenging traffic situation along I-80 in Wyoming, such as high altitude, high adverse weather events, and steep vertical curves. Being limited by the available time and resources, it is not feasible to calibrate and simulate a 402-mile freeway corridor. In case of further evaluating the performance of the entire corridor, a sensitivity analysis could be used to extrapolate the simulation results from the selected corridor to the 402-mile I-80 corridor in Wyoming.

7.2.1 Literature Review

A comprehensive literature review regarding using microsimulation tools for connected vehicle performance evaluation was conducted to summarize the start-of-the-art of research that related to connected vehicle research. The major topics involved in the literature review include impacts of CV on traffic operations and safety, the commonly used microsimulation software and measures for CV performance evaluation, driving simulator method for driving behavior study, impacts of CV penetration rates on system performance.

7.2.1.1 Impacts of CV on Traffic Safety and Mobility

This section aims to review existing studies that evaluated the impacts of connected vehicle technology on traffic operations and safety using microscopic simulation methods.

Mahmassani (2016) and Talebpour, Mahmassani, & Bustamante (2016) have evaluated the impacts of connected vehicles on traffic flow and operations. In their studies, a framework that utilizes different models with technology-appropriate assumptions was developed to simulate different vehicle types with distinct communication capabilities. The stability analysis of the resulting traffic stream behavior using the developed framework is presented for different market penetration rates of connected and autonomous vehicles. The analysis reveals that connected and autonomous vehicles can improve string stability. In addition to stability, the effects of these technologies on throughput are explored, suggesting substantial potential throughput increases under certain penetration scenarios. Travel Time Reliability (TTR) was modeled considering five connected vehicle characteristics, congestion level, penetration rate, compliance rate, release delay time, and following rate (Wang, Wang, Zhang, & Li., 2017). The results indicated that penetration and compliance rates have a positive effect on TTR, the average improvement rate was found to be about 77% and 73% with the increase of penetration and compliance rate, respectively.

7.2.1.2 Microsimulation for Performance Evaluation

Using microsimulation for safety evaluation, the most commonly used method is the Surrogate Safety Assessment Model (SSAM) (Gettman et al., 2008). Among various surrogate measures of safety used in the literature, time-to-collision (TTC) was found to be an efficient surrogate safety measure. Genders & Raviza (2016) evaluated the potential safety benefits of deploying a connected vehicle system on a traffic network in the presence of a work zone. The modeled connected vehicle system in the study uses vehicle-to-vehicle (V2V) communication to share information about work zone links and link travel times. Vehicles which receive work zone information will also modify their driving behavior by increasing awareness and decreasing aggressiveness. Traffic microsimulation software was used to model the network and a C plugin was developed to implement connected vehicle in the simulation. The surrogate safety measure improved time to collision (TTC) is used to assess the safety of the network. Various market penetrations of connected vehicles were utilized along with three different behavior models to account for the uncertainty in driver response to connected vehicle information. The results show that network safety is strongly correlated with the behavior model used; conservative models yield conservative changes in network safety. The results also show that market penetrations of connected vehicles under 40% contribute to a safer traffic network, while market penetrations above 40% decrease network safety. The decrease in safety when rerouting more than 40% of traffic on a work zone is attributed to longer average trip distances (Genders & Raviza, 2016). This also could be explained by the fact that more traffic will be diverted to other alternate routes resulting in more exposure to higher traffic volumes and increased crash risks. Fyfe (2016) investigated the ability to evaluate the safety of connected vehicle applications using surrogate safety measures through a combination of micro-simulation model VISSIM and Surrogate Safety Assessment Model (SSAM). Olia, Genders, & Razavi (2013) attempted to quantify potential safety benefits of deploying a Connected Vehicle system through microscopic traffic simulation modelling. PARAMICS was used to model Connected Vehicles, construction zones and incidents associated with work zones. The result of this research clearly demonstrates the effectiveness of Connected Vehicle systems to improve network safety. The percentage of Connected Vehicles within the network is the most significant factor to increase network safety and can be explained by re-routing to alternate routes and increased driver awareness with improvements of up to 50% in network safety. Another study evaluated the impact of connected vehicle on work zone safety (Genders, 2014). A dynamic route guidance system based on decaying average-travel-time and shortest path routing was developed and tested in a microscopic traffic simulation environment to avoid routes with work zones. To account for the unpredictable behavior and psychology of driver’s response to information, three behavior models, in the form of multinomial distributions, are proposed and studied in this research. The surrogate safety measure improved Time to Collision was used to gauge network safety at various market penetrations of connected vehicles. Results show that higher market penetrations of connected vehicles decrease network safety due to increased average travel distance, while the safest conditions, 5%-10% reduction in critical Time to Collision events, were observed at market penetrations of 20%-40% connected vehicle, with network safety strongly influenced by behavior model.

A comprehensive simulation framework to model driver behavior in a connected driving environment was presented by Talebpour, Mahmassani, & Bustamante (2016). The framework consists of a microscopic traffic simulator integrated with a discrete-event communications network simulator, Network Simulator 3, forms a basis for exploration of the properties of the resulting traffic systems and assessment of the system-level impacts of the CV technology. Furthermore, the connectivity of a vehicle-to-vehicle and vehicle-to-infrastructure communications network was investigated with the FHWA Next Generation Simulation: US-101 Highway dataset. Smith & Razo (2016) have established a methodology to develop a regional traffic microsimulation model. The methodology includes the following steps: (a) converted the existing network planning model for the Ann Arbor area to a regional microsimulation model, (b) developed a method to identify the numbers, origins, and destinations of trips using equipped vehicles, and (c) developed post-processing code to track all equipped vehicles from the second-by-second microsimulation vehicle snapshot data and to identify interactions between equipped vehicles. A recent study presented a thorough microscopic simulation investigation of a recently proposed methodology for highway traffic estimation with mixed traffic, i.e., traffic comprising both connected and conventional vehicles, which employs only speed measurements stemming from connected vehicles and a limited number (sufficient to guarantee observability) of flow measurements from spot sensors (Fountoulakis, Bekiaris-Liberis, Roncoli, Papamichail, & Papageorgiou, 2017). The estimation scheme is tested using the commercial traffic simulator AIMSUN under various penetration rates of connected vehicles, employing a traffic scenario that features congested as well as free-flow conditions. Paikari, Tahmasseby, & Far (2014) explored a low cost modeling approach to provide guidelines for improving safety and mobility on freeways, specifically by using advisory speed and re-routing guidance in V2V and V2I systems. The study tested fifteen scenarios differentiated by the V2V percentage penetration (0%, 10%, 20%, 30%, and 40%), and demand loading (60%, 80%, and 100%) implicitly representing peak and off-peak traffic, the study demonstrated that CV technology can enhance traffic safety on freeways, if the percentage of CVs is significant (e.g. 30-40%) and when it is accompanied by advisory speed reflected on VMSs not only upstream but also downstream of the incident location.

In Summary, findings from several representative research reveal that connected and autonomous vehicle technologies can improve traffic flow string stability and throughputs, improve travel time reliability, and promote traffic safety. A number of simulation software packages have been used for CV simulation, including VISSIM, PARAMICS, AIMSUM, NGSIM, etc.

7.2.2 Microsimulation Framework

It is known that microsimulation software cannot directly simulate traffic crashes. In current practice, using Surrogate Measures of Safety derived from data output by traffic simulation models has been proved as an efficient method for safety evaluation. This safety performance simulation will employ the VISSIM simulation with the Surrogate Safety Assessment Model (SSAM) for safety performance evaluation. The surrogate measures developed for safety evaluation are based on the traffic conflicts (crash opportunities determined by safety assessment parameters such as Time-to-Collison, TTC) generated by the VISSIM simulation model. Since currently there is no available TTC data from the field for SSAM model calibration, at this stage we will adopt common TTC from the literature for trucks on freeways.

7.2.2.1 Freeway Corridor Network Coding

In order to assess the suitability of simulation modeling for providing insight into the safety effectiveness of CV technology, a VISSIM model was built for a selected freeway segment on the Cheyenne-Laramie (mileposts 317 to 340) Variable Speed Limit corridor. The basic corridor network was uploaded from the standard map data in VISSIM; then, the roadway geometric data, including number of lanes, roadway segment lengths and grades, location of lane additions and drops, locations of rest and/or parking areas, etc., have been manually coded in VISSIM. Additional detailed traffic control parameters have been or will be incorporated into the VISSIM network to better reflect existing operational conditions. Key traffic parameters include traffic composition, vehicle dynamics data, posted speed limits, presence of work zones (including location, length, lane closure condition, etc.), amongst other.

7.2.2.2 Traffic Flow Parameters

7.2.2.2.1 Traffic Comparison

For this study, two default vehicle types in VISSIM – Car and HGV were used to define traffic composition. Traffic comparison data mainly refer to the proportion of commercial truck in the traffic flow and the percentage of connected vehicles (for both passenger vehicles and trucks). For each vehicle type, the research team have obtained the detailed vehicle classification (such as Sedans, SUVs, Pickups, Vans, Trucks and Buses) and corresponding percentages from WYDOT TMC traffic database. A single vehicle type shares the default vehicle performance attributes. These attributes include model, lengths maximum speed, acceleration and deceleration capabilities, weight, power, and other mechanical features.

7.2.2.2.2 Driving Behavior Settings

The driver behavior in VISSIM is modeled through car-following and lane-changing models. The driving behavior is linked to each link by its link type and the mechanical capabilities of the driver’s vehicle. For each vehicle class, a different driving behavior parameter set is defined. The behavior model for the driver involves a classification of reactions in response to the perceived relative speed and distance with respect to the preceding vehicle. For the car following model, since this study focuses on performance evaluation on a freeway corridor, driving behavior settings include standstill distance, headway time, safe distance, look ahead and back distances, temporary lack of attention, etc. For the lane-changing model, the following driving behavior parameters is considered:

lane utilization, acceleration/deceleration profiles, minimum headway, lane-changing gap acceptance, waiting time before diffusion, safety distance reduction factor, etc.

The impact of adverse weather on freeway operations could be simulated by changing the driving behavior parameters. Weather-responsive microsimulation modeling is a substantial task and the PM team hopes to leverage ongoing research efforts from a SHRP2 *Naturalistic Driving Study* (NDS) project that is being done on this topic at the University of Wyoming. As part of this project, driving behavior models are calibrated to represent driving behavior in various adverse weather conditions. It is proposed that the observed behavioral changes of drivers, as identified from the SHRP2 NDS project, will be used to inform the development of driving behavior models for the CV Pilot microsimulation modeling. Driver behavior from SHRP 2 will need to be assessed and adjusted to Wyoming I-80 conditions. Given the timeline of the NDS and CV Pilot study, it is proposed that a simulation model utilizing currently available driver behavior models be developed in Phase 2 and that incorporation of weather responsive driver behavior and CV technology components be done in Phase 3. In case of road closure due to severe weather or accident, since in reality there is no alternative routes (or very limited access to alternative routes) along the selected I-80 corridor in Wyoming, it is assumed that truck drivers will cancel the current trip, exit the freeway from the nearest exit, and reschedule the trip after road re-open. The waiting time will be treated as delay in the mobility analysis.

7.2.2.3 Confounding Factors

To provide an accurate evaluation of the CV deployment program, it is critical to identify confounding factors and isolate their impacts so that performance improvements are neither overstated nor understated. Potential confounding factors that may affect the Wyoming CV Pilot Deployment evaluation have been identified and corresponding mitigation approaches have been proposed by the Wyoming project team (Kitchener et al, 2016). For instance, a key confounding factor that may be involved in the performance evaluation is the potential changes in weather conditions between the baseline scenarios and CV post-deployment scenarios. Since changes in weather conditions have the potential to invalidate conclusions about the effectiveness of the CV Pilot deployment, comparisons must be made between similar (adverse/non-adverse) weather conditions to help ascertain the true impacts of CV technology. The baseline conditions, including the type, intensity, and extent of the weather and road surface conditions, will be documented; during the post-deployment period, the performance evaluation will include similar weather and road condition data. Driver behavior data (such as reaction time to traffic conditions, car-following headway, speed preference, etc.) with and without CV notifications will be collected from the field, field demonstration, and from the driving simulator (the WYOSIM lab). The driver behavior data will be used to calibrate weather sensitive VISSIM microsimulation model parameters. Based on the calibrated microscopic simulation model, the research team will be able to control for weather variables in the developed simulation scenarios.

7.2.2.4 Surrogate Safety Assessment Model

The analysis will focus on safety performance measures PM 18-21 (i.e., reductions of total and truck crash rates on normal and work zone corridors, reduction of total and truck critical crash rates in a corridor, and reductions of the number of vehicles involved in a crash). An analysis scenario, a combination of operational conditions, and a CV application (or combination of applications) will be examined against the base condition scenarios.

Since microsimulation cannot directly evaluate safety performance measures listed in the PM plan, Surrogate Safety Assessment Model (SSAM) for safety performance evaluation such as time-to-collision (TTC), post encroachment time (PET), deceleration rate, speed, speed differential, location of the conflict event, and maximum post collision will be used as Surrogate Measures of Safety. The SSAM approach utilized several algorithms to identify conflicts from vehicle trajectory files generated by the microscopic simulation model. The outputs of SSAM include the number, type, severity and locations of simulated conflicts for traffic facilities.

This model considers two types of simulated conflicts, including rear-end conflict and lane-change conflict. A conflict is recorded in SSAM when the minimum TTC and PET values exceed the predetermined threshold values, and the conflict type associated with each conflict is identified according to the lane and link information or the angle between the two converging vehicles.

7.2.2.5 Calibration of Simulation Models

Accuracy of the microsimulation results (baseline condition) is expected to be validated through field collected traffic performance data. The baseline traffic flow and speed data collected at the selected freeway corridor will be used for model calibration and validation. The research team is calibrating the baseline simulation model based on historical traffic flow and speed data measured at the selected corridor. Statistical tests will be employed to verify the differences between simulation results and observations.

Then, for model calibration, it is expected to adjust crucial parameters in VISSIM and SSAM to replicate the safety measures observed in the field; accordingly, obtain the simulation parameters that can best match the real-world condition. For model calibration under connected vehicle environment, since at this stage there are no available traffic flow and safety performance data from field, the VISSIM model calibration will be based on driver behavior data generated from the CV Pilot Deployment Program – Participant Training and Education, which is undergoing at the Driving Simulator Lab, University of Wyoming (WYOSIM) during Phase 2 and 3. The calibration of SSAM will also be based on the simulated safety performance data from the WYOSIM's high fidelity driving simulator.

A two-stage model calibration procedure has been proposed to illustrate how we will calibrate the simulation models. In the first stage, we will use field collected microscopic traffic data (including 2-minute high-resolution traffic volume counts, spot speed, time headways) measured at the selected freeway corridor to calibrate the VISSIM simulation model. With the validated VISSIM model, simulation results will be analyzed by SSAM to identify simulated conflicts. Then, the research team will compare simulated conflicts to field collected data and accordingly calibrate SSAM safety parameters, such as TTC, to make the simulation match field data. The research team selected 2-hour traffic flow data from one day under normal winter weather condition and other days under two levels of snowy and severe weather conditions. In addition, 2-hour field data will be used for calibration for summer condition to be utilized for the assessment of work zone CV application. Descriptions of the selected traffic flow data are presented in Section 7.2.3.2. Overview of the model calibration procedure is illustrated in Figure 7-2.

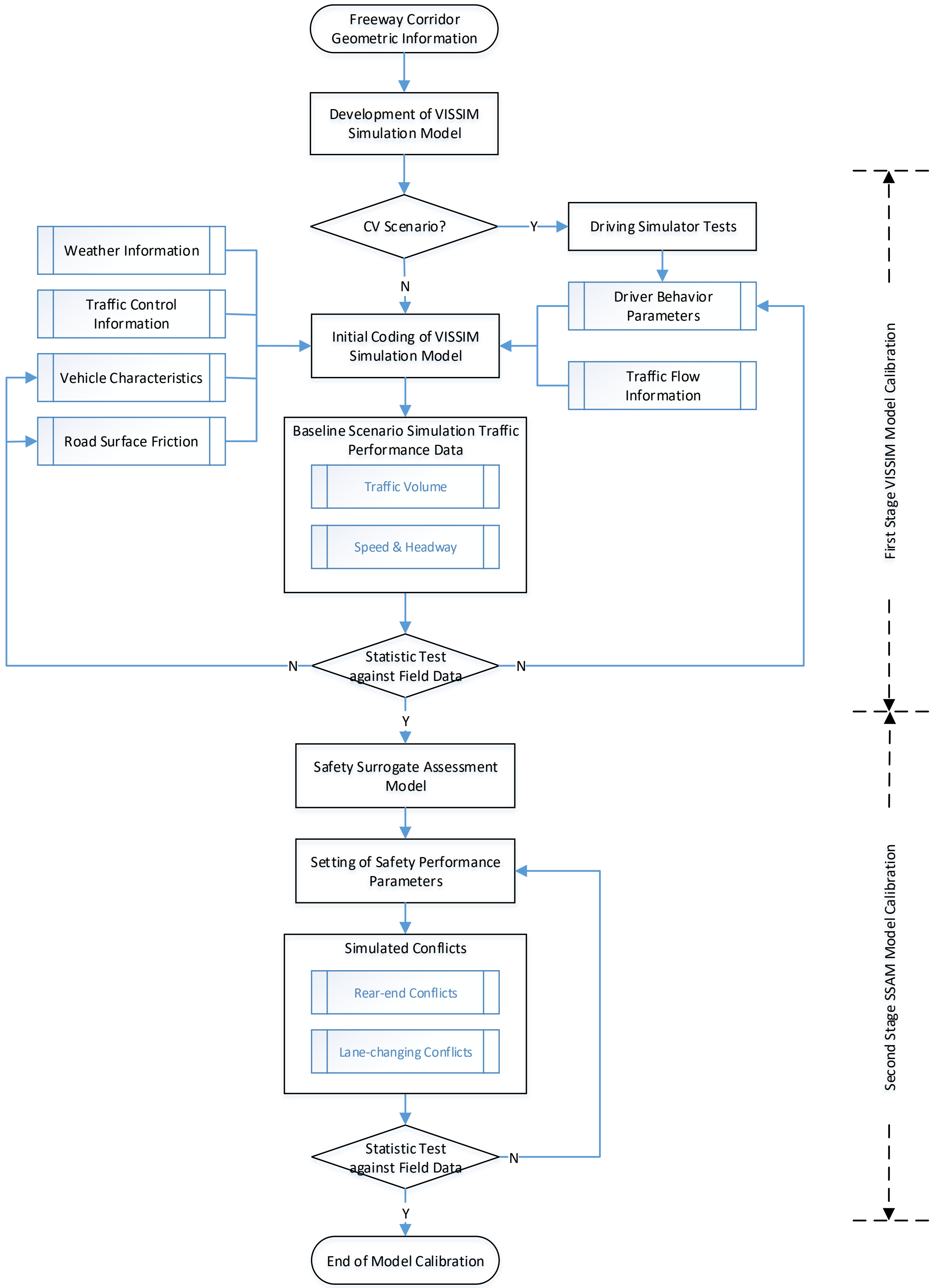


Figure 7-2 Procedure for Calibration of VISSIM Simulation Model and SSAM (Source: WYDOT)

7.2.3 Model Calibration

7.2.3.1 Data Collection Locations

During VISSIM calibration stage, the VISSIM simulation models will be calibrated to reproduce performance measures collected by WYDOT's Wavetronix speed sensors and RWIS sensors. The key traffic performance data used for model calibration are 2-min traffic volume counts and spot speed at each speed sensor. Based on the available dataset, traffic performance data from two speed sensors were selected: Sensor #2146 (nearest RWIS sensor: WY28) and Sensor #2178 (nearest RWIS sensor: KVDW). In VISSIM model, data collection points were added at the same location to report the simulated traffic flow and speed data. Locations of the speed and RWIS sensors and VISSIM data collection points are illustrated in Figure 7-3.

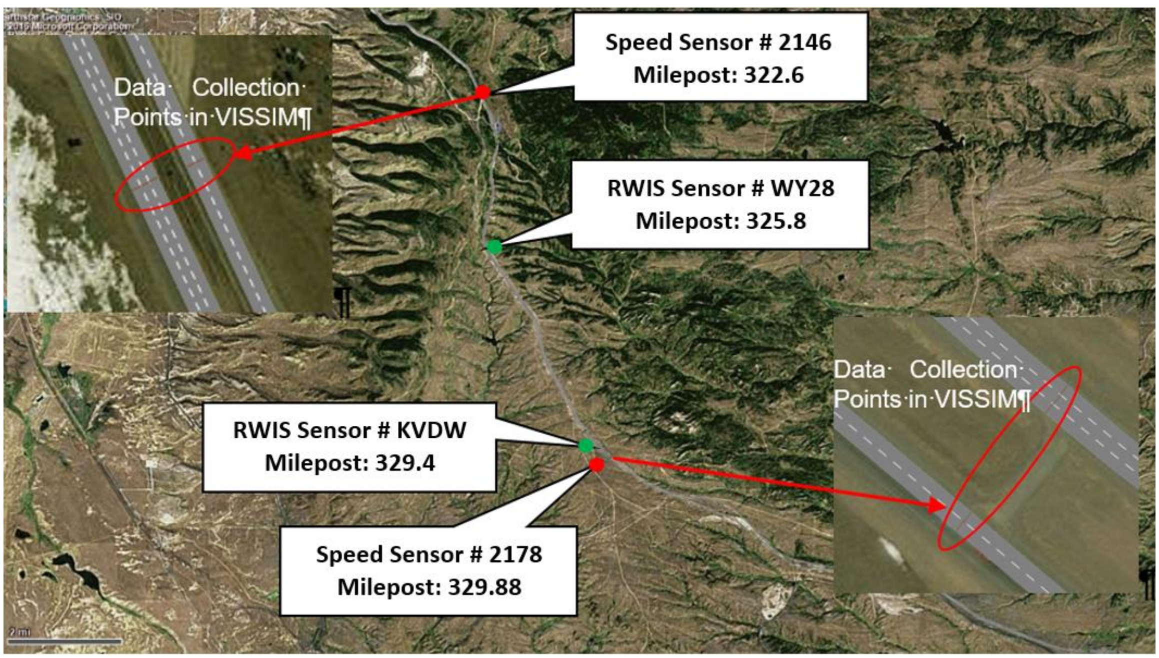


Figure 7-3 Location of Data Collection Points in VISSIM (Source: WYDOT)

7.2.3.2 Data Preparation

It is expected that traffic flow data under both normal weather condition and adverse weather conditions will be employed to calibrate the VISSIM simulation model. Being limited by the available field data and time to process the huge dataset, it is not feasible to calibrate and simulate all the weather conditions. Therefore, the research team selected 3 representative weather conditions for microsimulation. Specifically, we selected 2-hour traffic flow data from one day under normal winter weather condition and other days under two levels of snowy and severe weather conditions. The 3 weather levels were identified based on the WYDOT weather sensor data (normal-weather code #1; snowy-weather code #4&5; severe-weather code # 8), as presented in Table 7-3. With the calibrated microsimulation models, the research team will match traffic volume during the pre- to post- deployment period. At present, there is no available work zone data for calibrating simulation model under work zone conditions; when available, the research team will collect 2-hour work zone data for calibrating the microsimulation model for summer condition, which will be utilized for the assessment of work zone CV application. Truck information, including the proportion of 3, 4, 5 axles trucks, proportion of loaded and un-loaded truck, will be obtained from WYDOT TMC and will be coded into the VISSIM simulation model. Road surface friction information will also be coded into the VISSIM model to represent the impacts of various winter weather conditions.

Table 7-3. Weather information at speed sensors #2146 and #2178

Data Field	Normal Weather Condition	Snow Weather Condition	Severe Weather Condition
DateTime	May 2, 2017, 12:00-14:00	Jan 9, 2017, 12:00-14:00	Jan 4, 2017, 13:00-15:00
RoadCondition	1	5	8
SurfaceTemp	1	1	3
WindSpeed	1	1	1
Visibility	1	1	3
StormNumber	NA	NA	205

The extracted traffic flow and speed data are illustrated in Table 7-4 through Table 7-9. Eventually, this information was coded into the VISSIM simulation models.

Table 7-4 Traffic flow data under normal weather condition

Sensor ID & Location	Two-Hour Traffic Volume (veh)	Eastbound		Westbound	
		Car	Truck	Car	Truck
2146 (MP322.6)	Traffic Volume	266	230	306	521
	Percentage	53.6%	46.4%	37.0%	63.0%
2178 (MP329.88)	Traffic Volume	373	415	216	575
	Percentage	47.4%	52.6%	27.3%	72.7%

Table 7-5. Speed data under normal weather condition

Sensor ID & Location	Speed (mph)	Eastbound		Westbound	
		Car	Truck	Car	Truck
2146 (MP322.6)	Average	74.0	67.6	68.9	64.3
	S.D.	5.74	9.92	7.72	7.76
	Maximum	91.2	87.2	86.9	82.2
	95th %	82.1	80.8	80.9	75.8
	85th %	79.3	77.6	76.9	71.8
	75th %	77.7	75.6	75.1	69.4
	50th %	75.1	68.3	69.2	65.1

	25th %	70.5	62	69.2	60.3
	15th %	67.6	56.9	64.0	57.1
	5th %	63.9	48.8	55.9	50.1
	Minimum	52.0	37.0	39.9	26.8
2178 (MP329.88)	Average	76.6	71.2	76.2	64.7
	S.D.	5.27	5.2	6.35	8.86
	Maximum	94.8	84.8	93.5	88.3
	95th %	84.2	79.8	87	79.9
	85th %	81.1	76.6	82.3	74.5
	75th %	79.7	75	79.7	69.9
	50th %	77	71.4	76.5	64
	25th %	74.1	67.3	74.2	59.8
	15th %	72.2	65.1	70.7	57.3
	5th %	66.6	63	63.9	48.6
	Minimum	55.4	56.2	51.7	38

Table 7-6. Traffic flow data under snow weather condition

Sensor ID & Location	Two-Hour Traffic Volume (veh)	Eastbound		Westbound	
		Car	Truck	Car	Truck
2146 (MP322.6)	Traffic Volume	139	93	225	371
	Percentage	60%	40%	37.8%	62.2%
2178 (MP329.88)	Traffic Volume	202	194	137	398
	Percentage	51%	49%	25.6%	74.4%

Table 7-7. Speed data under snow weather condition

Sensor ID & Location	Speed (mph)	Eastbound		Westbound	
		Car	Truck	Car	Truck
2146 (MP322.6)	Average	67.9	65.1	65.9	59.3
	S.D.	6.72	8.45	8.45	8.67
	Maximum	85.2	80.5	86.6	92.0
	95th %	78.3	77.3	78.6	71.7
	85th %	76.1	73.7	75.2	68.0
	75th %	73.0	71.2	71.9	65.0
	50th %	68.0	67.0	66.0	60.0
	25th %	62.4	59.0	60.9	54.4
	15th %	60.7	57.1	58.4	50.4
	5th %	58.3	49.1	50.3	44.1
	Minimum	53.1	40.4	41.6	19.3
2178 (MP329.88)	Average	72.5	69.5	71.1	62.9
	S.D.	6.17	5.35	7.55	8.56
	Maximum	94.4	85	89.2	89.3
	95th %	82.2	78.8	83.3	78.7

	85th %	78.6	75.7	79.5	72.8
	75th %	76.9	74	77	68.5
	50th %	73.2	68.4	70.8	62.1
	25th %	67.8	65.2	66.3	57.5
	15th %	66.3	63.8	63.7	54.3
	5th %	63.2	62.1	58	50.4
	Minimum	56.5	60.3	47.9	36.2

Table 7-8. Traffic flow data under severe weather condition.

Sensor ID & Location	Two-Hour Traffic Volume (veh)	Eastbound		Westbound	
		Car	Truck	Car	Truck
2146 (MP322.6)	Traffic Volume	47	52	105	303
	Percentage	47.5%	52.5%	25.7%	74.3%
2178 (MP329.88)	Traffic Volume	107	157	58	288
	Percentage	40.5%	59.5%	26.8%	83.2%

Table 7-9. Speed data under severe weather condition

Sensor ID & Location	Speed (mph)	Eastbound		Westbound	
		Car	Truck	Car	Truck
2146 (MP322.6)	Average	53.3	48.5	41.1	39.0
	S.D.	5.54	7.10	8.04	8.09
	Maximum	63.3	69.4	61.6	62.8
	95th %	63.2	58.4	53.4	51.1
	85th %	60.7	53.8	49.5	47.2
	75th %	57.0	53.0	46.7	44.7
	50th %	53.2	49.7	41.5	39.6
	25th %	50.4	44.7	35.2	33.3
	15th %	48.5	43.4	32.4	31.0
	5th %	44.2	35.0	29.4	24.9
	Minimum	40.6	29.0	22.8	17.1
2178 (MP329.88)	Average	54.4	54.9	48.3	49.6
	S.D.	7.03	5.78	8.06	6.98
	Maximum	79.3	68.3	71.1	67.8
	95th %	64.8	63.7	65.6	60.2
	85th %	62.1	61.1	56.5	55.8
	75th %	58.9	58.6	53.5	53.5
	50th %	54.7	55.4	48.3	50.1
	25th %	49.6	51.1	42.7	46.1
	15th %	47.7	50	41.1	43.3
	5th %	43.6	45.5	36.7	37.8
	Minimum	37.7	38.7	31.1	28.7

Model outputs are expected to be compared against field data to determine if the output was within acceptable levels. For instance, by comparing the traffic flow distribution pattern and travel speeds observed in the field to those generated by the simulation model, the research team would identify whether a correct number of vehicles are generated in the simulation model and running at reasonable speeds. Statistical tests, such as the GEH test and Mean Absolute Percent Error (MAPE) tests will be employed to verify the differences between simulation results and observations. Validation criteria used for this present study will be based on the suggestions provided by the Oregon Department of Transportation (Oregon DOT, 2011).

7.2.3.3 Adjustment of VISSIM Parameters

The desired speed distribution was created based on free flow speeds obtained from WYDOT's Wavetronix detectors. The cumulative speed distribution curve was plotted for the free flow time intervals because the cumulative speed distribution curve is the input used in VISSIM for desired speed. Figure 7-4 illustrates an example of the field collected speed distribution profiles for Car and Truck under normal weather condition, and the speed profiles in Figure 7-5 were manually matched in the VISSIM input.

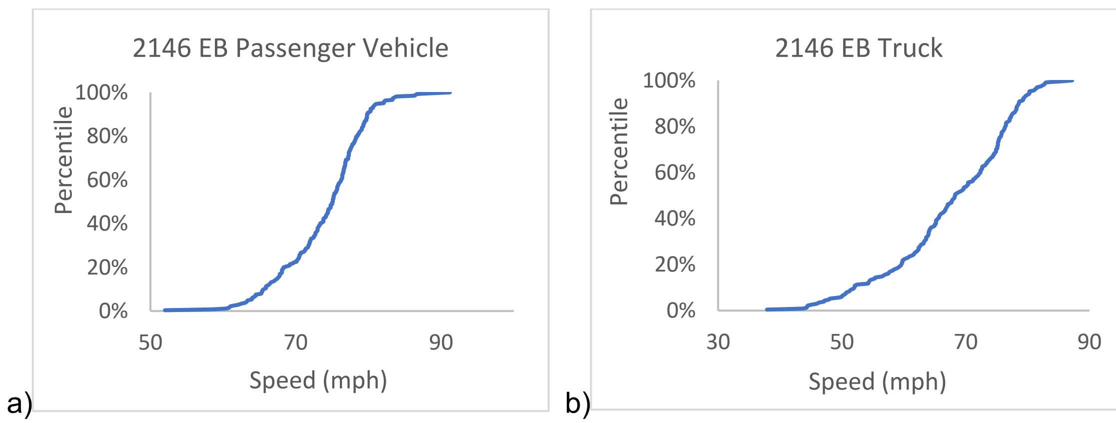


Figure 7-4. Field collected speed distribution under normal weather condition: (a) Speed distribution of Car; (b) Speed distribution of Truck (Source: WYDOT)

a) b)

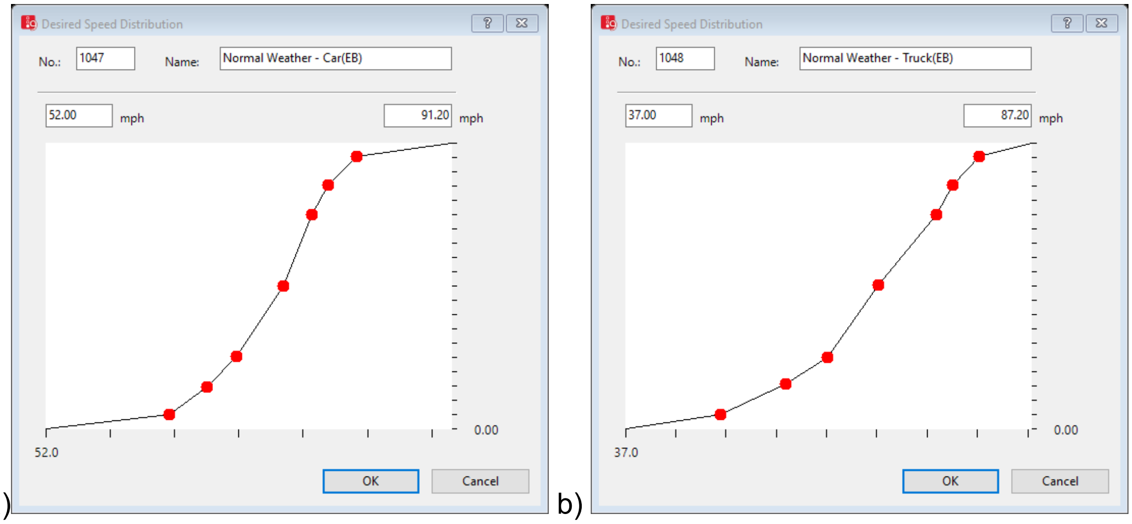


Figure 7-5. Adjustment of speed distribution in VISSIM to represent field collected speed profile: (a) Speed distribution of Car; (b) Speed distribution of Truck (Source: WYDOT)

VISSIM uses a psycho-physical car-following model and lane-changing model to simulate individual vehicle movements. The model calibration needs to determine the suitable parameters that can best represent real-world conditions. It involves checking the simulation results against observed data and adjusting parameters until simulation results fall within an acceptable range of error. Figure 7-6and Figure 7-7 illustrate the calibration of VISSIM car-following and lane-changing models for normal weather condition.

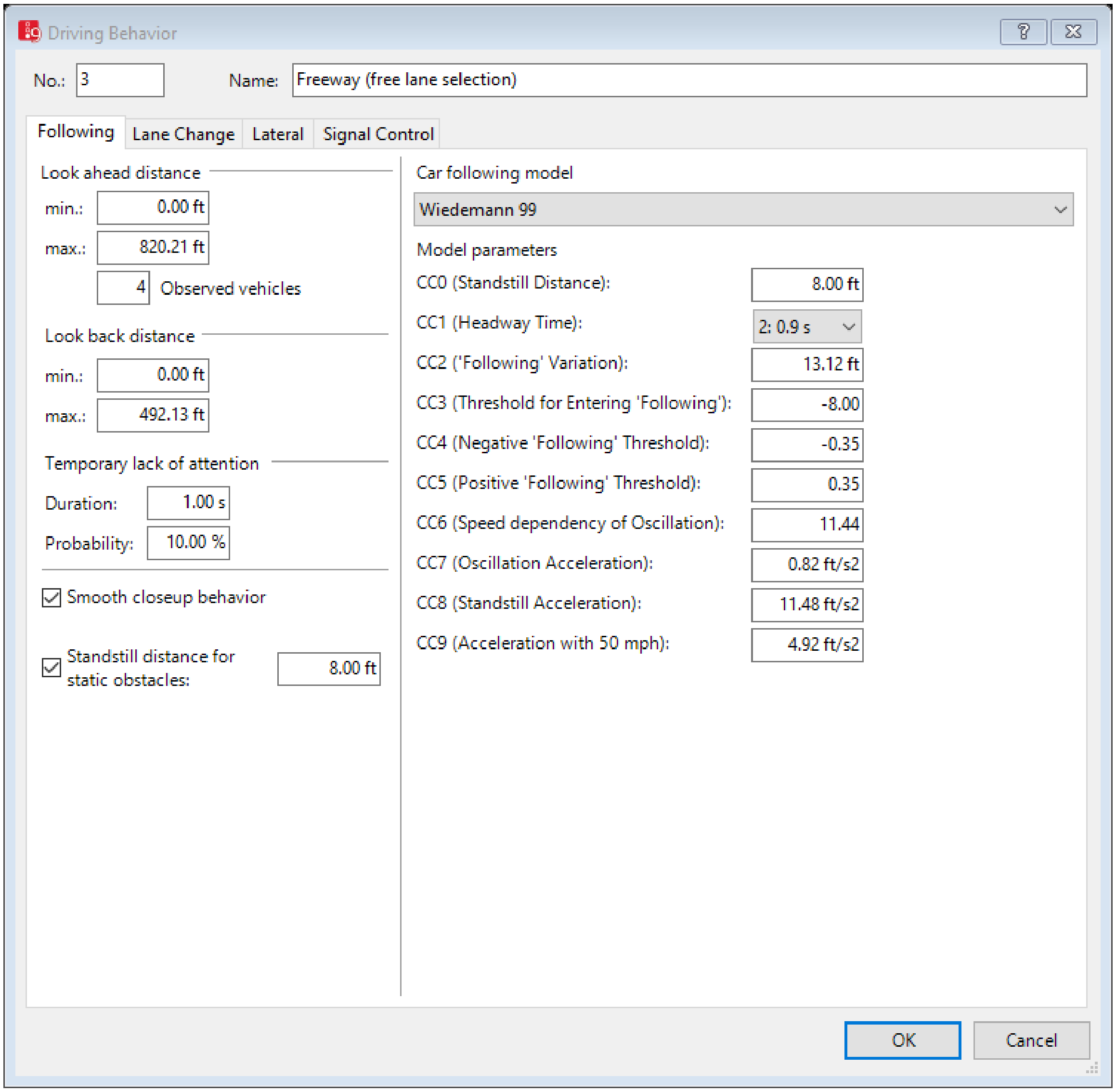


Figure 7-6. Calibration of Car-following Driver Behavior Parameters under normal weather condition (Source: WYDOT)

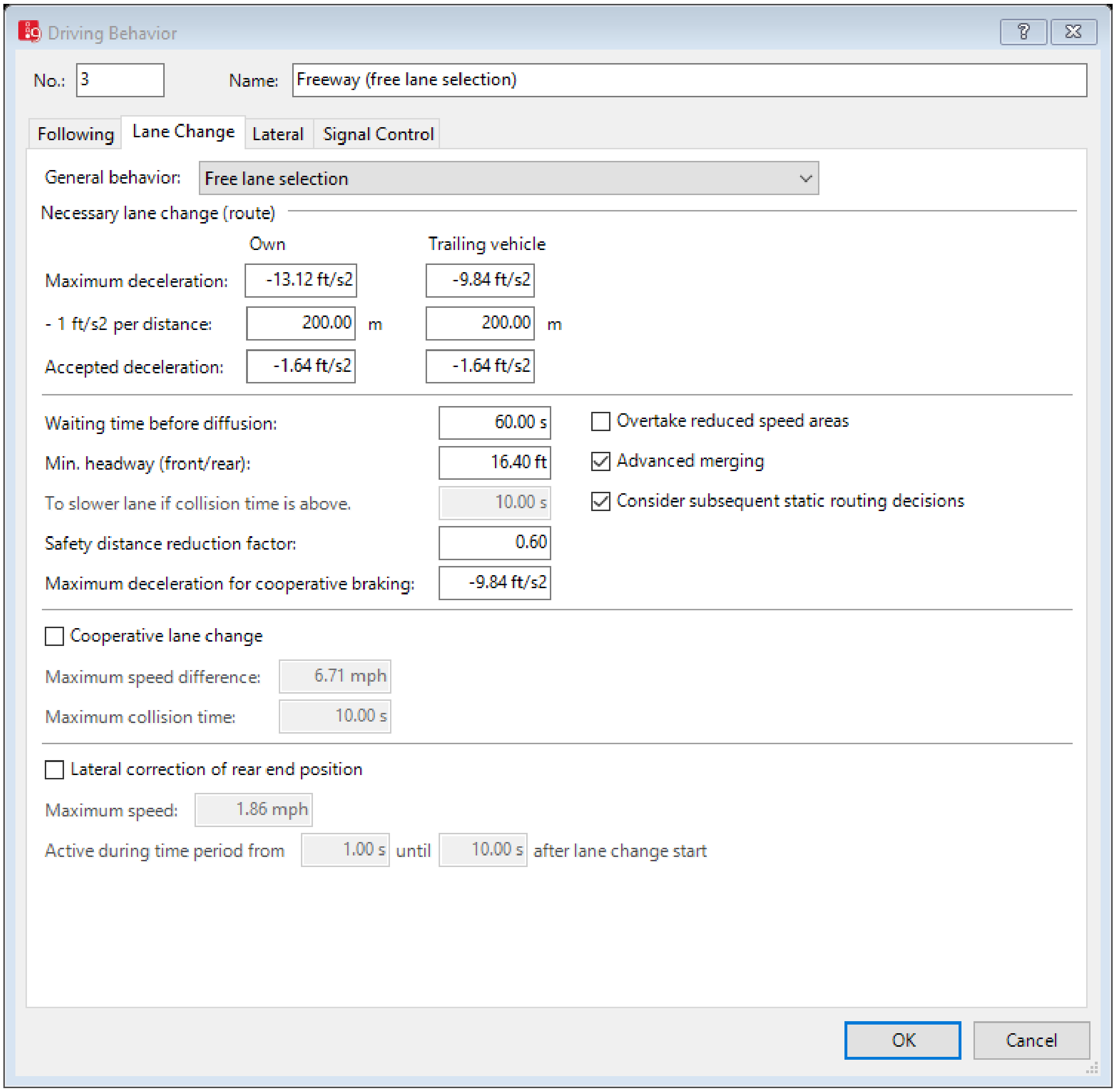


Figure 7-7. Calibration of Lane-changing Driver Behavior Parameters under normal weather condition (Source: WYDOT)

7.2.3.4 Testing of Simulation Results

7.2.3.4.1 Traffic Volume

After running the simulation using the calibrated parameters, simulation results were compared against field observed data to check the errors between simulation inputs and outputs. One reliable measure to compare traffic volume inputs and outputs is the GEH statistics (Oregon DOT, 2011). The GEH formula is descripted as follows:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

Where:

M = hourly traffic volume output from the simulation model (vph)

C = real-world hourly traffic volume input (vph)

To determine if an acceptable fit is achieved, this report employed the GEH interpretation guide presented in Table 7-10 (Oregon DOT, 2011).

Table 7-10. GEH interpretation guide

GEH Statistic Result	Reference
GEH < 5.0	Acceptable fit
5.0 <= GEH <= 10.0	Caution: possible model error or bad data
GEH>10.0	Unacceptable

For the traffic volume simulation results with the calibrated parameters, the GEHs were calculated, as presented in Table 7-11. It can be concluded that the GEH test results for all the four sensor locations are in the acceptable range.

Table 7-11. GEH results at the four sensor locations

Location	Input Volume (Vehicle per 2-hr)	Simulated Volume (Vehicle per 2-hr)	GEH	Acceptable
Sensor 2146 WB	827	784	1.5	Yes
Sensor 2146 EB	496	493	0.1	Yes
Sensor 2178 EB	788	782	0.2	Yes
Sensor 2178 WB	791	791	0	Yes

7.2.3.4.2 Traffic Speed

In addition to the GEH statistic test of traffic volume inputs and outputs, this report also employed the Mean Absolute Percentage Error (MAPE) statistic test to verify the errors between simulated and the observed speed profiles. It was assumed that a MAPE value that is lower than 5 percent indicates a good fit; and a MAPE value that is between 5 and 10 percent indicates an acceptable fit. The MAPEs were calculated using the following equation:

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\frac{|S_i - A_i|}{A_i}$$

Where:

A_i = Actual value of quantity (speed) being simulated,

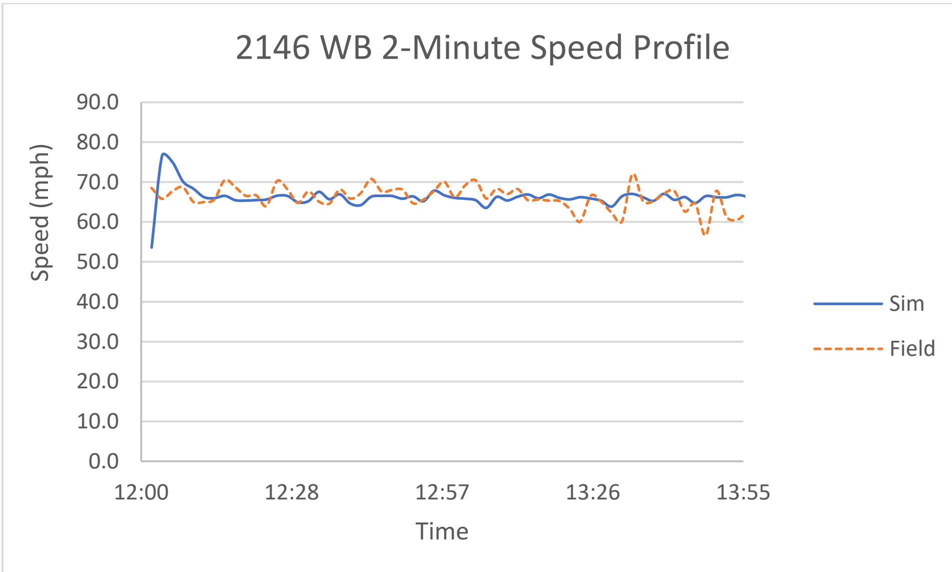
S_i = Simulated speed

n = Number of different times for which variable is simulated.

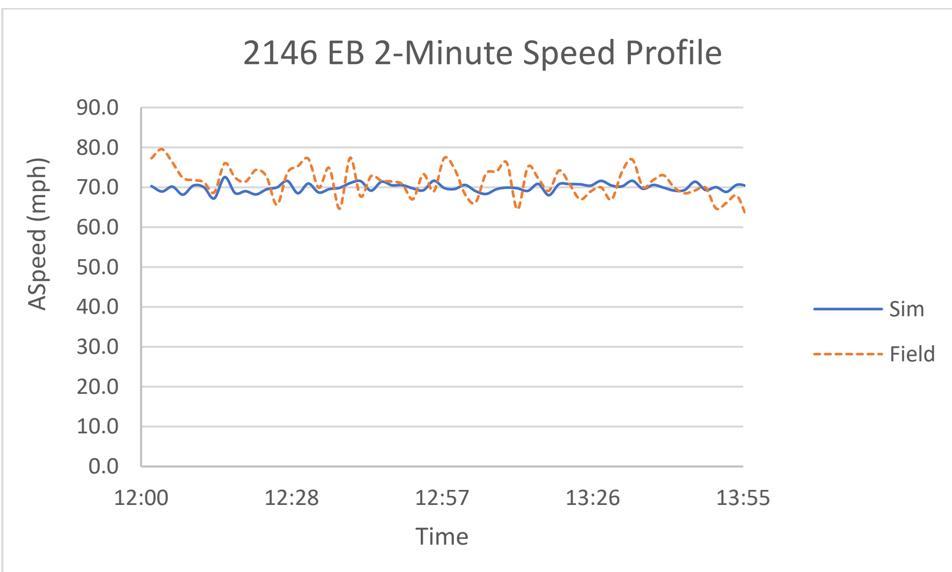
For the traffic speed simulation results with the calibrated parameters, the MAPEs were calculated, as presented in Table 7-12. It can be concluded that the MAPE test results for all the four sensor locations are in the acceptable range. Detailed comparisons between the simulated and field collected 2-minute speed profiles are illustrated in Figure 7-8.

Table 7-12. MAPE results at the four sensor locations

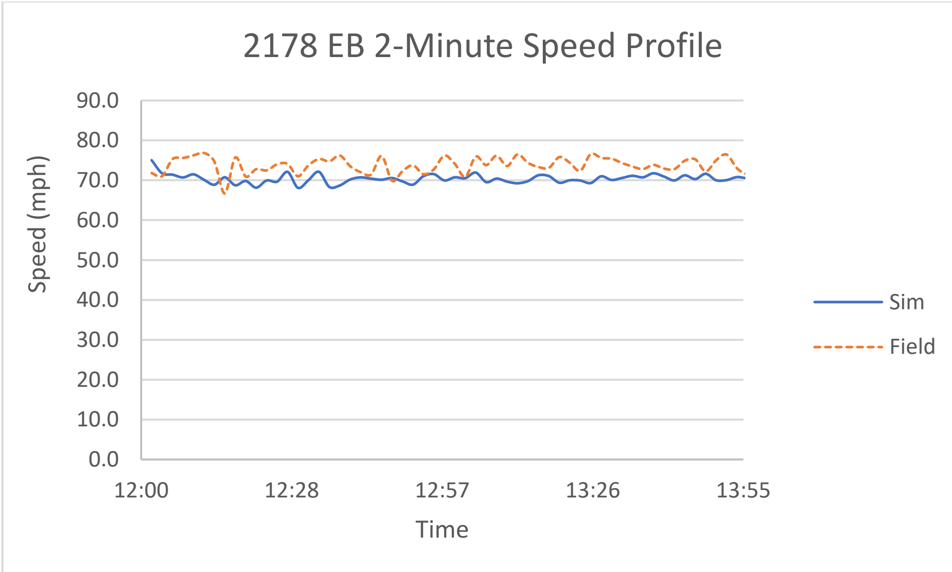
Location	MAPE	Acceptable
Sensor 2146 WB	4.1%	Yes
Sensor 2146 EB	4.9%	Yes
Sensor 2178 EB	4.8%	Yes
Sensor 2178 WB	4.0%	Yes



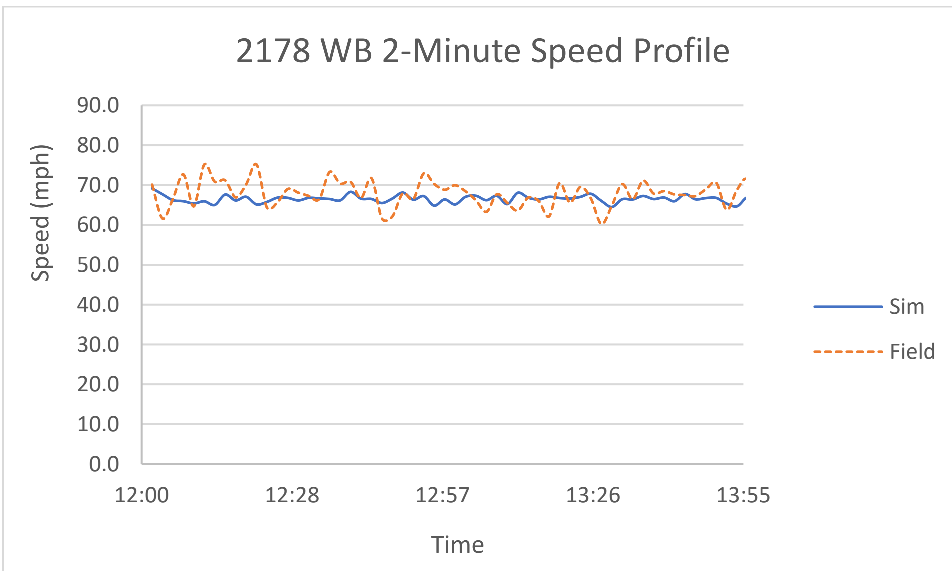
(a)



(b)



(c)



(d)

Figure 7-8. Comparison of simulated speed profile and field data: (a) Sensor 2146 westbound; (b) Sensor 2146 eastbound; (c) Sensor 2178 westbound; (d) Sensor 2178 eastbound (Source: WYDOT)

7.2.3.5 Calibration of SSAM

The vehicle trajectory data generated by the VISSIM simulation model will be processed in SSAM for identifying the simulated conflicts. With the calibrated VISSIM simulation model, the research team will run simulation for the baseline conditions to generate safety performance measures (traffic conflicts). Then, for model calibration, it is expected that the research team will adjust the crucial parameters in VISSIM and SSAM to improve the consistency between the simulated and the field observed (or from historical crash data) safety measures (or the SHRP2 Naturalistic Driving Study traffic safety performance data);

accordingly, identify the simulation parameters that can best replicate the real-world condition. For instance, it is usually assumed that time-to-conflict (TTC) is one of the key parameters that affect the simulated safety performance measures. Since in SSAM, a conflict is identified when the minimum TTC value between two converging vehicles exceeds the default threshold value; for model calibration, the research team will adjust the TTC threshold value to obtain the number of simulated conflicts (including the rear-to-end conflicts and the lane-change conflicts), and employ statistical methods to determine the suitable TTC threshold value for this study.

7.3 Performance Evaluation

With the coded VISSIM simulation model, the pre-CV-deployment condition will be simulated to act as a baseline for the CV evaluation. Traffic, weather, closures, and construction data for before CV deployment period will be collected and simulation scenarios will be designed.

Simulation scenarios could be a single scenario or a combination of scenarios. Single scenario may include weather condition (e.g., rain, snow, fog, wind, and severe weather conditions), road surface condition (e.g., ice, wet, and slick spots), presence of an accident, work zone, and VSL control strategy. Combined scenarios may include any logical combination of single scenarios such as adverse weather and accident ahead, adverse weather and VSL, work zone in rainy condition with VSL, etc. Being limited by the available time and resources, it is crucial to identify and simulate relevant scenarios that would most represent the real-world condition. Cluster analysis will be used to identify simulation scenarios based on available data. Eventually, the predicted crashes will be compared with the observed crashes during post-deployment period to determine whether or not there are reductions in crashes due to CV deployment program.

7.3.1 Before-After Study

The key approach for CV performance evaluation is “Before-After” study with statistical tests. This approach quantitatively compares data under baseline conditions (before deployment) with data during the Wyoming CV Pilot demonstration (post-deployment). Actual data, to the extent it is available, will be used to assess the performance of the Wyoming Pilot. Simulation will be used to supplement the assessment in areas where complete actual data was not available.

7.3.1.1 “Before” Study

For safety performance evaluation, this research will use the SSAM model to predict the crash probabilities and severities associated with typical events, weather conditions, and demands scenarios (using baseline driver behavior data). For mobility performance evaluation, this research will use the microscopic simulation model to estimate the capacity and travel time (or delay) associated with typical events, crashes, weather conditions, and demands scenarios. Total annual performance under the “before” condition will be estimated by applying probabilities of each identified simulation scenario under the “before” condition. The “before” simulation model will be developed by March 2018.

7.3.1.2 “After” Study

In accordance with each “before” scenario, for safety performance evaluation, this research will use the SSAM model to predict the crash probabilities and severities associated with typical events, weather conditions, and demands scenarios using the driver behavior data under CV condition. For mobility performance evaluation, this research will re-calibrate the VISSIM simulation model using the driver behavior data under connected vehicle environment from the field, field demonstration, and from the driving simulator. Then, using the actual traffic flow data during the CV post-deployment period to evaluate the capacity and travel time of the freeway corridor. The simulation will use data from an actual day in the “post-deployment” period that has similar weather and road conditions as “pre-deployment” period. Driver behavior data form the driving simulator will be used in case field data is not available.

7.3.2 Benefit-Cost Analysis

Based on the simulation results generated by the before-after study, the research team will further investigate the benefit-cost ratio of the CV deployment program by conducting benefit-cost analysis (BCA). The usefulness of a BCA for transportation projects are generally monetized into both the direct benefits from crash reductions, and indirect benefits from travel time savings, vehicle operating costs savings, and emission reductions for all travelers due to reduced crashes on I-80. The change in travel time, operating costs, and emissions for all travelers due to a crash for different crash types and severity levels will be estimated. The change in these measures will be summed for all crash types and severities. While costs to be considered in analysis include capital costs (costs to plan, implement, and operate the CV deployments), annual maintenance costs, and rehabilitation costs.

7.3.3 Sensitivity Analysis

With the calibrated microsimulation model, a series of sensitivity analyses will be conducted to provide better understanding of different behavioral phenomena and benefits of the CV applications. The sensitivity analysis focuses on two main parameters: changes of demand and CV penetration rates. Based on the sensitivity analysis results, it is possible to identify the short-term and long-term Benefit-Cost ratios of CV deployment program, the optimal settings for the CV applications, and the optimal CV market penetration rate. Demand changes might be assumed as no change, moderate change, and large change. For Wyoming and based on historical traffic data, it is expected to have no to moderate changes in demand. Moderate change assumes future demand levels to increase by 50%.

It is necessary to point out that due to the randomness nature of traffic flow, the connected trucks traveling on I-80 may not be uniformly distributed, and the traffic demand at different segments on I-80 will also fluctuate. These fluctuations will affect the actual CV penetration rate during the simulation. In this regard, a non-uniform traffic flow distribution patterns, such as Poisson or Gaussian distributions will be coded into the VISSIM simulation model to simulate the fluctuations of CV penetration rate. Another factor that may affect actual CV penetration rate is drivers' compliance rates. While due to the limitations of the available time and resources, the research team may not be able to account for all issues that related to the compliance and penetration rates in details. In this research, the actual compliance rate will be obtained from field data where possible, and the driving simulator training and testing.

8 Data Collection and Processing Status

The Wyoming CV Pilot team is continuing to deploy data collection and processing units. Currently, the following activities have been accomplished that support data collection and processing:

- A total of 47 RSUs installed. Remaining RSUs require a more complex installation.
- About 35 OBUs have been installed: 20 OBUs on snowplows and highway patrol vehicle; 11 on Trihydro vehicles; and 4 on test vehicles.
- Installed a few Weather Cloud devices – beginning to test end-to-end.
- No commercial vehicle partner trucks have had equipment installed, but that is planned in the near future.
- Work continues with Lear to collect and off load data. Expecting one additional firmware release. Also, Lear is working to integrate with SCMS.
- Work continues to complete integration with the commercial SCMS.
- Data collection from Connected Vehicle resources is underway and come from three primary sources; the OBU, the HMI, and the RSU. The logs are detailed in Section 7.13 of the ICD.
- The OBU transmits these logs to the Operational Data Environment (ODE) as described in Section 5.16 (ODE <->OBU) of the ICD. These logs are prioritized because in most cases the OBU has more log data than it can send to the ODE in an interaction at highway speed. Additionally, these logs have a prioritized purge order based on the criticality of the data to allow the OBU to protect its data storage.
- The HMI logs data to the OBU about driver interactions and software problems. These logs are also sent to the ODE for processing.
- The RSU collects data about data it sends (TIMs) and receives (BSMs). It also collects maintenance logs. These logs are also sent to the ODE for processing.
- The ODE is operational and receives these logs, decrypts the information and makes the data available on Kafka streams for other systems. This data is collected and archived in the WYDOT Data Warehouse. The data is additionally sent to the CVPEP/SDC and a subset to the RDE.
- The Pikalert system is also operational and collects the environmental data. The Pikalert system directly sends data to the Data Warehouse. The details of these flows are in chapter five of the ICD.
- Data collection is also being accomplished for non-Connected Vehicle resources. Data from the 511-mobile application for smart phones about truck parking availability is done at the data broker. Data from the WTI, Construction Administration, Incident Console, and RCRS are all collected by the Data Broker and stored in the Data Warehouse. The details of the flows are also in chapter five of the ICD.

At the time of this document publication, end-to-end data collection, storage, and processing capability testing was underway, and mostly complete. An update will be provided to USDOT at the conclusion of Phase 2.

9 Conclusions

The information documented in this Final System Performance Report describes the data collection approaches and analytical methods that have been established for just over half of the performance measures. Analyses were conducted on data collected during the baseline period and pre-deployment conditions were established for eleven performance measures. Additionally, statistical data was collected and presented on the impacts of this past winter on the transportation system and travelers.

The baseline data collection period was one of the most severe on record, especially the number and intensity of strong wind events in the corridor. Fifty-six (56) separate significant winter weather events were documented between December 2016 and November 2017. These weather events resulted in extensive use of variable speed limit systems and dynamic message signs, constant updates of the Wyoming traveler information system and the commercial vehicle operator portal, and numerous road closures. Of the crashes in this period, over 17% were blown over trucks due to extreme strong winds. Additionally, there were 7 fatalities. Indeed, this was a very impactful baseline winter season on the traveling public and commercial vehicle operators.

The primary focus of the Wyoming Connected Vehicle Pilot is to improve safety in the I-80 corridor. The analysis of historical and current speed adherence and crash data presented herein provides some early insight into how connected vehicle technology may achieve this goal of improved safety. For instance:

- During this baseline data collection period for all weather conditions, about 14.2% of vehicles are currently traveling 5 mph above the post speed (speed adherence is good) and a 29.6% of the vehicles are traveling outside a +/- 10 mph buffer (speed variation is moderate). For certain severe storm conditions, like ice and high winds (storm category 6), the compliance rate drops to 53.4% and the speed buffer to 45%. These conditions can translate or contribute to the number of crashes and crash severity. We anticipate an improvement in these values through CV-technologies to improve Situational Awareness (TIM messages) regarding posted speeds, especially in variable speed limit (VSL) areas. Additionally, the VSL systems and dynamic message signs (DMS) will have more accurate and timely information based on improved and expanded data collection and enhanced analysis from Pikalert.
- 1,310 crashes were recorded from October 2016 through May 2017. Weather conditions existing during the crashes included clear (48%) and snowing (21%). Road conditions existing during the crashes included ice/frost (39%), dry (36%) and snow (15%). We believe CV-enabled technologies can help to reduce the number of crashes during all conditions. Forward Collision Warning can help avoid a crash in any condition. Spot Weather Impact Warnings can alert a driver to poor weather or road conditions resulting in an avoided crash. Improved driver

Situational Awareness through TIM messages can also result in an avoided crash, especially during inclement weather and hazardous road conditions.

- Historically, about 30% of crashes on I-80 are multi-vehicle crashes, which include some events with tens of vehicles involved. Our goal is to reduce the number of secondary crashes by using CV technologies to alert drivers of a crash ahead so they can stop earlier or otherwise avoid becoming a crash victim. Further, these crashes can be the reason a section of I-80 need to be closed. During the data collection period from October 2016 through May 2017, a cumulative total of 3,632 hours of closures on 52 road closure segments were issued. We anticipate that implementation of CV applications such as Forward Collision Warning, Distress Notification, Work Zone Warnings, and in-vehicle TIM messages have the potential to reduce the number of vehicles in a crash by warning the driver of a crash just ahead.
- Finally, since 2010, 553 critical injury crashes have resulted from crashes on I-80. Of those, 132 fatal crashes occurred. Through implementation of CV technologies mentioned above, we believe we have the potential to significantly reduce these numbers either by drivers avoiding a crash all together or speeds being reduced during a crash.

Appendix A. Road Condition Ratings

Table A-1. Road condition ratings.

Condition	Impact	Text Page Column Name
Surface Conditions		
81 (dry)	L	Conditions
82 (wet)	L	Conditions
83 (slick)	H	Conditions
84 (slick in spots)	M	Conditions
85 (drifted snow)	M	Conditions
86 (closed)	C	Conditions
86 (closed - seasonal)	E	Conditions
Atmospheric Conditions		
91 (favorable)	No Impact	Conditions
92 (snowfall)	L	Conditions
93 (rain)	L	Conditions
94 (strong wind)	M	Conditions
94 (dangerous wind w/EBOR or C2LHPV)	H	Conditions
95 (fog)	M	Conditions
96 (blowing snow)	H	Conditions
97 (reduced visibility)	H	Conditions
Advisories		
BI (Black Ice)	H	Advisories
NUT (No Unnecessary Travel)	H	Advisories
EBOR (Extreme Blow Over Risk)	H	Advisories
NTT (No Trailer Traffic) March 25 - November 22	H	Advisories

NTT (No Trailer Traffic) November 23 - March 24	E	Advisories
ANLT (Advise No Light Trailers)	M	Advisories
FR (Falling Rock)	L	Advisories
Restrictions		
CL1/CL2 (Chain Law 1 & 2)	H	Restrictions
C2LHPV (Closure to Light, High Profile Vehicle)	C	Restrictions

Appendix B. Corridor Devices

The following sections provide details on the roadside equipment located in the project corridor including the radar speed sensors, road weather information system (RWIS), variable speed limit signs, variable speed limit corridors, and static speed limit signs.

Speed Sensors

The table below lists the information for the radar speed sensors on the corridor including which RWIS and Variable Speed Limit Signs are associated with each sensor. The 2105 Average daily traffic is also provided. The Horiz_D variable is a horizontal curvature variable for the decreasing milepost direction and Horiz_I is for the increasing milepost direction with 0 indicating no curvature, category 1 having radius greater than 5,000 feet, category 2 having radius between 2,500 and 5,000 feet, category 3 having between 1,000 and 2,500 feet, and category 4 having less than 1,000 feet centerline radius. The vertical grade in the increasing and decreasing milepost direction is shown in the last two categories.

Table B-1. Speed sensors along I-80

DEVICEID	SITENAME	MP	Sensor _Loc	RWIS	2015_ADT	VSL_ID	EB_VSL	WB_VSL	Horiz_D	Horiz_I	Vert_I	Vert_D
2334	East Evanston	8.45	EB	WY31	12,345	V1	2322	2336	1	1	0.36%	-0.67%
2346	Painter	10.16	WB	WY31	12,345	V1	2322	2360	0	0	0.23%	-0.23%
2359	Painter	11.86	EB	WY31	12,345	V1	2348	2360	2	2	2.16%	-2.09%
2372	First Divide	13.45	EB	KFIR	12,345	V1	2348	2384	2	2	4.98%	-5.14%
2383	First Divide	14.59	EB	KFIR	12,345	V1	2373	2384	0	0	-4.58%	4.51%
2395	US 189 Interchange	17.66	WB	KFIR	12,345	V1	2373	2410	0	0	-2.41%	2.61%
2409	US 189 Interchange	19	EB	KFIR	12,345	V1	2397	2410	0	0	4.21%	-4.21%

DEVICEID	SITENAME	MP	Sensor _Loc	RWIS	2015_ADT	VSL_ID	EB_VSL	WB_VSL	Horiz_D	Horiz_I	Vert_I	Vert_D
2421	MP 20.95	20.95	EB	KFIR	12,345	V1	2397	2434	0	0	-5.03%	5.04%
2433	MP 21.05	21.05	EB	KFIR	12,345	V1	2422	2434	0	0	-5.03%	5.04%
2445	Leroy	23.35	WB	KFIR	12,345	V1	2422	2457	0	0	-0.99%	1.03%
2607	Leroy	24.56	EB	KFIR	12,345	V1	2446	2457	0	0	1.03%	-1.03%
2609	French	27.6	WB	KFIR	12,345	V1	2446	1	3	3	-0.64%	0.64%
2916	Little America	69.7	WB	KCMS	14,620	N2	2	2	0	0	-0.62%	0.62%
3236	Green River Tunnel East	90.45	WB	KPER	26,454	V2	2674	3253	0	0	0.42%	-0.39%
3296	East Green River	91.99	EB	KPER	21,484	V2	3289	3253	0	0	-2.14%	2.08%
1084	Rock Springs West	97.9	EB	WY10	21,484	V2	3262	2024	4	4	-0.42%	0.42%
2020	Flaming Gorge	99.9	EB	WY10	17,269	V2	2013	2024	0	0	-0.90%	0.13%
2032	Dewar Drive	101.71	WB	WY10	17,269	V2	2013	2043	0	0	0.04%	-0.04%
2049	College Dr	103.2	WB	WY10	17,269	V2	2035	2062	0	0	2.57%	-2.67%
2070	Elk Street	104.55	WB	WY10	17,269	V2	2055	2084	0	0	0.07%	-0.06%
2079	Elk Street	105.65	EB	WY10	14,000	V2	2075	2084	2	2	0.07%	-0.06%
2090	Pilot Butte	106.8	WB	WY10	14,000	V2	2075	2095	0	0	-0.28%	0.27%
2578	Baxter Rd	110.36	EB	WY10	14,000	N3	1	2095	0	0	-2.63%	1.91%
1134	Point of Rocks	129.8	WB	WY10	12,585	N3	2	2	0	4	-0.80%	0.80%
1145	Bitter Creek	141.83	EB	WY10	12,585	N3	2	2	0	0	-0.28%	0.20%
1153	Tipton	156.72	WB	WY10	12,585	N3	2	2	0	0	-1.78%	1.82%
411	Creston Junction	187.42	WB	WY19	12,585	N3	1	2	0	0	-1.90%	1.91%

DEVICEID	SITENAME	MP	Sensor _Loc	RWIS	2015_ADT	VSL_ID	EB_VSL	WB_VSL	Horiz_D	Horiz_I	Vert_I	Vert_D
3897	Peterson	238.8	WB	WY19	10,645	V3	1810	1	0	0	0.46%	0.18%
3899	MP 242.2	242.2	EB	WY19	10,645	V3	1810	1	0	4	0.89%	-0.63%
3901	MP 246.7	246.65	EB	WY19	10,645	V3	1810	1	0	3	-2.69%	2.65%
1219	Elk Mountain	256.17	EB	WY19	10,645	V3	438	435	3	3	-0.89%	0.80%
400	CR 402 West	260.25	WB	WY19	10,645	V3	438	430	0	0	1.63%	-1.97%
1241	Wagonhound	266.58	WB	WY19	10,645	V3	433	426	3	3	4.38%	-4.22%
1251	Wagonhound	267.71	EB	WY28	10,645	V3	428	426	3	3	0.14%	-0.52%
482	Arlington East	273.1	WB	WY28	10,645	V3	428	422	0	0	2.51%	-2.49%
1269	Arlington East	273.85	EB	WY28	10,645	V3	424	422	0	4	-1.12%	1.11%
3907	MP 276.7	276.7	WB	WY28	10,645	V3	424	422	0	0	-2.24%	2.25%
1280	Cooper Cove	279.36	WB	WY28	10,645	V3	424	416	0	0	2.65%	-2.65%
405	Cooper Cove East	282.5	WB	WY28	10,645	V3	417	416	0	0	2.14%	-2.03%
3909	Strouss Hill	286	WB	WY28	10,645	V3	417	416	0	0	-0.76%	-1.22%
1327	Quealy Dome	289.5	WB	WY28	10,645	V3	417	1	3	3	-0.64%	0.97%
1342	Herrick Lane	297.66	WB	WY28	10,645	N4	417	1	0	0	-2.04%	2.14%
396	Laramie East	317.68	EB	WY28	13,890	V4	2118	3668	0	0	1.83%	-3.24%
3911	Telephone Canyon	320.7	WB	WY28	13,890	V4	2118	2128	0	0	4.62%	-4.63%
395	Summit	322.05	WB	WY28	13,890	V4	2118	2128	0	4	3.75%	-3.75%
2146	Summit	322.6	WB	WY28	13,890	V4	2118	2148	0	0	2.41%	-2.41%
2147	Summit	323.85	EB	WY28	13,890	V4	2136	2148	4	4	-2.91%	-0.38%
383	Summit East	324.9	EB	WY28	13,890	V4	2136	2148	0	0	0.60%	-0.06%

DEVICEID	SITENAME	MP	Sensor _Loc	RWIS	2015_ADT	VSL_ID	EB_VSL	WB_VSL	Horiz_D	Horiz_I	Vert_I	Vert_D
385	Tavern	326.9	EB	WY28	13,890	V4	2155	2163	4	4	-2.95%	2.91%
2178	Vedauwoo	329.88	EB	KVDW	13,890	V4	2170	2179	0	2	-3.12%	2.80%
386	Buford	334.5	WB	KVDW	13,890	V4	2192	2226	0	0	-1.87%	1.00%
387	Buford East	336.1	WB	KVDW	13,890	V4	2192	2226	3	3	-1.66%	1.68%
388	Buford East	336.5	WB	KVDW	13,890	V4	2214	2226	0	0	-1.98%	2.10%
389	Buford East	338.1	WB	KVDW	13,890	V4	2214	2247	0	0	-0.86%	0.78%
2246	Remount	339.86	EB	KVDW	13,890	V4	2234	2247	3	4	-2.79%	2.78%
390	Remount	340.5	WB	KVDW	13,890	V4	2234	2247	4	0	-2.87%	2.86%
2263	Harriman	343.24	EB	KVDW	13,890	V4	2255	2266	0	0	1.23%	-1.22%
391	Harriman	343.8	WB	KVDW	13,890	V4	2255	2266	0	4	-2.50%	2.53%
2274	Warren	344.69	WB	KVDW	13,890	V4	2255	2311	0	4	-1.28%	1.28%
2289	Warren	345.9	EB	KVDW	13,890	V4	2275	2311	3	0	-0.34%	0.34%
2298	Otto	347.69	WB	KVDW	13,890	V4	2275	2311	0	0	-1.52%	2.61%
2310	Otto	349.15	EB	KVDW	13,890	V4	2299	2311	0	0	-1.79%	1.64%
2319	MP 353.0	353	WB	KVDW	13,890	V4	2299	1	0	0	-0.67%	2.40%
1839	Roundtop Interchange	356.7	WB	KVDW	13,890	N5	1	1	0	4	-1.19%	1.19%
3482	Cheyenne East	373	WB	KVDW	9,990	N5	1	1	0	0	-0.71%	0.54%
382	Pine Bluffs	401.8	WB	KVDW	8,147	N5	1	2	0	0	-0.54%	0.37%
3249	Green River	94.2	WB	WY10	21,484	V2	3262	2006	4	4	-2.31%	2.77%
1100	Baxter Road	111.5	WB	WY10	14,000	N3	1	1	0	0	-2.59%	2.53%
1167	Hadsell	206	WB	WY19	12,585	N3	1	2	2	2	-2.04%	-1.01%
3903	Elk Mountain	252.9	WB	WY19	10,645	V3	3400	1776	0	0	-2.09%	-2.20%
1258	Foote Creek	269.5	WB	WY28	10,645	V3	428	426	2	2	0.59%	1.92%
3905	Arlington	270.65	EB	WY28	10,645	V3	428	426	0	0	2.92%	-3.33%

DEVICEID	SITENAME	MP	Sensor _Loc	RWIS	2015_ADT	VSL_ID	EB_VSL	WB_VSL	Horiz_D	Horiz_I	Vert_I	Vert_D
3654	MM 318.5	318.5	WB	WY28	13,890	V4	2118	2128	0	0	4.63%	-2.89%
394	Summit East	324	EB	WY28	13,890	V4	2136	2148	0	0	0.32%	-0.38%
2191	Lone Tree	332.29	WB	KVDW	13,890	V4	2170	2205	0	4	-2.00%	0.35%
2213	Buford	334.3	WB	KVDW	13,890	V4	2192	2226	0	0	-1.87%	1.73%
1075	Peru Hill	82.31	EB	KCMS	14,620	N2	1	1982	0	0	1.21%	-1.19%
3243	Green River	92.75	EB	WY10	21,484	V2	1997	3253	3	3	1.20%	-0.50%
408	Sinclair	221.7	EB	WY19	12,339	N3	1	2	4	4	-1.69%	1.63%
407	Walcott Junction	234.66	EB	WY19	10,645	N3	1	2	0	0	-0.37%	0.96%
1837	Dana Ridge	244.8	EB	WY19	10,645	V3	1810	1	0	0	1.40%	2.94%
1838	Mile Marker 249.1	249.1	EB	WY19	10,645	V3	1824	3418	4	0	-2.45%	2.30%
3402	MM 250.0	250	EB	WY19	10,645	V3	3400	1776	0	0	0.94%	-0.36%
1231	County Road 402	262	EB	WY19	10,645	V3	438	430	2	2	-3.63%	3.58%
398	CR 402 East	263.5	EB	WY19	10,645	V3	433	430	0	0	0.50%	-0.62%
384	Summit East	325.8	WB	WY28	13,890	V4	2136	2163	0	0	-1.00%	-0.06%
393	Vedauwoo	330	EB	KVDW	13,890	V4	2170	2179	0	0	-3.12%	2.80%
2202	Lone Tree	333.32	EB	KVDW	13,890	V4	2192	2205	3	2	-2.00%	0.85%

Road Weather Information Systems (RWIS)

Below is a full list of the RWIS located along the Wyoming I-80 corridor. The DeviceID is the number used by WYDOT systems. The MesoWest name is used for pulling data from the MesoWest archive. RWIS highlighted in table are the priority sensors used for the baseline performance measure activities.

Table B-2. List of the RWIS located along the Wyoming I-80 corridor

DEVICEID	SITENAME	MILEPOST	MesoWest
R001042	Evanston	4.2	WY7
R003348	Painter	10.16	WY31
R000362	First Divide	13.86	KFIR
R003356	US 189 Interchange	17.66	WY32
R003373	Coal Road	20.95	WY33
R003381	Leroy	23.35	WY34
R003389	French	27.6	WY35
R001058	Church Butte	52.65	WY8
R000363	Peru Hill	82.31	KCMS
R000366	Green River Tunnel East	90.5	KPER
R001078	Rock Springs West	97.9	WY9
R001093	Baxter Road	111.5	WY10
R001116	Superior	124.5	WY11
R001128	Point of Rocks	129.8	WY12
R000348	Bitter Creek	141.83	KBIT
R001150	Tipton	156.72	WY13
R000347	Continental Divide	184.3	KCTD
R001169	Sinclair	221.7	WY14
R001177	Walcott Junction	234.66	WY15
R001191	Dana Ridge	244.8	WY16
R001200	Mile Marker 249.1	249.1	WY17
R001205	Halleck Ridge	252.16	WY18
R001220	Elk Mountain	256.17	WY19
R001232	County Road 402	262	WY20
R001242	Wagonhound	266.58	WY21
R001259	Foote Creek	269.5	WY22
R000346	Arlington	271.8	KARL
R001270	Arlington East	273.85	WY23
R001281	Cooper Cove	279.36	WY24
R001295	Strouss Hill	283.75	WY25
R001328	Quealy Dome	289.5	WY26
R001343	Herrick Lane	297.66	WY27
R001354	Summit East	325.8	WY28
R000360	Vedauwoo	329.4	KVDW
R000367	Vedauwoo	329.4	KVED

DEVICEID	SITENAME	MILEPOST	MesoWest
R003422	Lone Tree	333.32	WY36
R003430	Buford East	336.5	WY37
R001366	Remount	340.5	WY29
R003443	Otto	347.69	WY38
R003451	MP 353.0	353	WY39
R003472	Cheyenne East	373	WY46

Variable Speed Limit Signs

The variable speed limit signs are shown in the table below along with the milepost, direction of travel (I for increasing milepost and D for decreasing milepost), and the maximum speed limit posting for each sign.

Table B-3. List of the VSL Signs located along the Wyoming I-80 corridor

Milepost	Route	Direction	Name	Corridor	Max Speed
8.45	ML80B	I	East Evanston	Evanston-Three Sisters	75
10.16	ML80B	D	Painter	Evanston-Three Sisters	75
11.86	ML80B	I	Painter	Evanston-Three Sisters	75
13.45	ML80B	D	Divide	Evanston-Three Sisters	75
14.59	ML80B	I	Divide	Evanston-Three Sisters	75
17.66	ML80B	D	US 189	Evanston-Three Sisters	75
21.05	ML80B	I		Evanston-Three Sisters	75
23.35	ML80B	D	Leroy	Evanston-Three Sisters	75
24.56	ML80B	I	Leroy	Evanston-Three Sisters	75
27.6	ML80B	D		Evanston-Three Sisters	75
88.86	ML80B	I	West of Green River	Green River-Rock Springs	65
90.08	ML80B	I	Green River West	Green River-Rock Springs	65
90.45	ML80B	I	East of Tunnel	Green River-Rock Springs	75
90.45	ML80B	D	Green River East	Green River-Rock Springs	65
91.99	ML80B	I		Green River-Rock Springs	75
92.75	ML80B	I	Green River East	Green River-Rock Springs	75
94.2	ML80B	I		Green River-Rock Springs	75
94.2	ML80B	D		Green River-Rock Springs	75
97.9	ML80B	D	US 191 South	Green River-Rock Springs	75
99.9	ML80B	I	US 191 South	Green River-Rock Springs	75
101.71	ML80B	D	Dewar	Green River-Rock Springs	75
103.2	ML80B	I	Dewar	Green River-Rock Springs	75

103.2	ML80B	D	College	Green River-Rock Springs	75
104.55	ML80B	I	College	Green River-Rock Springs	75
104.55	ML80B	D	Elk St.	Green River-Rock Springs	75
105.65	ML80B	I	Elk St.	Green River-Rock Springs	75
110.36	ML80B	D	Baxter	Green River-Rock Springs	75
238.8	ML80B	I	Peterson	Elk Mountain	75
246.7	ML80B	I	Dana Ridge	Elk Mountain	75
246.7	ML80B	D	Dana Ridge	Elk Mountain	75
250	ML80B	I		Elk Mountain	75
250	ML80B	D		Elk Mountain	75
254.87	ML80B	D	Elk Mountain	Elk Mountain	75
256.17	ML80B	I	Elk Mountain	Elk Mountain	75
259.77	ML80B	D	CR 402	Elk Mountain	75
267.71	ML80B	I	Wagon Hound	Elk Mountain	75
271.8	ML80B	D	Arlington	Elk Mountain	75
273.85	ML80B	I	Arlington	Elk Mountain	75
279.36	ML80B	D	Cooper Cove	Elk Mountain	75
317.68	ML80B	I	Grand Ave	Cheyenne-Laramie	75
318.5	ML80B	D		Cheyenne-Laramie	75
322.6	ML80B	D	Summit	Cheyenne-Laramie	65
323.85	ML80B	I	Summit	Cheyenne-Laramie	75
325.78	ML80B	D	Summit East	Cheyenne-Laramie	75
325.82	ML80B	I	Summit East	Cheyenne-Laramie	75
328.74	ML80B	D	Vedauwoo Road	Cheyenne-Laramie	75
329.8	ML80B	I	Vedauwoo Road	Cheyenne-Laramie	75
332.29	ML80B	D	Lone Tree	Cheyenne-Laramie	75
333.32	ML80B	I	Lone Tree	Cheyenne-Laramie	75
334.3	ML80B	D	Buford Interchange	Cheyenne-Laramie	75
336.16	ML80B	I	Buford Interchange	Cheyenne-Laramie	75
338.1	ML80B	D	Remount	Cheyenne-Laramie	75
339.86	ML80B	I	Remount	Cheyenne-Laramie	75
341.6	ML80B	D	Harriman	Cheyenne-Laramie	75
343.24	ML80B	I	Harriman	Cheyenne-Laramie	75
344.69	ML80B	D	Warren	Cheyenne-Laramie	75
345.9	ML80B	I	Warren	Cheyenne-Laramie	75
349.15	ML80B	I	Otto	Cheyenne-Laramie	75
353	ML80B	D		Cheyenne-Laramie	75

VSL Roadway Segments

The CV Pilot Corridor can be subdivided into sections using several WYDOT conventions including maintenance sections, road reporting sections, and by major towns. The tables below use the variables speed limit corridors as a segmentation method. The first table identifies beginning and ending mileposts for both the Eastbound (I) and Westbound (D) directions. The second table is a simplified version of this where the mile markers are not dependent on direction of travel.

Table B-4. List of VSL Segments along the Wyoming I-80 corridor

ROUTE	BEG_MP	END_MP	DIR	VSL_CORR	CORR_ID
ML80B	0	8.45	I		N1_I
ML80B	8.45	29.21	I	Evanston-Three Sisters	V1_I
ML80B	29.21	88.859	I		N2_I
ML80B	88.859	107.9	I	Rock Springs-Green River	V2_I
ML80B	107.9	238.8	I		N3_I
ML80B	238.8	291	I	Elk Mountain	V3_I
ML80B	291	317.68	I		N4_I
ML80B	317.68	353.5	I	Cheyenne-Laramie	V4_I
ML80B	353.5	402	I		N5_I
ML80B	6.26	0	D		N1_D
ML80B	27.6	6.26	D	Evanston-Three Sisters	V1_D
ML80B	88.85	27.6	D		N2_D
ML80B	110.36	88.85	D	Rock Springs-Green River	V2_D
ML80B	237.7	110.36	D		N3_D
ML80B	289.5	237.7	D	Elk Mountain	V3_D
ML80B	316	289.5	D		N4_D
ML80B	353	316	D	Cheyenne-Laramie	V4_D
ML80B	402.78	353	D		N5_D

Table B-5. List of VSL Corridors located along the Wyoming I-80 corridor

ROUTE	BEG_MP	END_MP	VSL_CORR	CORR_ID
ML80B	0	6.26		N1
ML80B	6.26	29.21	Evanston-Three Sisters	V1
ML80B	29.21	88.85		N2
ML80B	88.85	110.36	Rock Springs-Green River	V2
ML80B	110.36	238.8		N3
ML80B	238.8	291	Elk Mountain	V3
ML80B	291	316		N4
ML80B	316	353.5	Cheyenne-Laramie	V4
ML80B	353.5	402.78		N5

Static Speed Limit Signs

Outside of the variable speed limit zones, the roadway is controlled by static speed limit signs posting 65, 75, or 80 mph speed limits. The figure below lists all the static speed limit signs for the project corridor.

Sign	Sign Class	Legend	Maint. Sec	WY Route #	Route	Direction	Lane	Start MP	End MP	AH MP	District	County	Sign Owne	Position
307095	Regulatory	SPEED LIMIT 75	UI01A	I-80	ML80	Dec	Ramp (On/Off)	1.36	1.36		3030 - District #3 Ma	Uinta (19)	WyDOT	Left
281708	Regulatory	SPEED LIMIT 75	UI01A	I-80	ML80	Both	All	2.94	2.94		3030 - District #3 Ma	Uinta (19)	WyDOT	Left
281902	Regulatory	SPEED LIMIT 75	UI01A	I-80	ML80	Both	All	6.35	6.35		3030 - District #3 Ma	Uinta (19)	WyDOT	Right
282156	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	29.14	29.14		3030 - District #3 Ma	Uinta (19)	WyDOT	Right
282164	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	29.63	29.63		3030 - District #3 Ma	Uinta (19)	WyDOT	Left
282207	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	31.09	31.09		3030 - District #3 Ma	Uinta (19)	WyDOT	Right
282215	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	32.05	32.05		3030 - District #3 Ma	Uinta (19)	WyDOT	Left
403529	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	32.98	32.98		3030 - District #3 Ma	Uinta (19)	-1	Left
282256	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	33.60	33.60		3030 - District #3 Ma	Uinta (19)	WyDOT	Left
403533	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	33.90	33.90		3030 - District #3 Ma	Uinta (19)	-1	Left
282313	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Both	All	35.57	35.57		3030 - District #3 Ma	Uinta (19)	WyDOT	Right
282449	Regulatory	SPEED LIMIT 75	UI01B	I-80	ML80	Inc	Left	47.58	47.58		3030 - District #3 Ma	Uinta (19)	WyDOT	Left
443502	Regulatory	SPEED LIMIT 80	UI01B	I-80	ML80	Inc	All	47.70	47.70		3030 - District #3 Ma	Uinta (19)	WyDOT	Right
282495	Regulatory	SPEED LIMIT 80	UI01B	I-80	ML80	Both	All	49.00	49.00		3030 - District #3 Ma	Uinta (19)	WyDOT	Right
443501	Regulatory	SPEED LIMIT 80	SW01C	I-80	ML80	Both	All	65.20	65.20		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
277620	Regulatory	SPEED LIMIT 80	SW01C	I-80	ML80	Both	All	67.30	67.30		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
277631	Regulatory	SPEED LIMIT 80	SW01C	I-80	ML80	Both	All	68.21	68.21		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
277688	Regulatory	SPEED LIMIT 80	SW01C	I-80	ML80	Both	All	69.85	69.85		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
277715	Regulatory	SPEED LIMIT 80	SW01C	I-80	ML80	Both	All	71.57	71.57		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
443444	Regulatory	SPEED LIMIT 80	SW01C	I 80	ML80	Both	All	73.12	73.12		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
443443	Regulatory	SPEED LIMIT 80	SW01C	I 80	ML80	Both	All	77.55	77.55		3030 - District #3 Ma	Lincoln (12)	WyDOT	Right
277782	Regulatory	SPEED LIMIT 75	SW01C	I-80	ML80	Both	All	82.30	82.30		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
306029	Regulatory	SPEED LIMIT 75	SW01D	I-80	ML80	Both	All	84.03	84.03		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
443442	Regulatory	SPEED LIMIT 75	SW01D	I 80	ML80	Both	All	85.00	85.00		3030 - District #3 Ma	Lincoln (12)	WyDOT	Left
276913	Regulatory	SPEED LIMIT 75	SW01G	I-80	ML80	Both	All	97.85	97.85		3030 - District #3 Ma	Sublette (23)	WyDOT	Left
278114	Regulatory	SPEED LIMIT 75	SW01D	I-80	ML80	Both	All	101.71	101.71		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
443412	Regulatory	SPEED LIMIT 75	SW01D	I-80	ML80	Both	All	101.71	101.71		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
443424	Regulatory	SPEED LIMIT 75	SW01G	US-30 BUS	ML80	Both	All	104.05	104.05		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
443425	Regulatory	SPEED LIMIT 75	SW01G	US-30 BUS	ML80	Both	All	104.05	104.05		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Median
443426	Regulatory	SPEED LIMIT 75	SW01G	US-30 BUS	ML80	Both	All	104.05	104.05		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Median
443427	Regulatory	SPEED LIMIT 75	SW01G	US-30 BUS	ML80	Both	All	104.05	104.05		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
278848	Regulatory	SPEED LIMIT 75	SW01G	I-80	ML80	Both	All	107.66	107.66		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
443421	Regulatory	SPEED LIMIT 75	SW01G	I-80	ML80	Both	All	107.66	107.66		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Median
443419	Regulatory	SPEED LIMIT 80	SW01G	I-80	ML80	Both	All	110.30	110.30		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
443420	Regulatory	SPEED LIMIT 80	SW01G	I-80	ML80	Both	All	110.30	110.30		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Median
278873	Regulatory	SPEED LIMIT 75	SW01G	I-80	ML80	Both	All	110.62	110.62		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
437291	Regulatory	SPEED LIMIT 75	SW01G	I-80	ML80	Both	All	110.62	110.62		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
278934	Regulatory	SPEED LIMIT 80	SW01G	I-80	ML80	Inc	Left	121.60	121.60		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
278308	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	122.94	122.94		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
278315	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	130.32	130.32		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
278361	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	131.44	131.44		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
278456	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	141.72	141.72		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
278502	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	142.80	142.80		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
423575	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	155.32	155.32		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
423572	Regulatory	SPEED LIMIT 80	SW01E	I-80	ML80	Both	All	157.08	157.08		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
423585	Regulatory	SPEED LIMIT 75	SW01E	I-80	ML80	Both	All	157.81	157.81		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
423527	Regulatory	SPEED LIMIT 80	SW01A	I-80	ML80	Both	All	159.25	159.25		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
277260	Regulatory	SPEED LIMIT 80	SW01A	I-80	ML80	Both	All	164.85	164.85		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
437287	Regulatory	SPEED LIMIT 80	SW01A	I-80	ML80	Both	All	164.85	164.85		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Median
437286	Regulatory	SPEED LIMIT 80	SW01A	I-80	ML80	Both	All	164.85	164.85		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
437288	Regulatory	SPEED LIMIT 80	SW01A	I-80	ML80	Both	All	164.85	164.85		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Median
443416	Regulatory	SPEED LIMIT 75	SW01A	I-80	ML80	Both	All	171.26	171.26		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
277416	Regulatory	SPEED LIMIT 75	SW01A	I-80	ML80	Both	All	172.71	172.71		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
277463	Regulatory	SPEED LIMIT 75	SW01A	I-80	ML80	Both	Right	174.20	174.20		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right
380185	Regulatory	SPEED LIMIT 75	SW01B	I-80	ML80	Dec	All	186.59	186.59		1030 - District #1 Ma	Sweetwater (4)	WyDOT	Right
277524	Regulatory	SPEED LIMIT 75	SW01A	I-80	ML80	Both	All	186.59	186.59		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Left
443414	Regulatory	SPEED LIMIT 75	SW01B	I-80	ML80	Both	All	187.11	187.11		3030 - District #3 Ma	Sweetwater (4)	WyDOT	Right

274368	Regulatory SPEED LIMIT 75	SW01B	I-80	ML80	Inc	All	187.88	187.88	1030 - District #1 Mz Carbon (5)	WyDOT	Right
443415	Regulatory SPEED LIMIT 75	SW01B	I-80	ML80	Both	All	188.05	188.05	3030 - District #3 Mz Sweetwater (4)	WyDOT	Right
380728	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Dec	All	210.84	210.84	1030 - District #1 Mz Carbon (5)	WyDOT	Right
381141	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Dec	All	213.35	213.35	1030 - District #1 Mz Carbon (5)	WyDOT	Right
270475	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Inc	All	214.99	214.99	1030 - District #1 Mz Carbon (5)	WyDOT	Right
270488	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Inc	All	216.84	216.84	1030 - District #1 Mz Carbon (5)	WyDOT	Right
427351	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Inc	All	216.87	216.87	1030 - District #1 Mz Carbon (5)	WyDOT	Right
381508	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Dec	All	218.87	218.87	1030 - District #1 Mz Carbon (5)	WyDOT	Right
270525	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Inc	All	222.63	222.63	1030 - District #1 Mz Carbon (5)	WyDOT	Right
385535	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Dec	All	227.79	227.79	1030 - District #1 Mz Carbon (5)	WyDOT	Right
270547	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Inc	All	228.85	228.85	1030 - District #1 Mz Carbon (5)	WyDOT	Right
386027	Regulatory SPEED LIMIT 75	CB01A	I-80	ML80	Dec	All	234.40	234.40	1030 - District #1 Mz Carbon (5)	WyDOT	Right
273938	Regulatory SPEED LIMIT 75	CB01B	I-80	ML80	Inc	All	235.99	235.99	1030 - District #1 Mz Carbon (5)	WyDOT	Right
386316	Regulatory SPEED LIMIT 75	CB01B	I-80	ML80	Dec	All	237.81	237.81	1030 - District #1 Mz Carbon (5)	WyDOT	Right
411922	Regulatory SPEED LIMIT 75	CB01B	I-80	ML80	Dec	All	237.81	237.81	1030 - District #1 Mz Carbon (5)	WyDOT	Median
405615	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Inc	All	291.13	291.13	1030 - District #1 Mz Albany (5)	WyDOT	Median
274093	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Inc	All	291.13	291.13	1030 - District #1 Mz Albany (5)	WyDOT	Right
274204	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Dec	All	296.85	296.85	1030 - District #1 Mz Albany (5)	WyDOT	Right
274111	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Inc	All	298.26	298.26	1030 - District #1 Mz Albany (5)	WyDOT	Right
274236	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Dec	All	309.77	309.77	1030 - District #1 Mz Albany (5)	WyDOT	Right
274172	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Inc	All	312.47	312.47	1030 - District #1 Mz Albany (5)	WyDOT	Right
395290	Regulatory SPEED LIMIT 75	AL01A	I-80	ML80	Dec	All	312.89	312.89	1030 - District #1 Mz Albany (5)	WyDOT	Right
395389	Regulatory SPEED LIMIT 75	AL01B	I-80	ML80	Inc	All	313.89	313.89	1030 - District #1 Mz Albany (5)	WyDOT	Right
395420	Regulatory SPEED LIMIT 75	AL01B	I-80	ML80	Dec	All	316.05	316.05	1030 - District #1 Mz Albany (5)	WyDOT	Right
421856	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Inc	All	353.45	353.45	1030 - District #1 Mz Laramie (2)	WyDOT	Right
421857	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Inc	All	353.45	353.45	1030 - District #1 Mz Laramie (2)	WyDOT	Median
399548	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	All	356.65	356.65	1030 - District #1 Mz Laramie (2)	WyDOT	Right
401102	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Inc	All	360.20	360.20	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402769	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	Center	361.39	361.39	1030 - District #1 Mz Laramie (2)	WyDOT	Right
401666	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Inc	All	362.57	362.57	1030 - District #1 Mz Laramie (2)	WyDOT	Right
403424	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	All	363.16	363.16	1030 - District #1 Mz Laramie (2)	WyDOT	Right
401992	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Inc	All	364.87	364.87	1030 - District #1 Mz Laramie (2)	WyDOT	Right
403239	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	All	366.50	366.50	1030 - District #1 Mz Laramie (2)	WyDOT	Right
403198	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Inc	All	368.30	368.30	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402038	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	All	369.57	369.57	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402088	Regulatory SPEED LIMIT 80	LA01A	I-80	ML80	Inc	All	371.22	371.22	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424062	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	All	372.75	372.75	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424063	Regulatory SPEED LIMIT 75	LA01A	I-80	ML80	Dec	All	372.75	372.75	1030 - District #1 Mz Laramie (2)	WyDOT	Left
402645	Regulatory SPEED LIMIT 80	LA01A	I-80	ML80	Dec	Right	376.66	376.66	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402631	Regulatory SPEED LIMIT 80	LA01B	I-80	ML80	Inc	Right	378.06	378.06	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424051	Regulatory SPEED LIMIT 80	LA01B	I-80	ML80	Dec	Right	385.75	385.75	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424057	Regulatory SPEED LIMIT 80	LA01B	I-80	ML80	Inc	Right	387.07	387.07	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402353	Regulatory SPEED LIMIT 80	LA01B	I-80	ML80	Dec	Right	390.63	390.63	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402352	Regulatory SPEED LIMIT 80	LA01B	I-80	ML80	Inc	Right	392.08	392.08	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424060	Regulatory SPEED LIMIT 80	LA01B	I-80	ML80	Dec	Right	400.25	400.25	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424058	Regulatory SPEED LIMIT 75	LA01B	I-80	ML80	Inc	Right	400.25	400.25	1030 - District #1 Mz Laramie (2)	WyDOT	Right
424059	Regulatory SPEED LIMIT 75	LA01B	I-80	ML80	Inc	Right	400.25	400.25	1030 - District #1 Mz Laramie (2)	WyDOT	Left
402332	Regulatory SPEED LIMIT 75	LA01B	I-80	ML80	Dec	Right	400.85	400.85	1030 - District #1 Mz Laramie (2)	WyDOT	Right
402199	Regulatory SPEED LIMIT 75	LA01B	I-80	ML80	Dec	Right	402.59	402.59	1030 - District #1 Mz Laramie (2)	WyDOT	Right

Figure B- 1. Static speed limit signs (Source: WYDOT)

Appendix C. Data Descriptions

The following sections provide the data description documents for the primary data sets used in the performance measurement analyses.

Data Description – Individual Speed Data

Individual speed data comes from 74 of the 88 Wavetronix speed radar devices installed along I-80. These devices were existing on the corridor prior to the CV Pilot project and are concentrated in the four variable speed limit corridors. These sensors are primarily described by a three- or four-digit device ID number. Secondary descriptors include a device name and a route milepost. The 12 sensors IDs that there is no data for are likely older sensors that have been replaced prior to the CV Pilot project but their sensor IDs have been retained for purposes of archived data.

Information of the 88 speed sensors including sensor ID, description, and milepost can be found at in the Speed Sensor tab of the spreadsheet titled **Corridor_Devices.xlsx**. This spreadsheet has also been merged with other data sources so that it indicates the nearest Road Weather stations, the 2015 Annual Daily Traffic, a VSL corridor ID number to indicate if it's in a VSL corridor (IDs beginning with V) or not (IDs beginning with N), the appropriate Variable speed limit sign for speed data in the eastbound and westbound directions, a Horizontal Curve category in either both the increasing and decreasing milepost direction (see comment on column heading) and a vertical grade in both the increasing and decreasing direction.

Data Availability

Until the CV Pilot project, the sensors collected aggregate speed data in 30 second bins. In order to determine speed variance and speed compliance, the TMC's IRIS software had to be reconfigured to allow for sensors to be recorded in individual speed data mode. This software change proved challenging and different versions of the software were tested in December 2016 through the spring of 2017. One of the primary challenges with the software modifications is that moving the sensors to log individual speeds caused the sensors to be unavailable to the TMC operators, which was viewed as an unacceptable safety concern during the winter months. Therefore, only a subset of individual speed data is available from January to mid-May when all the sensors were moved over to individual speed mode.

Archived speed data directly from the IRIS software is stored in a cumbersome .vlog file format. While this format can be read as a .txt file, the file itself does not contain the sensor ID or the date. The sensor ID is found in the file name and the date is stored in the file folder. A separate file folder is created for each date. Because of this format, WYDOT has created a script that creates a single .csv file for each month that combines all the individual files for that month and adds a sensor ID field and adds the date to the time field. These monthly .csv files are what are provided as the individual speed data files.

A summary of the speed data from January through June is provided in the **Vlogs_Query_Summary.xlsx** file. This file provides for each month by sensor ID the number of records, average speeds, minimum and maximum lane number of total records, total speed records, number of null speed observations, the percentage of null values, and the minimum and maximum date and time of observations for that month.

Filename convention for the actual individual speed data sets are **vlogs_[four digit year, two digit month].csv**. So vlogs_201701.csv contains individual speed observations for January of 2017. Currently data is available for the months of January – June of 2017.

Data Description – Unprocessed Data

In its unprocessed state, there are six data fields for individual speeds, which are described in the table below.

Table C-1. Unprocessed Speed Observation Data Fields

Data field	Description	Units	Notes
Date_Time	Date and time of observation	Mountain time zone (MST and MDT)	
Sensor	Sensor ID	Unique three or four digit number	See sensor description spreadsheet to link sensor ID to information of the location and roadway characteristics.
Speed	Speed of vehicle to one decimal place	MPH	Null speeds have been retained
Length	Length of vehicle	Feet	
Class	Length Based Classification	Class 1 < 20 feet, Class 2 20-40’, Class 3 > 40’. Class 0 is unknown.	There are instances where the length and class values do not match up but these definitions are generally true. Observations with a null speed and a length of 6’ are believed to be erroneous observations. For our analysis we’ve assumed Class 0 and 1 to be passenger cars and Class 2 and above to be trucks.
Lane	Lane number	Lane 1 is the closest lane to the speed sensor and all subsequent lanes are numbered increasingly from that lane. The direction	The sensor description spreadsheet indicates if a sensor reads in both directions (B), the increasing milepost direction (I), or the decreasing milepost direction (D) as well as the description of which side of

		(eastbound or westbound) and lane position (inside, outside, and occasionally middle) are both dependent on which side of the road the sensor is installed on.	the road the sensor is installed on. Wavetronix sensors can read up to 16 lanes of traffic. For I-80 there are no sections above lanes. Most sections are two lanes in each direction with periodic climbing lanes. In some cases, the median width is too wide so a senor only reads in one direction.

Data Description – Processed

Additional fields are appended to each speed observation to aid in the calculation of performance measures to create processed data sets. No data is removed during processing so all records and fields remain unchanged, only additional fields are added. This section describes these additional fields. For more details on the methodology behind the calculations used to determine values for these fields, please refer to the performance measurement reports.

The processing of speed data appends applicable weather (from RWIS data) and posted speed variables to the original data. See **Corridor_Devices.xlsx** for a full listing of which weather station and speed limit signs are associated with each speed sensor.

Generally, the closest priority RWIS by milepost was associated with each speed sensor. An exception to this rule is when that sensor was found to be located in an area where it was too protected from weather conditions and was found not to adequately represent the conditions at the sensor and when the RWIS sensor was located in close proximity to another RWIS. See the data description for RWIS for more details on how the original RWIS data were processed.

Speed sensors are installed closest to either the inside eastbound or westbound lanes. Lane numbers are assigned so that the closest lane is given lane ID 1 and are number sequentially outward. Therefore, in order to determine if a particular lane is in the eastbound or westbound direction, you must first know what side of the road the sensor is located. Because lane direction dependent on the sensor location, the speed observations for EB sensors are processed separately from those for WB sensors. Note that WB processed data includes vehicles traveling in both the westbound and eastbound direction since a westbound sensor can typically read across all four lanes of traffic. The WB and EB designation is only necessary for assigning lane direction to a particular observation so that the appropriate static or variable speed limit sign can be associated with that observation.

Two processed data fields (Speed Compliance +5 and Speed Buffer + 10) are based on the definitions for Performance Measures 14 and 15. The next fields are related to weather conditions and include the identification code for the Road Weather Information System (RWIS ID) that is associated with that speed observation based on proximity of that RWIS and the rating of five primary weather variables associated from previous research with changes in observed speeds. These weather variable ratings lead to 216 unique combinations, which are assigned a storm category code. Additional analyses will lead to the refinement of these storm categories down to a list of 10 – 15 unique storm types, which will be used to combine speed observations into storm category bins for calculation of performance measures.

Filename convention for the processed individual speed data sets are **vlogs_[four digit year, two digit month]P.txt**. So vlogs_201701P.txt contains processed speed observations for January of 2017 for speed observations.

Additional fields may be added to the processed data as the analysis of performance measures continue. Two likely variables include a field for linking particular storm observations to defined storm events used in other performance measures. Another variable would be one that identifies whether a speed observation is associated with a defined work zone event.

Table C-2 Processed Speed Observation Data Fields

Data field	Description	Units	Notes
Date_Time, Sensor, Speed, Length, Class, and Lane fields remain same as unprocessed data. See Table C-1 for details			
PostedSpd	Posted Speed at time of observation from either static speed signs or variable speed signs	MPH	Posted speed is dependent on the roadway direction so varies by lane designation and time and date.
RWIS	Station ID for Road Weather Information System associated with speed observation	Unique alphanumeric identifier to each RWIS	See sensor description spreadsheet to link RWIS ID to information of the location
WB_VSL	Sign ID for closest upstream speed sign for westbound observations		Sign ID of 1 is for static speed limit sign of 75, Sign ID of 2 is for static speed limit sign of 80
EB_VSL	Sign ID of closest upstream speed sign for westbound observations		
Sensor_Loc	Location of speed sensor relative to closest lane (EB or WB)		Since lanes are numbered 1 to 4 based on closest lane, lane direction is dependent on what side of the road the sensor is installed on.
MILEPOST	Milepost of speed sensor		
LaneDir	Direction of travel for speed observation	Assigns 1 for WB observations and 2 for EB observations	Assigning direction to lane numbers is depending on sensor location variable
StationID	Station ID for Road Weather Information System associated with speed observation	Unique alphanumeric identifier to each RWIS	See sensor description spreadsheet to link RWIS ID to information of the location
PostedSpd_VSLTime	Time that Posted Speed was set by VSL system.	Time in MST/MTD. NaN for static speed limit signs.	
RoadCond	Road Condition Rating of 1-4	1 = dry pavement, 2=wet pavement, 3= snow, 4= ice	Road condition surface conditions from RWIS converted to rating system
Vis	Visibility rating of 1 – 3	1 = >0.95 miles, 2 = between 0.57 and 0.95 miles, 3 = <0.57 miles	Visibility readings from RWIS sensors converted to rating system

RH	Relative Humidity rating of 1 -2	1 = <92%, 2 = > 92%	Relative Humidity readings from RWIS sensors converted to rating system
SurfTemp	Surface Temperature rating of 1 – 3	1 = >32°F, 2 = between 25 and 32°F, 3 = <25°F	Surface Temp readings from RWIS sensors converted to rating system
WdSpd	Wind Speed Rating of 1 - 3	1 = <30 mph, 2 = between 30 and 45 mph, 3=>45 mph	Wind Speed readings from RWIS sensors converted to rating system
StormNum	Storm number between 1 and 216	Unique storm number between 1 and 216 based on ratings of 5 weather variables	Storm numbers will be compressed down to 10 – 15 storm types after additional analyses of speed data
PostedSpd	Posted speed associated with observed speed	Miles per hour (MPH)	Posted speed from either static or VSL sign
PostedSpd_VSLTime	Time associated with posted speed	Time of most current speed change for speeds in VSL corridors	Static speed signs given null or "Not a Time (NaT) value
SpeedCompliant5	Binary variable for whether speed observation is at or below the posted speed plus 5 mph	1 = speed observation is compliant, 0 = speed observation is not compliant	Definition of speed compliance as posted speed plus 5 mph comes from definition of PM #14
SpeedBuffer10	Binary variable for whether speed observation is within 10 mph +/- of the posted speed	1= speed observation is within buffer, 0 = speed observation is not within buffer	Definition of speed buffer of +/- 10 mph of posted speed comes from definition of PM #15
DataQuality	Binary variable for whether speed observation is flagged for data quality parameters	1 = acceptable per data quality standards, 0 = unacceptable per data quality standards	At this point all records flagged as 1 but additional analysis will likely lead to adoption of data quality rules
StormCat	Storm Category number of 0 to 11	StormCat = 0 is for uncategorized storm numbers. StormCat =1 associated with ideal or low speed impact storms. StormCat 2 - 11 have varying levels of speed impacts	Based on cluster analysis of 216 storm numbers

Data Description – Variable Speed Limit Data

Individual speed data comes from 59 Variable Speed Limit signs located along the I-80 corridor. These devices are integrated into four separate sections along I-80. The four VSL corridors are located between Evanston and Three Sisters, Rock Springs and Green River, along Elk Mountain, and from Cheyenne to Laramie. Latitude and longitude as well as mileposts are used to describe the approximate location of each VSL sign.

Information for the VSL signs are separated by month and offer information regarding device ID, milepost range, location, default speed setting and current speed setting in 5-minute intervals**.** This dataset is typically merged with individual speed data in order to establish speed compliance and speed buffers compared to individual speeds.

Data Availability

VSL data is collected by WYDOT and recorded every 5 minutes for each variable speed limit sign. WYDOT outputs the VSL data into monthly .csv files which become available a couple weeks after month's end. There is currently data from October 2016 to June 2017 plus for October and November of 2017.

Data Description – Unprocessed Data

The unprocessed data gives thirteen data fields, which are described in the table below. The data does not require additional data fields or formatting; therefore, this data remains unprocessed.

Table C-3. Unprocessed VSL Data Fields

Data Field	Description	Units	Notes
DEVICEID	Individual ID of the sign	Unique three- or four-digit number	
ROUTE	Road the signs are installed on	N/A	All signs are located on I-80 corridor
FROM_RM	Starting milepost	Miles	
TO_RM	Ending milepost	Miles	
DISPLAY_NAME	Describes placement of signs based on geography	N/A	
LAT_DECIMAL	Latitude location of sign	N/A	Some sensors are not located exactly at these coordinates but can be located within a quarter mile of the coordinates
LONG_DECIMAL	Longitude locations of sign	N/A	Some sensors are not located exactly at these coordinates but can be located within a quarter mile of the coordinates

DIRECTION	The direction the sign is facing	N/A	D: decreasing milepost I: increasing milepost
DEFAULT_SPEED	Unadjusted speed limit	MPH	
BLANK			
VSL_MPH	Current speed limit	MPH	
UPDATED	Time and date of data reading	MDY with military time	Data is collected every 5 minutes
MILEPOST	Location of the sensor	Miles	

Data Description – Crash Data

Crash records for the State of Wyoming are maintained by the Wyoming Department of Transportation's Highway Safety Program. All reported crashes in the state, regardless of roadway jurisdiction, are contained in this crash database. WYDOT adopted a Model Minimum Uniform Crash Criteria (MMUCC) compliant electronic crash form January 1, 2008. Details on crash reporting in Wyoming can be found in the *Wyoming's Investigators Traffic Crash Reporting Manual*, which was revised in July 2016[4]

Data Availability

For the CV Pilot project, periodic queries are run by the Highway Safety Program and updated crash data provided. The crash data for the baseline safety performance measures covers the time period from January 1, 2010, to December 31, 2017.

Table C-4. Summary of crashes per year on I-80 in Wyoming

Year	Total
2010	1,659
2011	1,678
2012	1,406
2013	1,544
2014	1,592
2015	1,409
2016	1,641
2017	892 (partial)
Total	**11,821**

Data Description – Unprocessed Data

In its unprocessed state, there are three spreadsheet worksheets containing the crash data. The BulkBase worksheet is the summary crash data, with each row representing a crash event. Table C-5 is a summary of the fields available in the data. Only a basic data

[4] Wyoming's Investigators Traffic Crash Reporting Manual http://www.dot.state.wy.us/files/live/sites/wydot/files/shared/Highway_Safety/2016/2016%20Investigators%20Traffic%20Crash%20Report%20Manaul%20(1).pdf

description is provided. Refer to the MMUCC or the *Wyoming's Investigators Traffic Crash Reporting Manual* for more comprehensive details on the data.

The safety performance measurements mainly relied on the Bulk Base data so only those data fields are described below.

Table C-5. Unprocessed Crash Data Fields – Bulk Base Data

Data field	Description	Notes
ReportNo	Unique identifier for each crash report.	First four numbers represent the crash year
Crash Date/Time	Date and time in Mountain Time Zone	
Day of Week	Day of week that crash occurred	
County	County that crash occurred in	
City	City that crash occurred in.	Only provided if crash occurred on portion of I-80 within city limits
Crash Location	Roadway location of crash	Query run by Highway Safety Program limits crash records to Interstate 80.
Milepost	Route milepost for reported crash	I-80 extends from milepost 0 to milepost 402.8
Direction	Direction of interstate	I = direction of increasing milepost (Eastbound); D = direction of decreasing milepost (Westbound); U or X = unknown direction
Latitude/Longitude	Columns for latitude and longitude of reported crash	
# Vehicles	Number of vehicles in reported crash	Crashes involving large number of vehicles are often reported as multiple crashes since they have different reporting officers
# Drivers	Number of drivers listed in crash report	Only counts those listed in crash report. See Involved worksheet for additional data related to this field.
# Persons	Number of persons listed in crash report	Only counts those listed in crash report. See Involved worksheet for additional data related to this field.
# Motorist	Number of motorists listed in crash report	Only counts those listed in crash report. See Involved worksheet for additional data related to this field.
# NonMotorists	Number of non-motorists listed in crash report	Only counts those listed in crash report. See Involved worksheet for additional data related to this field.
# Pedestrians	Number of pedestrians listed in crash report	Only counts those listed in crash report. See Involved worksheet for additional data related to this field.
# Pedacyclists	Number of bicyclists listed in crash report	Only counts those listed in crash report. See Involved worksheet for additional data related to this field.
# Injured	Number of people with reporting injuries listed in crash report	
# Killed	Number of people killed as listed in crash report	

Hit&Run	Was the crash a hit and run crash?	Y = yes; N = no; left blank if unknown
First harmful event	Crash classification by first harmful event	Ex: Jackknife, non-fixed object, overturn/rollover, etc.
First harmful event location	Location of first harmful event	Examples: Bridge, Gore, Median, etc.
Manner of Collision	Type of Collision	Ex: Angle, head on, etc.
Direction of Force	Direction of force between vehicles and objects or other vehicles	Ex: angle, meeting, opposing, etc.
Junction Relation	Relationship between crash and nearby junctions	Ex: crossover related, driveway related, non-junction, etc.
Intersection Type	Type of intersection where crash occurred	Ex: 4-way, T, Not an intersection, etc.
Severity	Crash Severity type	KABCO scale descriptions. Note language changed during time period, so multiple categories can be associated with each level on KABCO scale.
Alcohol Involved	Was alcohol involvement reported	Y = yes; N = no; left blank if unknown
Drug Involved	Was drug involvement reported	Y = yes; N = no; left blank if unknown
Light	Reported lighting condition	
Weather	Reported weather condition	
Road Condition	Reported road surface condition	

The WYDOT query provides two additional worksheets for crash data – Involved and Vehicle. Refer to the MMUCC or the *Wyoming's Investigators Traffic Crash Reporting Manual* for details on the data fields in these two worksheets.

The Involved worksheet provides additional information on the drivers, passengers and pedestrians as reported in the crash report. The Report No column links this information back to the Bulk Base data so there can be more than one record for each crash report in this worksheet. No information from the involved worksheet was used in the Performance measurement analyses.

The Vehicle worksheet provides additional information about the vehicles involved in the crash as reported in the crash report. The field "Vehicle Type" was used to identify whether a particular crash was considered a truck crash or not.

Data Description – Processed

Additional fields are appended on to each crash record in the Bulk Base worksheet to aid in the calculation of performance measures to create processed data sets. No data is removed during processing so all records and fields remain unchanged, only additional fields are added. Table C-6 describes these additional fields. For more details on the methodology behind the calculations used to determine values for these fields, please refer to the performance measurement reports.

All data fields from unprocessed data in Bulk Base remain. The fields in Table C-6 are added. Processing only adds field to Bulk Base worksheet.

Table C-6. Processed Crash Data Fields – Bulk Base Only

Data field	Description	Notes
Year	Crash year	Year extracted from report number
Route	Route that crash occurred on	This field used for GIS location finding.
TruckPM	Binary variable for whether crash is considered a truck crash	Analysis of Vehicle data. If one or more vehicles involved in a crash is considered a truck then variable assigned a 1, 0 otherwise. See PM Methodology for more on what vehicle types are considered a truck.
SecondaryCrash	Variable for whether crash is considered a secondary crash	Reported as 0 if crash is not linked to another crash. Reported as primary crash report number if crash is linked to another crash. See PM Methodology for more on algorithm for determining secondary crashes.
SeriousCrash	Serious crashes defined as fatal and serious or incapacitating injury crashes (i.e. K or A on KABCO scale)	0 = crash is non-serious; 1 = crash is serious
WorkZone	Variable for whether a crash is considered a work zone crash.	Reported as 0 if crash not linked to a work zone. Reported as work zone project ID number from construction console data if crash is considered work zone related. If reported as NA then the crash occurred before work zone data was available. Work Zones have not yet been analyzed for 2017.

Data Description – RWIS Sensor Data

RWIS sensor data is collected from 10priority stations of the 50 total stations installed along I-80. These sensors can be described in one of two ways: a seven-character WYDOT ID or a three-/four-character MesoWest Station. Each of the stations are also characterized by a route milepost.

Additional information of all 50 RWIS stations can be found in Corridor Devices Appendix**.** This section provides the four-character MesoWest Station, latitude, longitude, and elevation. The stations highlighted in green are the 10 priority sensors chosen.

Data Availability

Each RWIS station collects data points every five minutes. In the MesoWest database, data can be collected by date or by year. For the purpose of the CV Pilot project, data is collected by month. The downloaded data for each sensor is written to a **.csv** or a comma separated values file. This file will need to be changed to an **.xlsx** or excel file. This is for the purpose of processing the data further using Matlab.

Each RWIS station outputs all variables available for that sensor. These variables may include heat index, wind direction, dew point, air temperature, etc. The variables included for all stations include relative humidity, wind speed, road temperature, road surface condition, and visibility. These are the variables to be used to determine storm number.

Filename convention for data collected at each RWIS station is **[three/four-character MesoWest Station]_Month Abbr_[Full/Input/Results].[csv/xlsx].** For example, the unprocessed data for a station in December is named **KCMS_Dec_Full.csv**. The name for the processed data for a station in December is **KCMS_Dec_Input.xlsx**. The name for the processed data for a station in December is **KCMS_Dec_Results.xlsx**. Currently, data is downloaded from MesoWest for December 2016 – May 2017 and for October and November of 2017.

Data Description – Unprocessed Data

In the unprocessed data, there could be as many as 24 variables provided by MesoWest. All RWIS stations may not be able to record data for all possible variables. The full list of variables with their respective units is provided in Table C- 7.

All data fields remain unchanged from the original download of MesoWest except for Date & Time. The format of Date & Time is provided in UTC (Coordinated Universal Time). In order to process the data, the Date & Time format needs to be converted into MST (Mountain Standard Time). UTC does not account for daylight savings time. In converting to MST, daylight savings time will need to be accounted for. (Note: Daylight savings time for 2017 begins on March 12 at 2:00 am).

Table C- 7. Unprocessed RWIS Data Fields

MesoWest Variable Output	Unit
Station ID	
Date & Time	UTC
Air Temperature	Farenheit
Relative Humidity	%
Wind Speed	mph
Wind Direction	Degrees
Wind Gust	mph
Road Temperature	Farenheit
Solar Radiation	W/m**2
Soil Temperature	Farenheit
Cloud Layer	Code
Accumulated Precipitation	Inches
Road Freezing Temperature	Farenheit
T Water Temperature	Farenheit
Road Subsurface Temperature	Farenheit
Metar Remark	Text
Metar	Text
Weather Condition Code	Code
Road Surface Condition	Code
Fuel Temperature	Farenheit
Fuel Moisture	gm

Visibility	Statute miles
Dew Point Temperature	Farenheit
Wind Chill	Farenheit
Wind Cardinal Direction	Farenheit
Heat Index	Farenheit

Data Description – Processed Data

In its processed state, the output consists of all processed data fields and a category of storm number. To obtain the processed data, the processed data is input into a Matlab file named **RWIS_Output_RKY.m.** This Matlab code writes the processed data into a **.txt** file. All data fields are coded based upon the thresholds of each data field. Each data field's threshold (except for storm category) and its respective code can be seen in Table C-8 below. The definitions of each storm category can be seen in the file **StormCategories.csv**.

Table C-9 shows how the processed data is presented in a final excel file. This final excel file consists of two sheets: one being the original input data (named **Input Data**) and one the processed results (named **Results**). The headings used in the **Results** sheet must remain consistent and identical to the headings given in Table C-9.

Table C-8. Processed Data Thresholds and Codes.

Key		
Road Condition		
Code		
1	Dry	**ideal
2	Wet	
3	Snow	
4	Ice	
Visibility		
Code	Miles	
1	>0.95	**ideal
2	0.57-0.95	
3	<0.57	
Relative Humidity		
Code	%	
1	<92%	**ideal
2	>92%	
Surface Temperature		
Code	°F	
1	>32	**ideal
2	25-32	
3	<25	
Wind Speed		
Code	mph	
1	<30	**ideal
2	30-45	
3	>45	

Table C-9. Processed RWIS Data Fields

Data field	Description	Units	Notes
Station_ID	3- or 4-character MesoWest station		
DateTime	Date and Time in MST/MDT	MST/MDT Format: mm/dd/yyyy h:mm AM/PM	Orignal data converted to MST/MDT from UTC
RelativeHumidity	Low or high humidity based on weather conditions.	1 = <92%, 2 = > 92%	Relative Humidity readings from RWIS sensors converted to rating system
WindSpeed	Wind speed based on current weather conditions.	1 = <30 mph, 2 = between 30 and 45 mph, 3= >45 mph	Wind Speed readings from RWIS sensors converted to rating system
SurfaceTemp	Temperature of road surface based on current weather conditions. Rating of 1 – 3	1 = >32°F, 2 = between 25 and 32°F, 3 = <25°F	Surface Temp readings from RWIS sensors converted to rating system
RoadCondition	Condition of road surface based on current weather conditions. Rating of 1 – 4	1 = dry pavement, 2 = wet pavement, 3 = snow, 4 = ice	Road surface condition is given on a scale of 0-10. Code 1 is ideal, dry conditions. Code 0,9,10 are defaulted to ideal conditions. Code 2 through Code 8 ranges from damp to black ice conditions.
Visibility	Forward length visible to the driver	1 = >0.95 miles, 2 = between 0.57 and 0.95 miles, 3 = <0.57 miles	Visibility readings from RWIS sensors converted to rating system
StormNumber	Number given to storm based on combination of above five variables	Unique storm number between 1 and 216 based on ratings of 5 weather variables	Storm numbers will be compressed down to 10 – 15 storm types after additional analyses of speed data

Data Description – DMS Data

Dynamic Message Sign (DMS) data comes from 40 DMS located along the corridor. DMS signs on the corridor are either overhead or roadside mounted signs. At this time, the DMS sign data are only used to verify conditions on the roadway and are not formally part of any performance measure analyses.

Data Availability

DMS data is collected by WYDOT and an event record is created every time a DMS sign is updated. WYDOT outputs the VSL DMS into monthly .csv files which become available a couple weeks after month’s end. There is currently data from October 2016 to June 2017.

Data Description – Unprocessed Data

The unprocessed data gives ten data fields, which are described in the table below. The data does not require additional data fields or formatting; therefore, this data remains unprocessed.

Table C-10. Unprocessed DMS Data Fields

Data Field	Description	Units	Notes
DEVICEID	Individual ID of the sign	Unique two- to four-digit number	
ROUTE	Road the signs are installed on	N/A	All signs are located on I-80 corridor
DISPLAY_NAME	Describes placement of signs based on geography	N/A	
LAT_DECIMAL	Latitude location of sign	N/A	
LONG_DECIMAL	Longitude locations of sign	N/A	
DIRECTION	The direction the sign is facing	N/A	D: decreasing milepost I: increasing milepost
BLANK			Field not used
SIGN_TEXT	Text of sign message	N/A	
UPDATED	Time and date of data reading	MDY with military time	
MILEPOST	Location of the Sign	Miles	

Appendix D. Storm Categories

There are 216 unique combinations of the five categorical weather variables that have been defined based on RWIS data. Each combination is given a unique storm identification number shown in Table D-1. A final set of 11 storm categories was developed that will be used in Phase 3 analyses (Table D-2). Table D-3 provides the number of speed observations by month for each storm category.

Table D-1. 216 Storm Numbers

RoadCond	Visibility	RH	WindSpeed	SurfTemp	StormNum
1	1	1	1	1	1
1	1	1	1	2	2
1	1	1	1	3	3
1	1	1	2	1	4
1	1	1	2	2	5
1	1	1	2	3	6
1	1	1	3	1	7
1	1	1	3	2	8
1	1	1	3	3	9
1	1	2	1	1	10
1	1	2	1	2	11
1	1	2	1	3	12
1	1	2	2	1	13
1	1	2	2	2	14
1	1	2	2	3	15
1	1	2	3	1	16
1	1	2	3	2	17
1	1	2	3	3	18
1	2	1	1	1	19
1	2	1	1	2	20
1	2	1	1	3	21
1	2	1	2	1	22
1	2	1	2	2	23
1	2	1	2	3	24
1	2	1	3	1	25
1	2	1	3	2	26
1	2	1	3	3	27
1	2	2	1	1	28
1	2	2	1	2	29
1	2	2	1	3	30
1	2	2	2	1	31
1	2	2	2	2	32
1	2	2	2	3	33
1	2	2	3	1	34
1	2	2	3	2	35
1	2	2	3	3	36
1	3	1	1	1	37
1	3	1	1	2	38
1	3	1	1	3	39
1	3	1	2	1	40
1	3	1	2	2	41
1	3	1	2	3	42
1	3	1	3	1	43
1	3	1	3	2	44
1	3	1	3	3	45
1	3	2	1	1	46
1	3	2	1	2	47
1	3	2	1	3	48
1	3	2	2	1	49
1	3	2	2	2	50
1	3	2	2	3	51
1	3	2	3	1	52
1	3	2	3	2	53
1	3	2	3	3	54
2	1	1	1	1	55
2	1	1	1	2	56
2	1	1	1	3	57
2	1	1	2	1	58
2	1	1	2	2	59
2	1	1	2	3	60
2	1	1	3	1	61
2	1	1	3	2	62
2	1	1	3	3	63
2	1	2	1	1	64
2	1	2	1	2	65
2	1	2	1	3	66
2	1	2	2	1	67
2	1	2	2	2	68
2	1	2	2	3	69
2	1	2	3	1	70
2	1	2	3	2	71
2	1	2	3	3	72
2	2	1	1	1	73
2	2	1	1	2	74
2	2	1	1	3	75
2	2	1	2	1	76
2	2	1	2	2	77
2	2	1	2	3	78
2	2	1	3	1	79
2	2	1	3	2	80
2	2	1	3	3	81
2	2	2	1	1	82
2	2	2	1	2	83
2	2	2	1	3	84
2	2	2	2	1	85
2	2	2	2	2	86
2	2	2	2	3	87
2	2	2	3	1	88
2	2	2	3	2	89
2	2	2	3	3	90
2	3	1	1	1	91
2	3	1	1	2	92
2	3	1	1	3	93
2	3	1	2	1	94
2	3	1	2	2	95

2	3	1	2	3	96
2	3	1	3	1	97
2	3	1	3	2	98
2	3	1	3	3	99
2	3	2	1	1	100
2	3	2	1	2	101
2	3	2	1	3	102
2	3	2	2	1	103
2	3	2	2	2	104
2	3	2	2	3	105
2	3	2	3	1	106
2	3	2	3	2	107
2	3	2	3	3	108
3	1	1	1	1	109
3	1	1	1	2	110
3	1	1	1	3	111
3	1	1	2	1	112
3	1	1	2	2	113
3	1	1	2	3	114
3	1	1	3	1	115
3	1	1	3	2	116
3	1	1	3	3	117
3	1	2	1	1	118
3	1	2	1	2	119
3	1	2	1	3	120
3	1	2	2	1	121
3	1	2	2	2	122
3	1	2	2	3	123
3	1	2	3	1	124
3	1	2	3	2	125
3	1	2	3	3	126
3	2	1	1	1	127
3	2	1	1	2	128
3	2	1	1	3	129
3	2	1	2	1	130
3	2	1	2	2	131
3	2	1	2	3	132
3	2	1	3	1	133
3	2	1	3	2	134
3	2	1	3	3	135
3	2	2	1	1	136
3	2	2	1	2	137
3	2	2	1	3	138
3	2	2	2	1	139
3	2	2	2	2	140
3	2	2	2	3	141
3	2	2	3	1	142
3	2	2	3	2	143
3	2	2	3	3	144
3	3	1	1	1	145
3	3	1	1	2	146
3	3	1	1	3	147
3	3	1	2	1	148
3	3	1	2	2	149
3	3	1	2	3	150
3	3	1	3	1	151
3	3	1	3	2	152
3	3	1	3	3	153
3	3	2	1	1	154
3	3	2	1	2	155
3	3	2	1	3	156
3	3	2	2	1	157
3	3	2	2	2	158
3	3	2	2	3	159
3	3	2	3	1	160
3	3	2	3	2	161
3	3	2	3	3	162
4	1	1	1	1	163
4	1	1	1	2	164
4	1	1	1	3	165
4	1	1	2	1	166
4	1	1	2	2	167
4	1	1	2	3	168
4	1	1	3	1	169
4	1	1	3	2	170
4	1	1	3	3	171
4	1	2	1	1	172
4	1	2	1	2	173
4	1	2	1	3	174
4	1	2	2	1	175
4	1	2	2	2	176
4	1	2	2	3	177
4	1	2	3	1	178
4	1	2	3	2	179
4	1	2	3	3	180
4	2	1	1	1	181
4	2	1	1	2	182
4	2	1	1	3	183
4	2	1	2	1	184
4	2	1	2	2	185
4	2	1	2	3	186
4	2	1	3	1	187
4	2	1	3	2	188
4	2	1	3	3	189
4	2	2	1	1	190
4	2	2	1	2	191

4	2	2	1	3	192
4	2	2	2	1	193
4	2	2	2	2	194
4	2	2	2	3	195
4	2	2	3	1	196
4	2	2	3	2	197
4	2	2	3	3	198
4	3	1	1	1	199
4	3	1	1	2	200
4	3	1	1	3	201
4	3	1	2	1	202
4	3	1	2	2	203
4	3	1	2	3	204
4	3	1	3	1	205
4	3	1	3	2	206
4	3	1	3	3	207
4	3	2	1	1	208
4	3	2	1	2	209
4	3	2	1	3	210
4	3	2	2	1	211
4	3	2	2	2	212
4	3	2	2	3	213
4	3	2	3	1	214
4	3	2	3	2	215
4	3	2	3	3	216

Table D-2. 11 Storm Categories

Storm Category	Description	Storm Numbers Assigned to Category
0	No category assigned	
1	Ideal	1, 2, 3, 10, 11, 55, 56, 64, 65, 82
2	Wind Event	4, 5, 7, 9, 13, 16, 34, 40, 52
3	Snow or Ice Surface Condition	109, 110, 113, 118, 127, 145, 163, 164, 172, 190, 208
4	Low Visibility	37
5	Wet pavement, moderate wind	60
6	Ice, high wind	170
7	Ice, low visibility or moderate wind	211, 212
8	High wind, high RH, wet roads	71, 88, 107
9	Mixed Conditions	8, 12, 25, 62, 76, 79, 85, 94, 97, 98, 103, 106, 169, 175, 187, 188, 193, 196, 205
10	Wind Events with Cold Surface Temps	6, 63, 77, 95, 176, 185, 203, 206
11	Mixed Conditions 2	28, 43 46, 49, 57, 58 59, 61, , 67, 68, 70, 73, 80, 100,111, 112, 115, 119, 121, 124, 136, 139, 154, 157, 166, 167, 178, 181, 184, 202, 214

Table D-3. Number of Speed Observations by Storm Category

Summary - All Sensors		Storm Category												
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
Jan-17	Processed Records	1,307	393,094	534,916	80,804	69	11	607	1,565	2,214	62,780	791	771,540	1,849,698
	Records after Data Quality Screening	206	304,311	418,575	68,683	51	9	436	291	1,048	41,119	68	633,475	1,468,272
Feb-17	Processed Records	102	4,864,223	1,312,212	504,737	22	89	0	12,340	299	105,616	2,622	870,386	7,672,648
	Records after Data Quality Screening	61	4,101,519	1,110,244	438,747	16	88	0	9,221	248	73,361	1,119	700,030	6,434,654
Mar-17	Processed Records	497	8,911,923	550,726	653,069	24	199	0	4,801	1,497	60,519	27,582	446,475	10,657,312
	Records after Data Quality Screening	243	7,615,116	467,399	572,429	24	199	0	2,477	1,408	39,346	16,292	371,408	9,086,341
Apr-17	Processed Records	64	9,783,722	344,685	706,875	124	11	0	10,514	467	35,354	329	357,692	11,239,837
	Records after Data Quality Screening	27	8,633,203	295,972	626,148	121	11	0	5,847	227	24,784	165	316,873	9,903,378
May-17	Processed Records	0	11,683,167	23,513	233,474	0	0	0	1,387	0	2,299	0	82,933	12,026,773
	Records after Data Quality Screening	0	9,725,956	22,298	186,723	0	0	0	1,248	0	2,121	0	70,932	10,009,278
Oct-17	Processed Records	1,832	10,298,811	600,743	127,962	0	0	0	4,262	129	6,427	0	152,528	11,192,694
	Records after Data Quality Screening	1,744	9,619,257	574,036	121,917	0	0	0	3,885	122	5,981	0	146,864	10,473,806
Nov-17	Processed Records	246	7,480,665	1,113,456	437,018	31	0	0	14,219	155	68,080	30	586,098	9,699,998
	Records after Data Quality Screening	236	6,963,401	1,036,701	403,511	17	0	0	13,111	140	63,470	30	559,157	9,039,774
Baseline	**Processed Records**	**4,048**	**53,415,605**	**4,480,251**	**2,743,939**	**270**	**310**	**607**	**49,088**	**4,761**	**341,075**	**31,354**	**3,267,652**	**64,338,960**
	Records after Data Quality Screening	**2,517**	**46,962,763**	**3,925,225**	**2,418,158**	**229**	**307**	**436**	**36,080**	**3,193**	**250,182**	**17,674**	**2,798,739**	**56,415,503**

Appendix E. Analysis of Two Storm Events

To validate the performance measure methodology and data sources, two storm events were analyzed in depth and presented to the CV Pilot team and representatives from USDOT, Volpe, and the Independent Evaluator team in June at a Wyoming site meeting. Table E-1 shows the thresholds and color legend for the weather variables shown in Figures E- 1 and E-4. Figures E-2 and E-3 show the results for the speed analyses for the first storm for four different sensors. Figures E-5 and E-6 are the speed analyses results for the second storm.

Table E- 1 Storm Variables and Thresholds

KEY		
Road Condition		
Code		
1	Dry	**Ideal
2	Wet	
3	Snow	
4	Ice	
Visibility		
Code	Miles	
1	>0.95	**Ideal
2	0.57-0.95	
3	<0.57	
Relative Humidity		
Code	%	
1	<92%	**Ideal
2	>92%	
Surface Temperature		
Code	°F	
1	>32	**Ideal
2	25-32	
3	<25	
Wind Speed		
Code	mph	
1	<30	**Ideal
2	30-45	
3	>45	

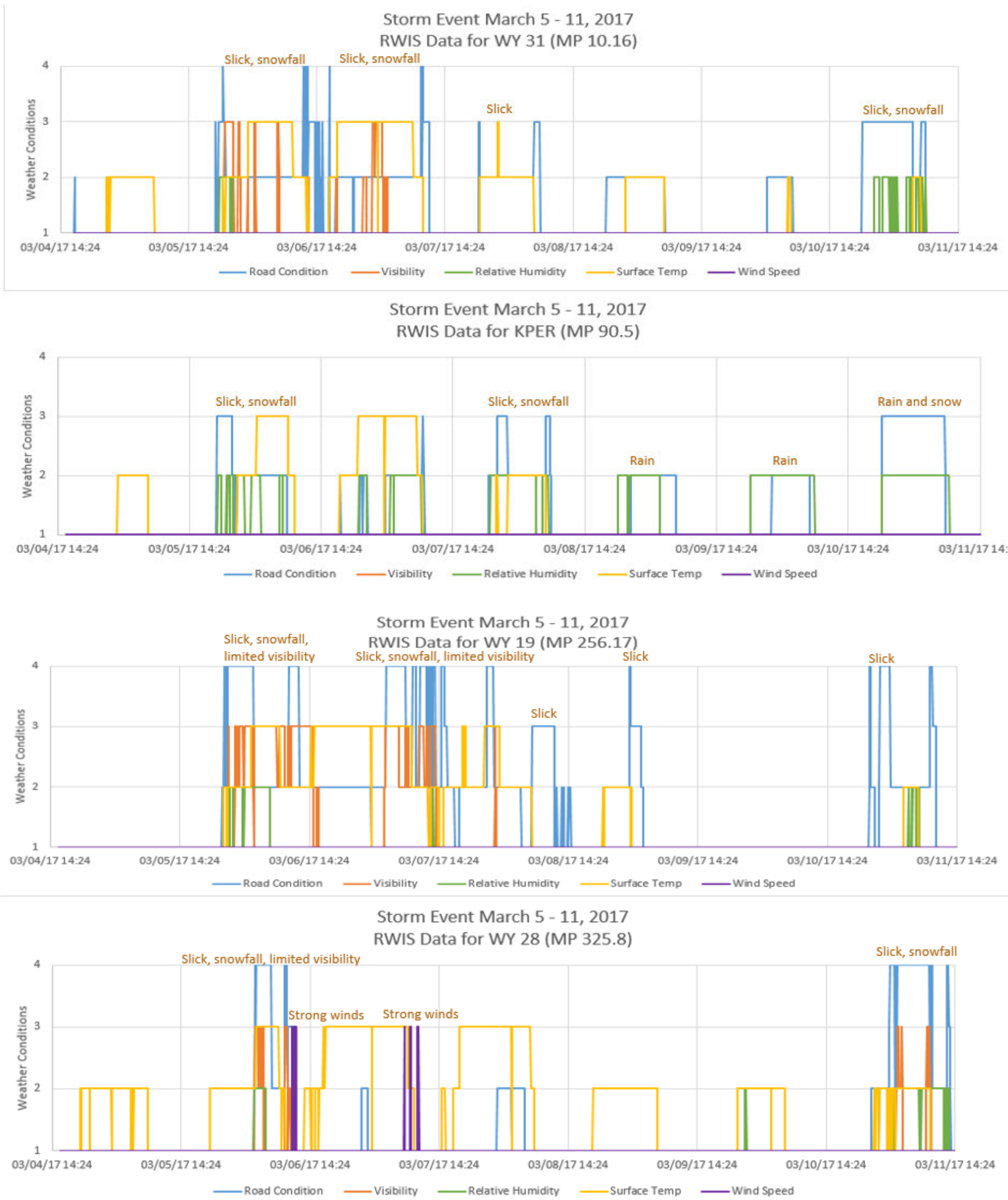


Figure E-1 Weather Variable Analysis for March 5-11, 2017 Storm Event for MP 10.16 (top), MP 90.5, MP 256.17, and MP 325.8 (Bottom) (Source WYDOT)

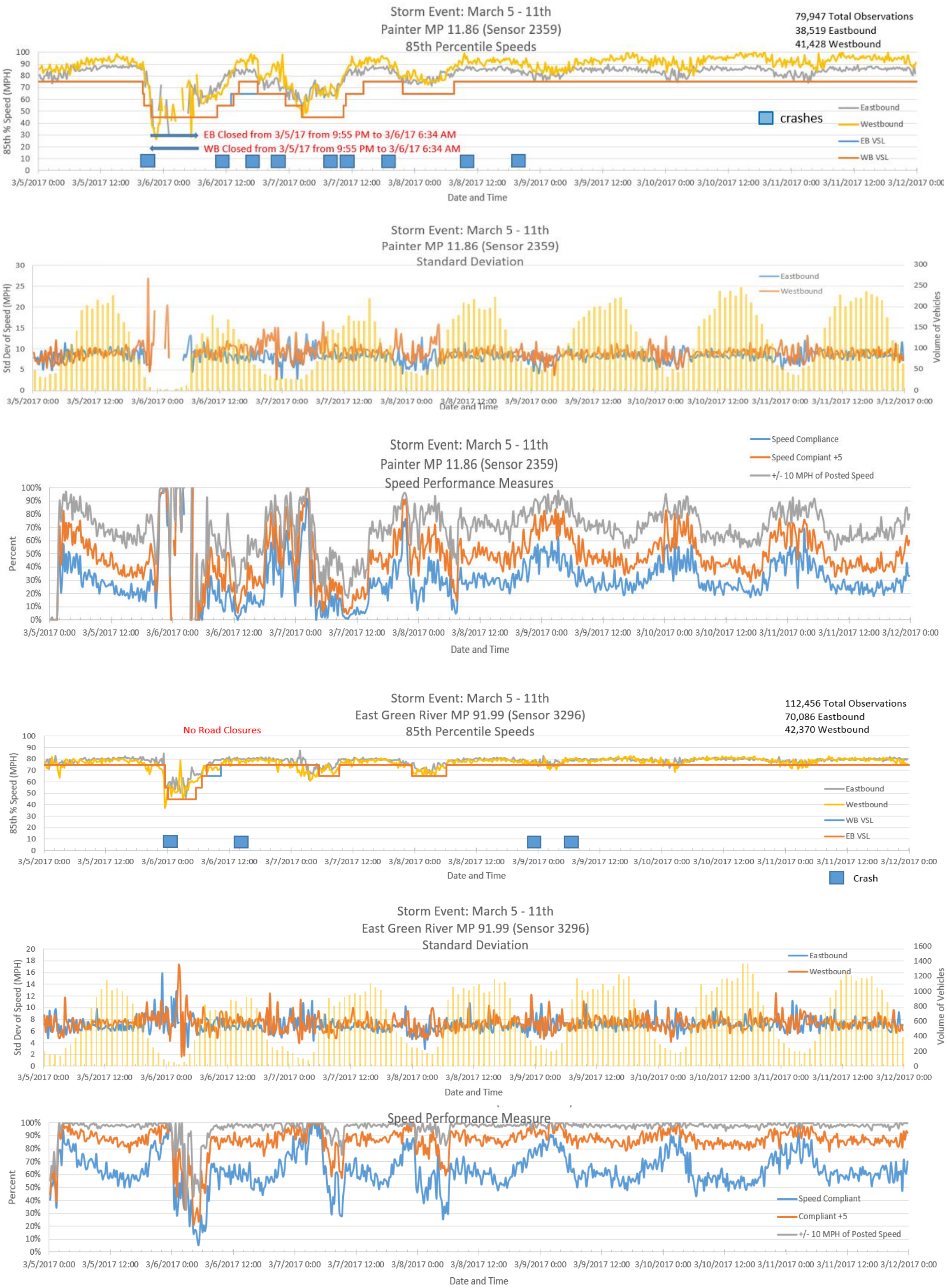


Figure E-2. Speed Analysis for March 5-11, 2017 Storm Event for MP 11.86 (top), and MP 91.99 (Bottom) (Source: WYDOT)

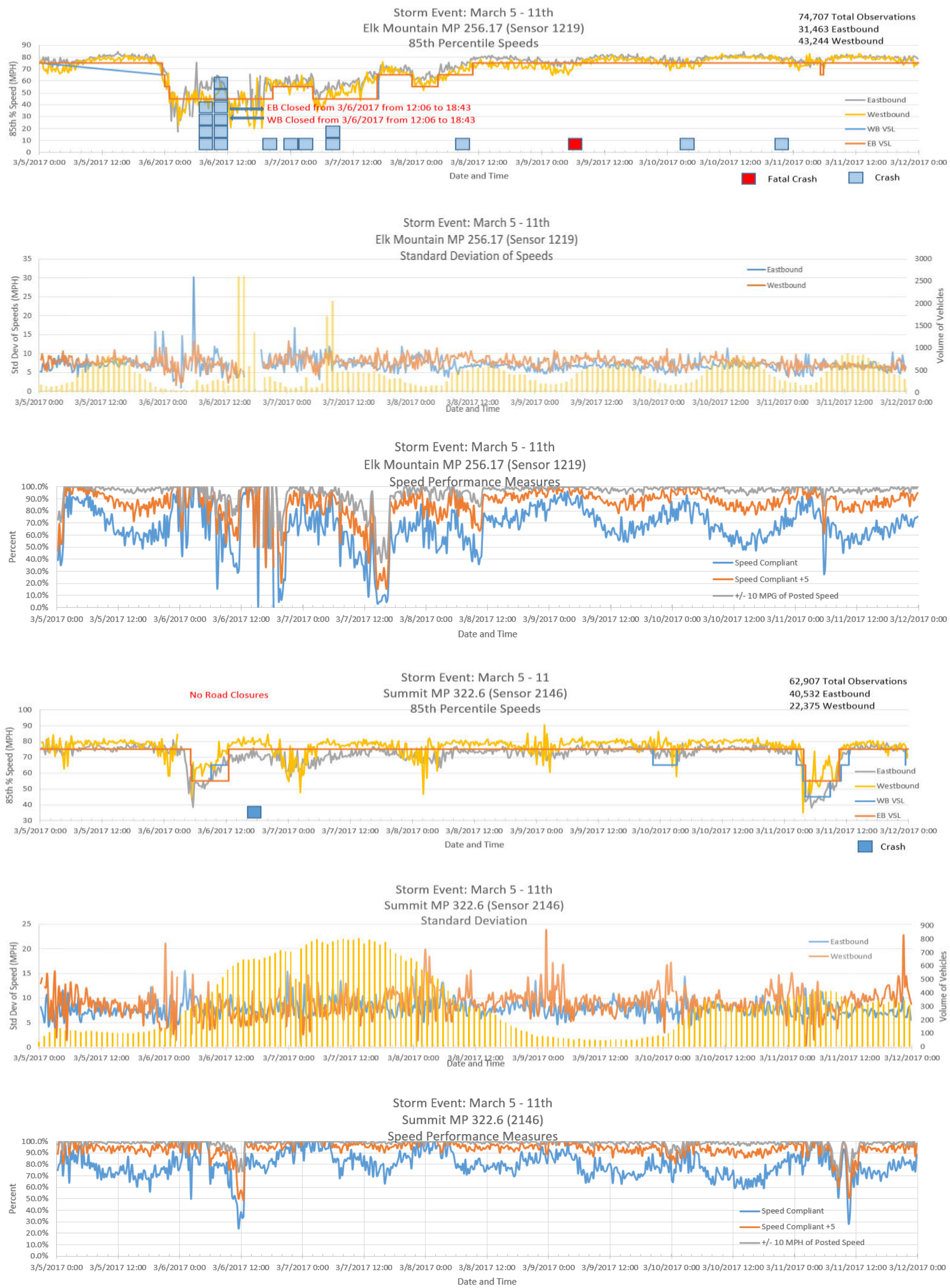
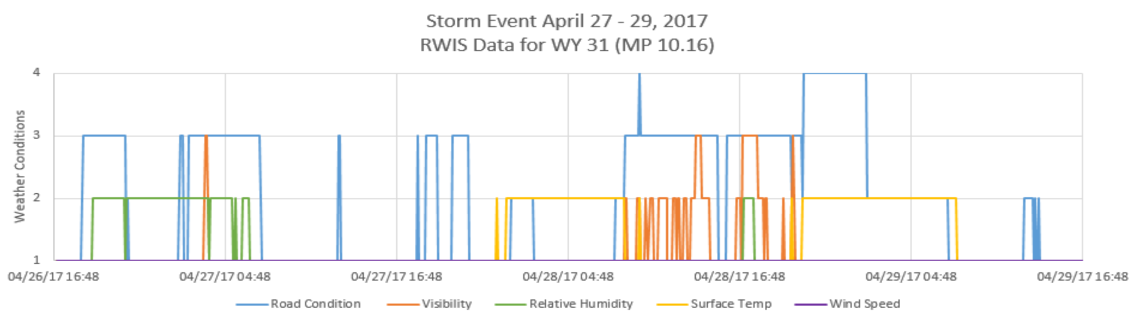
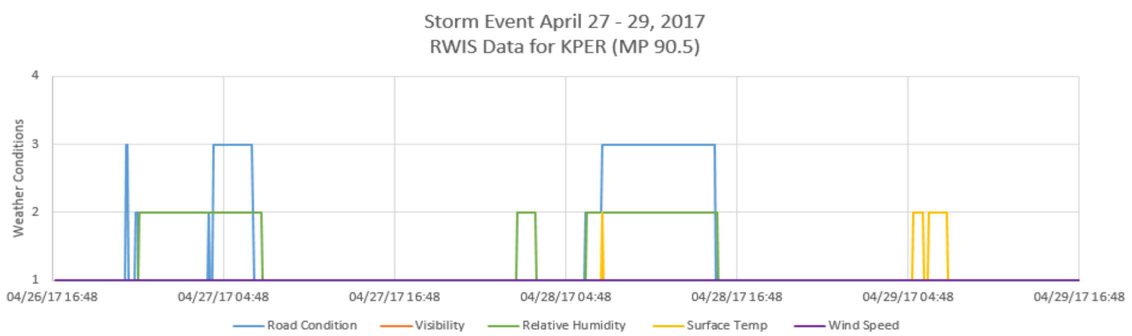
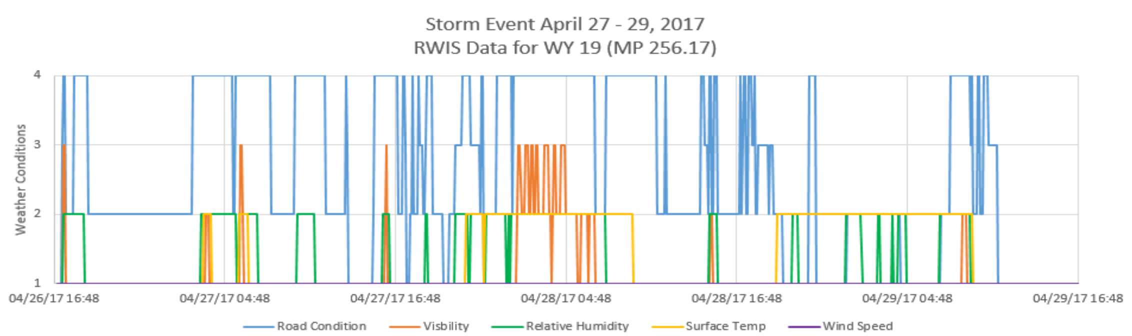


Figure E-3. Speed Analysis for March 5-11, 2017 Storm Event for MP 256.17 (top), and MP 322.6 (Bottom) (Source: WYDOT)







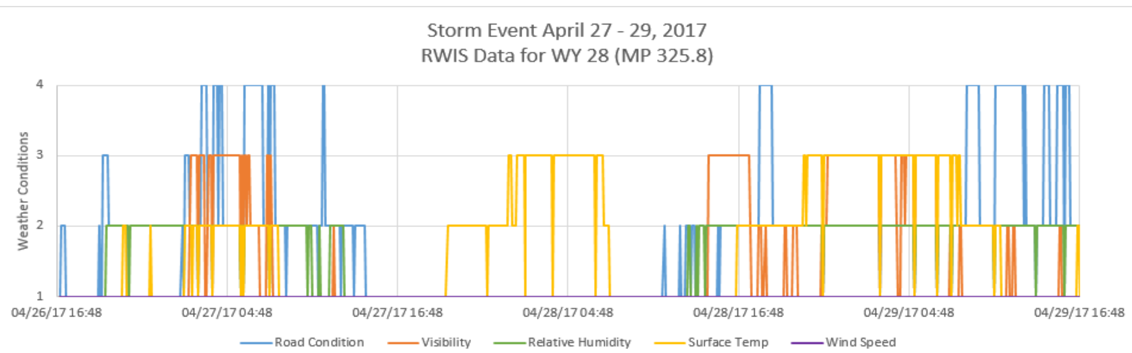


Figure E-4. Weather Variable Analysis for March April 27-29, 2017 Storm Event for MP 10.16 (top), MP 90.5, MP 256.17, and MP 325.8 (Bottom) (Source: WYDOT)

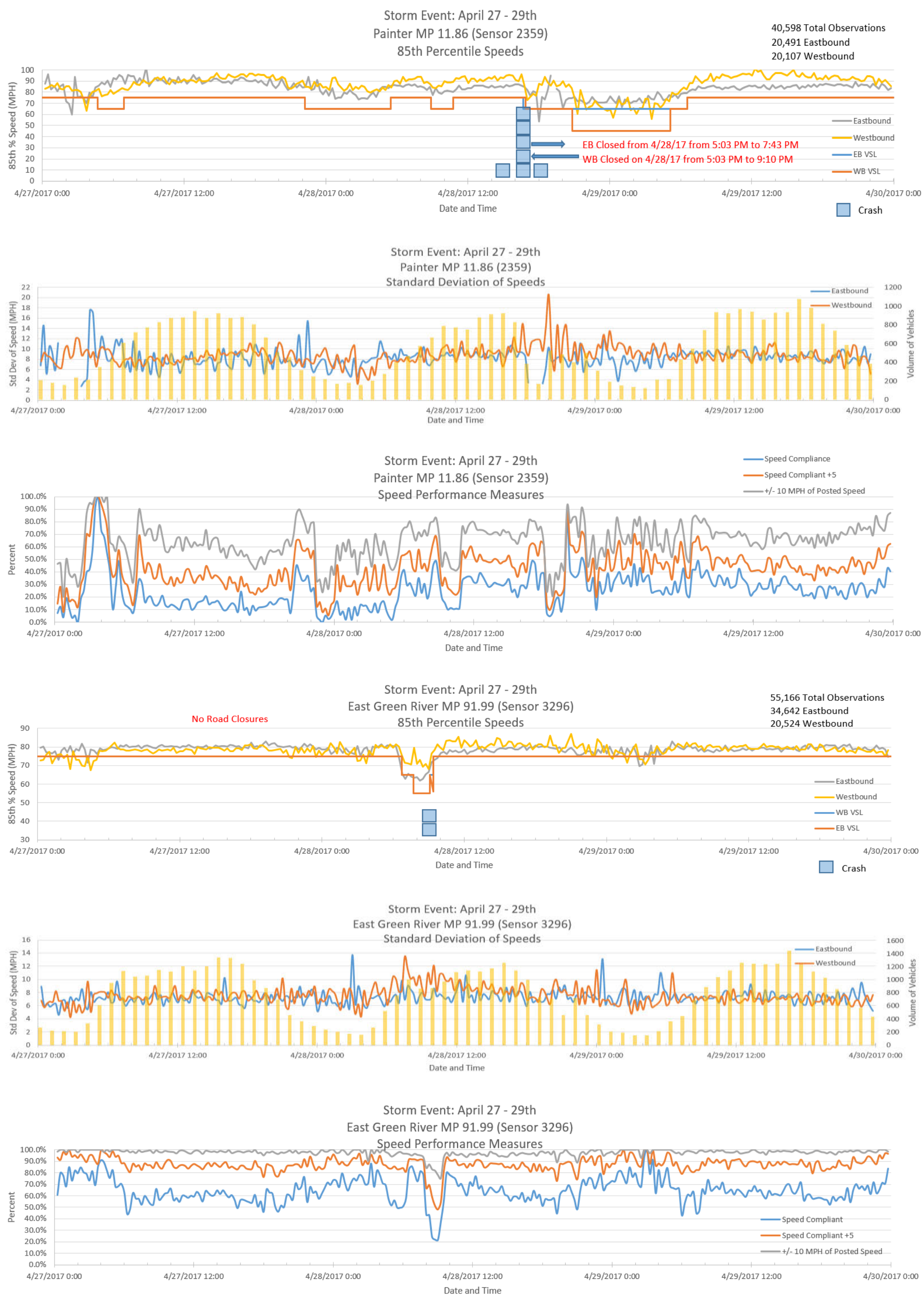


Figure E-5. Speed Analysis for April 27-29, 2017 Storm Event for MP 11.86 (top), and MP 91.99 (Bottom) (Source: WYDOT)

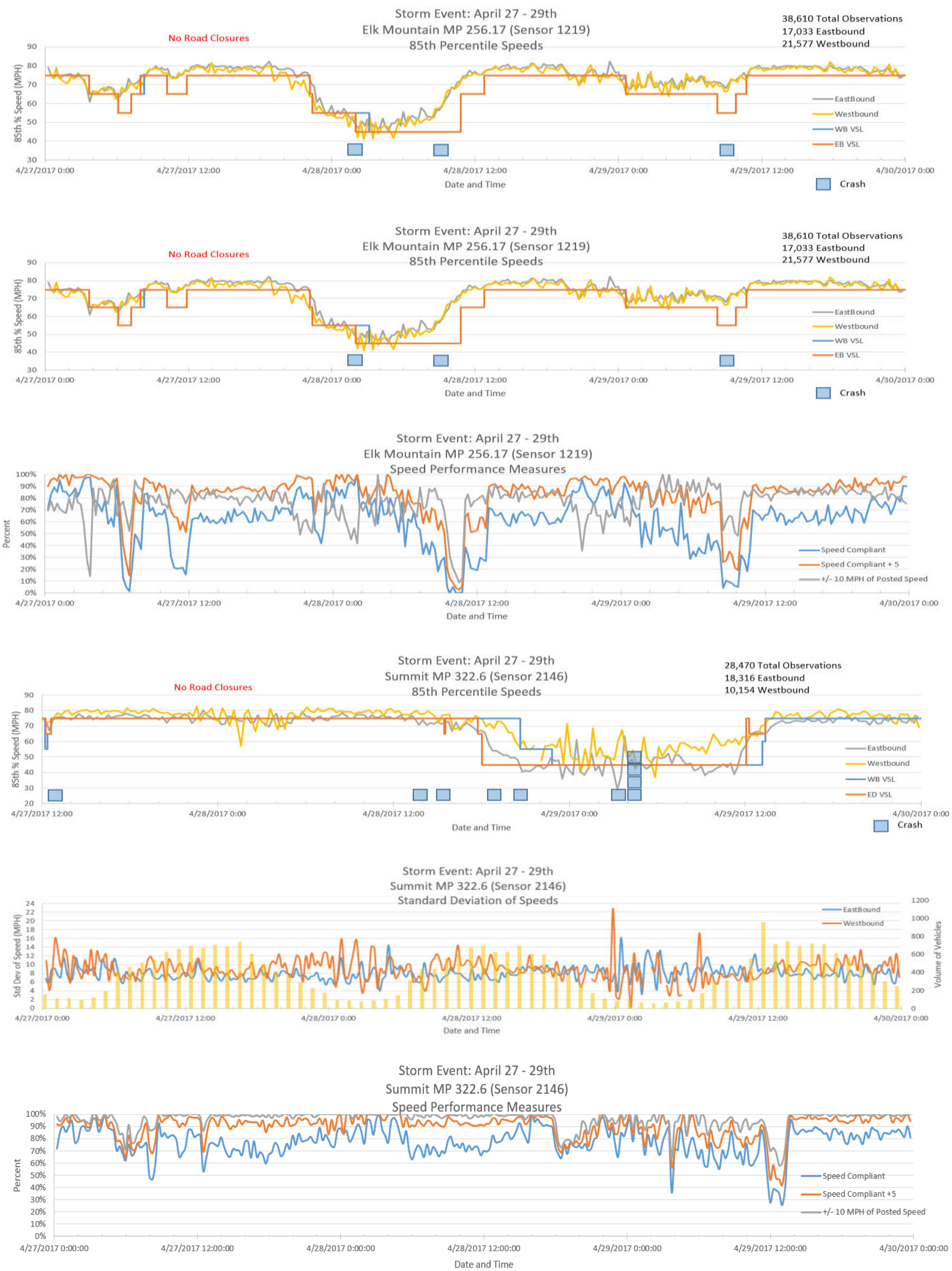


Figure E-6. Speed Analysis for April 27-29, 2017 Storm Event for MP 256.17 (top), and MP 322.6 (Bottom) (Source: WYDOT)

Appendix F. Results of PMs 1-3

Table F-1 summarizes the results of the following PMs by storm event.

1. Number of road condition reports per road section/day (quantity)
2. Number of road section with at least one reported road condition per hour (coverage)
3. Average refresh time of road condition reported in each section (latency)

These values were used to calculate the final pre-deployment condition performance measures described in Section 6.1.

Table F-1 Summary Results of PMs 1-3, Road Condition Reports Quantity, Coverage, Latency.

Count	Event Date		Event Time		Location		Conditions (All)	Statistics		Number of Road Condition Reports/ Section/ Day	Number of Road Sections with At Least One Report/ Hour	Average Refresh Time (Hours) of Reports/ Section
	Start	End	Start	End	Full Extents	Most Intense		# of unique reporting sections	Hours of storm			
1	10/2/2017	10/3/2017	5:40AM	12:29PM	Entire I-80 corridor	Cheyenne to Elk Mountain	slick, slick in spots, fog, reduced visibility, black ice	30	30	3.5	3.8	4.2
2	10/4/2017	10/5/2017	2:47AM	3:32AM	Rawlins to Cheyenne	Laramie	strong wind, fog, reduced visibility	36	23	2.4	3.5	3.4
3	10/6/2017	10/8/2017	10:12AM	3:58PM	Entire I-80 corridor	Elk Mountain to Laramie	strong wind, extreme blow over risk, closed to light, high profile vehicles	54	32	2.1	4.8	5.5
4	10/8/2017	10/9/2017	6:22PM	3:58PM	Entire I-80 corridor	Cheyenne to Elk Mountain	slick, slick in spots, closed, fog, reduced visibility, no unnecessary travel	38	22	6.0	8.5	4.4
5	10/11/2017	10/13/2017	5:23AM	7:02PM	Entire I-80 corridor	Elk Mountain	strong wind	32	27	1.7	2.2	3.8
6	10/14/2017	10/14/2017	2:17AM	6:38PM	Entire I-80 corridor	Evanston, Arlington, Laramie	slick in spots, strong wind, fog, reduced visibility	46	17	3.5	5.8	2.7
7	10/20/2017	10/23/2017	10:23AM	6:13PM	Entire I-80 corridor	Laramie	slick in spots, strong wind, fog, blowing snow, black ice, extreme blow over risk, closed to light, high profile vehicles	56	64	2.4	5.2	6.9
8	10/25/2017	10/27/2017	7:28AM	8:24AM	Entire I-80 corridor	Cheyenne	strong wind, blowing snow, reduced visibility	34	29	3.1	3.6	5.9
9	10/29/2017	10/30/2017	8:10PM	1:48PM	Cheyenne to Elk Mountain	All	slick in spots, fog, reduced visibility, black ice	20	17	7.3	5.2	4.1
10	10/30/2017	11/2/2017	6:55PM	5:49PM	Entire I-80 corridor	All	slick in spots, strong wind, extreme blow over risk, closed to light, high profile vehicles, fog, reduced visibility, black ice	54	61	2.4	5	5.5
11	11/2/2017	11/3/2017	7:10PM	11:57PM	Entire I-80 corridor	All	strong wind, extreme blow over risk, closed to light, high profile vehicles	36	20	3.2	4.3	4.3
12	11/4/2017	11/8/2017	0:54AM	10:52PM	Entire I-80 corridor	Cheyenne to Elk Mountain	slick, slick in spots, drifted snow, closed, fog, blowing snow, reduced visibility, black ice, no unnecessary travel	56	105	3.0	6	3.0
13	11/15/2017	11/21/2017	8:29PM	2:07PM	Entire I-80 corridor	All	slick, slick in spots, drifted snow, closed, strong wind, blowing snow, reduced visibility, extreme blow over risk, closed to light, high profile vehicles	56	103	4.0	8.1	5.6
14	11/21/2017	11/27/2017	3:20PM	4:54PM	Entire I-80 corridor	Arlington, Elk Mountain, Laramie	strong wind, extreme blow over risk, closed to light, high profile vehicles	44	79	1.9	3.4	5.5
15	11/28/2017	11/29/2017	11:48PM	8:03PM	Laramie, Arlington	All	strong wind, extreme blow over risk, closed to light, high profile vehicles	34	19	2.9	4	2.5
16	12/13/2016	12/21/2016	5:41PM	1:42PM	Entire I-80 corridor	Cheyenne to Elk Mountain	slick in spots, strong wind, blowing snow, reduced visibility, extreme blow over risk, closed to light, high profile vehicles	56	153	3.9	7.9	5.7
17	12/22/2016	12/23/2016	6:42 PM	2:14 PM	Rawlins to Cheyenne	Elk Mountain area	fog, strong wind, blowing snow, slick, reduced visibility	25	19	3.9	3.8	3.5
18	12/23/2016	12/23/2016	6:22 PM	11:24 PM	Point of Rocks to Elk Mountain	All	strong winds	16	5	4.8	3.2	3.1
19	12/24/2016	12/24/2016	12:11 AM	2:15 PM	Elk Mountain to Laramie	All	strong winds	24	9	3.3	3.3	3.5

Count	Event Date		Event Time		Location		Conditions (All)	Statistics		Number of Road Condition Reports/ Section/ Day	Number of Road Sections with At Least One Report/ Hour	Average Refresh Time (Hours) of Reports/ Section
	Start	End	Start	End	Full Extents	Most Intense		# of unique reporting sections	Hours of storm			
20	12/24/2016	12/31/2016	7:31 PM	9:12 PM	Entire I-80 corridor	12-25-16: Entire corridor Entire storm: Elk Mountain, Arlington, Laramie, Cheyenne	slick, closed, strong wind, fog, blowing snow, drifted snow, reduced visibility, no unnecessary travel, extreme blow over risk, closed to light, high profile vehicles	56	112	4.0	7.9	6.0
21	1/1/2017	1/1/2107	7:58AM	9:05PM	Cheyenne to Arlington	All	strong winds	14	10	3.1	1.8	4.5
22	1/1/2017	1/16/2017	2:43pm	2:43PM	Entire I-80 corridor	Laramie to Rawlins, AND Evanston area	slick, slick in spots, drifted snow, strong wind, blowing snow, reduced visibility, black ice, no unnecessary travel, extreme blow over risk, closed to light, high profile vehicles, chain law level 1	56	312	5.1	10.4	5.0
23	1/18/2017	2/12/2017	4:57AM	10:23AM	Entire I-80 corridor	Arlington to Elk Mountain, AND Laramie area, AND Evanston area	slick, slick in spots, drifted snow, strong wind, blowing snow, low visibility, black ice, extreme blow over risk, closed to light, high profile vehicles, chain law level 1	56	486	3.7	7.5	7.1
24	2/14/2107	2/14/2017	2:25AM	9:09AM	Granger to Lyman	All	Fog	6	4	6.0	1.5	3.7
25	2/15/2107	2/15/2017	2:43AM	3:40AM	Granger to Lyman	All	Fog	4	2	12.0	2	3.8
26	2/15/2107	2/19/2017	3:52AM	9:52AM	Various locations throughout corridor	All	Strong winds	40	38	1.4	2.3	6.2
27	2/19/2017	3/3/2017	4:35PM	9:30PM	Entire I-80 corridor	Cheyenne to Elk Mountain, AND Lyman to Evanston	slick, slick in spots, drifted snow, closed, strong wind, blowing snow, reduced visibility, black ice, extreme blow over risk, closed to light, high profile vehicles	56	247	4.4	9	6.4
28	3/4/2017	3/4/2017	5:18AM	6:07PM	Arlington to Rawlins	All	Strong winds	16	8	3.0	2	9.4
29	3/5/2017	3/11/2017	1:08AM	1:12AM	Entire I-80 corridor	Cheyenne to Laramie	slick, slick in spots, drifted snow, strong wind, blowing snow, reduced visibility, black ice, extreme blow over risk, closed to light, high profile vehicles	56	108	4.7	8.9	4.4
30	3/11/2017	3/11/2017	3:18AM	10:49AM	Pine Bluffs to Laramie	Certain sections	slick, slick in spots, strong wind, fog, reduced visibility	14	7	12.7	5.1	1.4
31	3/12/2017	3/14/2017	2:13AM	5:51PM	Portions of I-80	Cheyenne to Elk Mountain	slick, closed, strong wind, black ice, extreme blow over risk, closed to light, high profile vehicles	44	44	3.6	5.7	4.3
32	3/15/2017	3/23/2017	5:42AM	6:29PM	Portions of I-80	Laramie, Arlington, Elk Mountain	strong wind, extreme blow over risk, closed to light, high profile vehicles	45	82	2.2	3.7	3
33	3/23/2017	3/24/2017	6:43PM	10:34AM	Cheyenne to Elk Mountain	All	slick in spots, strong wind, fog, black ice	20	17	4.2	3.2	1.9
34	3/26/2017	3/29/2017	1:47AM	10:42AM	Portions of I-80	Cheyenne to Elk Mountain	slick in spots, fog, reduced visibility, black ice	40	53	3.7	5.2	2.7
35	3/29/2017	3/30/2017	10:58PM	12:33PM	Cheyenne to Elk Mountain	All	Strong winds	16	14	2.6	1.4	3
36	3/30/2017	4/1/2017	7:16PM	12:00PM	Portions of I-80	Cheyenne to Elk Mountain	slick, slick in spots, strong wind, fog, reduced visibility, blowing snow, black ice, no unnecessary travel	54	41	3.7	7.3	2.9
37	4/2/2017	4/3/2017	9:09PM	4:52PM	Cheyenne to Elk Mountain	All	slick in spots, strong wind, black ice, fog	14	17	10.7	4.5	2

Count	Event Date		Event Time		Location		Conditions (All)	Statistics		Number of Road Condition Reports/ Section/ Day	Number of Road Sections with At Least One Report/ Hour	Average Refresh Time (Hours) of Reports/ Section
	Start	End	Start	End	Full Extents	Most Intense		# of unique reporting sections	Hours of storm			
38	4/4/2017	4/5/2017	2:57AM	9:40PM	Portions of I-80	Cheyenne to Elk Mountain, AND Rawlins, Point of Rocks, Evanston	slick, slick in spots, fog, blowing snow, reduced visibility, black ice	34	37	4.9	5.8	1.8
39	4/7/2017	4/8/2017	3:25AM	6:22PM	Portions of I-80	Cheyenne to Elk Mountain, AND Rawlins, Wamsetter, Evanston	strong wind, extreme blow over risk, closed to light, high profile vehicles	32	34	3.4	3.9	4.4
40	4/8/2017	4/10/2017	4:05PM	12:00PM	Entire I-80 corridor	All	slick, slick in spots, strong wind, blowing snow, reduced visibility, extreme blow over risk, closed to light, high profile vehicles, fog	56	31	4.1	8.2	3.3
41	4/13/2017	4/13/2017	10:59AM	7:57PM	Portions of I-80	All	Strong winds	36	10	3.1	4.6	3.3
42	4/13/2017	4/14/2017	11:45PM	9:23AM	Pine Bluffs to Elk Mountain	All	strong wind, fog, reduced visibility	22	10	4.6	4	2.2
43	4/14/2017	4/20/2017	2:18PM	2:59PM	Entire I-80 corridor	All	Strong winds	56	38	2.5	4.9	4.7
44	4/20/2017	4/22/2017	3:10PM	11:03AM	Cheyenne to Elk Mountain	Laramie	slick, slick in spots, closed, fog, blowing snow, reduced visibility	36	43	3.3	4.3	3
45	4/23/2017	4/24/2017	10:43AM	4:12PM	Portions of I-80	All	Strong winds	36	15	2.3	3.3	2
46	4/24/2017	4/26/2017	4:48PM	9:15PM	Portions of I-81	Arlington and Laramie	slick, slick in spots, strong wind, blowing snow, black ice, fog	36	40	3.6	4.5	1.4
47	4/27/2017	4/29/2017	0:59AM	1:42PM	Entire I-80 corridor	All	slick, slick in spots, strong wind, blowing snow, black ice, drifted snow, reduced visibility, fog	56	61	3.6	7.3	3.0
48	4/29/2017	4/30/2017	7:28PM	8:35PM	Pine Bluffs to Laramie	All	slick in spots, strong wind	14	9	4.2	2.4	7.8
49	5/2/2017	5/3/2017	11:44PM	10:31AM	Cheyenne to Elk Mountain	All	slick, slick in spots, fog, reduced visibility	18	12	7.1	4.5	3.3
50	5/9/2017	5/9/2017	0:15AM	12:25PM	Cheyenne to Wamsutter	All	fog, reduced visibility	16	13	8.1	3.1	2.8
51	5/13/2017	5/13/2017	9:22AM	11:28PM	Arlington to Evanston	All	Strong winds	36	12	3.4	5	4.2
52	5/17/2017	5/19/2017	8:05PM	10:10PM	Entire I-80 corridor	Pine Bluffs to Laramie	slick, slick in spots, drifted snow, fog, blowing snow, reduced visibility, no unnecessary travel	48	60	4.6	10.5	4.6
53	5/20/2017	5/20/2017	7:16AM	5:06PM	Pine Bluffs to Laramie	All	slick in spots, closed, strong winds	12	9	5.3	2.4	1.3
54	5/22/2017	5/23/2017	12:34PM	7:16AM	Portions of I-80	Cheyenne to Elk Mountain, AND Rawlins to Evanston	slick in spots, strong wind, fog, reduced visibility	40	20	2.8	4.1	2
55	5/24/2017	5/25/2017	4:32AM	6:46PM	Portions of I-80	All	Strong winds	48	22	2.5	4.3	4.1
56	5/26/2017	5/26/2017	3:13AM	8:43AM	Cheyenne to Elk Mountain	All	fog, reduced visibility	14	5	11.0	4.8	0.7

Appendix G. Results of PMs 14-15

Table G-1 summarizes the results of the results for PMs 14 and 15 by storm category. Whereas Table G-2 summarizes the results for PMs 14 and 15 by individual priority sensor and storm category.

Table G-1. Summary of PM 14 and 15 Results for All Speed Data by Storm Category

Summary - All Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
Jan-17	Processed Records	1,307	393,094	534,916	80,804	69	11	607	1,565	2,214	62,780	791	771,540	1,849,698
	Records after Data Quality Screening	206	304,311	418,575	68,683	51	9	436	291	1,048	41,119	68	633,475	1,468,272
	Speed Compliant Records	125	230,491	344,706	51,826	38	9	268	227	774	29,781	35	479,113	1,137,393
	Speed Buffer Records	128	200,883	258,428	41,442	32	7	268	142	690	25,346	39	357,918	885,323
Feb-17	Processed Records	102	4,864,223	1,312,212	504,737	22	89	0	12,340	299	105,616	2,622	870,386	7,672,648
	Records after Data Quality Screening	61	4,101,519	1,110,244	438,747	16	88	0	9,221	248	73,361	1,119	700,030	6,434,654
	Speed Compliant Records	55	3,524,170	958,121	342,019	13	66	0	8,114	221	57,442	942	556,935	5,448,098
	Speed Buffer Records	16	2,864,653	733,861	268,603	9	39	0	4,370	120	38,716	725	415,372	4,326,484
Mar-17	Processed Records	497	8,911,923	550,726	653,069	24	199	0	4,801	1,497	60,519	27,582	446,475	10,657,312
	Records after Data Quality Screening	243	7,615,116	467,399	572,429	24	199	0	2,477	1,408	39,346	16,292	371,408	9,086,341
	Speed Compliant Records	216	6,555,820	409,231	463,034	24	78	0	2,207	1,221	31,461	12,138	294,539	7,769,969
	Speed Buffer Records	107	5,419,745	306,780	380,528	15	91	0	959	666	21,051	8,376	233,226	6,371,544
Apr-17	Processed Records	64	9,783,722	344,685	706,875	124	11	0	10,514	467	35,354	329	357,692	11,239,837
	Records after Data Quality Screening	27	8,633,203	295,972	626,148	121	11	0	5,847	227	24,784	165	316,873	9,903,378
	Speed Compliant Records	25	7,456,176	255,900	506,797	55	11	0	5,086	148	20,287	66	265,474	8,510,025
	Speed Buffer Records	14	6,147,001	199,060	423,084	71	1	0	3,257	136	14,643	82	197,567	6,984,916
May-17	Processed Records	0	11,683,167	23,513	233,474	0	0	0	1,387	0	2,299	0	82,933	12,026,773
	Records after Data Quality Screening	0	9,725,956	22,298	186,723	0	0	0	1,248	0	2,121	0	70,932	10,009,278

Summary - All Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Speed Compliant Records	0	8,365,821	19,839	157,408	0	0	0	1,181	0	1,874	0	58,914	8,605,037
	Speed Buffer Records	0	7,038,311	14,762	125,008	0	0	0	339	0	1,024	0	48,693	7,228,137
Oct-17	Processed Records	1,832	10,298,811	600,743	127,962	0	0	0	4,262	129	6,427	0	152,528	11,192,694
	Records after Data Quality Screening	1,744	9,619,257	574,036	121,917	0	0	0	3,885	122	5,981	0	146,864	10,473,806
	Speed Compliant Records	1,606	8,373,248	507,483	98,827	0	0	0	3,664	122	5,511	0	123,387	9,113,848
	Speed Buffer Records	1,315	6,908,576	396,315	82,331	0	0	0	1,323	4	2,072	0	88,611	7,480,547
Nov-17	Processed Records	246	7,480,665	1,113,456	437,018	31	0	0	14,219	155	68,080	30	586,098	9,699,998
	Records after Data Quality Screening	236	6,963,401	1,036,701	403,511	17	0	0	13,111	140	63,470	30	559,157	9,039,774
	Speed Compliant Records	208	6,019,256	935,586	331,861	17	0	0	10,609	124	51,629	30	462,759	7,812,079
	Speed Buffer Records	140	5,040,618	709,079	274,662	7	0	0	6,992	73	34,887	0	353,322	6,419,780
Baseline	**Processed Records**	**4,048**	**53,415,605**	**4,480,251**	**2,743,939**	**270**	**310**	**607**	**49,088**	**4,761**	**341,075**	**31,354**	**3,267,652**	**64,338,960**
	Records after Data Quality Screening	**2,517**	**46,962,763**	**3,925,225**	**2,418,158**	**229**	**307**	**436**	**36,080**	**3,193**	**250,182**	**17,674**	**2,798,739**	**56,415,503**
	Speed Compliant Records	**2,235**	**40,524,982**	**3,430,866**	**1,951,772**	**147**	**164**	**268**	**31,088**	**2,610**	**197,985**	**13,211**	**2,241,121**	**48,396,449**
	Speed Buffer Records	**1,720**	**33,619,787**	**2,618,285**	**1,595,658**	**134**	**138**	**268**	**17,382**	**1,689**	**137,739**	**9,222**	**1,694,709**	**39,696,731**
	Percent Included	**62.2%**	**87.9%**	**87.6%**	**88.1%**	**84.8%**	**99.0%**	**71.8%**	**73.5%**	**67.1%**	**73.4%**	**56.4%**	**85.6%**	**87.7%**
	Percent Compliant	**88.8%**	**86.3%**	**87.4%**	**80.7%**	**64.2%**	**53.4%**	**61.5%**	**86.2%**	**81.7%**	**79.1%**	**74.7%**	**80.1%**	**85.8%**
	Percent Speed Buffer	**68.3%**	**71.6%**	**66.7%**	**66.0%**	**58.5%**	**45.0%**	**61.5%**	**48.2%**	**52.9%**	**55.1%**	**52.2%**	**60.6%**	**70.4%**

Table G-2. Summary of PM 14 and 15 Results by Sensor ID by Storm Category

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
1075	Processed Records	0	18607	52768	7059	0	0	0	0	0	805	0	35595	114834
	Records after Data Quality Screening	0	18607	52768	7059	0	0	0	0	0	805	0	35595	114834
	Speed Compliant Records	0	14939	45406	6115	0	0	0	0	0	771	0	33981	101212
	Speed Buffer Records	0	14373	38956	5342	0	0	0	0	0	432	0	16188	75291

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Percent Included	**0.0%**	**100.0%**	**100.0%**	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**100.0%**	**100.0%**
	Percent Compliant	**0.0%**	**80.3%**	**86.0%**	**86.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**95.8%**	**0.0%**	**95.5%**	**88.1%**
	Percent Speed Buffer	**0.0%**	**77.2%**	**73.8%**	**75.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**53.7%**	**0.0%**	**45.5%**	**65.6%**
1219	Processed Records	1033	1618153	147614	101713	31	0	0	5567	517	41329	5739	171842	2093538
	Records after Data Quality Screening	0	766548	53515	46748	15	0	0	2902	25	16871	0	49790	936414
	Speed Compliant Records	0	655222	47314	36429	12	0	0	2071	15	11172	0	32281	784516
	Speed Buffer Records	0	621031	42098	35677	11	0	0	1886	15	11857	0	35121	747696
	Percent Included	**0.0%**	**47.4%**	**36.3%**	**46.0%**	**48.4%**	**0.0%**	**0.0%**	**52.1%**	**4.8%**	**40.8%**	**0.0%**	**29.0%**	**44.7%**
	Percent Compliant	**0.0%**	**85.5%**	**88.4%**	**77.9%**	**80.0%**	**0.0%**	**0.0%**	**71.4%**	**60.0%**	**66.2%**	**0.0%**	**64.8%**	**83.8%**
	Percent Speed Buffer	**0.0%**	**81.0%**	**78.7%**	**76.3%**	**73.3%**	**0.0%**	**0.0%**	**65.0%**	**60.0%**	**70.3%**	**0.0%**	**70.5%**	**79.8%**
1269	Processed Records	362	629937	118510	39336	31	0	299	6529	955	53913	391	158455	1008718
	Records after Data Quality Screening	69	96519	34816	6238	11	0	128	659	390	15077	38	52980	206925
	Speed Compliant Records	44	71633	26919	4442	3	0	45	317	199	9266	16	31945	144829
	Speed Buffer Records	45	74567	27057	4905	4	0	77	322	227	10628	23	34919	152774
	Percent Included	**19.1%**	**15.3%**	**29.4%**	**15.9%**	**35.5%**	**0.0%**	**42.8%**	**10.1%**	**40.8%**	**28.0%**	**9.7%**	**33.4%**	**20.5%**
	Percent Compliant	**63.8%**	**74.2%**	**77.3%**	**71.2%**	**27.3%**	**0.0%**	**35.2%**	**48.1%**	**51.0%**	**61.5%**	**42.1%**	**60.3%**	**70.0%**
	Percent Speed Buffer	**65.2%**	**77.3%**	**77.7%**	**78.6%**	**36.4%**	**0.0%**	**60.2%**	**48.9%**	**58.2%**	**70.5%**	**60.5%**	**65.9%**	**73.8%**
2032	Processed Records	361	3212569	273059	95725	0	0	0	1425	0	3881	0	43960	3630980
	Records after Data Quality Screening	355	3195044	271488	95191	0	0	0	1404	0	3838	0	43624	3610944
	Speed Compliant Records	341	3013704	256241	89288	0	0	0	1296	0	3464	0	37678	3402012
	Speed Buffer Records	253	2418734	199820	65651	0	0	0	948	0	2201	0	31048	2718655
	Percent Included	**98.3%**	**99.5%**	**99.4%**	**99.4%**	**0.0%**	**0.0%**	**0.0%**	**98.5%**	**0.0%**	**98.9%**	**0.0%**	**99.2%**	**99.4%**
	Percent Compliant	**96.1%**	**94.3%**	**94.4%**	**93.8%**	**0.0%**	**0.0%**	**0.0%**	**92.3%**	**0.0%**	**90.3%**	**0.0%**	**86.4%**	**94.2%**
	Percent Speed Buffer	**71.3%**	**75.7%**	**73.6%**	**69.0%**	**0.0%**	**0.0%**	**0.0%**	**67.5%**	**0.0%**	**57.3%**	**0.0%**	**71.2%**	**75.3%**
2049	Processed Records	324	2921422	258633	86228	0	0	0	1027	0	3259	0	40300	3311193

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Records after Data Quality Screening	317	2852284	248444	83979	0	0	0	977	0	3136	0	38647	3227784
	Speed Compliant Records	308	2721952	235998	79061	0	0	0	865	0	2769	0	33360	3074313
	Speed Buffer Records	251	2202243	185908	58971	0	0	0	660	0	1867	0	27842	2477742
	Percent Included	**97.8%**	**97.6%**	**96.1%**	**97.4%**	**0.0%**	**0.0%**	**0.0%**	**95.1%**	**0.0%**	**96.2%**	**0.0%**	**95.9%**	**97.5%**
	Percent Compliant	**97.2%**	**95.4%**	**95.0%**	**94.1%**	**0.0%**	**0.0%**	**0.0%**	**88.5%**	**0.0%**	**88.3%**	**0.0%**	**86.3%**	**95.2%**
	Percent Speed Buffer	**79.2%**	**77.2%**	**74.8%**	**70.2%**	**0.0%**	**0.0%**	**0.0%**	**67.6%**	**0.0%**	**59.5%**	**0.0%**	**72.0%**	**76.8%**
2070	Processed Records	362	3192297	281616	94509	0	0	0	1139	0	3639	0	40544	3614106
	Records after Data Quality Screening	301	2725809	238913	80375	0	0	0	968	0	3064	0	34907	3084337
	Speed Compliant Records	292	2661646	233170	78090	0	0	0	892	0	2761	0	31813	3008664
	Speed Buffer Records	203	1803669	148102	45681	0	0	0	597	0	1691	0	21695	2021638
	Percent Included	**83.1%**	**85.4%**	**84.8%**	**85.0%**	**0.0%**	**0.0%**	**0.0%**	**85.0%**	**0.0%**	**84.2%**	**0.0%**	**86.1%**	**85.3%**
	Percent Compliant	**97.0%**	**97.6%**	**97.6%**	**97.2%**	**0.0%**	**0.0%**	**0.0%**	**92.1%**	**0.0%**	**90.1%**	**0.0%**	**91.1%**	**97.5%**
	Percent Speed Buffer	**67.4%**	**66.2%**	**62.0%**	**56.8%**	**0.0%**	**0.0%**	**0.0%**	**61.7%**	**0.0%**	**55.2%**	**0.0%**	**62.2%**	**65.5%**
2146	Processed Records	407	1492279	186230	62675	45	0	308	11732	1085	67987	381	212802	2035931
	Records after Data Quality Screening	389	1412028	179608	59692	45	0	308	11002	1053	65553	368	205995	1936041
	Speed Compliant Records	332	1293472	165802	50687	40	0	223	9982	904	53342	247	172344	1747375
	Speed Buffer Records	169	1023192	117583	38903	29	0	191	4095	616	35666	172	117758	1338374
	Percent Included	**95.6%**	**94.6%**	**96.4%**	**95.2%**	**100.0%**	**0.0%**	**100.0%**	**93.8%**	**97.1%**	**96.4%**	**96.6%**	**96.8%**	**95.1%**
	Percent Compliant	**85.3%**	**91.6%**	**92.3%**	**84.9%**	**88.9%**	**0.0%**	**72.4%**	**90.7%**	**85.8%**	**81.4%**	**67.1%**	**83.7%**	**90.3%**
	Percent Speed Buffer	**43.4%**	**72.5%**	**65.5%**	**65.2%**	**64.4%**	**0.0%**	**62.0%**	**37.2%**	**58.5%**	**54.4%**	**46.7%**	**57.2%**	**69.1%**
2178	Processed Records	0	1674315	152579	215390	0	232	0	0	0	23462	655	296410	2363043
	Records after Data Quality Screening	0	1497273	151247	199022	0	232	0	0	0	23021	655	293598	2165048
	Speed Compliant Records	0	1283454	124780	155527	0	111	0	0	0	18372	571	226336	1809151
	Speed Buffer Records	0	1099853	106809	143438	0	97	0	0	0	13039	325	201439	1565000
	Percent Included	**0.0%**	**89.4%**	**99.1%**	**92.4%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**98.1%**	**100.0%**	**99.1%**	**91.6%**

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Percent Compliant	**0.0%**	**85.7%**	**82.5%**	**78.1%**	**0.0%**	**47.8%**	**0.0%**	**0.0%**	**0.0%**	**79.8%**	**87.2%**	**77.1%**	**83.6%**
	Percent Speed Buffer	**0.0%**	**73.5%**	**70.6%**	**72.1%**	**0.0%**	**41.8%**	**0.0%**	**0.0%**	**0.0%**	**56.6%**	**49.6%**	**68.6%**	**72.3%**
2334	Processed Records	0	1166915	91238	166472	70	32	0	77	0	5430	0	56133	1486367
	Records after Data Quality Screening	0	950799	90091	157958	70	32	0	77	0	5378	0	54919	1259324
	Speed Compliant Records	0	422375	48777	85512	40	16	0	57	0	3946	0	30086	590809
	Speed Buffer Records	0	551188	53694	99430	36	14	0	42	0	2688	0	31335	738427
	Percent Included	**0.0%**	**81.5%**	**98.7%**	**94.9%**	**100.0%**	**100.0%**	**0.0%**	**100.0%**	**0.0%**	**99.0%**	**0.0%**	**97.8%**	**84.7%**
	Percent Compliant	**0.0%**	**44.4%**	**54.1%**	**54.1%**	**57.1%**	**50.0%**	**0.0%**	**74.0%**	**0.0%**	**73.4%**	**0.0%**	**54.8%**	**46.9%**
	Percent Speed Buffer	**0.0%**	**58.0%**	**59.6%**	**62.9%**	**51.4%**	**43.8%**	**0.0%**	**54.5%**	**0.0%**	**50.0%**	**0.0%**	**57.1%**	**58.6%**
2346	Processed Records	0	3717	4706	99	0	0	0	0	0	138	0	5802	14462
	Records after Data Quality Screening	0	3717	4706	99	0	0	0	0	0	138	0	5802	14462
	Speed Compliant Records	0	2224	4069	57	0	0	0	0	0	99	0	4025	10474
	Speed Buffer Records	0	2480	3578	67	0	0	0	0	0	119	0	3839	10083
	Percent Included	**0.0%**	**100.0%**	**100.0%**	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**100.0%**	**100.0%**
	Percent Compliant	**0.0%**	**59.8%**	**86.5%**	**57.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**71.7%**	**0.0%**	**69.4%**	**72.4%**
	Percent Speed Buffer	**0.0%**	**66.7%**	**76.0%**	**67.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**86.2%**	**0.0%**	**66.2%**	**69.7%**
2359	Processed Records	26	1876586	225875	222402	78	21	0	82	0	9151	0	159504	2493725
	Records after Data Quality Screening	26	1803067	219793	215315	75	21	0	81	0	8945	0	156315	2403638
	Speed Compliant Records	18	790421	110696	102689	39	15	0	60	0	4500	0	68151	1076589
	Speed Buffer Records	14	1136250	142916	132591	50	14	0	56	0	4942	0	87849	1504682
	Percent Included	**100.0%**	**96.1%**	**97.3%**	**96.8%**	**96.2%**	**100.0%**	**0.0%**	**98.8%**	**0.0%**	**97.7%**	**0.0%**	**98.0%**	**96.4%**
	Percent Compliant	**69.2%**	**43.8%**	**50.4%**	**47.7%**	**52.0%**	**71.4%**	**0.0%**	**74.1%**	**0.0%**	**50.3%**	**0.0%**	**43.6%**	**44.8%**
	Percent Speed Buffer	**53.8%**	**63.0%**	**65.0%**	**61.6%**	**66.7%**	**66.7%**	**0.0%**	**69.1%**	**0.0%**	**55.2%**	**0.0%**	**56.2%**	**62.6%**
2372	Processed Records	36	1488079	111625	90053	0	11	0	0	136	3923	0	222540	1916403
	Records after Data Quality Screening	36	1480076	109845	88873	0	9	0	0	132	2999	0	214834	1896804

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Speed Compliant Records	19	1365365	103121	79413	0	9	0	0	124	2202	0	188142	1738395
	Speed Buffer Records	29	1094313	72601	58274	0	7	0	0	52	2155	0	132721	1360152
	Percent Included	**100.0%**	**99.5%**	**98.4%**	**98.7%**	**0.0%**	**81.8%**	**0.0%**	**0.0%**	**97.1%**	**76.4%**	**0.0%**	**96.5%**	**99.0%**
	Percent Compliant	**52.8%**	**92.2%**	**93.9%**	**89.4%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	**93.9%**	**73.4%**	**0.0%**	**87.6%**	**91.6%**
	Percent Speed Buffer	**80.6%**	**73.9%**	**66.1%**	**65.6%**	**0.0%**	**77.8%**	**0.0%**	**0.0%**	**39.4%**	**71.9%**	**0.0%**	**61.8%**	**71.7%**
2383	Processed Records	0	1510583	94562	74435	0	0	0	0	160	1123	0	130502	1811365
	Records after Data Quality Screening	0	1504719	94236	74145	0	0	0	0	160	1112	0	129284	1803656
	Speed Compliant Records	0	1248463	80466	61621	0	0	0	0	144	766	0	105713	1497173
	Speed Buffer Records	0	1202183	69882	53492	0	0	0	0	58	827	0	88514	1414956
	Percent Included	**0.0%**	**99.6%**	**99.7%**	**99.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**99.0%**	**0.0%**	**99.1%**	**99.6%**
	Percent Compliant	**0.0%**	**83.0%**	**85.4%**	**83.1%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**90.0%**	**68.9%**	**0.0%**	**81.8%**	**83.0%**
	Percent Speed Buffer	**0.0%**	**79.9%**	**74.2%**	**72.1%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**36.3%**	**74.4%**	**0.0%**	**68.5%**	**78.4%**
2395	Processed Records	0	1903690	127898	93222	0	0	0	0	185	1505	0	171028	2297528
	Records after Data Quality Screening	0	1853967	126670	91571	0	0	0	0	185	1492	0	168074	2241959
	Speed Compliant Records	0	1616140	112902	76173	0	0	0	0	158	825	0	129282	1935480
	Speed Buffer Records	0	1504950	94657	69684	0	0	0	0	123	1092	0	122162	1792668
	Percent Included	**0.0%**	**97.4%**	**99.0%**	**98.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**99.1%**	**0.0%**	**98.3%**	**97.6%**
	Percent Compliant	**0.0%**	**87.2%**	**89.1%**	**83.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**85.4%**	**55.3%**	**0.0%**	**76.9%**	**86.3%**
	Percent Speed Buffer	**0.0%**	**81.2%**	**74.7%**	**76.1%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**66.5%**	**73.2%**	**0.0%**	**72.7%**	**80.0%**
2409	Processed Records	0	1091209	69504	54693	0	0	0	0	73	882	0	93460	1309821
	Records after Data Quality Screening	0	1058369	67875	53691	0	0	0	0	73	876	0	91318	1272202
	Speed Compliant Records	0	852174	58858	43158	0	0	0	0	63	636	0	74410	1029299
	Speed Buffer Records	0	651376	36394	32003	0	0	0	0	53	639	0	52204	772669
	Percent Included	**0.0%**	**97.0%**	**97.7%**	**98.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**99.3%**	**0.0%**	**97.7%**	**97.1%**
	Percent Compliant	**0.0%**	**80.5%**	**86.7%**	**80.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**86.3%**	**72.6%**	**0.0%**	**81.5%**	**80.9%**

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Percent Speed Buffer	**0.0%**	**61.5%**	**53.6%**	**59.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**72.6%**	**72.9%**	**0.0%**	**57.2%**	**60.7%**
2421	Processed Records	0	1122096	72705	53306	0	0	0	0	128	787	0	91098	1340120
	Records after Data Quality Screening	0	1119672	72560	53195	0	0	0	0	128	783	0	90676	1337014
	Speed Compliant Records	0	1025059	69141	48655	0	0	0	0	127	719	0	84482	1228183
	Speed Buffer Records	0	525855	24114	24142	0	0	0	0	27	400	0	30745	605283
	Percent Included	**0.0%**	**99.8%**	**99.8%**	**99.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**99.5%**	**0.0%**	**99.5%**	**99.8%**
	Percent Compliant	**0.0%**	**91.5%**	**95.3%**	**91.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**99.2%**	**91.8%**	**0.0%**	**93.2%**	**91.9%**
	Percent Speed Buffer	**0.0%**	**47.0%**	**33.2%**	**45.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**21.1%**	**51.1%**	**0.0%**	**33.9%**	**45.3%**
2433	Processed Records	0	1049069	67651	52261	0	0	0	0	67	745	0	89514	1259307
	Records after Data Quality Screening	0	1046331	67429	52106	0	0	0	0	67	728	0	88747	1255408
	Speed Compliant Records	0	940170	62990	46534	0	0	0	0	59	588	0	78948	1129289
	Speed Buffer Records	0	626504	33365	29281	0	0	0	0	44	529	0	47373	737096
	Percent Included	**0.0%**	**99.7%**	**99.7%**	**99.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**97.7%**	**0.0%**	**99.1%**	**99.7%**
	Percent Compliant	**0.0%**	**89.9%**	**93.4%**	**89.3%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**88.1%**	**80.8%**	**0.0%**	**89.0%**	**90.0%**
	Percent Speed Buffer	**0.0%**	**59.9%**	**49.5%**	**56.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**65.7%**	**72.7%**	**0.0%**	**53.4%**	**58.7%**
2445	Processed Records	0	1763265	119284	86218	0	0	0	0	168	1362	0	157218	2127515
	Records after Data Quality Screening	0	1753881	118743	85864	0	0	0	0	168	1357	0	156213	2116226
	Speed Compliant Records	0	1493884	106491	69999	0	0	0	0	131	861	0	122447	1793813
	Speed Buffer Records	0	1319923	82498	61781	0	0	0	0	133	1009	0	106705	1572049
	Percent Included	**0.0%**	**99.5%**	**99.5%**	**99.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**99.6%**	**0.0%**	**99.4%**	**99.5%**
	Percent Compliant	**0.0%**	**85.2%**	**89.7%**	**81.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**78.0%**	**63.4%**	**0.0%**	**78.4%**	**84.8%**
	Percent Speed Buffer	**0.0%**	**75.3%**	**69.5%**	**72.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**79.2%**	**74.4%**	**0.0%**	**68.3%**	**74.3%**
2607	Processed Records	0	1755964	119703	86138	0	0	0	0	158	1363	0	157800	2121126
	Records after Data Quality Screening	0	1747665	119160	85718	0	0	0	0	158	1349	0	156976	2111026
	Speed Compliant Records	0	1406175	102945	65816	0	0	0	0	96	683	0	114737	1690452

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Speed Buffer Records	0	1470696	96924	66752	0	0	0	0	114	900	0	116444	1751830
	Percent Included	**0.0%**	**99.5%**	**99.5%**	**99.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**99.0%**	**0.0%**	**99.5%**	**99.5%**
	Percent Compliant	**0.0%**	**80.5%**	**86.4%**	**76.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**60.8%**	**50.6%**	**0.0%**	**73.1%**	**80.1%**
	Percent Speed Buffer	**0.0%**	**84.2%**	**81.3%**	**77.9%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**72.2%**	**66.7%**	**0.0%**	**74.2%**	**83.0%**
2609	Processed Records	0	1433763	92910	69326	0	0	0	0	157	1024	0	123735	1720915
	Records after Data Quality Screening	0	1428247	92512	69085	0	0	0	0	156	1014	0	122758	1713772
	Speed Compliant Records	0	1235931	84786	61729	0	0	0	0	152	917	0	111828	1495343
	Speed Buffer Records	0	1078352	62603	46878	0	0	0	0	20	274	0	62246	1250373
	Percent Included	**0.0%**	**99.6%**	**99.6%**	**99.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**99.4%**	**99.0%**	**0.0%**	**99.2%**	**99.6%**
	Percent Compliant	**0.0%**	**86.5%**	**91.6%**	**89.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**97.4%**	**90.4%**	**0.0%**	**91.1%**	**87.3%**
	Percent Speed Buffer	**0.0%**	**75.5%**	**67.7%**	**67.9%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**12.8%**	**27.0%**	**0.0%**	**50.7%**	**73.0%**
2916	Processed Records	0	2056148	250585	71103	0	0	0	0	0	1913	13	109966	2489728
	Records after Data Quality Screening	0	2034989	248739	70579	0	0	0	0	0	1911	13	109549	2465780
	Speed Compliant Records	0	1845049	233305	66502	0	0	0	0	0	1879	13	106917	2253665
	Speed Buffer Records	0	1197664	115108	33222	0	0	0	0	0	515	5	28320	1374834
	Percent Included	**0.0%**	**99.0%**	**99.3%**	**99.3%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**99.9%**	**100.0%**	**99.6%**	**99.0%**
	Percent Compliant	**0.0%**	**90.7%**	**93.8%**	**94.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**98.3%**	**100.0%**	**97.6%**	**91.4%**
	Percent Speed Buffer	**0.0%**	**58.9%**	**46.3%**	**47.1%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**26.9%**	**38.5%**	**25.9%**	**55.8%**
3236	Processed Records	0	2111160	129106	85237	0	8	0	0	0	21	0	45515	2371047
	Records after Data Quality Screening	0	2075465	126877	83510	0	8	0	0	0	21	0	44336	2330217
	Speed Compliant Records	0	1998319	118730	77732	0	8	0	0	0	21	0	40512	2235322
	Speed Buffer Records	0	1158049	68678	41540	0	4	0	0	0	2	0	25667	1293940
	Percent Included	**0.0%**	**98.3%**	**98.3%**	**98.0%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**97.4%**	**98.3%**
	Percent Compliant	**0.0%**	**96.3%**	**93.6%**	**93.1%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**91.4%**	**95.9%**
	Percent Speed Buffer	**0.0%**	**55.8%**	**54.1%**	**49.7%**	**0.0%**	**50.0%**	**0.0%**	**0.0%**	**0.0%**	**9.5%**	**0.0%**	**57.9%**	**55.5%**

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
3249	Processed Records	175	1703578	137028	51367	0	0	0	533	0	2261	0	26131	1921073
	Records after Data Quality Screening	175	1698955	136195	51269	0	0	0	449	0	2049	0	25566	1914658
	Speed Compliant Records	166	1571960	120271	48060	0	0	0	436	0	1906	0	22738	1765537
	Speed Buffer Records	146	1281775	98975	36637	0	0	0	132	0	1039	0	17951	1436655
	Percent Included	**100.0%**	**99.7%**	**99.4%**	**99.8%**	**0.0%**	**0.0%**	**0.0%**	**84.2%**	**0.0%**	**90.6%**	**0.0%**	**97.8%**	**99.7%**
	Percent Compliant	**94.9%**	**92.5%**	**88.3%**	**93.7%**	**0.0%**	**0.0%**	**0.0%**	**97.1%**	**0.0%**	**93.0%**	**0.0%**	**88.9%**	**92.2%**
	Percent Speed Buffer	**83.4%**	**75.4%**	**72.7%**	**71.5%**	**0.0%**	**0.0%**	**0.0%**	**29.4%**	**0.0%**	**50.7%**	**0.0%**	**70.2%**	**75.0%**
3296	Processed Records	88	2707117	275238	125469	0	6	0	0	630	21	4	139238	3247811
	Records after Data Quality Screening	31	890200	100062	43430	0	5	0	0	217	14	3	53535	1087497
	Speed Compliant Records	11	775380	88324	36638	0	5	0	0	175	14	3	45733	946283
	Speed Buffer Records	20	681762	70824	29503	0	2	0	0	141	1	3	37021	819277
	Percent Included	**35.2%**	**32.9%**	**36.4%**	**34.6%**	**0.0%**	**83.3%**	**0.0%**	**0.0%**	**34.4%**	**66.7%**	**75.0%**	**38.4%**	**33.5%**
	Percent Compliant	**35.5%**	**87.1%**	**88.3%**	**84.4%**	**0.0%**	**100.0%**	**0.0%**	**0.0%**	**80.6%**	**100.0%**	**100.0%**	**85.4%**	**87.0%**
	Percent Speed Buffer	**64.5%**	**76.6%**	**70.8%**	**67.9%**	**0.0%**	**40.0%**	**0.0%**	**0.0%**	**65.0%**	**7.1%**	**100.0%**	**69.2%**	**75.3%**
407	Processed Records	8	713639	49081	50679	0	0	0	2273	21	11786	2547	41511	871545
	Records after Data Quality Screening	8	648513	48609	47333	0	0	0	2238	19	11675	2529	41216	802140
	Speed Compliant Records	8	469580	41107	36024	0	0	0	2056	19	10837	2030	36858	598519
	Speed Buffer Records	5	548242	40051	39148	0	0	0	1163	0	6239	1935	28413	665196
	Percent Included	**100.0%**	**90.9%**	**99.0%**	**93.4%**	**0.0%**	**0.0%**	**0.0%**	**98.5%**	**90.5%**	**99.1%**	**99.3%**	**99.3%**	**92.0%**
	Percent Compliant	**100.0%**	**72.4%**	**84.6%**	**76.1%**	**0.0%**	**0.0%**	**0.0%**	**91.9%**	**100.0%**	**92.8%**	**80.3%**	**89.4%**	**74.6%**
	Percent Speed Buffer	**62.5%**	**84.5%**	**82.4%**	**82.7%**	**0.0%**	**0.0%**	**0.0%**	**52.0%**	**0.0%**	**53.4%**	**76.5%**	**68.9%**	**82.9%**
408	Processed Records	10	874777	54426	53270	0	0	0	2276	10	12557	1507	46630	1045463
	Records after Data Quality Screening	10	581751	39773	40114	0	0	0	1160	10	7416	1454	30566	702254
	Speed Compliant Records	9	432518	35979	30756	0	0	0	1049	10	6919	1289	28208	536737
	Speed Buffer Records	6	483270	34029	33285	0	0	0	857	1	5184	1147	23052	580831

Summary - By Sensors		Storm Category 0	1	2	3	4	5	6	7	8	9	10	11	Total
	Percent Included	**100.0%**	**66.5%**	**73.1%**	**75.3%**	**0.0%**	**0.0%**	**0.0%**	**51.0%**	**100.0%**	**59.1%**	**96.5%**	**65.6%**	**67.2%**
	Percent Compliant	**90.0%**	**74.3%**	**90.5%**	**76.7%**	**0.0%**	**0.0%**	**0.0%**	**90.4%**	**100.0%**	**93.3%**	**88.7%**	**92.3%**	**76.4%**
	Percent Speed Buffer	**60.0%**	**83.1%**	**85.6%**	**83.0%**	**0.0%**	**0.0%**	**0.0%**	**73.9%**	**10.0%**	**69.9%**	**78.9%**	**75.4%**	**82.7%**
411	Processed Records	12	851332	52575	56988	13	0	0	2504	159	14239	3807	45319	1026948
	Records after Data Quality Screening	10	792566	49580	52941	11	0	0	2291	126	13042	3469	41459	955495
	Speed Compliant Records	10	724726	47189	48971	11	0	0	2238	125	12684	3303	39640	878897
	Speed Buffer Records	0	476785	27340	30375	3	0	0	852	15	4876	1688	19723	561657
	Percent Included	**83.3%**	**93.1%**	**94.3%**	**92.9%**	**84.6%**	**0.0%**	**0.0%**	**91.5%**	**79.2%**	**91.6%**	**91.1%**	**91.5%**	**93.0%**
	Percent Compliant	**100.0%**	**91.4%**	**95.2%**	**92.5%**	**100.0%**	**0.0%**	**0.0%**	**97.7%**	**99.2%**	**97.3%**	**95.2%**	**95.6%**	**92.0%**
	Percent Speed Buffer	**0.0%**	**60.2%**	**55.1%**	**57.4%**	**27.3%**	**0.0%**	**0.0%**	**37.2%**	**11.9%**	**37.4%**	**48.7%**	**47.6%**	**58.8%**
1100	Processed Records	113	1036046	78216	30634	0	0	0	154	0	1068	0	13814	1160045
	Records after Data Quality Screening	113	1035404	78135	30597	0	0	0	153	0	1060	0	13747	1159209
	Speed Compliant Records	99	923841	72990	29048	0	0	0	153	0	1053	0	13391	1040575
	Speed Buffer Records	75	745755	50032	18827	0	0	0	8	0	179	0	6076	820952
	Percent Included	**100.0%**	**99.9%**	**99.9%**	**99.9%**	**0.0%**	**0.0%**	**0.0%**	**99.4%**	**0.0%**	**99.3%**	**0.0%**	**99.5%**	**99.9%**
	Percent Compliant	**87.6%**	**89.2%**	**93.4%**	**94.9%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**0.0%**	**99.3%**	**0.0%**	**97.4%**	**89.8%**
	Percent Speed Buffer	**66.4%**	**72.0%**	**64.0%**	**61.5%**	**0.0%**	**0.0%**	**0.0%**	**5.2%**	**0.0%**	**16.9%**	**0.0%**	**44.2%**	**70.8%**
1837	Processed Records	11	764641	45802	46002	1	0	0	2045	4	9891	2119	39252	909768
	Records after Data Quality Screening	1	437522	27655	30150	1	0	0	1596	0	6232	233	17700	521090
	Speed Compliant Records	1	380000	26087	26746	1	0	0	1361	0	5424	202	15509	455331
	Speed Buffer Records	0	200199	8175	12600	1	0	0	853	0	3115	152	7220	232315
	Percent Included	**9.1%**	**57.2%**	**60.4%**	**65.5%**	**100.0%**	**0.0%**	**0.0%**	**78.0%**	**0.0%**	**63.0%**	**11.0%**	**45.1%**	**57.3%**
	Percent Compliant	**100.0%**	**86.9%**	**94.3%**	**88.7%**	**100.0%**	**0.0%**	**0.0%**	**85.3%**	**0.0%**	**87.0%**	**86.7%**	**87.6%**	**87.4%**
	Percent Speed Buffer	**0.0%**	**45.8%**	**29.6%**	**41.8%**	**100.0%**	**0.0%**	**0.0%**	**53.4%**	**0.0%**	**50.0%**	**65.2%**	**40.8%**	**44.6%**
2079	Processed Records	270	2411128	213634	70307	0	0	0	837	0	2730	0	31669	2730575

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Records after Data Quality Screening	256	2039547	195604	64295	0	0	0	766	0	2504	0	26980	2329952
	Speed Compliant Records	217	1762788	171918	56748	0	0	0	669	0	2102	0	21714	2016156
	Speed Buffer Records	193	1522413	139901	43274	0	0	0	481	0	1458	0	18251	1725971
	Percent Included	**94.8%**	**84.6%**	**91.6%**	**91.4%**	**0.0%**	**0.0%**	**0.0%**	**91.5%**	**0.0%**	**91.7%**	**0.0%**	**85.2%**	**85.3%**
	Percent Compliant	**84.8%**	**86.4%**	**87.9%**	**88.3%**	**0.0%**	**0.0%**	**0.0%**	**87.3%**	**0.0%**	**83.9%**	**0.0%**	**80.5%**	**86.5%**
	Percent Speed Buffer	**75.4%**	**74.6%**	**71.5%**	**67.3%**	**0.0%**	**0.0%**	**0.0%**	**62.8%**	**0.0%**	**58.2%**	**0.0%**	**67.6%**	**74.1%**
2090	Processed Records	158	1263536	95625	36556	0	0	0	414	0	1343	0	15780	1413412
	Records after Data Quality Screening	155	1244418	93849	36063	0	0	0	383	0	1256	0	15375	1391499
	Speed Compliant Records	146	1129265	83944	32977	0	0	0	343	0	1104	0	12721	1260500
	Speed Buffer Records	115	930441	67324	24505	0	0	0	174	0	604	0	10353	1033516
	Percent Included	**98.1%**	**98.5%**	**98.1%**	**98.7%**	**0.0%**	**0.0%**	**0.0%**	**92.5%**	**0.0%**	**93.5%**	**0.0%**	**97.4%**	**98.4%**
	Percent Compliant	**94.2%**	**90.7%**	**89.4%**	**91.4%**	**0.0%**	**0.0%**	**0.0%**	**89.6%**	**0.0%**	**87.9%**	**0.0%**	**82.7%**	**90.6%**
	Percent Speed Buffer	**74.2%**	**74.8%**	**71.7%**	**68.0%**	**0.0%**	**0.0%**	**0.0%**	**45.4%**	**0.0%**	**48.1%**	**0.0%**	**67.3%**	**74.3%**
2578	Processed Records	243	2122420	186567	62792	0	0	0	768	0	2622	0	30190	2405602
	Records after Data Quality Screening	237	2079939	183316	62008	0	0	0	758	0	2602	0	29904	2358764
	Speed Compliant Records	192	1741618	148457	53713	0	0	0	656	0	2180	0	24536	1971352
	Speed Buffer Records	187	1668474	134369	44002	0	0	0	235	0	906	0	16287	1864460
	Percent Included	**97.5%**	**98.0%**	**98.3%**	**98.8%**	**0.0%**	**0.0%**	**0.0%**	**98.7%**	**0.0%**	**99.2%**	**0.0%**	**99.1%**	**98.1%**
	Percent Compliant	**81.0%**	**83.7%**	**81.0%**	**86.6%**	**0.0%**	**0.0%**	**0.0%**	**86.5%**	**0.0%**	**83.8%**	**0.0%**	**82.0%**	**83.6%**
	Percent Speed Buffer	**78.9%**	**80.2%**	**73.3%**	**71.0%**	**0.0%**	**0.0%**	**0.0%**	**31.0%**	**0.0%**	**34.8%**	**0.0%**	**54.5%**	**79.0%**
3402	Processed Records	7	961167	53262	58162	0	0	0	2590	31	12539	2795	47894	1138447
	Records after Data Quality Screening	7	924919	51155	56367	0	0	0	2480	31	12162	2793	46196	1096110
	Speed Compliant Records	3	729520	41135	41028	0	0	0	1611	17	6672	662	25575	846223
	Speed Buffer Records	7	800131	41977	45186	0	0	0	1598	20	8098	1109	31158	929284
	Percent Included	**100.0%**	**96.2%**	**96.0%**	**96.9%**	**0.0%**	**0.0%**	**0.0%**	**95.8%**	**100.0%**	**97.0%**	**99.9%**	**96.5%**	**96.3%**

Summary - By Sensors		Storm Category 0	1	2	3	4	5	6	7	8	9	10	11	Total
	Percent Compliant	**42.9%**	**78.9%**	**80.4%**	**72.8%**	**0.0%**	**0.0%**	**0.0%**	**65.0%**	**54.8%**	**54.9%**	**23.7%**	**55.4%**	**77.2%**
	Percent Speed Buffer	**100.0%**	**86.5%**	**82.1%**	**80.2%**	**0.0%**	**0.0%**	**0.0%**	**64.4%**	**64.5%**	**66.6%**	**39.7%**	**67.4%**	**84.8%**
3901	Processed Records	13	1537787	91287	95184	1	0	0	4295	55	21918	4486	78559	1833585
	Records after Data Quality Screening	6	1269034	72307	78758	1	0	0	3825	50	18030	2330	55982	1500323
	Speed Compliant Records	6	1094362	66214	69023	1	0	0	3298	50	16484	2326	51174	1302938
	Speed Buffer Records	0	869091	41793	47429	0	0	0	1302	2	5088	110	19973	984788
	Percent Included	**46.2%**	**82.5%**	**79.2%**	**82.7%**	**100.0%**	**0.0%**	**0.0%**	**89.1%**	**90.9%**	**82.3%**	**51.9%**	**71.3%**	**81.8%**
	Percent Compliant	**100.0%**	**86.2%**	**91.6%**	**87.6%**	**100.0%**	**0.0%**	**0.0%**	**86.2%**	**100.0%**	**91.4%**	**99.8%**	**91.4%**	**86.8%**
	Percent Speed Buffer	**0.0%**	**68.5%**	**57.8%**	**60.2%**	**0.0%**	**0.0%**	**0.0%**	**34.0%**	**4.0%**	**28.2%**	**4.7%**	**35.7%**	**65.6%**
3897	Processed Records	5	131587	27733	11810	0	0	0	347	7	4271	315	17547	193622
	Records after Data Quality Screening	1	64028	14336	6202	0	0	0	178	5	2300	118	8124	95292
	Speed Compliant Records	1	56023	13218	5741	0	0	0	178	5	2279	111	7746	85302
	Speed Buffer Records	0	53047	10867	4569	0	0	0	13	1	590	76	5332	74495
	Percent Included	**20.0%**	**48.7%**	**51.7%**	**52.5%**	**0.0%**	**0.0%**	**0.0%**	**51.3%**	**71.4%**	**53.9%**	**37.5%**	**46.3%**	**49.2%**
	Percent Compliant	**100.0%**	**87.5%**	**92.2%**	**92.6%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**	**100.0%**	**99.1%**	**94.1%**	**95.3%**	**89.5%**
	Percent Speed Buffer	**0.0%**	**82.8%**	**75.8%**	**73.7%**	**0.0%**	**0.0%**	**0.0%**	**7.3%**	**20.0%**	**25.7%**	**64.4%**	**65.6%**	**78.2%**
3899	Processed Records	8	315955	24921	27637	0	0	0	738	7	5173	2162	27275	403876
	Records after Data Quality Screening	0	116841	5555	12682	0	0	0	313	0	1161	1	2689	139242
	Speed Compliant Records	0	100701	5160	10483	0	0	0	262	0	935	1	2323	119865
	Speed Buffer Records	0	83261	3294	8416	0	0	0	193	0	726	0	1534	97424
	Percent Included	**0.0%**	**37.0%**	**22.3%**	**45.9%**	**0.0%**	**0.0%**	**0.0%**	**42.4%**	**0.0%**	**22.4%**	**0.0%**	**9.9%**	**34.5%**
	Percent Compliant	**0.0%**	**86.2%**	**92.9%**	**82.7%**	**0.0%**	**0.0%**	**0.0%**	**83.7%**	**0.0%**	**80.5%**	**100.0%**	**86.4%**	**86.1%**
	Percent Speed Buffer	**0.0%**	**71.3%**	**59.3%**	**66.4%**	**0.0%**	**0.0%**	**0.0%**	**61.7%**	**0.0%**	**62.5%**	**0.0%**	**57.0%**	**70.0%**
3903	Processed Records	16	929072	46495	59482	0	0	0	1736	48	11014	4433	53120	1105416
	Records after Data Quality Screening	14	714050	39059	45936	0	0	0	1420	40	9211	3670	44763	858163

Summary - By Sensors		Storm Category												
		0	1	2	3	4	5	6	7	8	9	10	11	Total
	Speed Compliant Records	12	674929	35966	40587	0	0	0	1238	37	6833	2437	33837	795876
	Speed Buffer Records	2	497696	25989	30197	0	0	0	915	27	6164	2477	30231	593698
	Percent Included	**87.5%**	**76.9%**	**84.0%**	**77.2%**	**0.0%**	**0.0%**	**0.0%**	**81.8%**	**83.3%**	**83.6%**	**82.8%**	**84.3%**	**77.6%**
	Percent Compliant	**85.7%**	**94.5%**	**92.1%**	**88.4%**	**0.0%**	**0.0%**	**0.0%**	**87.2%**	**92.5%**	**74.2%**	**66.4%**	**75.6%**	**92.7%**
	Percent Speed Buffer	**14.3%**	**69.7%**	**66.5%**	**65.7%**	**0.0%**	**0.0%**	**0.0%**	**64.4%**	**67.5%**	**66.9%**	**67.5%**	**67.5%**	**69.2%**
Total Sensor Data														
Baseline	**Processed Records**	**4,048**	**53,415,605**	**4,480,251**	**2,743,939**	**270**	**310**	**607**	**49,088**	**4,761**	**341,075**	**31,354**	**3,267,652**	**64,338,960**
	Records after Data Quality Screening	**2,517**	**46,962,763**	**3,925,225**	**2,418,158**	**229**	**307**	**436**	**36,080**	**3,193**	**250,182**	**17,674**	**2,798,739**	**56,415,503**
	Speed Compliant Records	**2,235**	**40,524,982**	**3,430,866**	**1,951,772**	**147**	**164**	**268**	**31,088**	**2,610**	**197,985**	**13,211**	**2,241,121**	**48,396,449**
	Speed Buffer Records	**1,720**	**33,619,787**	**2,618,285**	**1,595,658**	**134**	**138**	**268**	**17,382**	**1,689**	**137,739**	**9,222**	**1,694,709**	**39,696,731**
	Percent Included	**62.2%**	**87.9%**	**87.6%**	**88.1%**	**84.8%**	**99.0%**	**71.8%**	**73.5%**	**67.1%**	**73.4%**	**56.4%**	**85.6%**	**87.7%**
	Percent Compliant	**88.8%**	**86.3%**	**87.4%**	**80.7%**	**64.2%**	**53.4%**	**61.5%**	**86.2%**	**81.7%**	**79.1%**	**74.7%**	**80.1%**	**85.8%**
	Percent Speed Buffer	**68.3%**	**71.6%**	**66.7%**	**66.0%**	**58.5%**	**45.0%**	**61.5%**	**48.2%**	**52.9%**	**55.1%**	**52.2%**	**60.6%**	**70.4%**

Appendix H. Results of Work Zone Speed Impacts

Figure H-1 through Figure H-6 summarize the results of construction season speed data to identify work zone impacts speeds

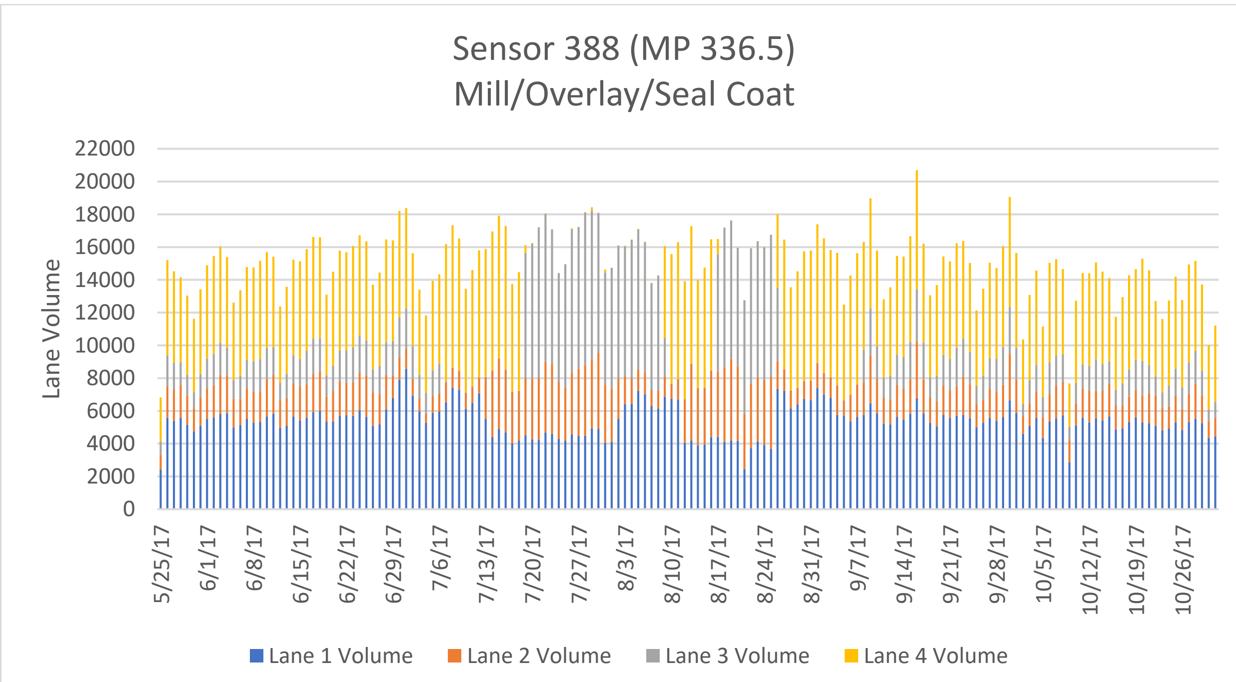


Figure H-1. Sensor 388 Work Zone Speed Analysis (Source: WYDOT)

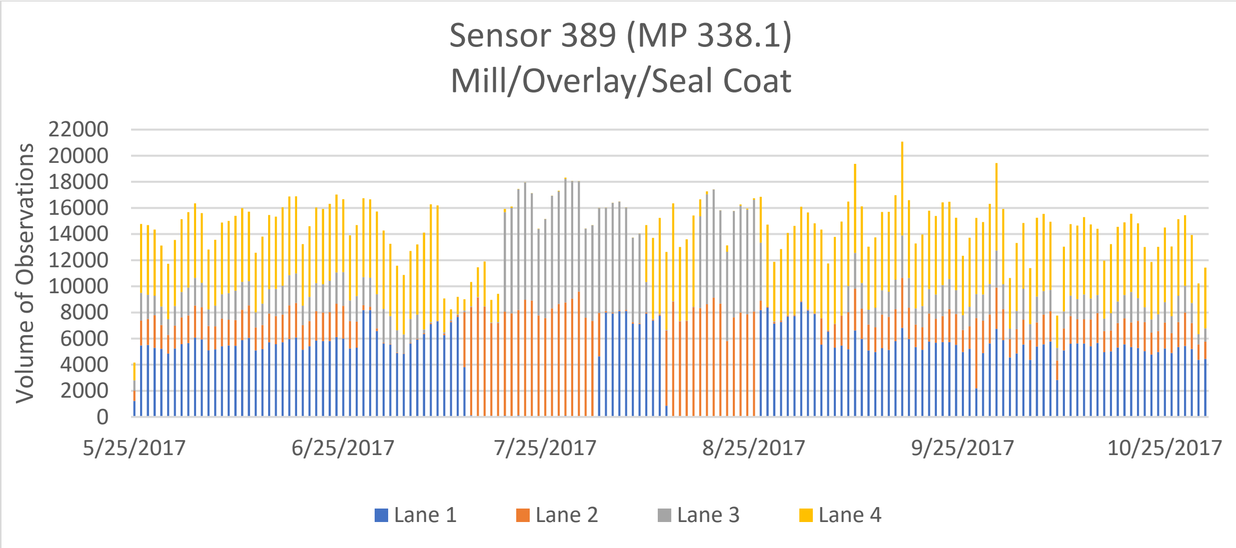


Figure H-2. Sensor 389 Work Zone Speed Analysis (Source: WYDOT).

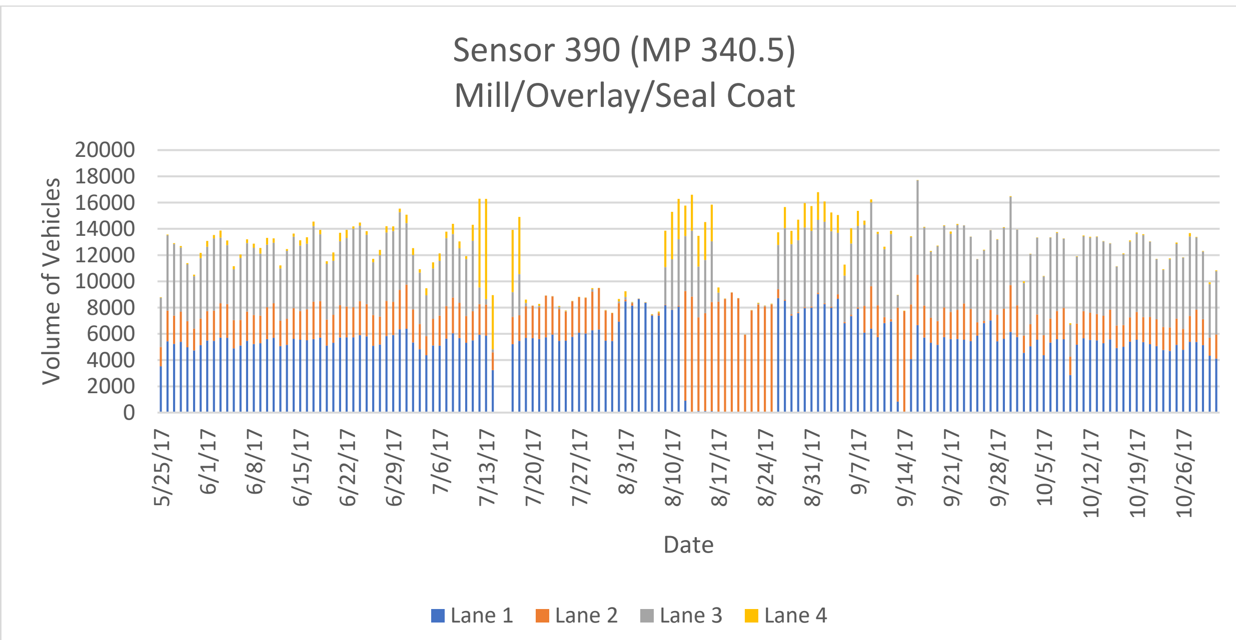


Figure H-3. Sensor 390 Work Zone Speed Analysis (Source: WYDOT).

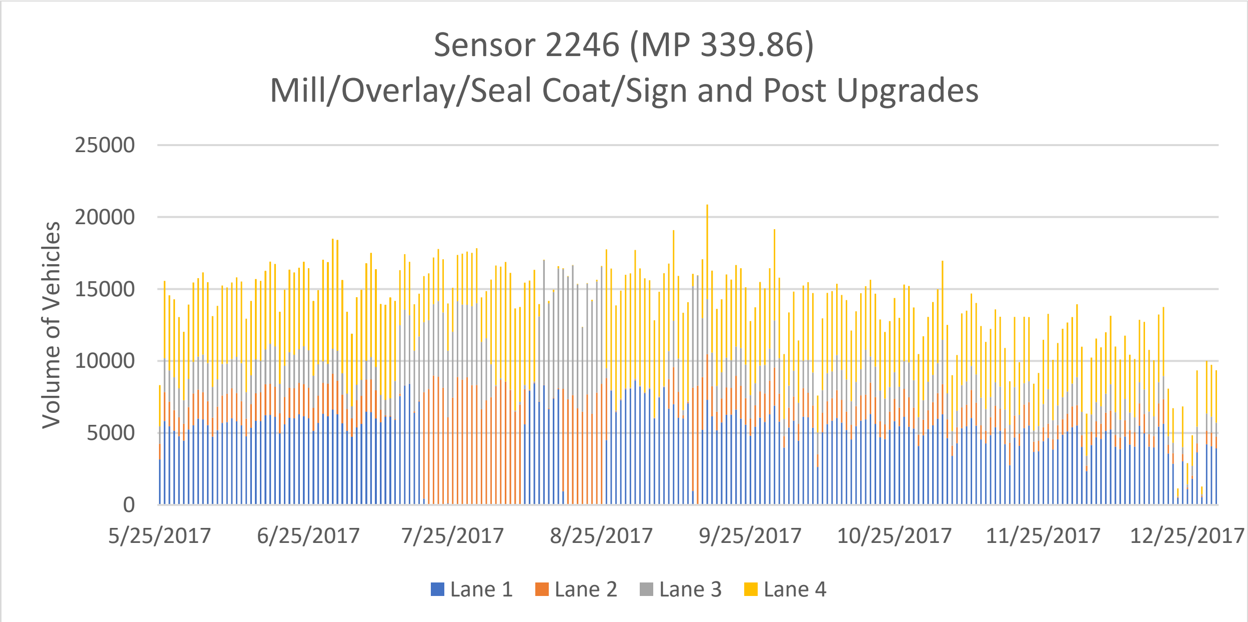


Figure H-4. Sensor 2246 Work Zone Speed Analysis (Source: WYDOT).

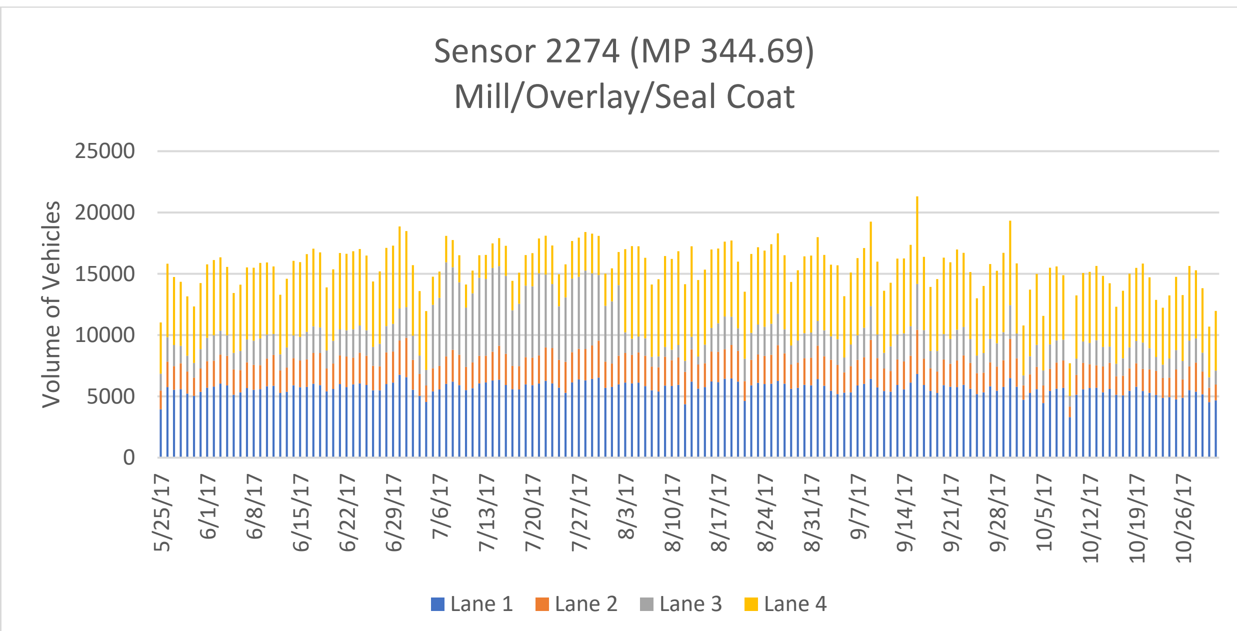


Figure H-5. Sensor 2274 Work Zone Speed Analysis (Source: WYDOT).

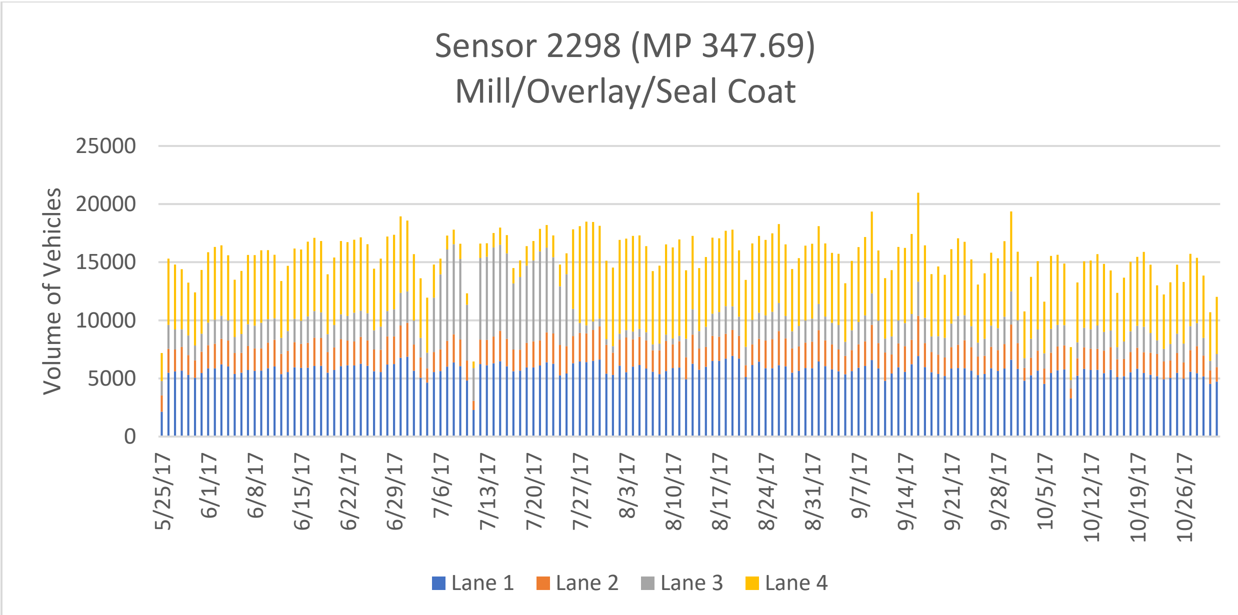


Figure H-6. Sensor 2298 Work Zone Speed Analysis (Source: WYDOT).

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