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MAINTENANCE PROGRAM DECISION-MAKING UTILIZING CRASH DATA

Prepared For:

Utah Department of Transportation
Research Division

Submitted By:

University of Utah
Department of Civil & Environmental Engineering

Authored By:

Douglas I. Anderson, P.E.
Jonathan Wood
Richard J. Porter, Ph.D., P.E.

Final Report
August 2013

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This document describes methods that may be used by UDOT Maintenance personnel to improve highway safety. Four programs have been recommended using crash data to make more informed decisions concerning maintenance programs as follows:
• Snow & Ice Crash Cluster Reduction Program
• Wild Animal Fence Evaluation Program
• Low Skid Number Correction Program
• Semi-Annual Inspection Crash Data Program
These programs require no new data and need very limited resources to deliver valuable information to UDOT Maintenance managers and stakeholders. The deliverables from these programs result from enhanced analysis methods and better coordination between division and region personnel.</td></tr>
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EXECUTIVE SUMMARY

Highway maintenance activities have a direct impact on the safety of the traveling public. The Utah Department of Transportation has an excellent history of addressing deficiencies in the highway system that may reduce transportation safety.

This report outlines four programs developed for use by maintenance managers. The main goal of these programs is to enhance the decision-making related to snow removal, wild animal fence management, slippery pavement correction, and other activities.

Snow & Ice Crash Cluster Reduction Program: Crash records are analyzed to identify where a higher than expected number of snow and ice related crashes are reported. The goal of this program is to aid maintenance personnel in fine-tuning snow removal plans in some areas to reduce or eliminate these crashes.

Wild Animal Fence Evaluation Program: Each section of highway that has wild animal fencing is reviewed for animal related crashes. These sections are evaluated for their effectiveness based on the number and severity of the crashes observed. Specific sites are identified that may need fence repair, fence expansion, or installation of animal escape ramps.

Low Skid Number Correction Program: UDOT identifies areas with low skid numbers using a Locked-Wheel Trailer. An aggressive program has been outlined to address these sites in a timely manner. Criteria have been infused into the process that aids in selecting the optimal approach to each deficient section. A "Skid Correction User's Manual" has been published for adoption by UDOT.

Semi-Annual Inspection Crash Analysis Program: Every six months UDOT personnel inspect each section of highway to identify needs and establish correction activities. This is an ideal time to review the safety aspects of these highway sections. Information in the form of tables, maps, and bar charts identifying problem areas are distributed for use by the team at each semi-annual inspection.

These programs are discussed in detail in this final report. Provided are data needs, analysis methods, strategy selection, the key stakeholders, program deliverables, legal considerations, and feedback processes for each program.

Methods recommended to aid in the implementation of these programs are presented. Templates and examples are included to aid in the use of the uPlan system to deliver the products of each program. Estimates of the resources needed for each program including manpower and budgets are provided. The resource needs are minimal. The budgets range from $3,000 to $20,000 to perform the program activities and management.

1.0 INTRODUCTION

Highway maintenance operations have a profound impact on safety. Programs that can reduce accidents are snow removal, slippery surface restoration, pot-hole repair, edge drop-off renovation, rut depth repair, deer fence placement and mending, right-of-way fence maintenance, placement of pavement markings, delineator replacement, jersey barrier maintenance, tree trimming, weed mowing, glare screen issues, work zone safety measures, and many others. Crash data feedback to these programs can be very useful in planning and fine-tuning these operations. Specific crash types and causes lead to the need for improvements or modifications to the operations listed above, including snow and ice related crashes, wet weather crashes, deer hits, domestic animal hits, obscured vision related, and work zone related crashes. This project outlines four programs aimed at utilizing selected crash data to make improvements or adjustments in these maintenance activities.

The occurrence of crash clusters (or lack of accidents) can be used to expand, eliminate, or modify activities within the various operations program. Crash data can be very useful at Semi-Annual Inspections and during the planning phase of various maintenance activities. This is where many decisions are made concerning the allocation of funding, and establishing tasks to be carried out in the field. Working closely with the experts managing these programs will be crucial. Strategies will be selected and the results observed over time. If unsuccessful a new approach can be implemented to address each problem area. This course of action has been shown to be effective in the past.

Setting a priority for each action is required. There is not enough available funding to address all of the identified deficiencies on our highway system. Lists in order of importance of the needed improvements are useful from a planning standpoint, and can be used to minimize UDOT's liability from lawsuits pursued by those involved in crashes. Constructive notice of a deficiency is used in lawsuits against the Department. They contend that information was available to show that corrective action was needed on a section of highway even if maintenance forces did not have first-hand knowledge of the problem. Priority lists can be used to indicate that UDOT forces have made appropriate decisions concerning highway sections. Properly expending the available funding in the best locations for the highway system to function safely and efficiently is vital.

UDOT has fostered many excellent initiatives to improve highway safety for the traveling public in Utah. Safety is one of the four main goals of the department, and significant resources are dedicated to this endeavor. Hopefully UDOT managers will embrace the programs proposed in this report as the next step in this endeavor.

1.1 Objectives

1. Enhance the effectiveness of maintenance programs by incorporating crash data into the decision-making process.
2. Provide information to maintenance personnel for use at Semi-Annual Inspections.
3. Improve the selection of strategies, location, timing, and feedback mechanisms for maintenance programs and activities.

1.2 Tasks

1. Form a Technical Advisory Committee (TAC) with operations and maintenance experts from each region and the complex to provide input and oversight to the program.
2. Develop a list of focus areas within the operations function that may be enhanced through crash data analysis.
3. Gather the needed data and perform cluster analysis to identify each area of concern for each focus area.
4. Compile the data into useable reports, tables, and maps to enhance decision-making.
5. Prepare priority lists for corrective actions on highway sections to aid in programming limited available funds, and to minimize liability to the Department.
6. Develop a report for use at Semi-Annual Inspections to review the crashes occurring on each section of highway. The lack of significant crashes can indicate that no action is needed and funding can be programmed elsewhere.
7. Confer with experts from the Regions and Complex to propose the most effective strategy to eliminate or reduce the crashes occurring in the area. Some activities may be reduced or eliminated freeing resources for use where the needs are greater.

8. Develop feedback mechanisms to efficiently evaluate the effectiveness of implemented strategies within the programs.

9. Establish programs and processes to conduct these activities in the future.

10. Aid in the implementation of the recommendations as needed

1.3 Programs Recommended for Implementation

Four programs are recommended using crash data to make more informed decisions concerning maintenance programs as follows:

- Snow & Ice Crash Cluster Reduction Program
- Wild Animal Fence Evaluation Program
- Low Skid Number Correction Program
- Semi-Annual Inspection Crash Analysis Program

These programs are discussed in detail in the report providing data needs, analysis methods, the key stakeholders, program deliverables, and feedback processes.

1.4 Deliverables

1. This Final Report has been prepared to document the processes and polices needed for each program. All tasks, data gathered, proposed strategies, and feedback processes are discussed.

2. A user's manual has been published to aid in the delivery and management of the Low Skid Number Correction Program.

3. Key data, a priority for each recommended action, and all charts and maps are available.

4. A presentation has been drafted for use in the implementation phase of the four programs.

5. Four templates were prepared for use in entering information into the uPlan system related to each program. These templates are included in Appendix A.

6. Useful information developed during the project was entered into uPlan for use by UDOT experts and managers.

1.5 Program Cost Issues

The budget limitations facing the Utah Department of Transportation have forced managers to make hard decisions concerning which activities to fund. The programs developed in this project were intentionally designed with very low budgetary requirements. This was accomplished in three ways:

The four programs recommended require no new data but utilize information from various divisions to make more informed decisions. The lack of the need for new data keeps program costs low.

The programs require very limited manpower to deliver valuable information to UDOT maintenance managers and stakeholders. The deliverables from these programs result from improved analysis methods and better coordination between the divisions and region personnel. The low manpower needs allows UDOT to implement and operate these programs with little expenditure of resources.

The needed actions resulting from the enhanced decision-making process are typically within the normal activities of the maintenance forces. Improvements or adjustments are made by focusing on high level needs, changing schedules to improve outcomes, or even to postpone certain activities that appear to be less pressing.

Estimates of the costs in terms of staff hours per year are provided in the following sections. An overview of the divisions, sections, and region personnel are included.

2.0 SNOW & ICE CRASH CLUSTER REDUCTION PROGRAM

Snow and ice related crash data can be used as very useful information when planning snow removal plans. Clusters of crashes occurring on snow packed or icy pavements may be reduced by making improvements in snow removal strategies.

Obviously the number and severity of crashes occurring on snow packed and icy road surfaces are a function of many factors. A few of the more important aspects that must be considered are:

- Storm intensity and duration
- Timing of the storm with high traffic hours
- Pavement and air temperatures
- Storms occurring during “no services” times and routes
- Knowledge of maintenance forces in terms of plowing, deicing, anti-icing, and storm forecasting
- Resources expended such as number of truck passes, person-hours, materials, etc.

Site-specific factors may contribute to the snow and ice related crashes such as:

- Geometric issues such as steep grades, curves, intersections, narrow shoulders, etc
- Congested areas
- Sections with traffic conflicts, such as driveways or turning movements
- Traffic generators with special issues such as schools, taverns, senior centers, events, etc
- Areas where drivers tend to travel faster than conditions would allow

It would be easy to conclude that snow and ice related crashes are not preventable, are related to poor driving, and should be accepted as inevitable. The Utah Department of Transportation should be commended for their “proactive” approach to this issue. UDOT has been one of the lead states in using innovative methods such as Road Weather Information Systems (RWIS), advanced forecasting and now-casting programs, improved plow blades, and anti-icing processes. These methods along with traditional techniques such as snow fence and station staff experience have served the state well over the years.

The effectiveness of these methods and programs can be further enhanced by adopting a "reactive" approach aimed at addressing snow and ice related crash clusters. By understanding where the clusters are and what types of crashes are occurring, UDOT managers can use methods available to them to reduce the numbers and severity of the crashes at these sites.

2.1 Data Needs and Process

The information needed to make this program effective is a meticulously constructed list of sites where snow and ice related crashes are determined to be higher than would be expected. Every cluster of snow and ice related crashes are not necessarily an indication of an abnormally high number. Expertise is needed to analyze each site to make recommendations concerning the significance of the crashes observed.

The steps listed in Table 2.1 are recommended to gather useful information about snow and ice related crash clusters. This information can then be used in preparing or modifying snow removal plans in the UDOT regions. The analysis of the data in many of these steps will require assistance from experts in the Division of Traffic & Safety.

The Colorado DOT uses a Level of Service of Safety (LOSS) to analyze road segments in determining locations that could benefit from safety improvements, suggested by Kononov & Allery [1]. To determine these locations, negative binomial regression is used to analyze the crash frequency of the road segments. Once the regression is performed, the resulting predicted crash counts and standard deviations can be calculated. Locations with crash counts greater than one and a half standard deviations above the mean are likely candidates for safety improvements.

This type of analysis has been done for freeway and non-freeway road segments in Utah using snow and ice crashes shown in Figures 2.1A-D from the years 2006-2008. The regression results and graphs showing crash counts on the segments as well as the mean and mean plus one and a half standard deviations have been constructed.

The statistical information related to this analysis is provided in Appendix B. Bar charts indicating the location of these snow and ice clusters are also included in Appendix B. Tables B1-4 provide a list of the locations with high potential for benefits from safety improvements.

These tables have been constructed listing the route, starting and ending mileposts, crash counts, predicted mean, standard deviation, and mean plus one and a half standard deviation. Locations that fell into this category but had a crash count of 3 or less were not included due to the low number of crash observations.

Also needed are plots of cumulative crash counts (snow and ice) verses milepost for the identified road segments. These plots can be used to help determine contributing factors for snow and ice crashes on the segment. If there is a cluster of crashes at a certain location, it could be due to a horizontal curve, intersection, steep grade, bridge, etc. If the crash count is high but spread out (lack of clusters), then it may be considered for more frequent plowing and application of sand/salt. Drainage issues can also contribute to snow and ice crashes. The plots should be used by the Maintenance Division to identify any possible issues and then determine what countermeasures to apply.

Table 2.1- Snow & Ice Cluster Reduction Program Steps

Program Steps	Person-Hours
1. Prepare a complete file of snow and ice related crashes by milepost	3 hrs
2. Conduct a regression analysis to determine which sections exceed a 1.5 standard deviation from the population	1 hr
3. Prepare bar charts for these sections showing how it compares to the nearby sections	10 hrs
4. For the high crash areas prepare bar charts on a 0.1 mile interval	5 hrs
5. Compile information on the severity of these crashes	4 hrs
6. Gather any additional information needed such as object struck, crash type, etc.	4 hrs
7. Conduct a site review by a team made up of the Region Operations Engineer, the Region Safety Coordinator, the Area Supervisor, and the Station Foreman	5 hrs
8. Select a strategy to make a change in the snow removal plan or continue to monitor the site in the future	2 hrs
9. Review feedback information in future years	5 hrs

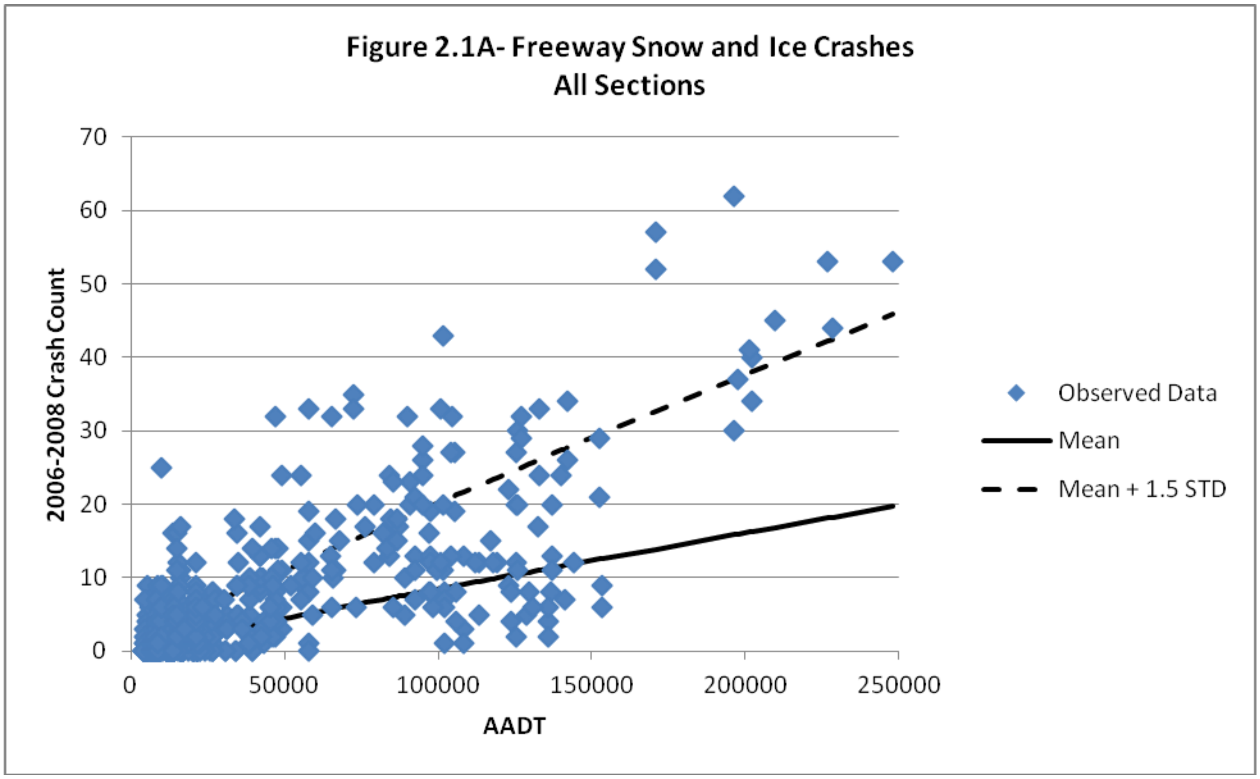


Figure 2.1A- Freeway Snow and Ice Crashes
All Sections
2006-2008 Crash Count
0
10
20
30
40
50
60
70
0
50000
100000
150000
200000
250000
AADT
Observed Data
Mean
Mean + 1.5 STD

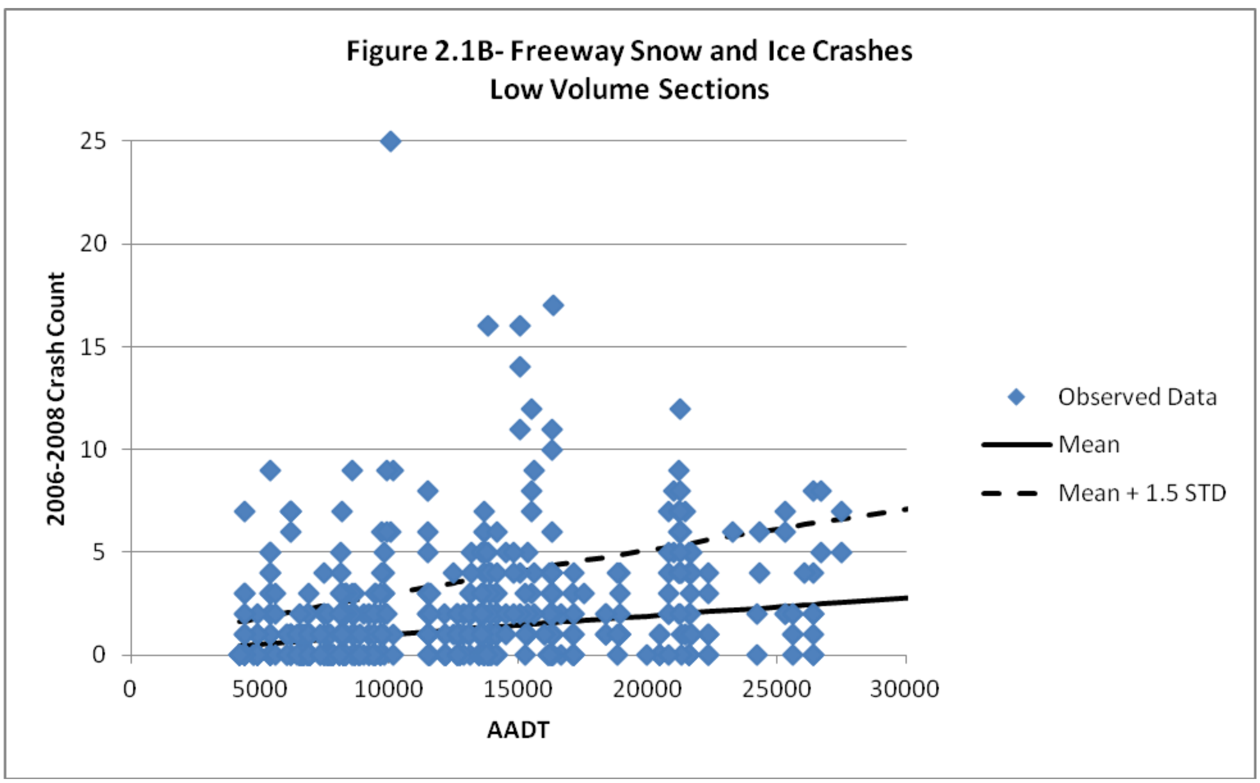
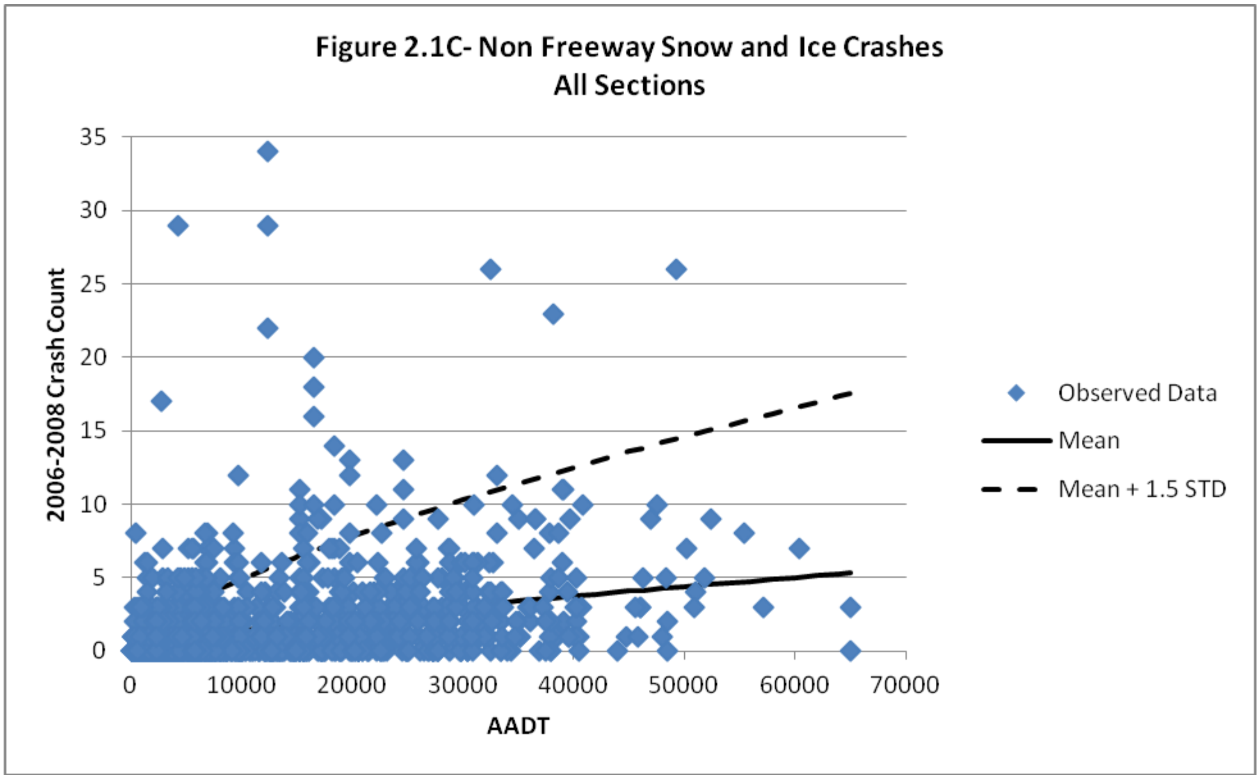
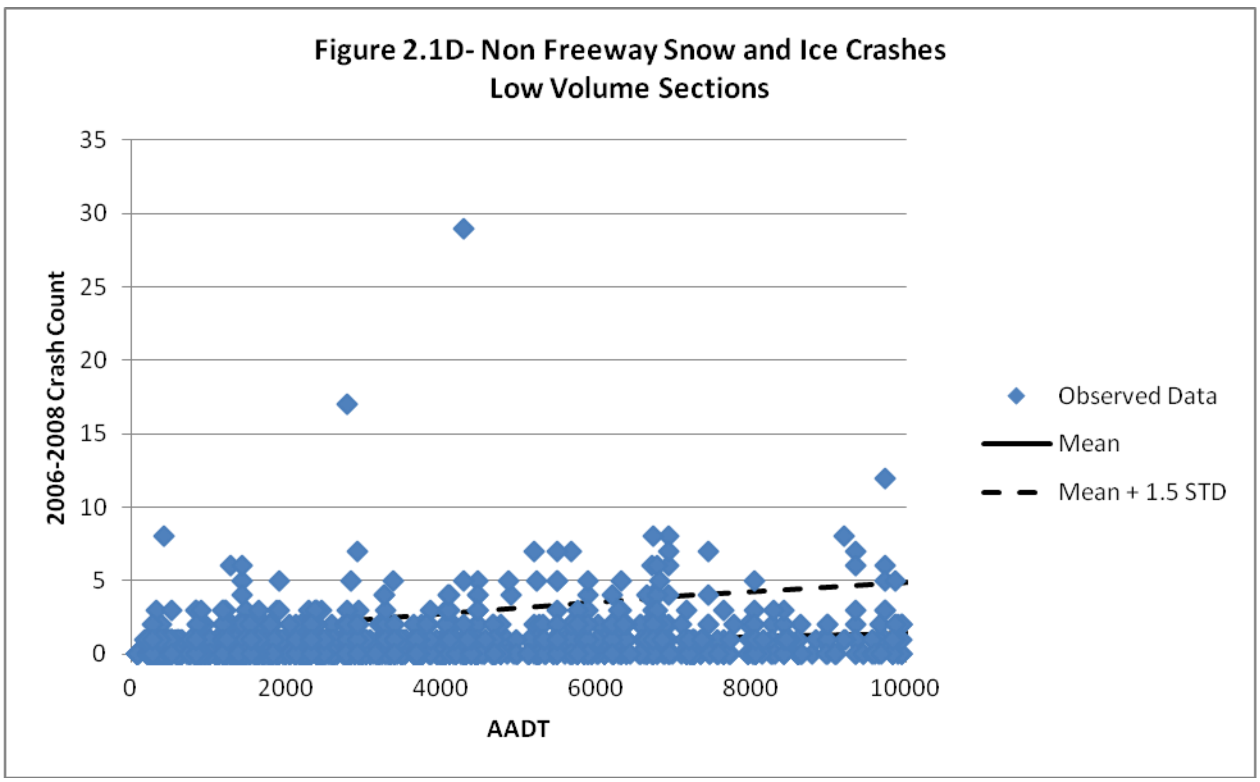


Figure 2.1B- Freeway Snow and Ice Crashes
Low Volume Sections
2006-2008 Crash Count
0
5
10
15
20
25
0
5000
10000
15000
20000
25000
30000
AADT
Observed Data
Mean
Mean + 1.5 STD





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This information is for demonstration purposes only since the data are from 2006 to 2008.

2.2 Deliverables of the Program

The information supplied to the end users of this program is basically related to the location and magnitude of the snow and ice related crash clusters. The decisions concerning the changes in the snow removal plans should be left to the experts and professionals who manage these activities. Awareness of the issue is the first crucial step in addressing the crash clusters.

Managers may choose to address these crash clusters using any or a combination of the following strategies:

- Increase the frequency of plow passes related to storm intensity
- Reduce the delay after storm onset
- Overlap the transition areas between station boundaries
- Improve forecasting and now-casting
- Expand RWIS information system
- Change the anti-icing or deicing materials used for the site conditions
- Modify the overall strategy used for the site conditions
- Make no changes but monitor more closely in the future

Using information at the location, such as crash types, severity, vehicle classes, highway geometrics, etc. can often indicate what strategies may be implemented to improve the winter safety aspects of the highway corridor. In some areas managers may choose to upgrade a site from a deicing strategy to an anti-icing plan to keep the pavement surface free of snow and ice during storms with low and moderate intensity. At other locations it may be appropriate to continue to monitor the snow and ice related crashes in an area to gain a better understanding of what improvements are needed.

In some extreme cases a site may be identified that is in need of more drastic actions or improvements. This could include actions such as geometric upgrades, wider shoulders, improved traffic control measures, or even more route closures over the winter months may be needed. Records indicate that for some locations and years the majority of snow and ice related crashes can occur during fewer than five large storms. For this reason it is crucial to plan and prepare for storms of significant intensity.

This program should identify specific strategies to reduce snow and ice crashes. This could be in the form of improved snow removal plans aimed at reducing the crash frequencies and severity.

A report should be prepared and maintained on an annual basis to document the information gathered and the steps taken to improve operations. This documentation should prove to be useful over time.

2.3 Stakeholders

Further analysis of the crash clusters should be made by an expert in the Central Traffic and Safety Division. This analysis should be based on the numbers, rates, severities, type of crashes, contributing circumstances, objects struck, roadway geometrics, and other factors.

Effective decisions related to snow removal programs will require input and oversight by the Area Supervisor, Station Foreman, Region Operations Engineer, and the Region Safety Coordinator.

2.4 Resource Needs

The fundamental aspect of this program is to identify the snow and ice related crash clusters across the state for analysis. This will require the time and expertise of a manager familiar with the UDOT crash data file and system. In addition each cluster identified will need to be included in the regression analysis described previously.

Table 2.1 provides an estimate of the manpower needed for each step in the process. A total of about 40 hours per year is required to complete the program tasks. This is approximately $3,000 to $5,000 per year to operate the program.

2.5 Legal Considerations

There have been few cases where UDOT has had to deal with legal issues due to crashes occurring due to inclement weather. However, it is advisable to keep records of analysis performed, steps taken, and the results of these strategies for use when needed. Specific strategies should be outlined designed to restore the section to a bare pavement in a reasonable time in compliance with state policies.

2.6 Program Implementation

The main goal of the snow and ice cluster reduction program should be to implement a strategy into the snow removal plan for each section to eliminate or reduce the observed cluster. This could be accomplished by including tasks into the performance plan of each of the program stakeholders.

The snow and ice related crash clusters could be identified each year using in-house personnel. This could also be accomplished by outsourcing the process to a university expert or to a knowledgeable consulting firm. The decisions related to selecting an appropriate strategy should be completed in-house with UDOT oversight.

UDOT management may choose to include a list of snow and ice cluster sites into the Highway Safety Improvement Program (HSIP) and Spot Safety Improvement Program (SSIP). Included on this list would be high priority clusters with a significant number and/or severity of crashes.

These programs are currently administered through Central Traffic & Safety Division by Scott Jones. Funding is available to the regions to address locations with a fatal and/or serious injury crash history. The HSIP and SSIP goals encourage close coordination with the regions to identify, analyze, prioritize, program and implement projects using these funds. Information on these programs is available in on-line manuals [2], [3].

2.7 Program Feedback

The most straight-forward way to provide feedback to this program is to evaluate the effectiveness of any changes in snow removal plans. Reductions in the number or severity of the snow and ice related crashes are the obvious goal, and should be monitored over time. Care should be taken to determine if changes in these statistics are related to the numbers, intensity and timing of the storms in subsequent years.

2.8 Examples-Snow & Ice Related Crash Clusters

Examples of the analysis methods that are required to identify the likely contributors to the snow and ice related crashes are shown in the following charts and discussion. This information is for demonstration purposes only since the snow and ice crash data are from 2006 to 2008.

Table 2.2
Snow & Ice Example Sections
With Snow & Ice Crash Numbers

Route	Beg MP	End MP	Site Description	Snow & Ice Related Crashes
I-84	107	108	I-84 East of Round Valley Int at Weber River Crossings	25
SR 89	406	407	State Route 89 at the I-84 Interchange	26
SR 154	8	10	Bangerter Hwy from 11400 South to South Jordan Pkwy	49 (25 ave)
SR 189	11	12	State Route 189 East of Rotary Park Near Provo River Scenic Dr	20
SR 189	12	15	State Route 189 Near Mountain Range Campground and SR 92 Intersection	84 (28 ave)
SR 190	5	7		49 (16 ave)

Table 2.3
Snow & Ice Example Sections
With Snow & Ice Accident Rates

Route	Beg MP	End MP	Snow & Ice Related Crashes	Average Annual Daily Traffic (AADT)	Modified Accident Rate*
I-84	107	108	25	10,100	2.3
SR 89	406	407	26	33,800	0.7
SR 154	8	10	49 (25 ave)	32,000	0.7
SR 189	11	12	20	11,900	1.5
SR 189	12	15	84 (28 ave)	9,600	2.7
SR 190	5	7	49 (16 ave)	27,500	0.8

*Rate based on snow and ice related crashes only.

AR* = (S&N crashes x 1,000,000)/(miles x AADT x 365 x 3 years)

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Interstate 84 MP 107 to 108

As shown in Figure 2.2A a cluster of snow and ice related crashes appears to be between mile posts 107 to 108 mile on I-84 near the Round Valley exit and two Weber River crossings. The areas on either side of this location show significantly fewer snow and ice related crashes.

To obtain a more informed view of these crashes the bar chart in Figure 2.2B was prepared showing the crashes on a 0.1 mile interval. The most pronounced clusters appears to be near mile post 107.5 and 107.9. The curves on ths section along with the river crossings may be conributing to the problem.

Figure 2.2C is included to obtain an indication of the severity of the accidents in this area. Three of the 25 crashes (12%) were injury accidents. High speeds on Interstate highways contribute to increases in severity.

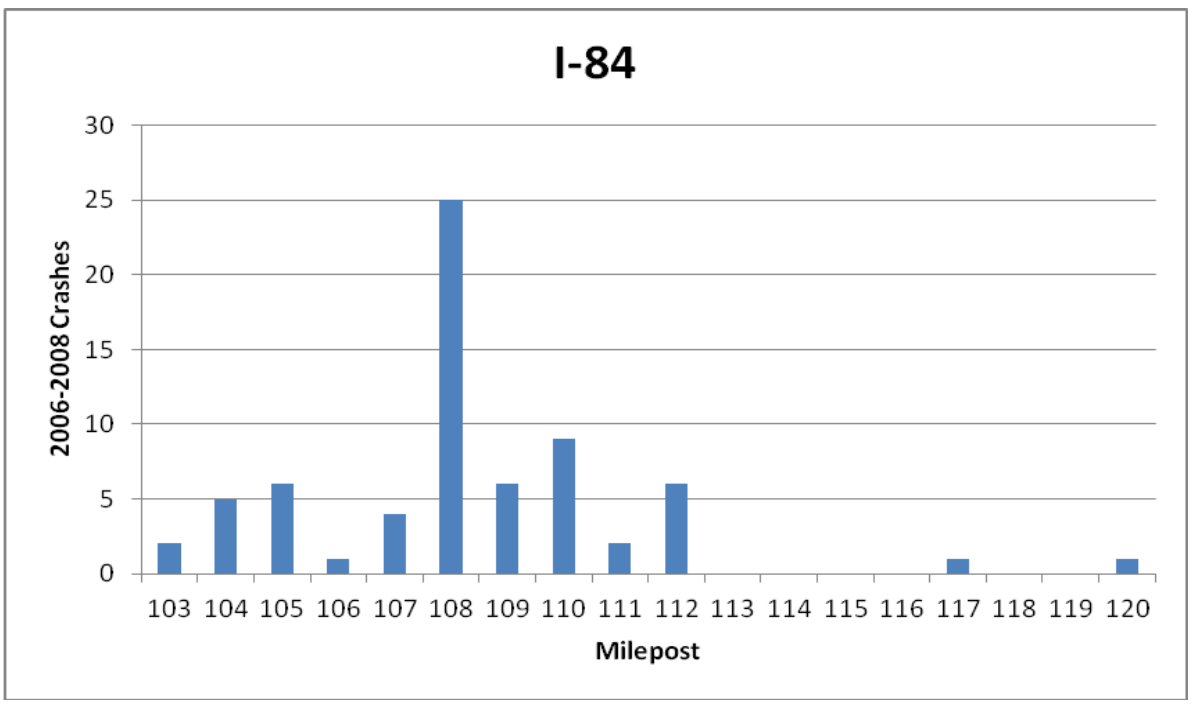


Figure 2.2A – I-84 Snow & Ice Related Crashes

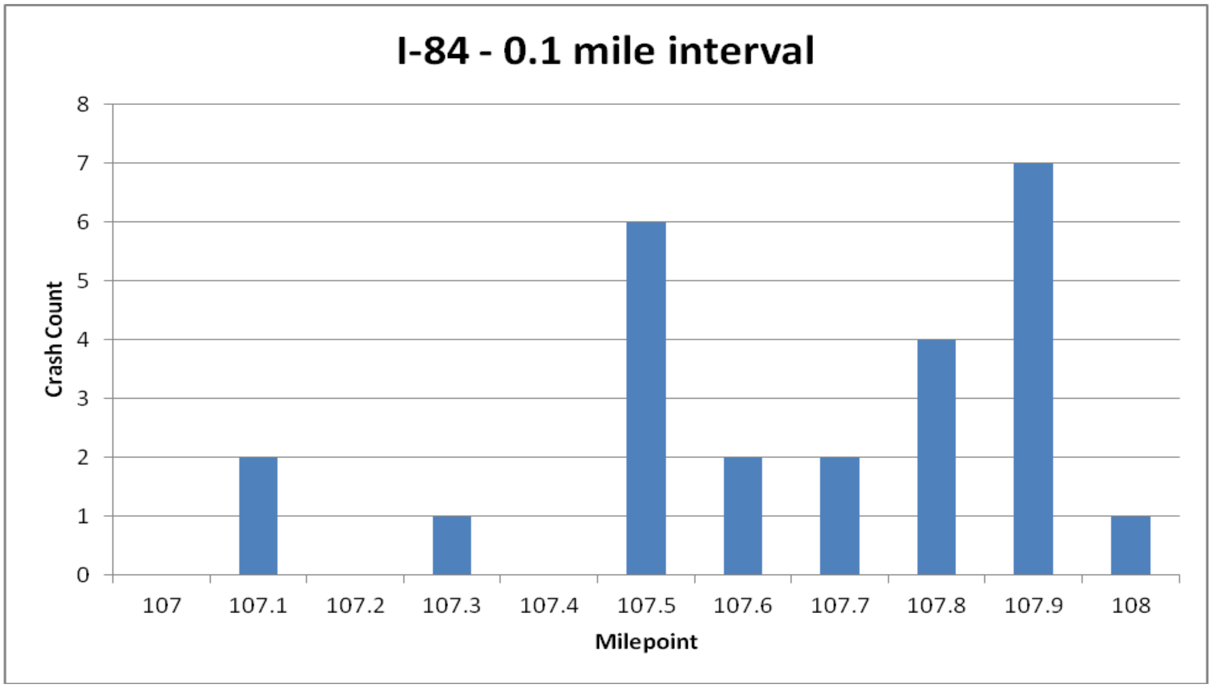


Figure 2.2B – I-84 Snow & Ice Related Crashes (0.1 mile interval)

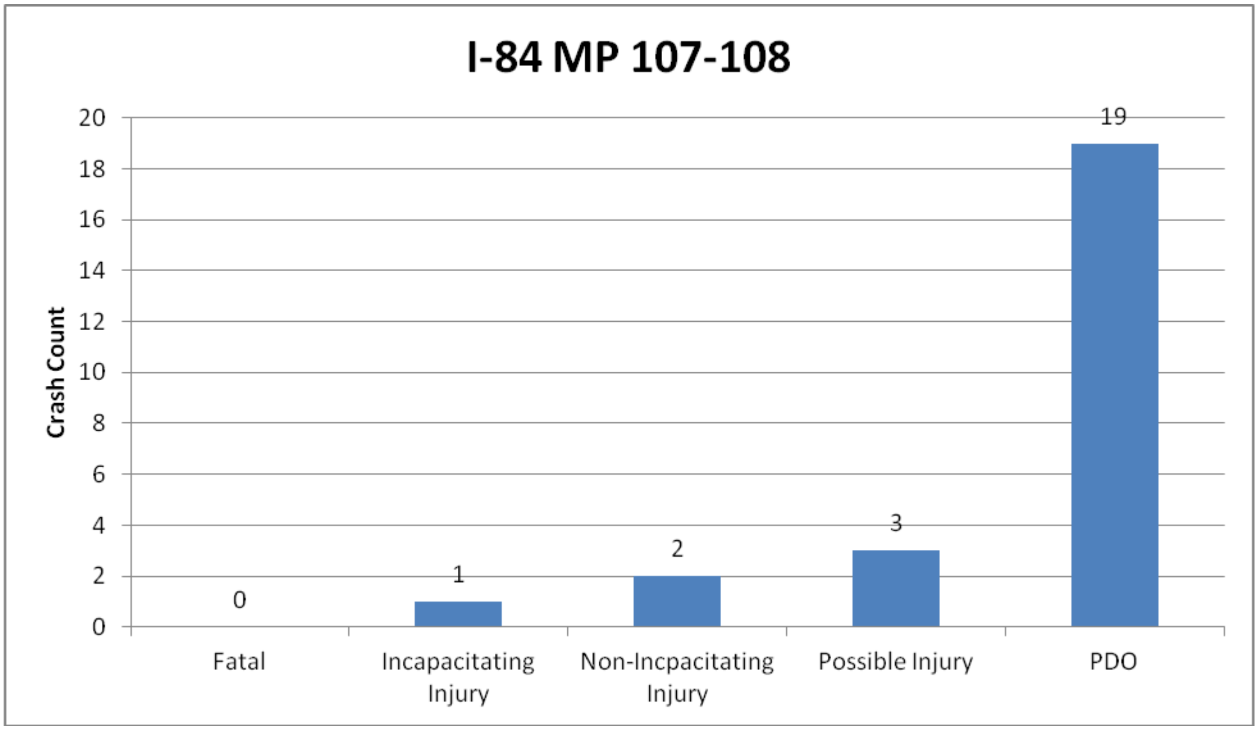


Figure 2.2C – I-84 Snow & Ice Related Crash Severity

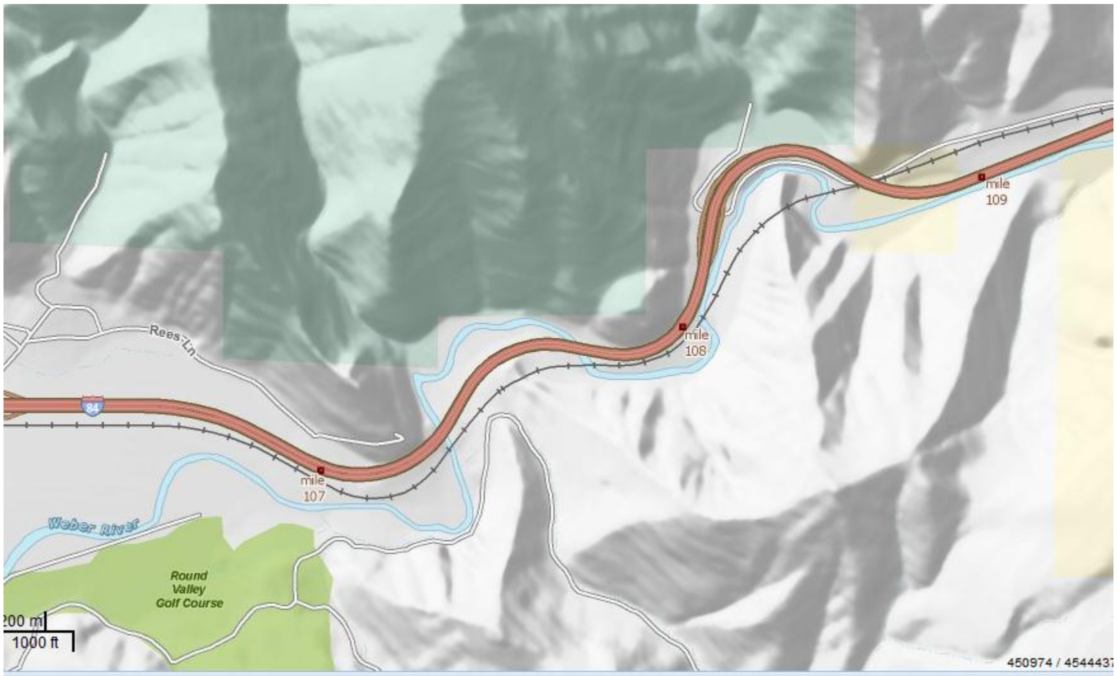


Figure 2.2D - I-84 near Round Valley

State Route 89 at the I-84 Interchange

A cluster of snow and ice related crashes were reported on State Route 89 near the I-84 Interchange over the three year period. From milepost 406 to 407 there were 27 crashes listed as seen in Figure 2.3A.

Figure 2.3B illustates the data using a 0.1 mile interval where it can be observed that the cluster was near milepost 406.2. Fortunately these crashes were not especially severe as seen in Figure 2.3C. Two (7%) of the crashes resulted in injuries. There were no fatalities.

A more detailed analysis will determine if certain ramps or conflict points are critical in the snow removal program. However, ramp related crashes are typically reported on the Interstate route not the surface street. The river crossing may be a contributor on this route as well.

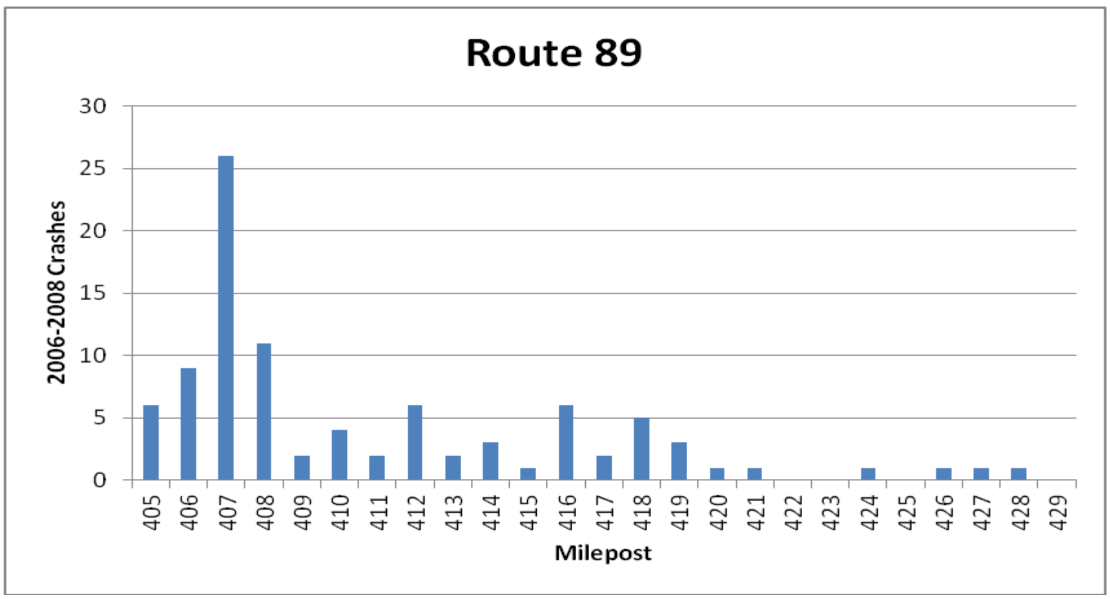


Figure 2.3A – SR 89 Snow & Ice Related Crashes

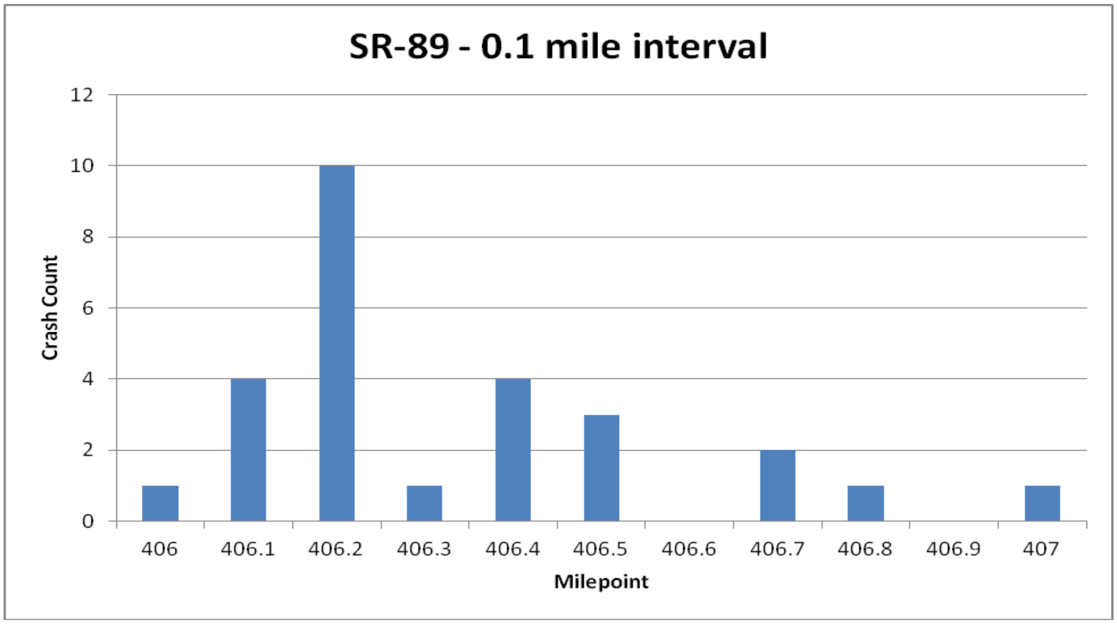


Figure 2.3B – SR 89 Snow & Ice Related Crashes (0.1 mile interval)

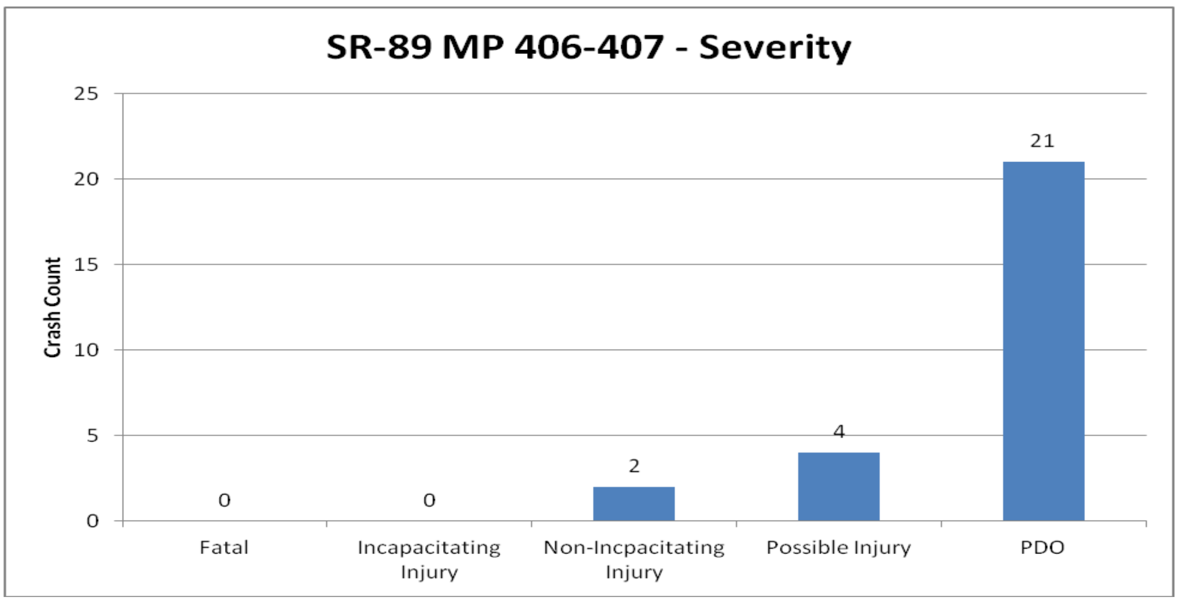


Figure 2.3C – SR 89 Snow & Ice Related Crash Severity

Figure 2.3D - SR 89 at I-84 Interchange

Bangerter Highway from 10400 South to 11400 South

The cluster of snow and ice related crashes from MP 8 to MP 10 on SR 154 are seen in Figure 2.4A. This stretch of Bangerter Highway is near the Day Break bench, has the two intersections, and has a curve along the corridor.

The 0.1 mile breakdown in Figure 2.4B indicates that the intersections at MP 8.2 and MP 9.6 have the most crashes as would be expected. Figure 2.4C shows that the severity of these crashes is low with only three of the 49 crashes (6%) showing injuries. There were no fatal accidents reported.

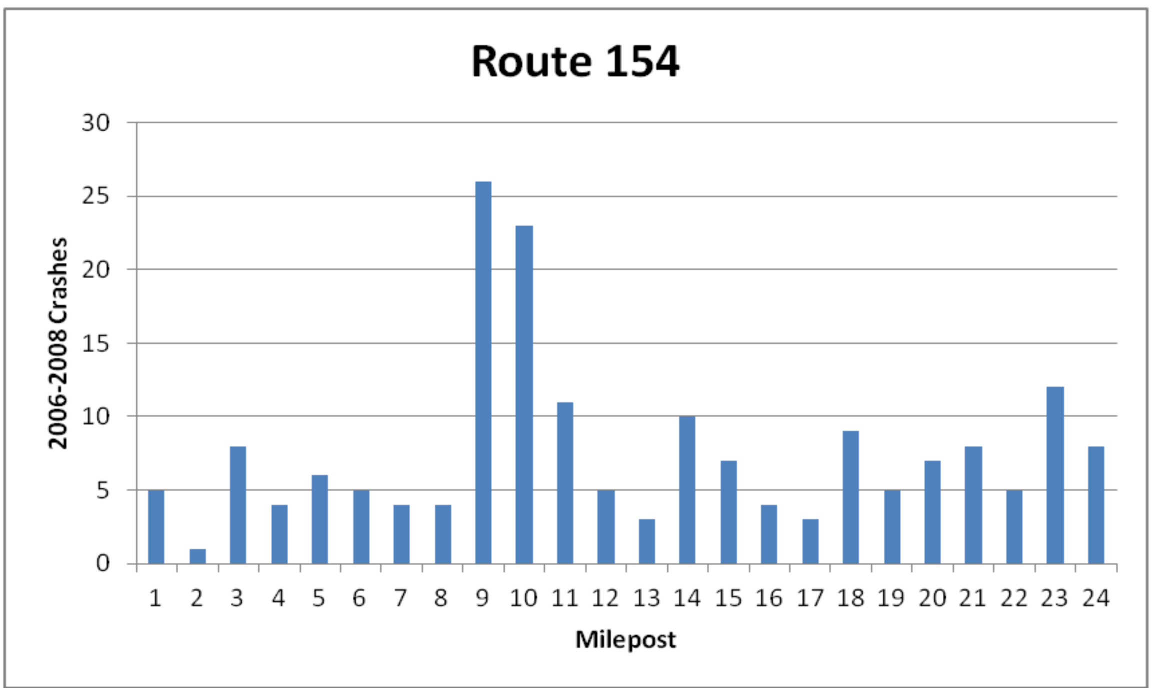


Figure 2.4A – SR 154 Snow & Ice Related Crashes

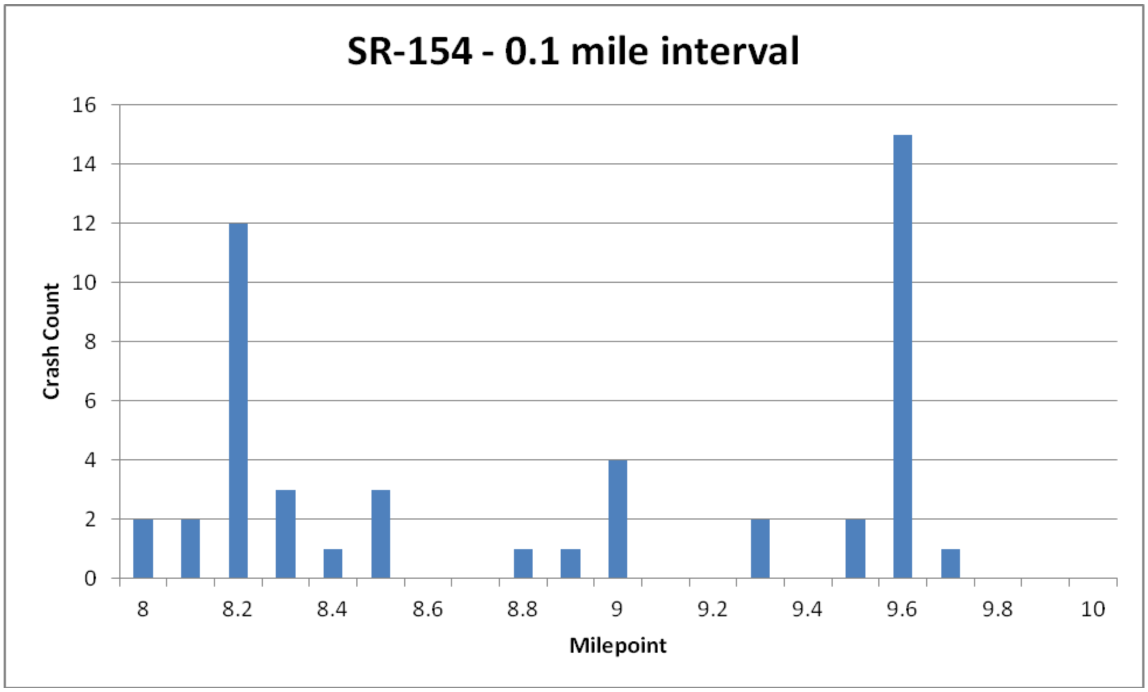


Figure 2.4B – SR 154 Snow & Ice Related (0.1 mile interval)

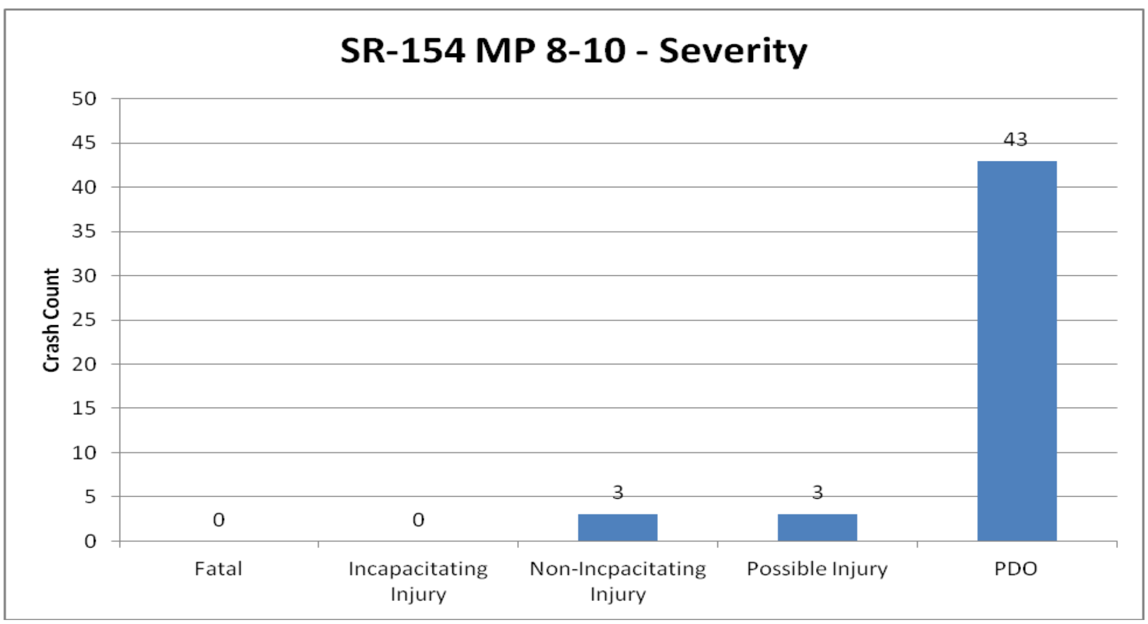


Figure 2.4C – SR 154 Snow & Ice Related Crash Severity

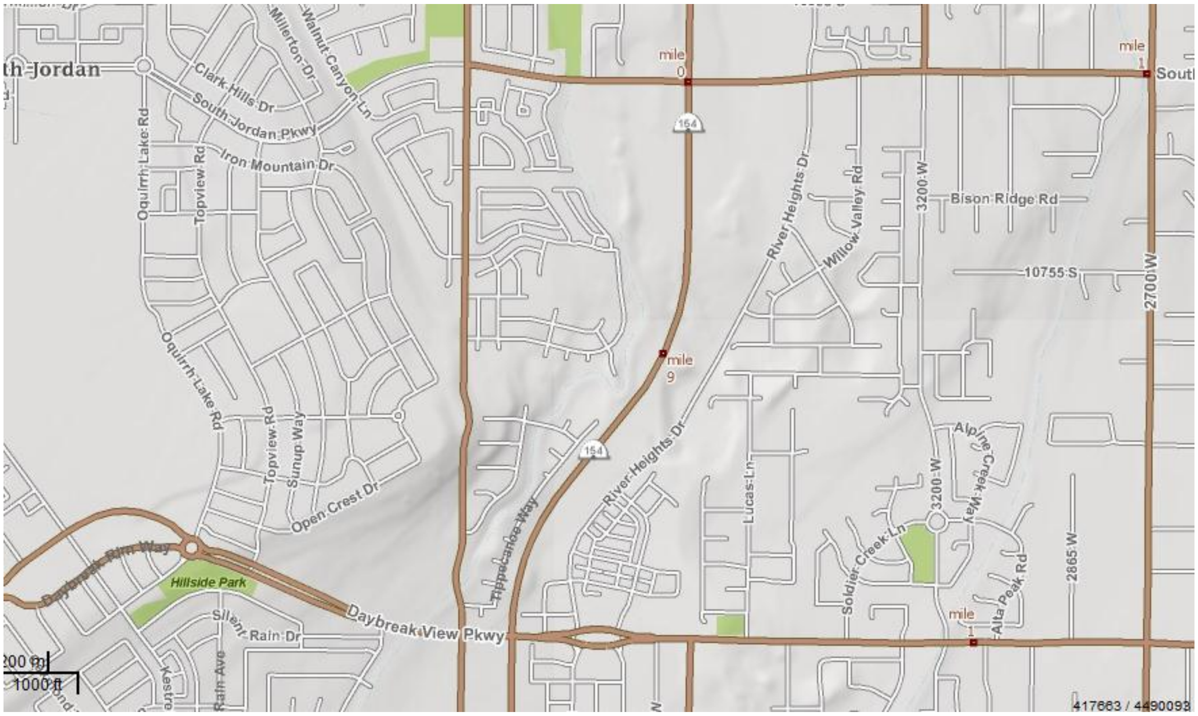


Figure 2.4D - SR 154, Bangerter Hwy from 10400 to 11400 South

State Route 189 in Provo Canyon

The snow and ice related crashes in this stretch of Provo Canyon appear to be significant as seen in Figure 2.5A. This is not surprising considering the terrain and altitude of the highway.

The cluster at MP 13.1 in Figure 2.5B is at the Mountain Range Campground intersection. Milepost 14.2 is at the intersection with State Route 92 toward the Sundance Ski Resort.

The severity of these crashes is mostly low, but there were four injury accidents and one fatality as seen in Figure 2.5C.

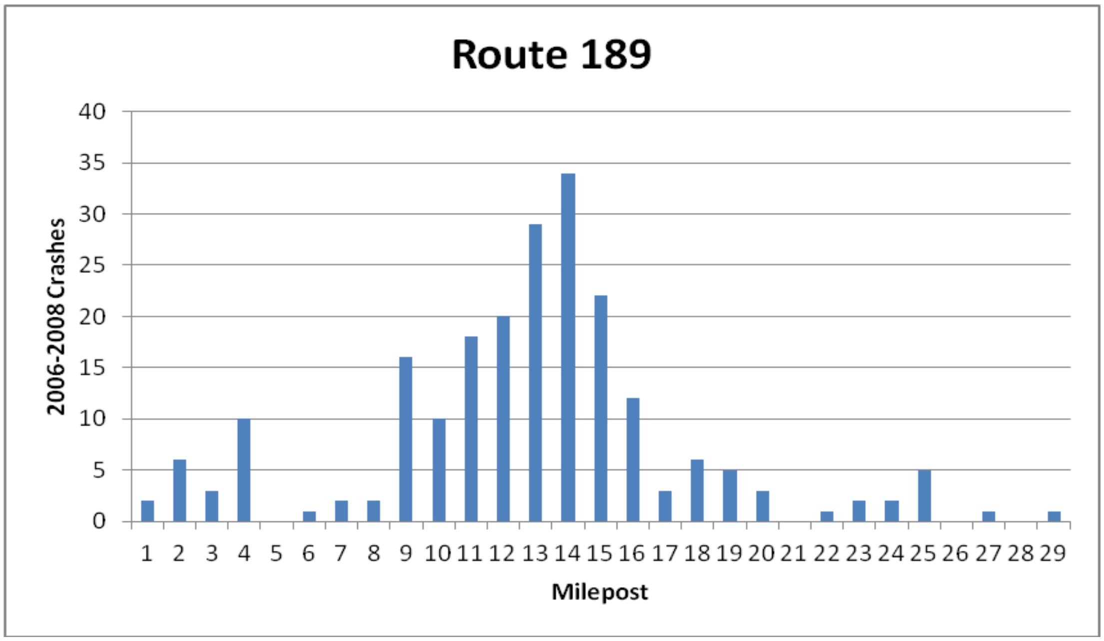


Figure 2.5A – SR 189 Snow & Ice Related Crashes

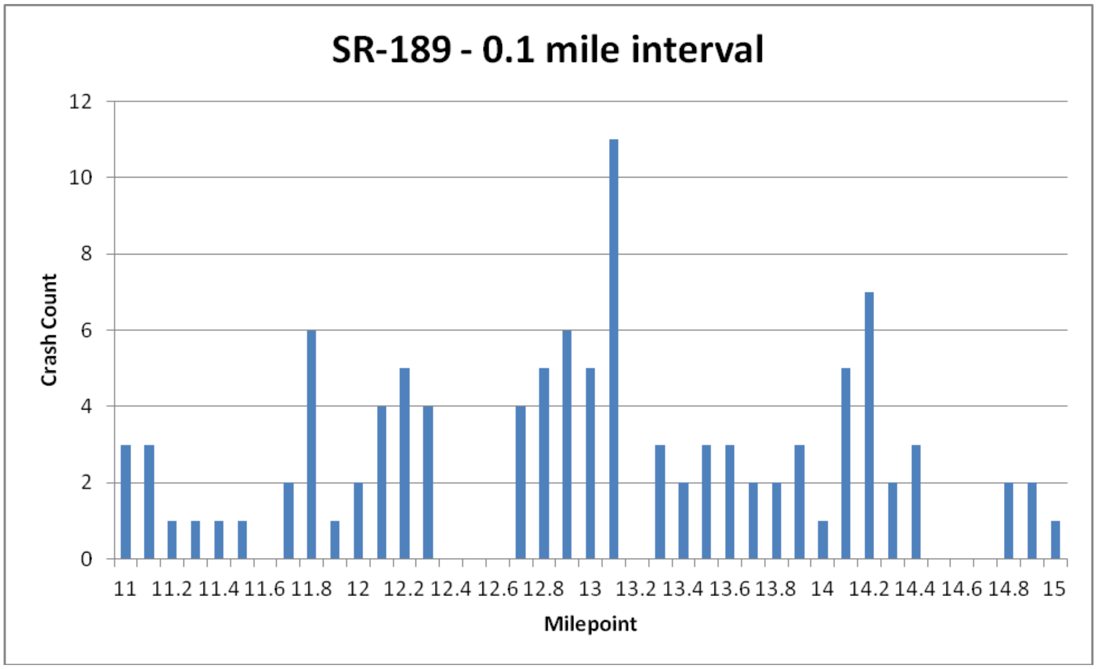


Figure 2.5B – SR 189 Snow & Ice Related (0.1 mile interval)

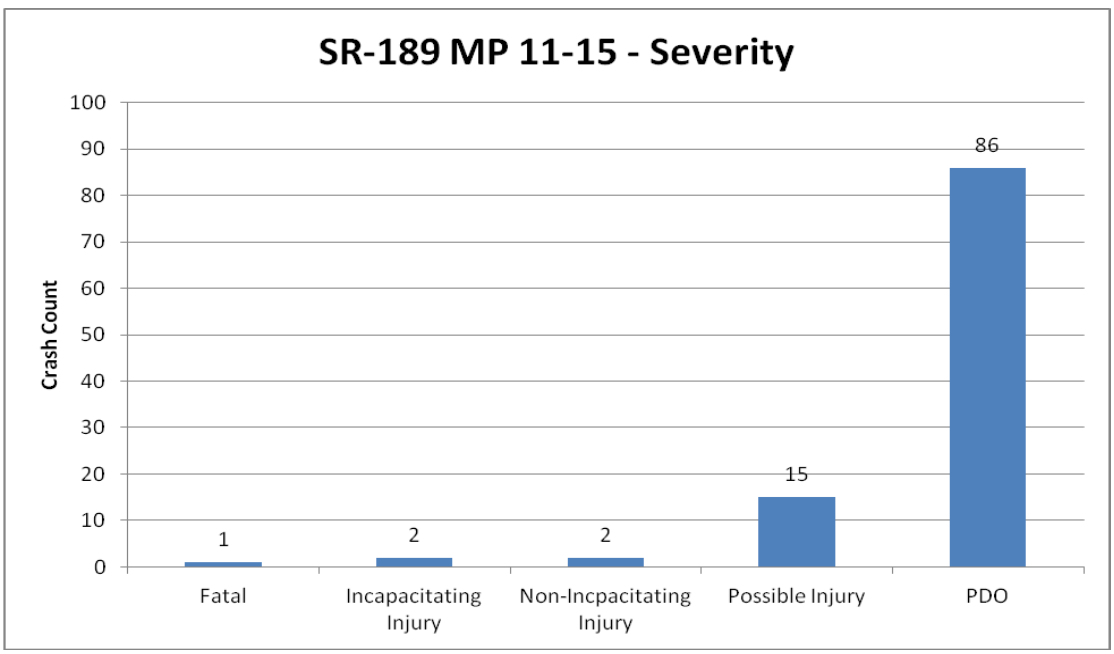


Figure 2.5C – SR 189 Snow & Ice Related Crash Severity

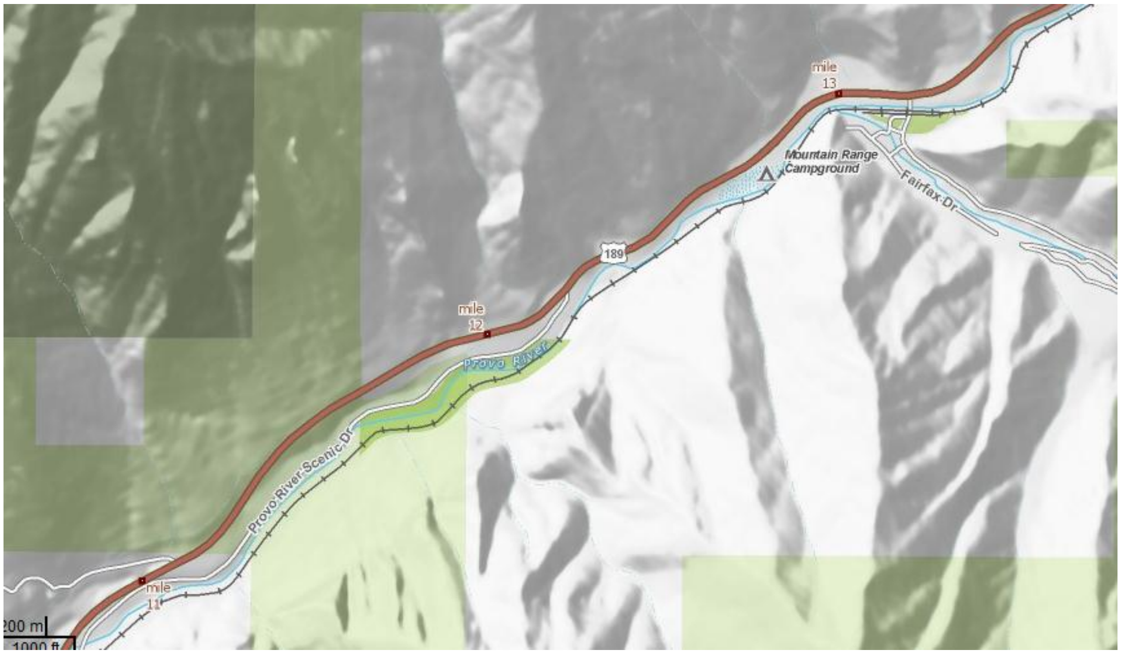


Figure 2.5 D - State Route 189 in Provo Canyon

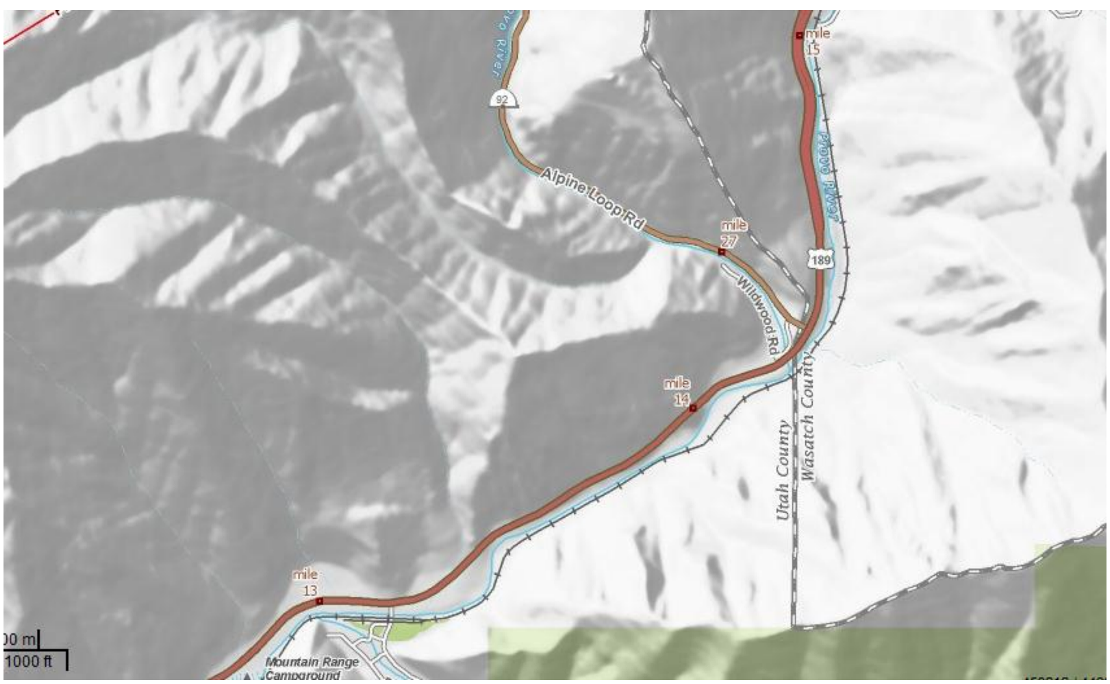


Figure 2.5E - State Route 189 in Provo Canyon

Figure 2.5F - SR189 in Provo Canyon

Big Cottonwood Canyon

Some areas on the Big Cottonwood Canyon road (SR190) have clusters of snow and ice related crashes as seen in Figure 2.6A. This is not unexpected considering the high winter traffic to the canyon ski resorts, and the altitude of the corridor. The section from MP 4 to 5 in Figure 2.6B near Storm Mountain has sharp curves and two river crossings. Further up canyon is a snow and ice related crash cluster at the "S" curve in Figure 2.5D near MP 6.3. This area also has very steep grades.

The severity of these crashes is significant as seen in Figures 2.6C and E. There were seven (24%) injury crashes from MP 4 to 5 during the three year period. From MP 6 to 7 there were two injury crashes (12%). No fatal crashes were reported when the surface was snow packed or icy.

The crew performing snow removal in this corridor has done an exceptional job in keeping the canyon safe using plowing, anti-icing, avalanche management, and canyon closures when needed. Variable message signs near the canyon entrance and web delivered information have kept the public informed about surface conditions and any travel restrictions in the canyon.

A high level of improvement to the canyon highway would likely be required to achieve a significant reduction in these crashes. Most options remain cost-prohibitive but any new technologies that are identified should be considered.

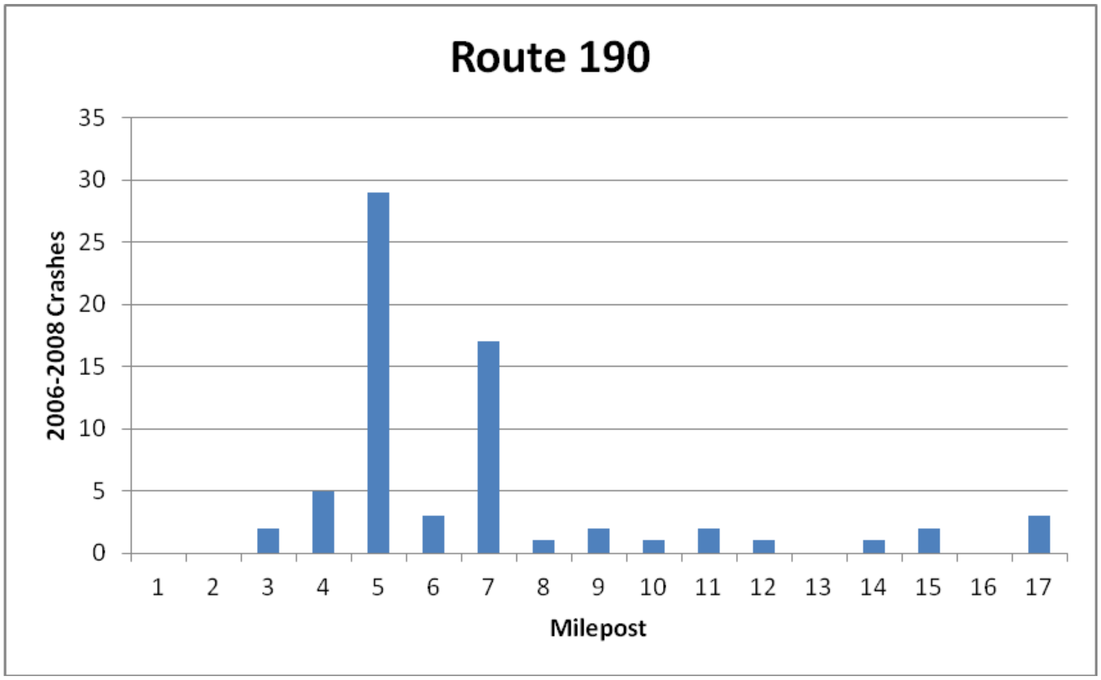


Figure 2.6A- SR 190 Snow & Ice Related Crashes

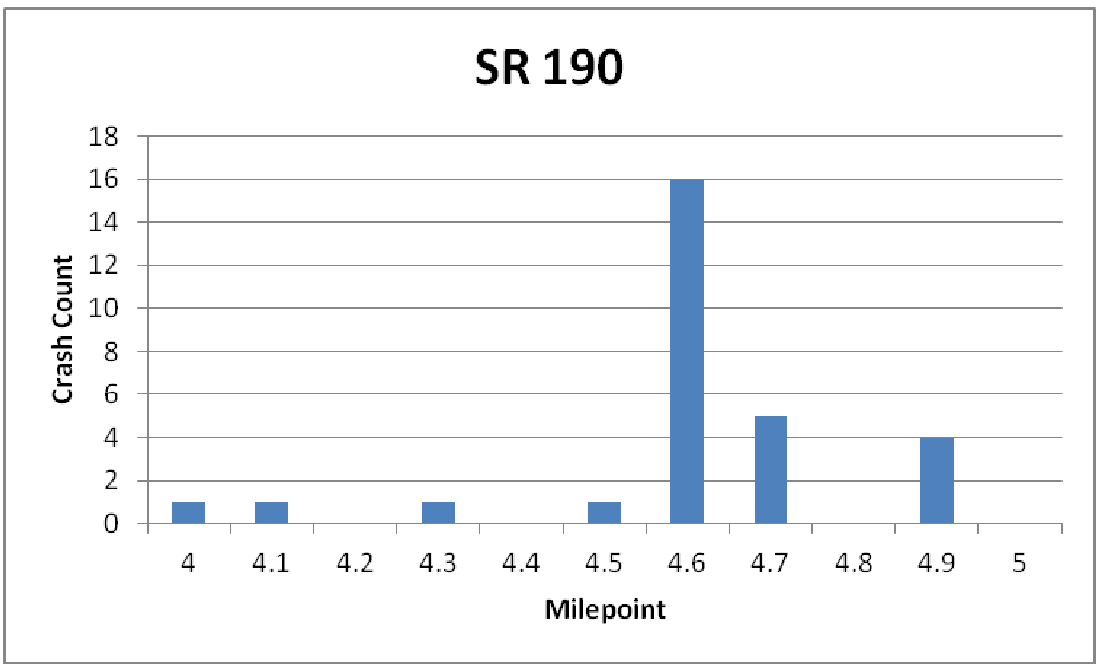


Figure 2.6B – SR 190 Snow& Ice Related (0.1 mile interval)

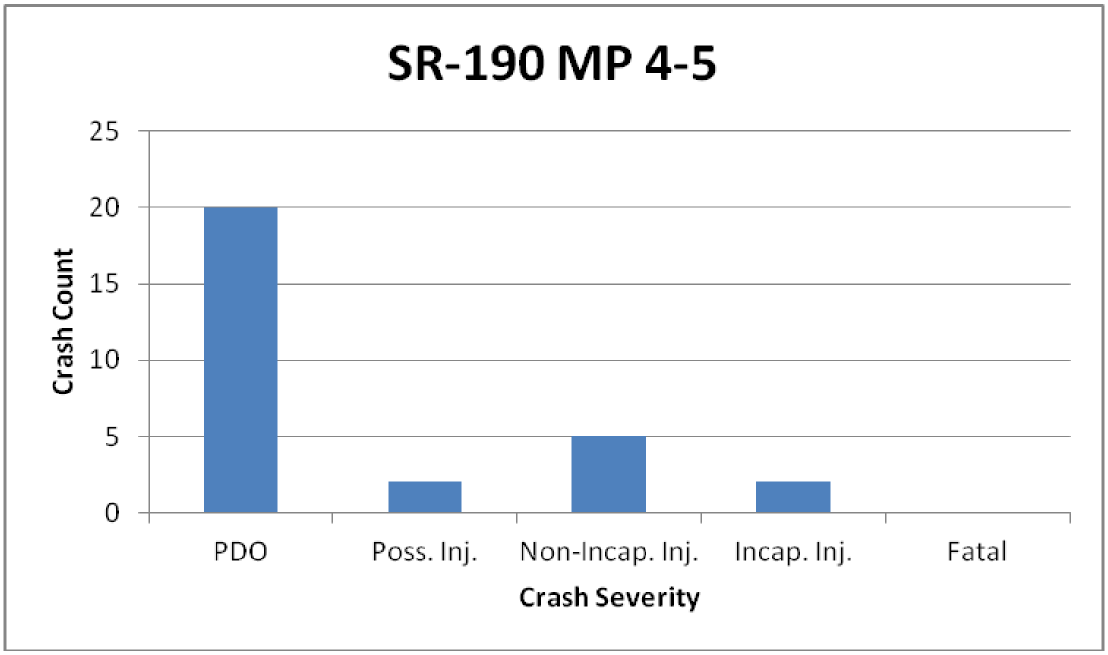


Figure 2.6C- SR 190 Snow & Ice Related Severity

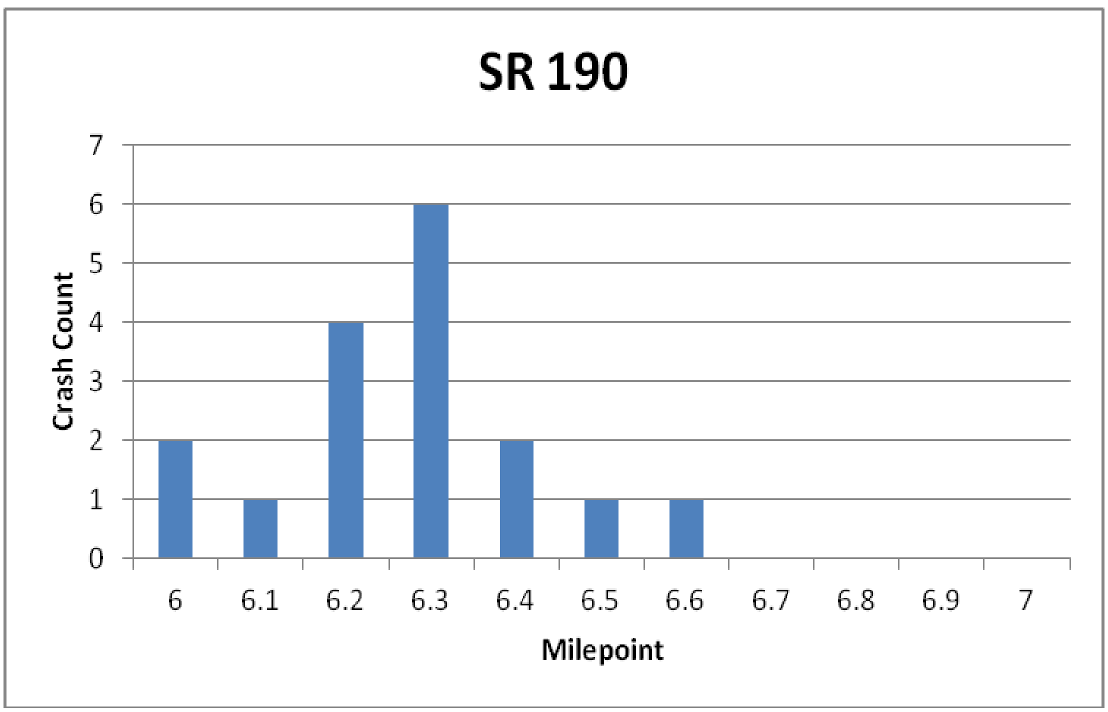


Figure 2.6D- SR 190 Snow & Ice Related (0.1 mile interval)

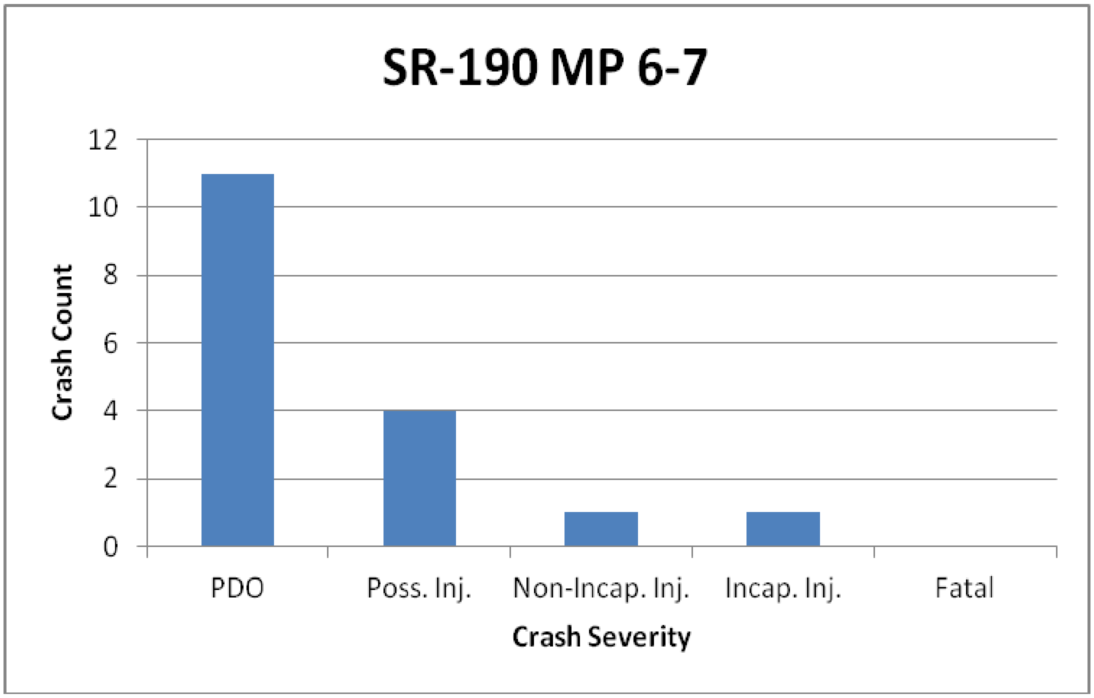


Figure 2.6E- SR 190 Snow & Ice Related Severity

Figure 2.6F – SR 190 Big Cottonwood Canyon near Storm Mountain

Figure 2.6G - Big Cottonwood Canyon "S" curve on steep mountain grade

Figure 2.6H - SR 190 in Big Cottonwood Canyon

3.0 WILD ANIMAL FENCE EVALUATION PROGRAM

Motor-vehicle conflicts with wild animals have been shown to persist in many cases even in areas with deer fence installed. These crashes with wild animals are typically due to breaches in the fencing, animals migrating around the fence locations, and gates being left open by land owners and others needing access.

Personnel responsible for the fence maintenance are not always aware of these problems, or the extent of the problems with motor-vehicle wild animal conflicts. An obvious but efficient way to evaluate the effectiveness of deer fence is to observe the number of wild animal hits reported in a corridor. Deer carcass removal information is also available in some locations that can be a useful indicator of wild animal fence effectiveness.

Although this reactive approach is far from ideal, it can be useful in determining if measures are needed to make the deer fence system more effective. Where these types of crashes are observed some actions could be undertaken such as on-site deer fence inspection, closer coordination with land owners in the area, and the strategic placement of well designed deer escape ramps.

The steps in Table 3.1 are recommended for this program to determine if wild animal fencing is effective in preventing wild animal related crashes.

Table 3.1
Wild Animal Fence Evaluation Program Steps

Program Actions	Stakeholder	Hours
1. Update the list of current wild animal fence locations	Central Maintenance/USU Wildland Resource Dept	1 hr
2. Compile information about the number and severity of crashes occurring in these areas	UDOT Division of Traffic & Safety/USU Wildland Resource Department	25 hrs
3. Post information about each site providing the effectiveness of the fence and system	UDOT Division of Traffic & Safety/USU Wildland Resource Department	5 hrs
4. Select a strategy to reduce the incidents or continue to monitor the site	UDOT Region Maintenance Team	10 hrs
5. Review feedback information in future years	UDOT Division of Traffic & Safety	4 hrs

3.1 Data Needs

The first step in making this program effective is to identify the location of the existing deer fence. UDOT's deer fence file has been down-loaded into useful formats for comparison with wild animal conflicts. Using the deer fence locations as the study areas, the number and severity of the wild animal collisions can be displayed.

3.2 Use of Carcass Removal Data

The use of the crash data supplied by the Traffic and Safety Division has been shown to be effective for this program. However, this information does not include all wild animals killed in the right-of-way since many of these crashes are not reported. It is estimated that more than half of the wild animal hits in some areas are not reported to the UDOT crash files. The use of carcass removal data should be more useful since it represents a more complete count of the animals hit along Utah's highways.

A new program at UDOT requires that all contractors in the state approved to remove wild animal carcasses utilize GPS location devices and record the type of animal carcass removed from the right-of-way. This data file will provide a more accurate count of the number of wild animal hits and a more precise location of these incidents since GPS location devices are used. In addition the species of the animal killed (deer, elk, moose or other) may be useful in developing a mitigation strategy.

This information gathered for the carcass removal program is managed by Utah State University under the direction of Dr. Patricia C. Cramer Research Assistant Professor with the Wildland Resources Department. Dr. Cramer specializes in transportation ecology, wildlife habitat connectivity, and wildlife movement [4].

3.3 Deliverables of the Program

The information supplied to the decision-makers of this program is a site by site listing of the numbers and severity of the motor-vehicle/wild animal related crashes reported. This allows the region staff personnel to select actions designed to reduce the crashes through their routine maintenance activities.

Also needed is a liability plan. Accurate records of each action should be kept at a central location to document that UDOT recognized the problem and took steps to address the issue.

3.4 Stakeholders

The key personnel involved in this program are the Area Supervisor, Station Foreman, and the Region Operations Engineer.

3.5 Resource Needs

An estimate of about 45 hours per year is required to complete the tasks of this program. This is approximately $3,000 to $5,000 per year to operate the program. A breakdown of the hours by stakeholder is included in Table 3.1.

3.6 Legal considerations

Legal action against UDOT is rare when the incident in question was a wild animal collision. One reason for this is that these types of crashes are generally lower in severity. However it is good practice to maintain formal records on actions taken to evaluate the effectiveness of the wild animal fencing in each corridor, and keep the fencing in good condition. This information should be maintained in one location by traffic and safety personnel.

3.7 Program Implementation

A Maintenance Activity Standard should be drafted and approved to evaluate wild animal fence using the tasks outlined in this report. UDOT uses Activity Standards mainly to describe when and where a particular activity is normally done, the expected production, and the typical equipment, material, and crew needed. This will ensure that the process will receive formal deliverables within UDOT guidelines, and that the tasks and goals will be included in the performance plans of maintenance personnel.

It is recommended that the data for the program be compiled by the Utah State University's Department of Wildland Resources. This phase of the program should be managed by Patricia Cramer an assistant research professor and ecologist who is an expert in reducing wildlife-vehicle collisions.

3.8 Program Feedback

The number of wild animal related crashes should be monitored over time in areas where improvements are made to the fence system and escape ramps. Reports circulated monthly would be ideal, but information provided at semi-annual inspections should be considered as a minimum in improved corridors.

3.9 Examples of Wild Animal Hit Clusters

The bar charts provided in Figures 3.1 through 3.4 are examples of ways to highlight where improvements in the wild animal fence system are needed. This information can then be compiled into a summary as shown in Table 3.2. A region team of maintenance managers will then be responsible to recommend and take actions to reduce the cluster.

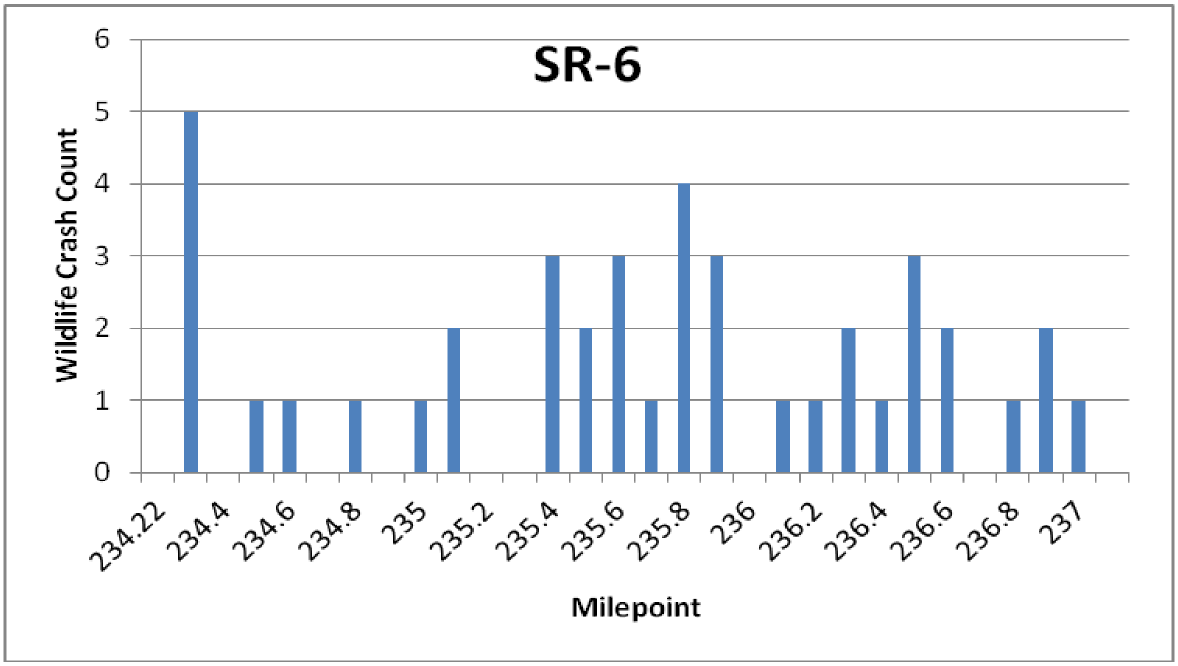


Figure 3.1 – SR-6 Wild Animal Hits

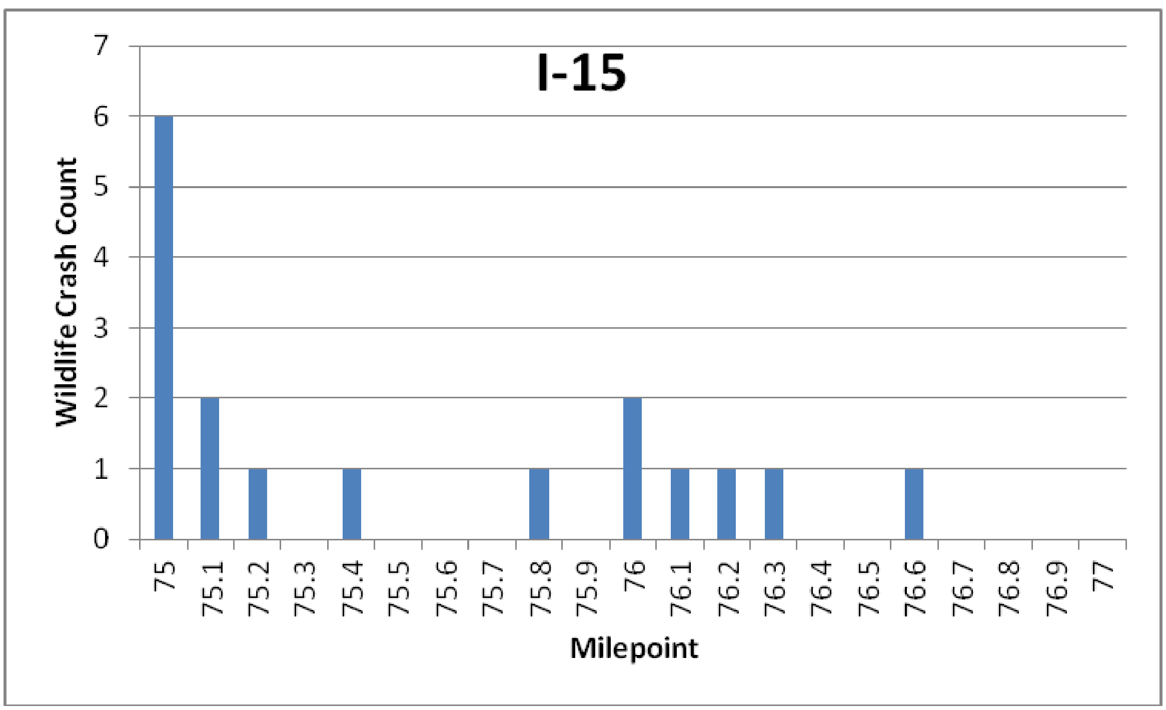


Figure 3.2 - I-15 Wild Animal Hits

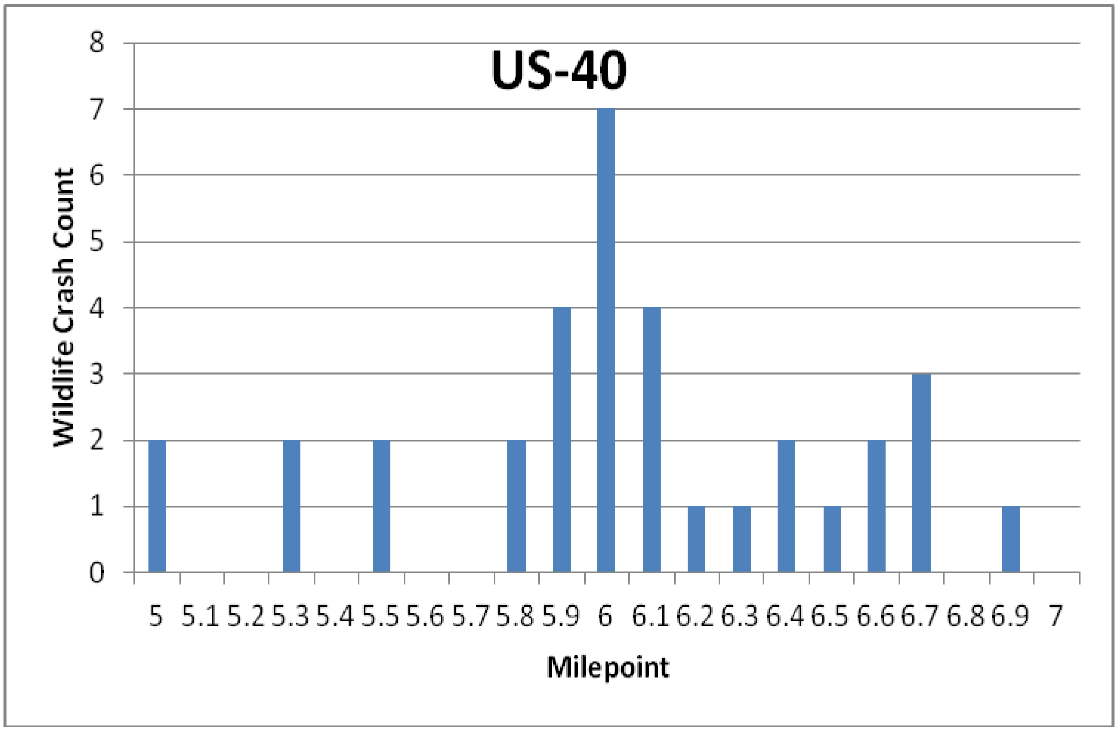


Figure 3.3 – SR 40 Wild Animal Hits

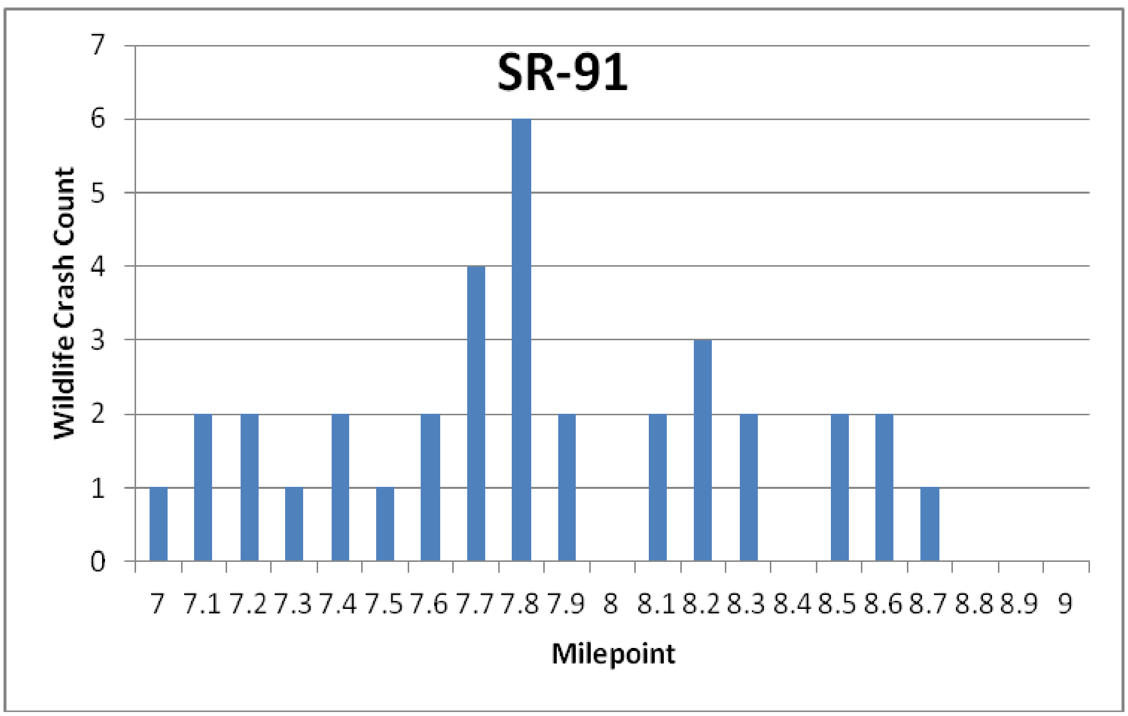


Figure 3.4 – SR-91 Wild Animal Hits

Table 3.2
Wild Animal Fence Performance

Route	Start MP	End MP	Wild Animal Crashes Ave (Max)	Fence Rating	Comments
SR 6	234.22	239.3	6 (10)	Poor	Clusters MP 234-237
SR 10	48.847	48.95	-0-	Excellent	
I-15	26.89	34.06	1.6 (3)	Very good	
	61.74	82.94	2.9 (9)	Fair	Cluster at MP 75
	94.19	108.48	0.5 (2)	Very good	
	169.88	187.06	0.5 (2)	Very good	
	192.45	193.78	-0-	Excellent	
	212.71	214.79	-0-	Excellent	
	272.805	277.46	0.9 (1)	Very good	
	279.26	283.69	1.5 (2)	Very good	
SR 40	2.72	15.88	6 (23)	Poor	Cluster at MP 6
	16.01	16.32	-0-	Excellent	
SR 50	89.402	119.29	0.8 (6)	Good	Clusters MP 100-102
I-70	7.63	22.4	6 (18)	Poor	Clusters MP 14-17
	26.37	38.06	0.7 (2)	Very good	
	39.79	56.85	0.4 (2)	Very good	
SR 89	161.81	163.58	1.5 (2)	Very good	
SR 91	3.9	16.8	2.0 (17)	Fair	Cluster MP 7.7-7.9
SR 118	0	0.14	-0-	Excellent	
SR 120	0	0.11	1	Very good	
	3.76	3.886	-0-	Excellent	
SR 160	0.18	0.29	13	Poor	Repairs needed
SR 191	59.243	62.308	-0-	Excellent	
SR 248	3.64	12.4	10 (21)	Poor	Deer crosswalk test section
SR 258	0	0.18	-0-	Excellent	
SR 259	0	0.321	10	Poor	Repairs needed

4.0 LOW SKID NUMBER CORRECTION PROGRAM

The goal of this program is to help UDOT address sections of highway with unacceptable levels of skid resistance with a formal and coordinated approach. An organized and systematic effort is needed between the Planning Statistics Section, the Region Offices, Central Maintenance, and the Division of Traffic & Safety to make the program function effectively. The stopping distance of vehicles is directly impacted by the skid number of the pavement surface. Low skid numbers can result in excessive increases in stopping distance resulting in the potential for increases in crashes. This is of greater concern when the pavement surface is wet.

The new surface transportation funding act has allocated funding through the Federal Highway Administration (FHWA). This program called MAP-21 has proposed a renewed importance on highway safety. A point of emphasis under the new legislation is "High Friction Surfaces" to reduce crash numbers and severity. The Low Skid Number Correction Program is a key component of the MAP-21 initiatives in Utah.

Within days of gathering the low skid numbers the process should be put into motion. Crash data and other information must be used to establish an effective correction strategy. This program is an efficient way to get the data compiled, a plan established, and set a priority with input from all stakeholders.

4.1 Data Needs and Correction Process

The steps described in Table 4.1 are recommended to analyze and address the skid resistance deficiencies of pavement surfaces in Utah. Included for each step is a target timetable aimed at completing the task in a reasonable amount of time. It is important to keep the time expended for each step to a minimum to allow UDOT personnel to implement actions in a prompt manner for highway sections with safety concerns. A flow chart is included in Figure 4.1 to illustrate the process used identifying the appropriate stakeholders and what deliverables they will be required to produce.

The recommended trigger values for skid numbers is shown in Table 4.2. These values were adopted based on studies done using measured skid numbers statewide and crash numbers from the Utah crash records. More information on these relationships is available in the "Skid Correction User's Manual" [5].

UDOT experts will need to establish a general policy on what constitutes a section with unacceptable skid numbers. Typically a one-quarter mile or greater section is used in rural areas. Sections as short as one-tenth mile may be considered for analysis in urban areas with medium to high AADTs and more traffic points of conflict.

Once a section has been entered into the program for analysis it is crucial to gather crash information on a wide range of issues. Obviously the number of crashes, the crash rate, and the severity of the incidents is important. Also the number and percentage of wet weather related crashes give an indication of how the skid numbers may be influencing the occurrence of crashes. Many DOTs around the country use 30% wet weather crashes as a trigger value. Other crash data that may be useful in some areas are the types of crashes, vehicle class information, contributing circumstances, and objects struck.

A plan with a specific strategy for dealing with the low skid numbers should be established for each section. The plan should include details about the actions selected and timing of the approach. As a priority for each plan is established the urgency of the strategy should be communicated to all stakeholders.

The current UDOT procedures should be continued for gathering the skid numbers using the Locked-Wheel Trailer to provide accurate data and precise location information. When a skid number below 35 is observed the test vehicle speed should be reduced to 40 mph and tests should be gathered on a 0.2 mile interval.

Testing should be performed during the months of May through September of each year. Calibration of the Locked-Wheel Trailer and tow vehicle should be done on a biannual interval for the first six years. Thereafter calibration should be done annually as the device ages.

UDOT managers should promote policies that create a culture in the regions where special skid testing would be requested when certain conditions are observed. This would be on pavement sections experiencing surface bleeding, chip seal failures, and other sections with lose of surface texture. This is often needed for concrete pavements when the surface becomes worn, since the micro-texture of many of those aggregates has been shown to be marginal.

4.2 Strategy Selection and Priority

Correction strategies can range from aggressive solutions to those where monitoring can be the best action. The following strategies are typical actions that may be taken to address a highway segment with low skid numbers:

- Schedule a surface treatment during the next construction season
- Schedule an overlay to correct the low skid numbers and other deficiencies on the roadway segment
- Mill the pavement surface if bleeding is observed
- Treat the pavement with blotter sand if a rejuvenator or flush seal is present and causing potential safety problems
- Diamond grind the surface of PCC pavement if an acceptable treatment life is predicted
- Apply a steel shot texture on PCC pavement
- Post "Slippery When Wet" signs and monitor the segment over time until acceptable skid numbers are restored

Establishing an appropriate priority for the strategy is very important aspect of the plan. UDOT engineers and managers are responsible to maintain all highway segments in an acceptable condition for the traveling public. Notice of a deficiency to UDOT personnel is considered the time for a decision to apply one of the following time-lines to the issue:

1. Act immediately with a solution to correct the low skid numbers
2. Schedule a correction in the near future, or
3. Monitor the skid numbers and accident history over time.

Highway segments with skid numbers that fall into the unacceptable range should be of major concern if any of the following safety issues exist:

- A high number of crashes are observed
- The crash rate is above the expected level

- The crash severity is above the expected level
- The wet weather crashes exceed 30% of the total number

4.3 Deliverables of the Program

The deliverables from the program needed on an annual basis to ensure that the goals are achieved are as follows:

- User's Manual outlining options on how to manage the program
- List of deficient sections including skid number history and crash history
- A plan for each section with specific recommendations and priority
- Liability Plan including justification of priorities
- An annual program report should be prepared and filed to document the information gathered and the steps taken to correct the low skid numbers

4.4 Stakeholders

The key stakeholders of this program are:

- Pavement Condition Engineer, Planning Statistics Section
- Crash Studies Engineer, Traffic & Safety Division
- Operations Engineer, Region
- Materials and/or Pavement Management Engineer, Region
- Traffic Operations Engineer, Region

The success of this program will require coordination between the region staff and personnel from the central divisions. They will need to act as a team to achieve the best possible strategies for the highway sections under analysis in the program and a wise use of available funding.

Table 4.1 - Skid Correction Program Steps

Skid Correction Program Steps	Complete by	Stakeholder	Person-Hours
1-Identify a problem using the Locked-Wheel Trailer testing as a trigger	Day 10	Pavement Condition Engineer, Planning Statistics Section	2 hrs
2-Determine the highway section boundaries using the results from the skid testing	Day 10	Pavement Condition Engineer, Planning Statistics Section	2 hrs
3-Produce a skid number history using data collected over the most recent 6 to 8 years	Day 10	Pavement Condition Engineer, Planning Statistics Section	4 hrs
4-Develop a crash history for the road section	Day 30	Crash Studies Engineer, Traffic & Safety Division	8 hrs
5-Gather information related to the severity of the crashes occurring in this section	Day 30	Crash Studies Engineer, Traffic & Safety Division	4 hrs
6-Calculate the number and percentage of wet weather crashes	Day 30	Crash Studies Engineer, Traffic & Safety Division	2 hrs
7-Identify other pavement deficiencies existing on the highway section for use in strategy selection	Day 40	Pavement Condition Engineer, Planning Statistics Section	4 hrs
8-Use sound pavement management techniques to recommend practical solutions	Day 60	Region Operations, Materials, and Traffic Operations Engineers	4 hrs
9-Select a corrective or mitigation strategy including the timing of the action and file plan into program records	Day 70	Region Operations, Materials, and Traffic Operations Engineers	6 hrs
10-Monitor the roadway section over time to determine the effectiveness of the strategy and file results	1 Year	Pavement Condition Engineer, Planning Statistics Section	2 hrs
11-Select a new strategy if needed based on the new information and the data from previous years	1 Year	Region Operations, Materials, and Traffic Operations Engineers	2 hrs

Figure 4.1

Low Skid Number Section
Process Flow Chart

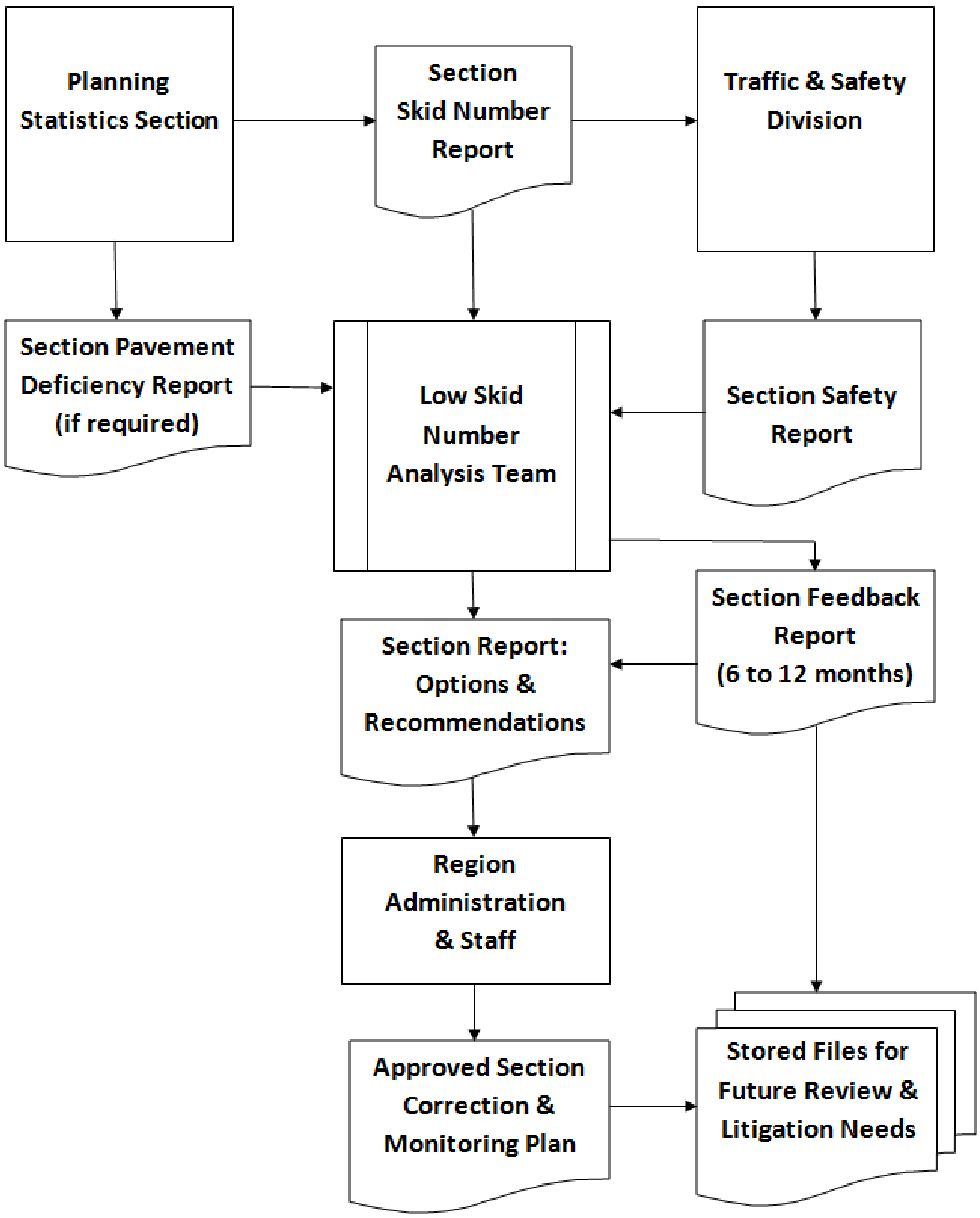


Table 4.2 - Skid Number Trigger Values

Functional Class	Unacceptable	Marginal	Acceptable
Interstate Highways	Less than 30	30 to 40	Greater than 40
Non-Interstate Highways	Less than 35	35 to 45	Greater than 45

4.5 Resource Needs

Table 4.1 provides an estimate of the manpower needed for each step in the process. A total of about 40 hours per site is required to complete the program tasks. This is approximately $3,000 to $4,000 per site to operate the program. Typically 4 or 5 sites require analysis per year, which indicates that about $12,000 to $20,000 is needed each year to manage the program. This does not include the crew and equipment that gathers the data in the field.

4.6 Legal Considerations

All UDOT programs that have a direct impact on the safety of the traveling public should take into consideration the legal aspects of the program activities. If a request is submitted through the Government Records Access and Management Act (GRAMA) or if any formal legal action is taken related to the program, the following information will be a necessity and will reduce UDOT's liability for safety issues:

- A formal process is in place to address highway segments that have measured or suspected skid resistance issues
- Documentation that the process has been followed including analysis and the correction of safety deficiencies
- Complete files of the data and other information compiled
- A description of the analysis done including the criteria used
- The actions taken based on the analysis
- The reasons this strategy was selected including any budget limitations
- A description of why the priority for the action was given compared to other road segments with safety concerns
- The results of any performance measures and feedback information assembled for the site

4.6.1 Record Keeping

Maintaining formal files with the information listed above will be of significant benefit to UDOT. These files indicate a commitment to safety and display an understanding of what is needed to succeed in addressing deficiencies. Most judges understand that UDOT does not have unlimited funding to deal with these issues, but has dealt with the deficient sections appropriately based on available time and resources.

Although this record keeping process seems like a time consuming activity, the cost and labor related to this can be minimized using creative forms and filing techniques. Time spent will be recovered through more efficient information generation during court ordered data submittals and GRAMA requests.

4.6.2 Constructive Notice

In legal actions, “constructive notice” of a highway safety issue is considered just as valid as “actual notice”. Constructive notice is in play if any UDOT employee is aware of an issue. Under the law all UDOT employees have notice of the deficiency and must act accordingly. This adds to the need for formal interaction between the various stakeholders within UDOT.

Lawsuits against highway agencies are more often dismissed when it can be demonstrated that good data was compiled, an effective strategy selected, an appropriate priority set, and the strategy was implemented. Priorities are crucial to show that deficiencies are analyzed and corrected based on sound data and policies. It is also important to show that projects that did not receive high priorities did not carry sufficient urgency compared to other issues based on the limited program funding.

4.7 Program Implementation

The first step towards implementation of this program is to establish strong policies within the divisions and regions that will ensure action when required. The “Skid Correction User’s Manual” is a useful tool in the implementation process for this program, and should be adopted as the guidelines used in the program.

This process can be made more manageable to the stakeholders by using the UDOT uPlan system or ProjectWise Program. Each responsible division, section and region could post the information on uPlan entry. The data entered will be password protected and for use by authorized personnel only.

The tasks outlined in the skid correction process should be entered into the performance plans of the key stakeholders listed in the process. This includes the Pavement Condition Engineer in the Planning Statistics Section, the Crash Studies Engineer in the Traffic and Safety Division, as well as the Operations, Materials, and Traffic Operations Engineers in each region.

Due to the importance of maintaining adequate skid numbers on Utah's highways it is recommended that UDOT include a list of unacceptable sections into the Highway Safety Improvement Program (HSIP) and Spot Safety Improvement Program (SSIP). This list would only include high priority sections with low skid numbers and significant safety issues.

The HSIP and SSIP are administered through Central Traffic & Safety Division by Scott Jones. Funding is available to the regions to address locations with a fatal and/or serious injury crash history. The program encourages close coordination with the regions to identify, analyze, prioritize, program and implement projects using these funds. Information on these programs is available in on-line manuals [4], [5].

4.8 Program Feedback

It is essential that the agency acquire and review feedback information to evaluate the effectiveness of the decisions made and actions taken concerning the impacted locations. Also the measured success of implemented actions is valuable in future decision-making. This information should be filed for use if needed during any litigation taken against the Department.

4.8.1 Feedback Testing

When the surface of a pavement is treated to improve the skid number, special testing of the site may be appropriate. Personnel in the Division of Planning, Pavement Management Section can provide this testing upon request. It is crucial to archive data showing that the deficiency was corrected in a timely manner related to the physical abilities of the staff and the budget limitations of the Department.

In cases where no action was taken, this feedback process may necessitate long-term monitoring of the highway segments. Once the surface is replaced due to the normal pavement maintenance program and the skid number has been returned to an acceptable level, the monitoring can be terminated. The feedback information should be maintained until any statute of limitations has expired, or the information is no longer needed. For many highway sections this information should be kept in a skid number log. These histories will be useful where low skid numbers reoccur at specific sites. This is especially useful on concrete pavements where the skid numbers return to certain values when applied textures wear out.

4.8.2 Aggregate Source Analysis to Improve Skid Resistance

Over the years UDOT materials engineers have observed certain aggregate sources that have poor skid resistance characteristics. These aggregates demonstrate unacceptable microtexture when used as a pavement surfacing material. Often the skid numbers measured are not satisfactory during the initial skid measurements or shortly after minimal traffic loading.

A study to evaluate the microtexture and polishing characteristics of aggregates around the state is recommended. Data gathered from the skid correction program is natural input to the aggregate source analysis.

Correlations between low skid numbers and aggregate sources are needed on a routine basis. This has been done in the past and two aggregate sources were restricted from use on pavement surfaces. Standard laboratory testing did not consistently identify this problem and on-site performance has emerged as the best evaluation tool. As new aggregate pits are opened around the state it is important to evaluate their skid resistance properties in the field.

4.9 Wet Weather Crash Cluster Analysis

It is essential for UDOT managers to undertake studies related to crash clusters occurring on wet pavement surfaces. Any crash cluster where the number of wet weather crashes is more than 30% of the total number should be investigated. Also any areas identified by the Utah

Highway Patrol, a local law enforcement agency, or region personnel as high wet weather crash locations should be included in the analysis. This is in alignment with recommendations from the MAP-21 program.

Wet weather crashes may result from factors other than unacceptable skid numbers. Clusters have been observed in locations where marginal skid numbers were measured (36 to 45), or even higher skid numbers in some cases. Stopping distances are higher than ideal for these marginal areas, and may be a contributing factor along with issues such as numerous conflict points, poor geometrics, high running speeds, areas with excessive water spray, and hydroplaning due to poor pavement drainage.

For this reason the wet weather crash study should be done annually and separate from the programs outlined in this report. Once a list of wet weather crash clusters is identified, steps should be taken to reduce the problems. This could include using the HSIP or SSIP processes, adding tasks to the performance plans of key stakeholders, and/or scheduling correction activities through pavement management programs.

4.10 Examples- Skid Number History, Crash Summary & Recommendations

Each of the following sections listed in Table 4.3 has been tested with the Locked-Wheel Trailer and has skid numbers below standard. A discussion of each section is provided in the following examples with recommendations on how the Utah Department of Transportation could address the problem.

Table 4.3 - Low Slid Number Sections

Route	Description	Mile points	AADT	2005	2006	2007	2008	2009	2010	2011
10	Route 1622 (Lawrence) to Huntington 400 No.	42.0 – 47.5	7,000		48		37		34	
18	I-15 to 1250 No in St George	0.0 – 3.5	24,300-42,700	33		42		32		33
34	St. George Blvd	0.0 – 2.0	16,500-39,300	38		41		33		38
68	Redwood Road-1565 So to 200 So	57.0 – 59.0	19,800-21,800		32		30		30	
73	3220 E in Eagle Mtn to 400 West in Lehi	33.0 – 36.0	19,500		29		28		31	
89	Junction SR-256 in Axtel to 100 So in Gunnison	233.5 – 241.0	3,200-4,200	41		43		42		30
115	SR-198 in Payson to I-15	0.0 – 1.0	9,300-13,000		33		29		33	
138	Park St in Grantsville to Lamb Lane	10.0 – 13.0	9,000		33		28		43	
198	12000 So in Spring Lake to 700 E in Payson	3.0 – 6.0	8,000-13,500		30		28		24	
289	Cedar City west on Center Street to 1150 West	0.0 – 2.0	2,500-9,000	26		36		33		36

FHWA Ride quality ranges: Poor IRI > 170, Fair IRI 95 to 170, Good IRI < 95.
CONFIDENTIAL: This information is protected under 23 USC 409.

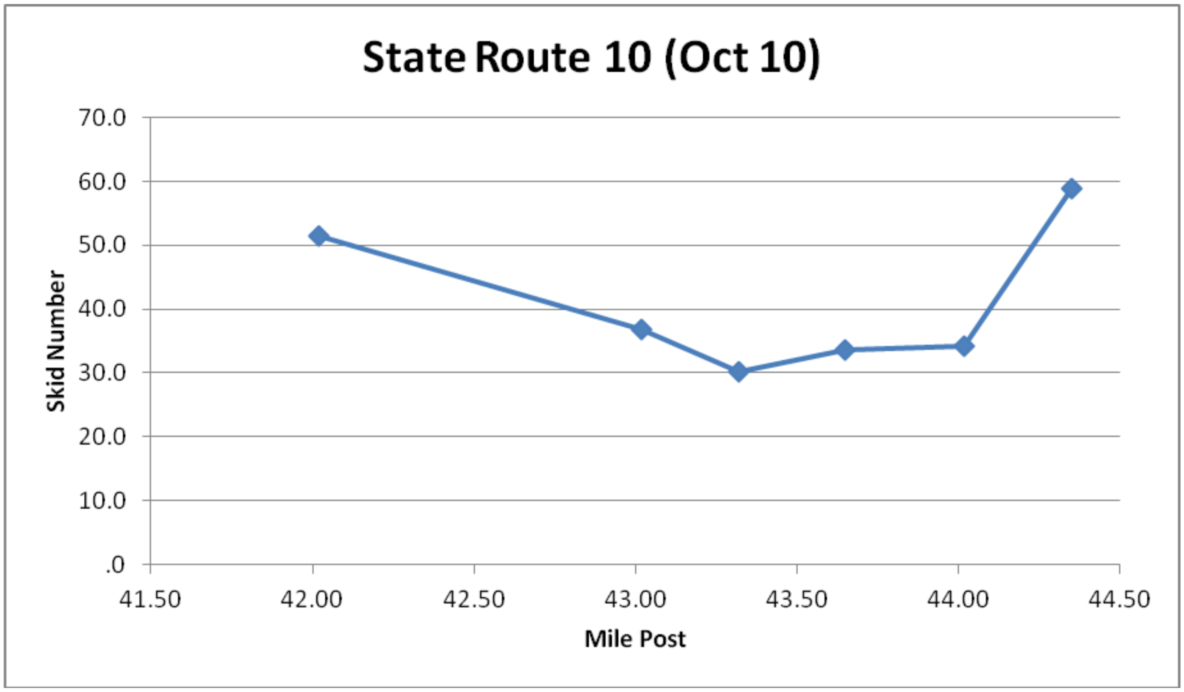


Figure 4.2A – SR 10 Skid Numbers

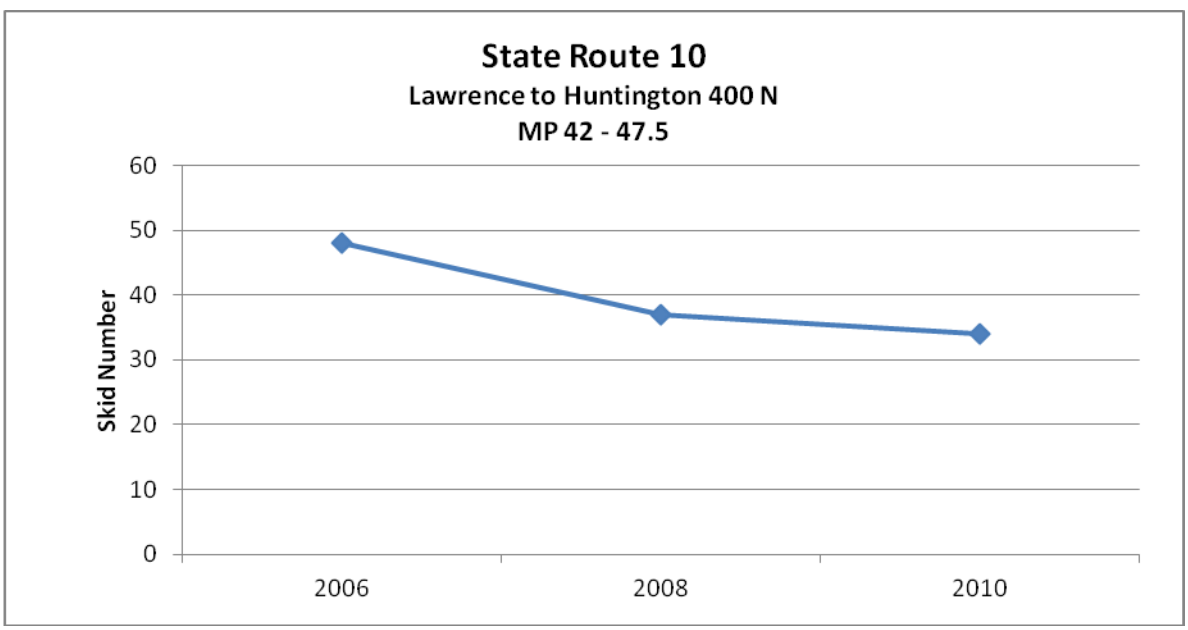


Figure 4.2B – SR 10 Skid Number History

State Route 10 Milepost 42.0 - 47.5								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	7180	48	13	0.9	3	0	2	15%
2007	5650	48	8	0.7	3	0	0	0%
2008	5505	37	15	1.4	4	1	0	0%
2009	5600	37	11	1.0	2	0	0	0%
2010	5710	34	12	1.0	4	0	2	17%
Average	5929	40.8	11.8	1.0	3.2	0.2	0.8	6%

Table 4.4 – SR 10 Crash History

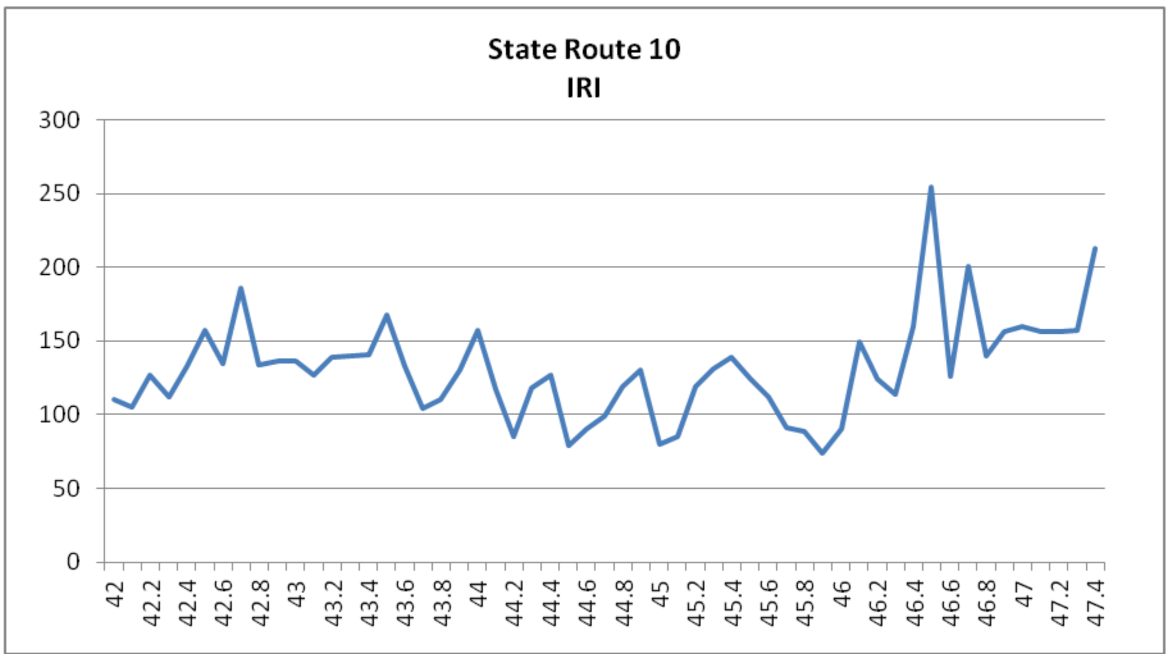


Figure 4.2C – SR 10 Pavement Roughness

Pavement Condition and Safety Analysis:

- The skid numbers from milepost 43 to 44 on SR10 are below standard and have been dropping over time.
- The number of crashes that has been occurring in the corridor is low.
- The severity of the crashes is somewhat high, most likely due to the high volume of truck traffic.
- The ride quality of this section is “fair”.
- The section has areas with unacceptable rutting that could result in hydroplaning. Combined with the low skid numbers the stopping distance on the section could be unacceptable.
- Many areas have significant wheel-path cracking and additional measures may be warranted beyond surface friction improvement.
- There are areas with significant patching on this section.
- The priority of this section is high and should be addressed within the next few years.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Correction of the pavement distress should be considered prior to resurfacing

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

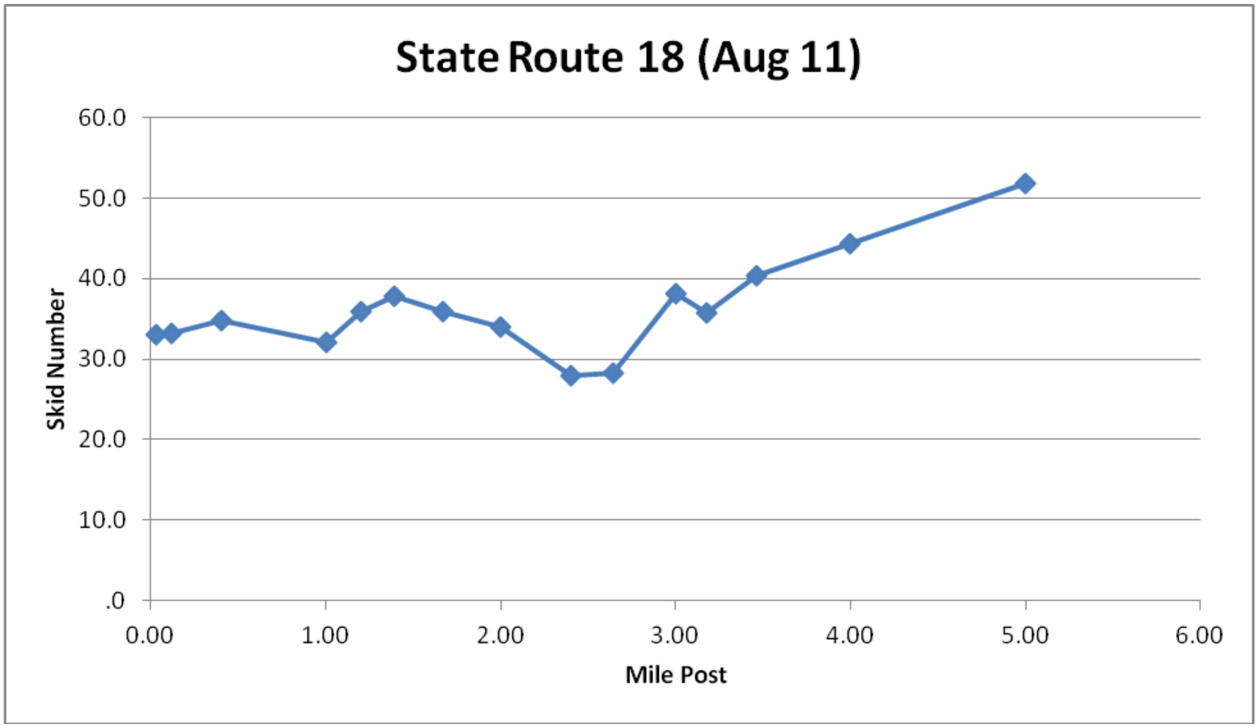


Figure 4.3A – SR 18 Skid Numbers

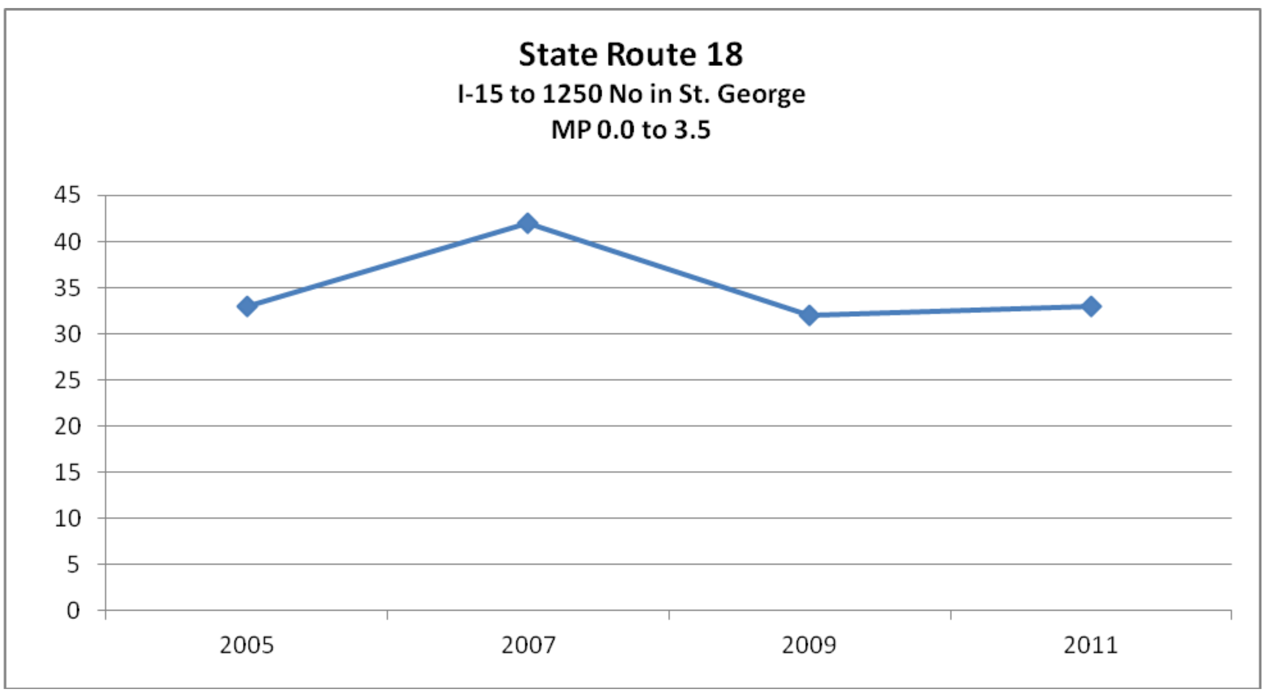


Figure 4.3B – SR 18 Skid Number History

State Route 18 Milepost 0.0 - 3.5								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	34882	34	257	5.8	87	0	13	5%
2007	37022	41	221	4.7	90	0	16	7%
2008	31222	41	161	4.0	61	1	10	6%
2009	28500	33	179	4.9	99	0	18	10%
2010	30250	33	136	3.5	58	0	9	7%
Average	32375	36.4	190.8	4.6	79	0.2	13.2	7%

Table 4.5 – SR 18 Crash History

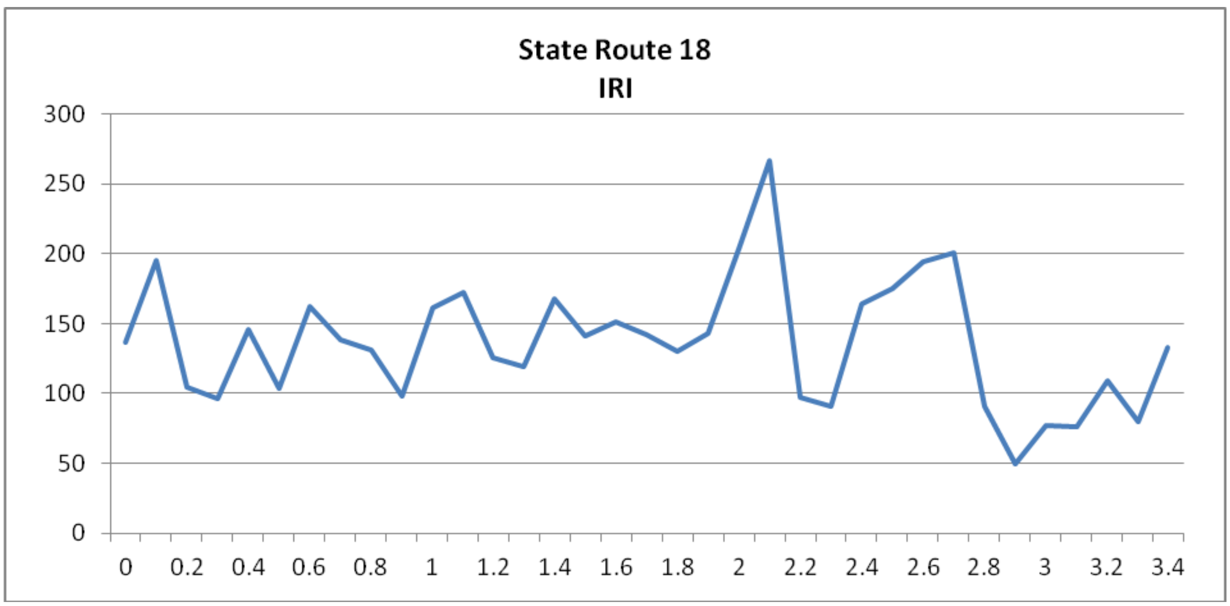


Figure 4.3C – SR 18 Pavement Roughness

Pavement Condition and Safety Analysis:

- This section of SR18 has skid numbers below standard from milepost 0.0 to 3.0.
- There are a high number of crashes on the section, but the accident rate is not excessive for this function class.
- The severity of the crashes is significant with numerous injuries and one fatality over the last five years.
- A few areas have high roughness.
- There are areas with significant patching on this section.
- This section has excessive wheel-path cracking.
- The priority of this section is very high and should be addressed ASAP.
- A priority swap with another section may be warranted.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Some pavement distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

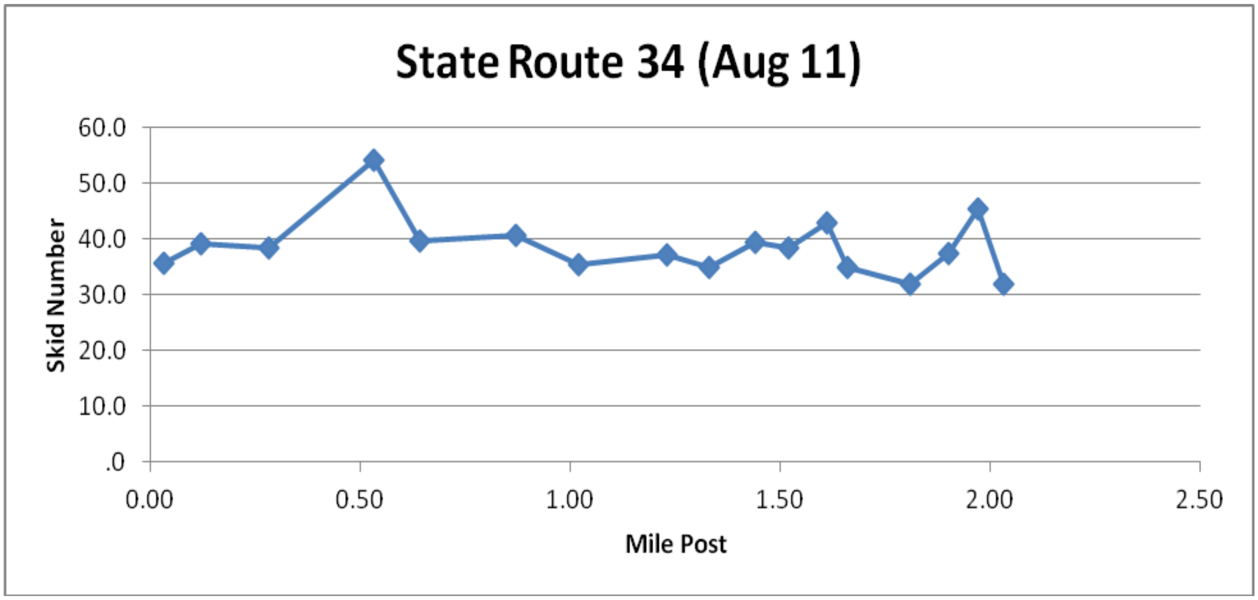


Figure 4.4A – SR 34 Skid Numbers

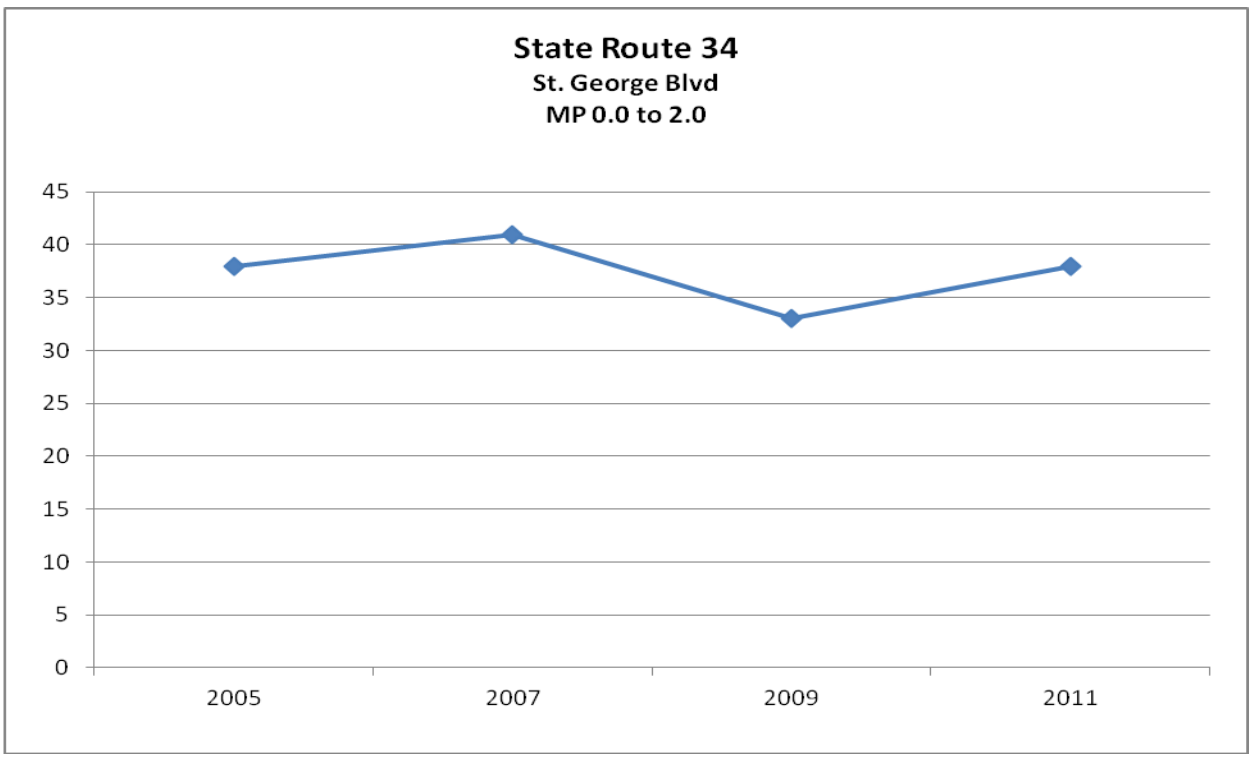


Figure 4.4B – SR 34 Skid Number History

State Route 34 Milepost 0.0 - 2.0								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	6915	38	83	16.4	26	0	5	6%
2007	35470	41	146	5.6	65	1	3	2%
2008	33765	41	127	5.2	45	0	12	9%
2009	32595	33	146	6.1	74	0	4	3%
2010	32400	33	110	4.7	31	0	9	8%
Average	28229	37.2	122.4	7.6	48.2	0.2	6.6	6%

Table 4.6 – SR 34 Crash History

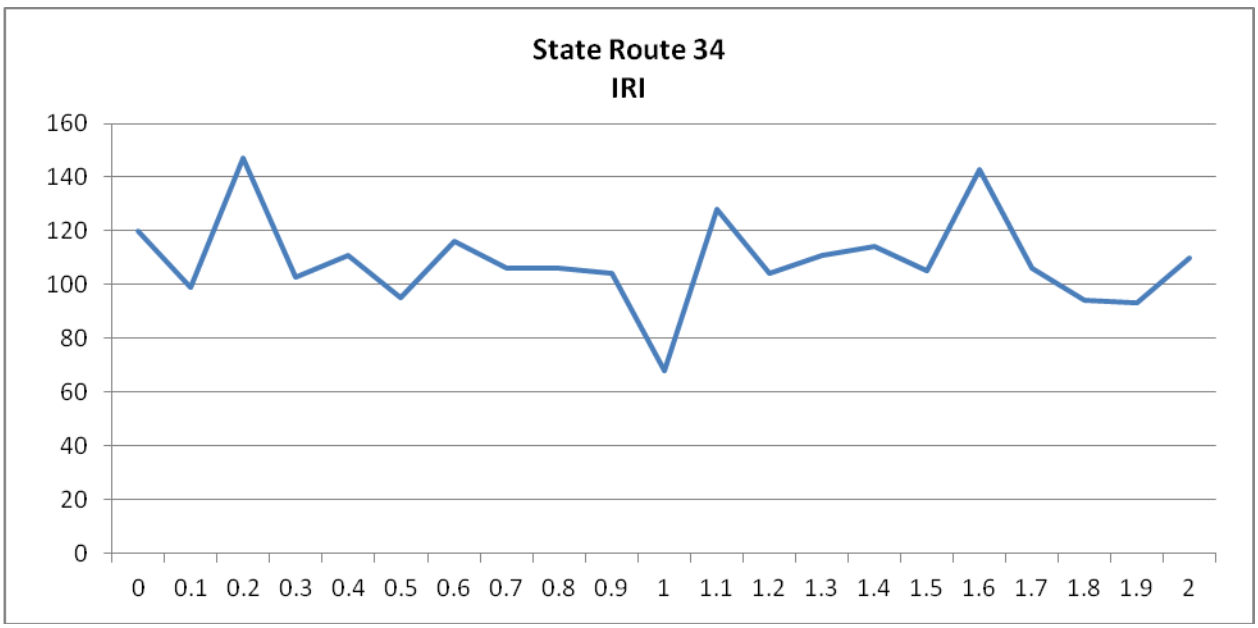


Figure 4.4C – SR 34 SR 68 Pavement Roughness

Pavement Condition and Safety Analysis:

- Much of this section of SR34 has below standard skid numbers from milepost 1.0 to 2.0.
- There are a high number of crashes on the section, but the accident rate is not excessive.
- A significant number of the crashes involve injuries with one fatality over the last five years.
- The pavement roughness is "fair".
- There are some areas have high bleeding and patching on this section.
- Some areas have significant wheel-path cracking.
- The priority of this section is high and should be addressed within the next few years

Possible Correction Strategies (check all that apply):

- ○ Chip seal/Open-graded surface course
- ○ Some pavement distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- ○ ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- ○ Recommended strategy:
- ○ Approved timing:

Feedback Information:

- ○ Skid Numbers: Date tested:
- ○ Crashes per Year: Date:

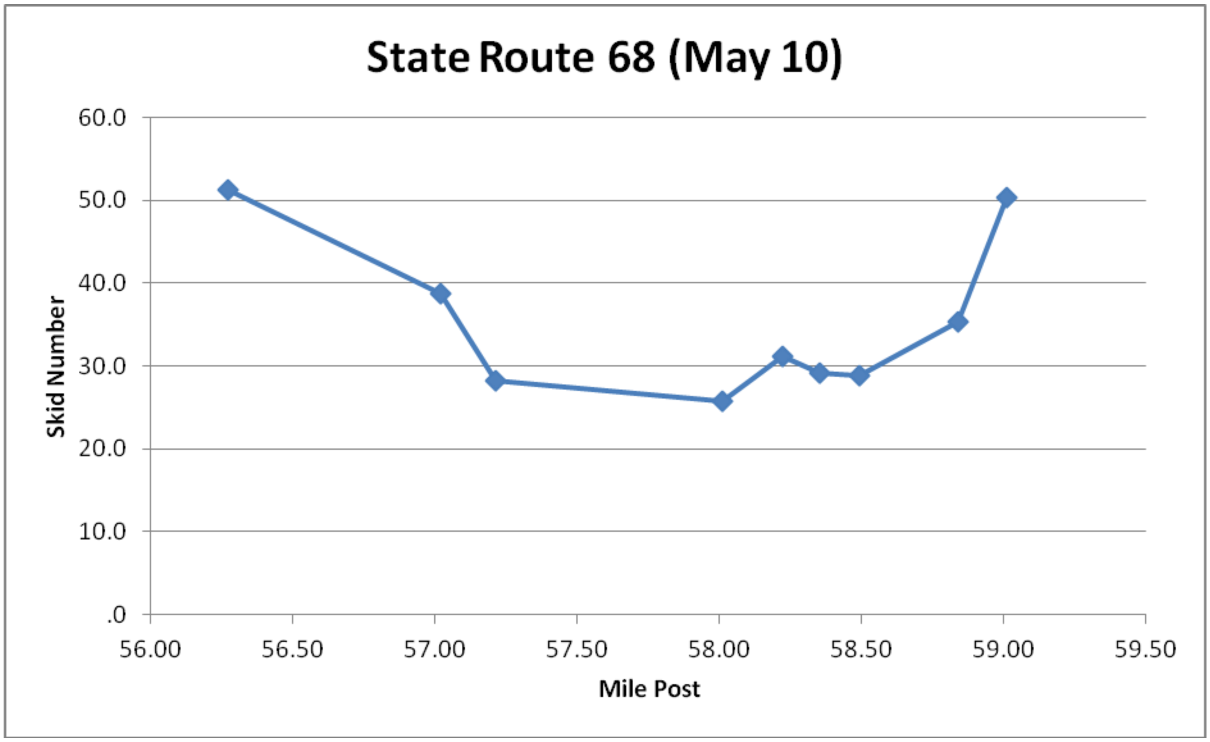


Figure 4.5A – Skid Numbers

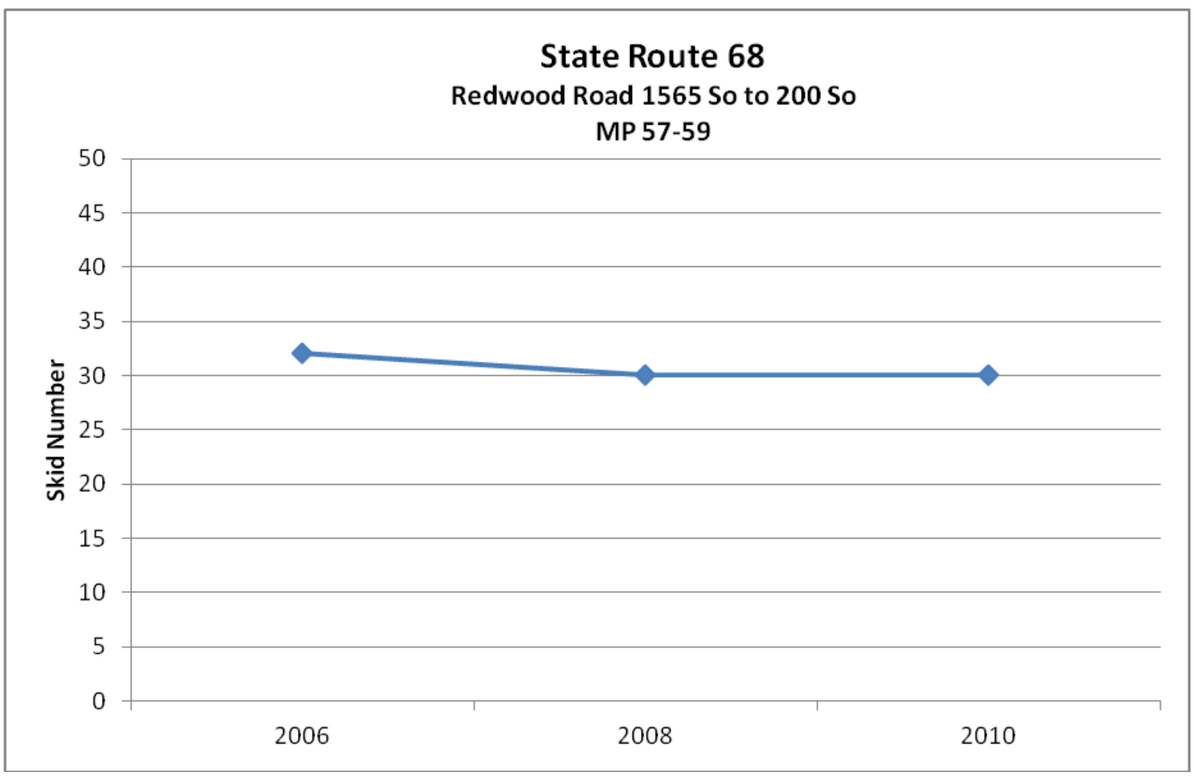


Figure 4.5B – SR 68 Skid Number History

State Route 68 Milepost 57.0 - 59.0								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	18435	32	55	4.1	30	0	14	25%
2007	18695	32	53	3.9	31	0	8	15%
2008	20550	30	78	5.2	46	1	11	14%
2009	20185	30	56	3.8	35	0	16	29%
2010	19780	30	37	2.6	22	0	9	24%
Average	19529	30.8	55.8	3.9	32.8	0.2	11.6	22%

Table 4.7 – SR 68 Crash History

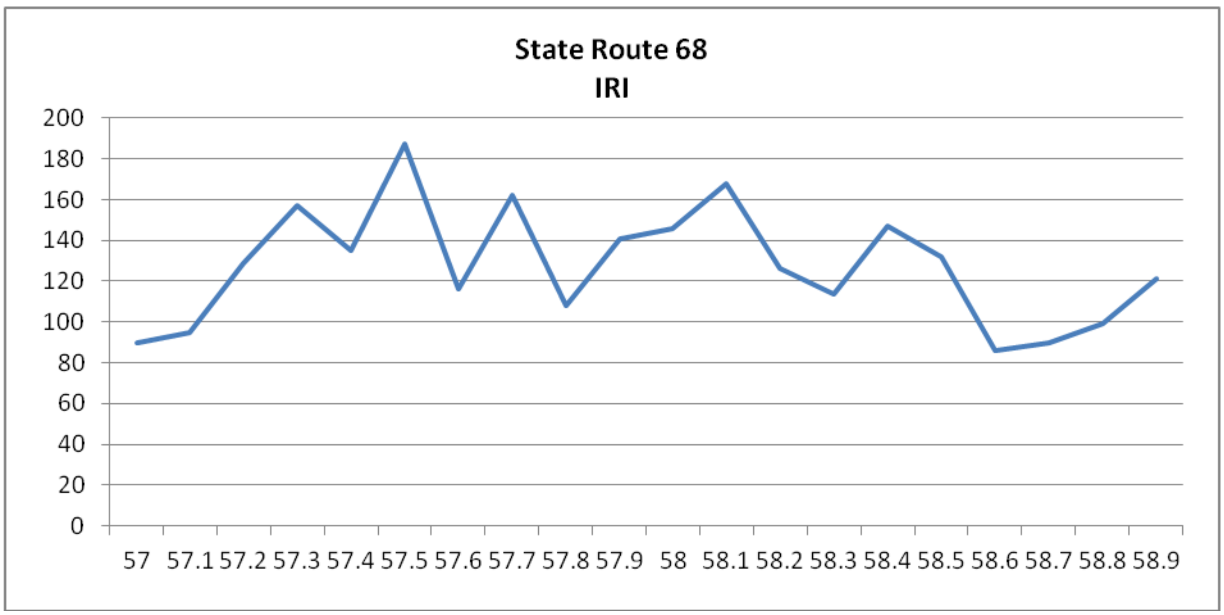


Figure 4.5C – SR 68 Pavement Roughness

Pavement Condition and Safety Analysis:

- This section of SR68 has below standard skid numbers from milepost 57.0 to 58.5
- The low skid numbers have been present since 2006 with a mild reduction over time.
- The number of crashes and the crash rate are not excessive.
- The percentage of crashes occurring during wet weather is high.
- The pavement roughness on this section is “fair”.
- Most areas have excessive wheel-path cracking.
- The priority of this section is high and should be addressed within the next few years

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Some pavement distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

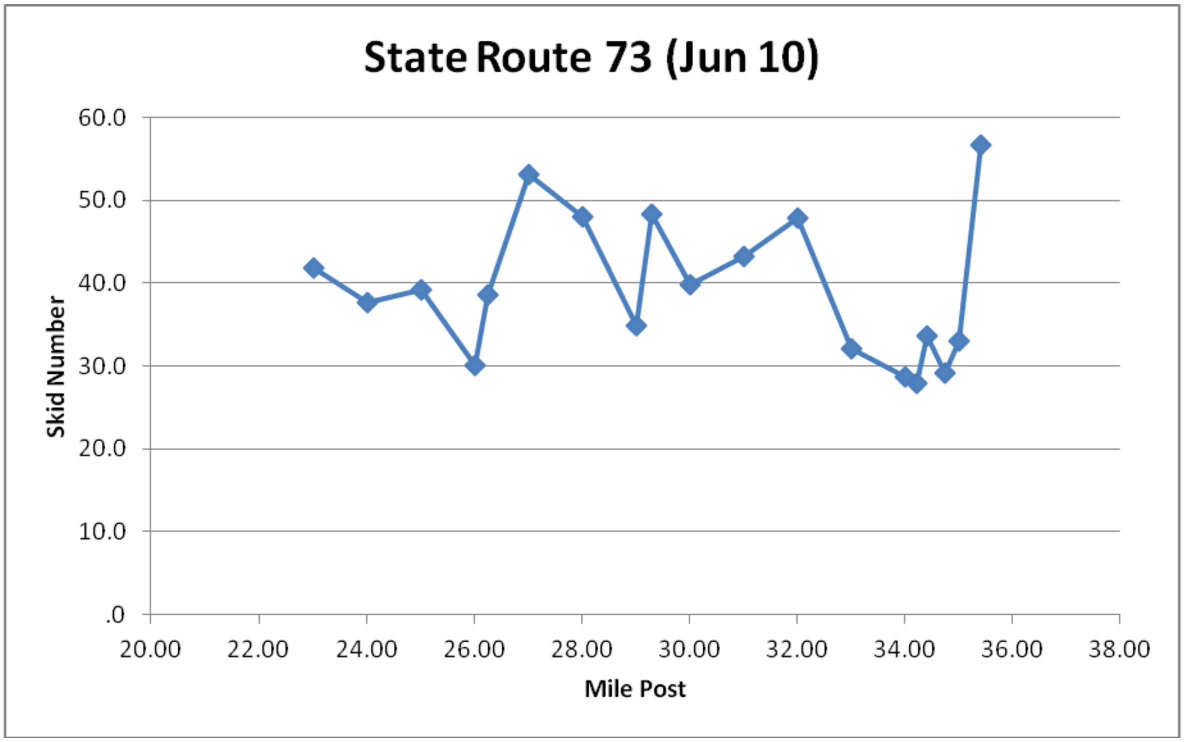


Figure 4.6A – SR 73 Skid Numbers

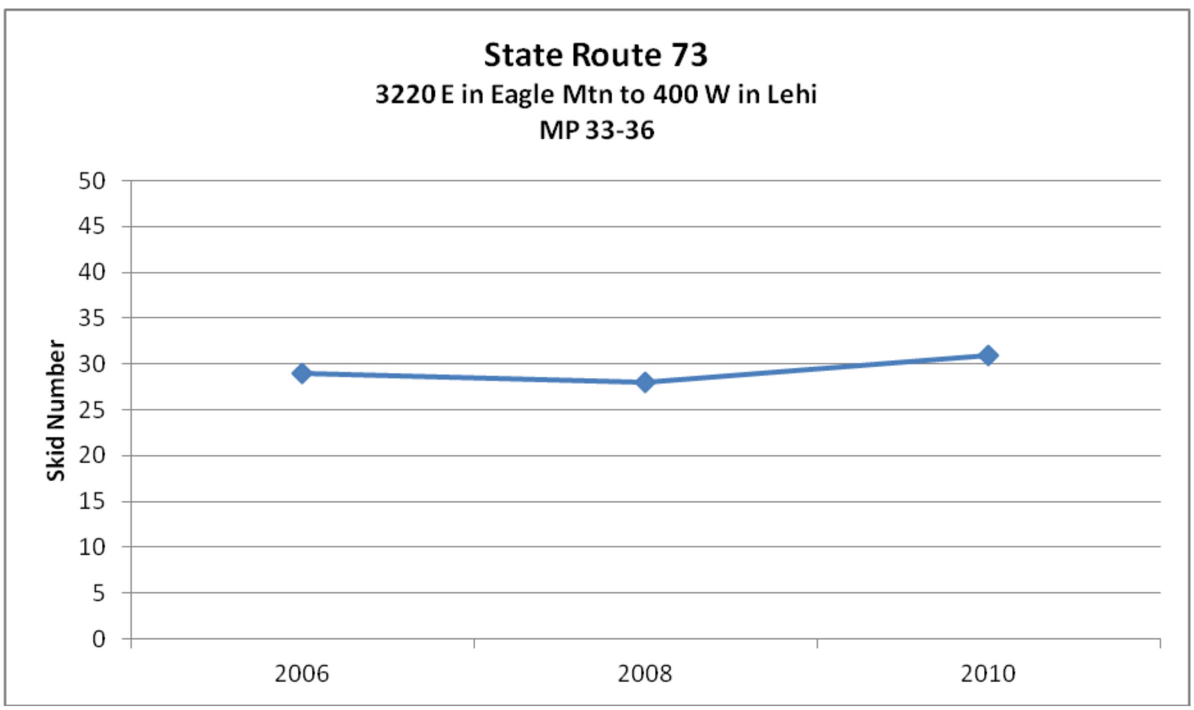


Figure 4.6B – SR 73 Skid Number History

State Route 73 Milepost 33.0 - 36.0								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	19040	29	34	1.6	13	0	5	15%
2007	20980	29	45	2.0	13	0	6	13%
2008	20185	28	17	0.8	1	0	5	29%
2009	22165	28	39	1.6	19	0	4	10%
2010	19550	31	38	1.8	12	1	6	16%
Average	20384	29	34.6	1.5	11.6	0.2	5.2	17%

Table 4.8 – SR 73 Crash History

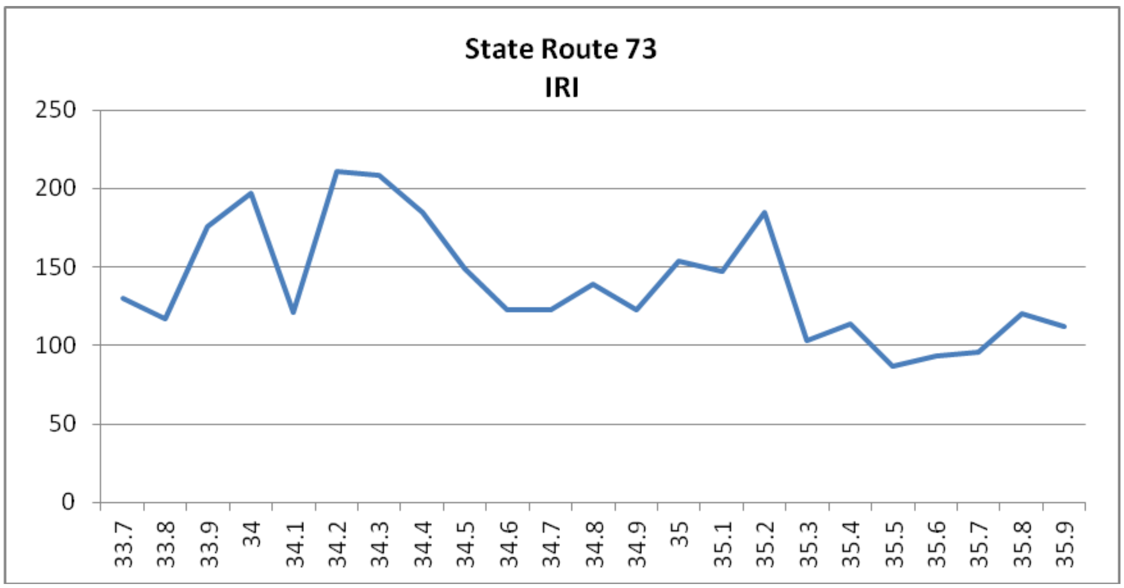


Figure 4.6C – SR 73 Pavement Roughness

Pavement Condition and Safety Analysis:

- Some areas of this section of SR73 have skid numbers that are below standard especially from milepost 33 to 35.
- The skid number has been low since 2006.
- The number of crashes is low and the crash rate is acceptable.
- The percentage of injury crashes is significant and one fatality occurred over the last five years.
- A significant number of the crashes occurred during wet weather conditions.
- Some segments have “poor” pavement roughness.
- There are areas with significant wheel-path cracking.
- The priority of this section is high and should be addressed within the next few years.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Some pavement roughness and distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

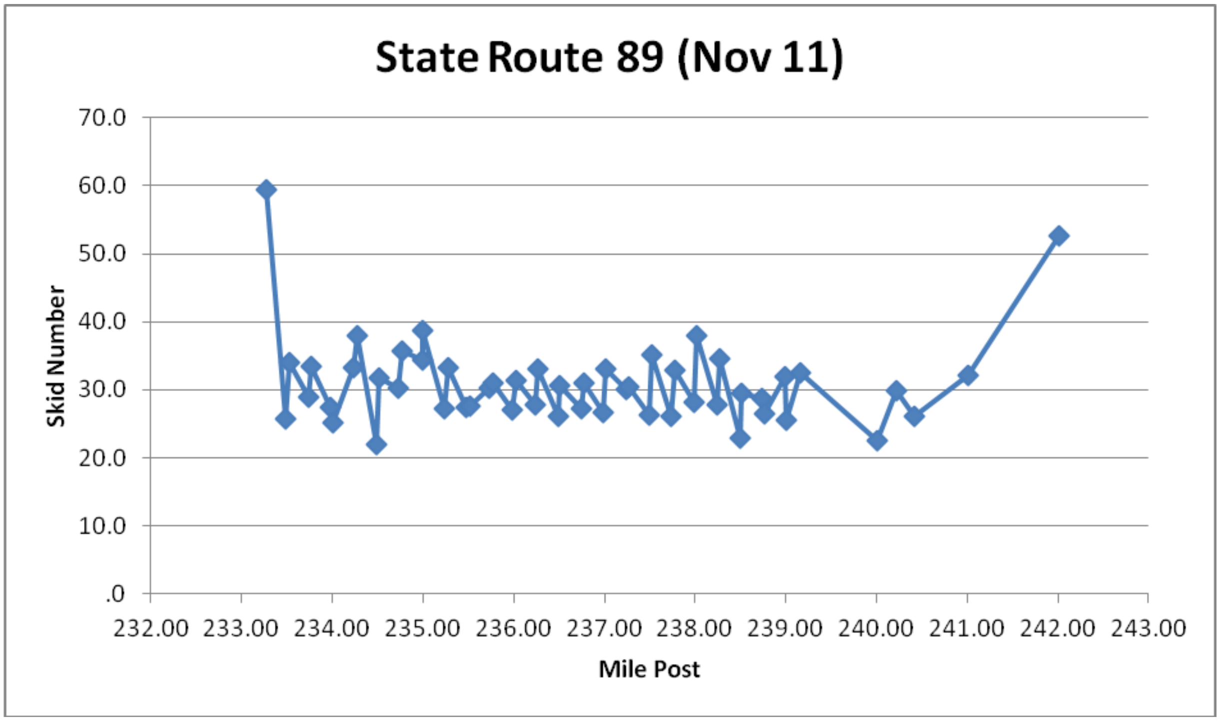


Figure 4.7A – SR 89 Skid Numbers

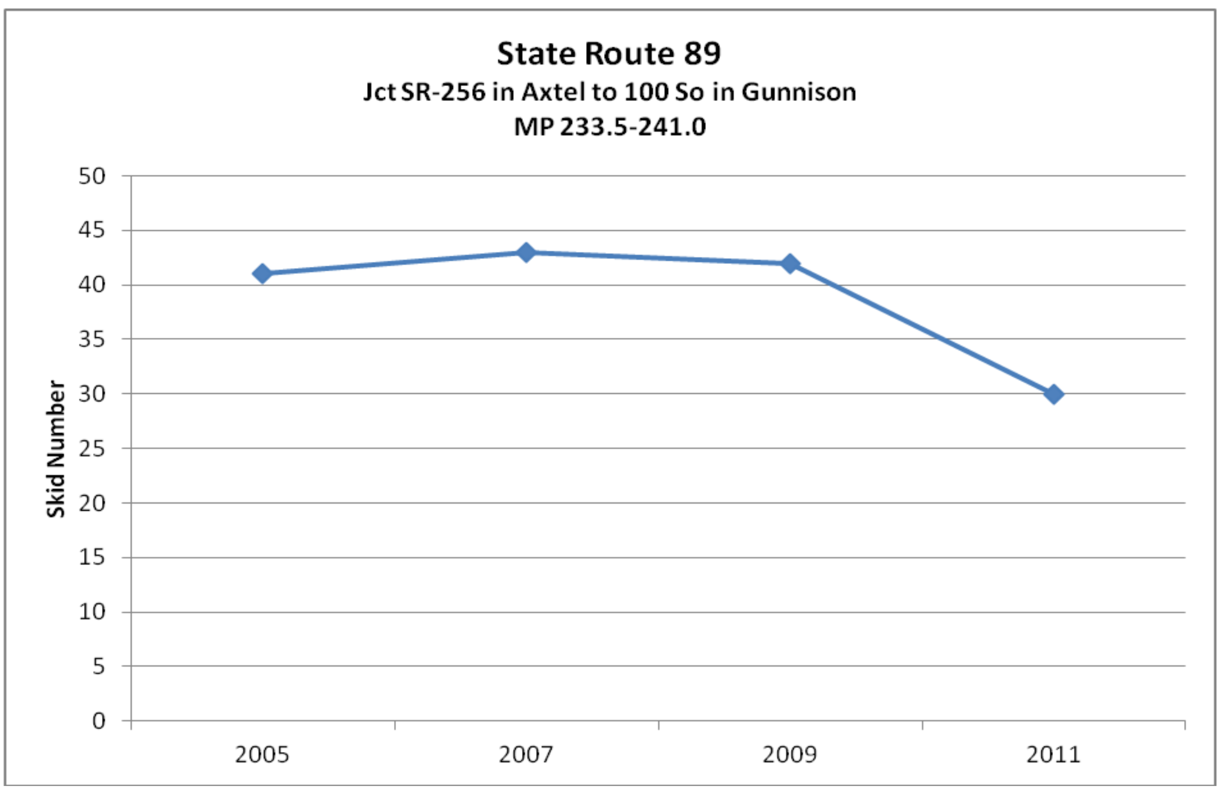


Figure 4.7B – SR 89 Skid Number History

State Route 89 Milepost 233.5 – 241								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	7695	41	37	1.8	12	1	4	11%
2007	4030	43	14	1.3	5	0	0	0%
2008	3850	43	22	2.1	9	0	0	0%
2009	3905	42	16	1.5	4	1	2	13%
2010	3290	42	16	1.8	4	1	2	13%
Average	4554	42.2	21	1.7	6.8	0.6	1.6	7%

Table 4.9 – SR 89 Crash History

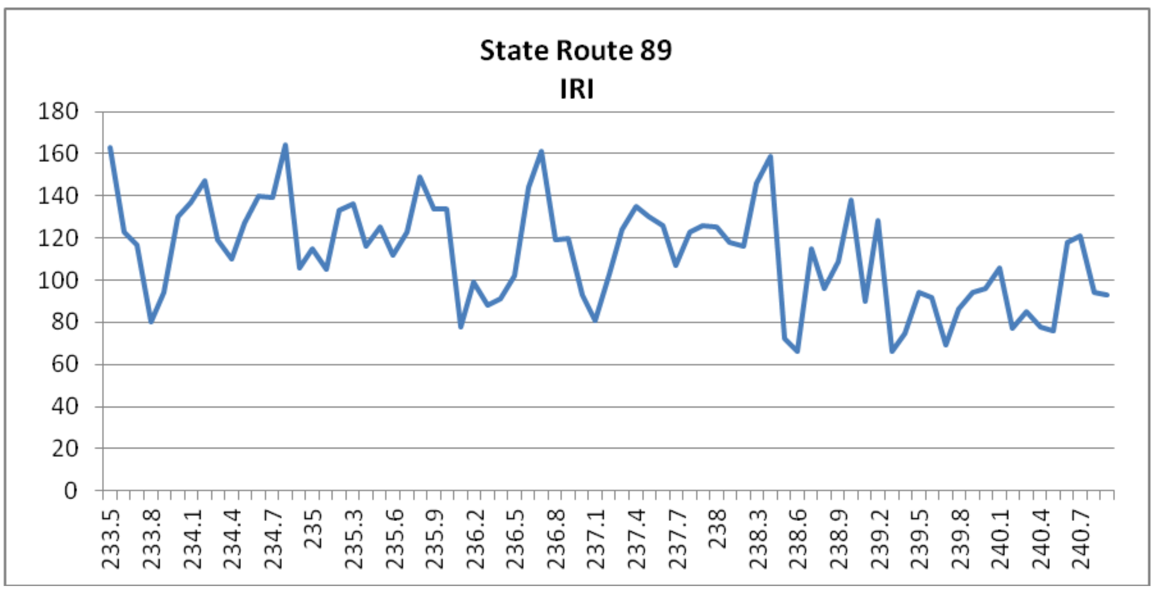


Figure 4.7C – SR 89 Pavement Roughness

Pavement Condition and Safety Analysis:

- State Route 89 from milepost 233 to 241 has numerous areas with very low skid numbers.
- The section has shown a significant drop over time.
- There are a low number of crashes occurring on the section and the accident rate is low.
- The percentage of injury crashes is high and three fatalities have occurred on the section over the last five years.
- The pavement roughness on this section is "fair".
- There are areas with significant patching on the pavement.
- Most areas have excessive wheel-path cracking.
- The priority of this section is high and should be addressed within the next few years.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Some pavement distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

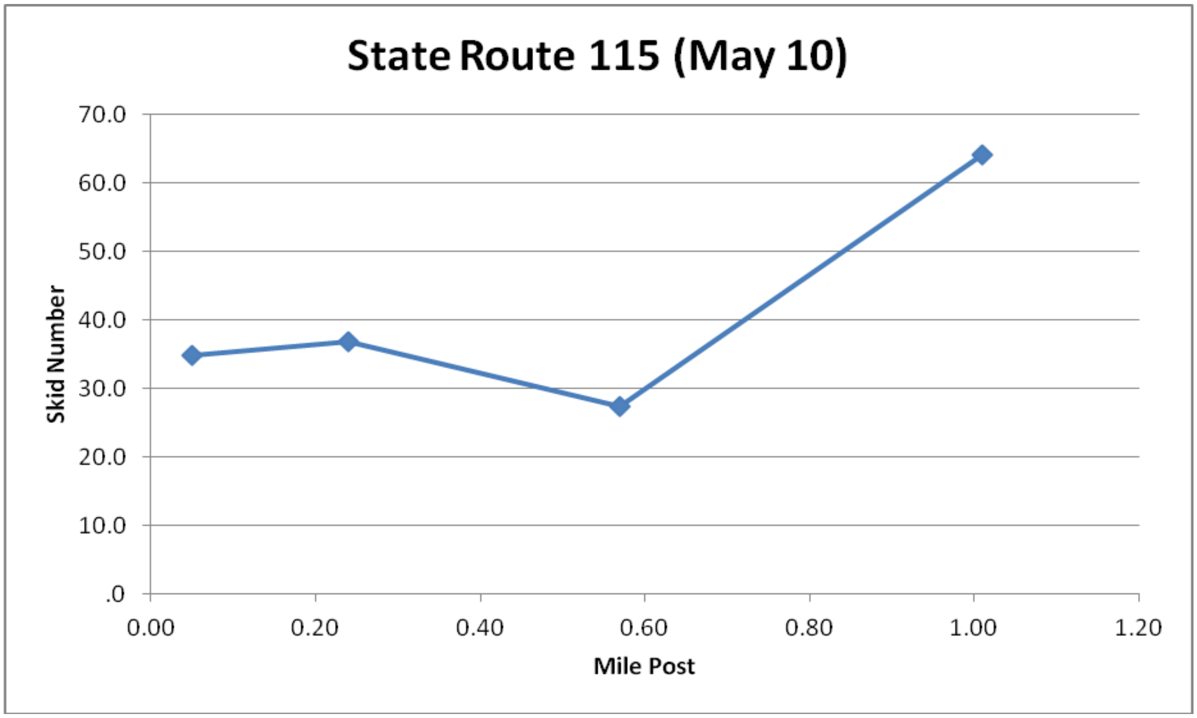


Figure 4.8A – SR 115 Skid Numbers

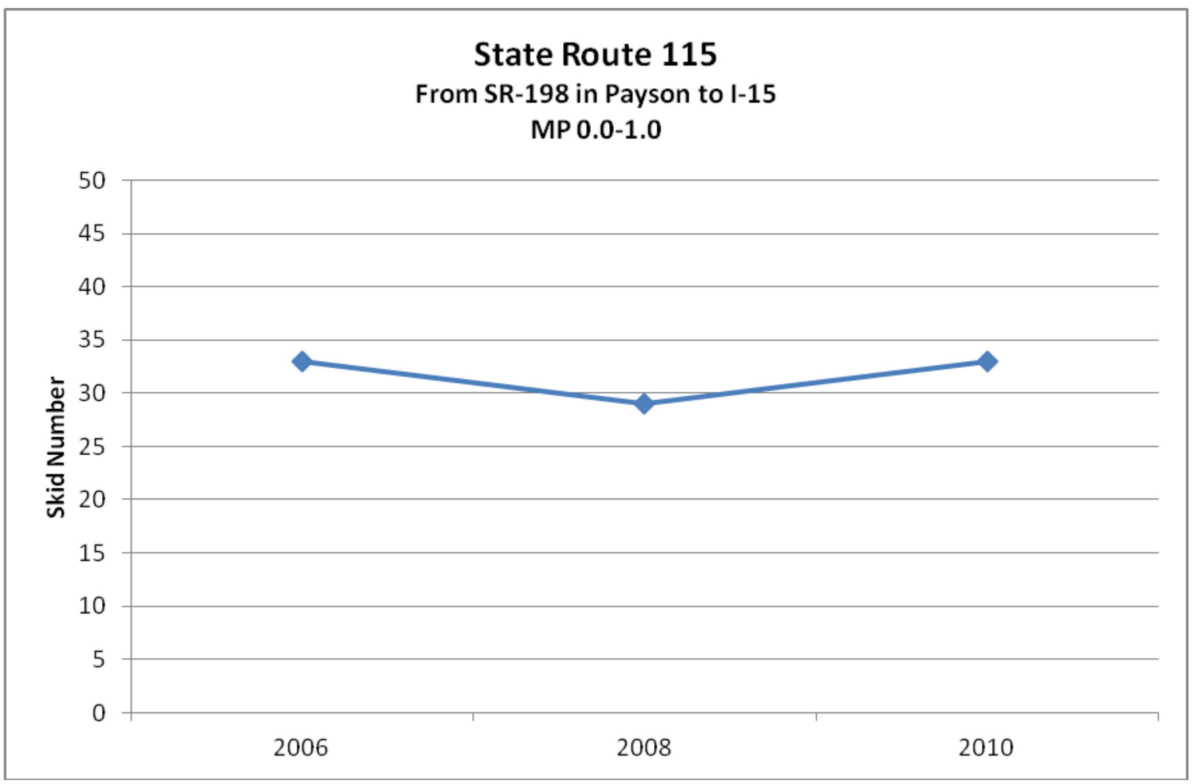


Figure 4.8B – SR 115 Skid Number History

State Route 115 Milepost 0.0 - 1.0								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	11818	33	21	4.9	10	0	2	10%
2007	12103	33	30	6.8	7	0	5	17%
2008	11510	29	20	4.8	5	0	1	5%
2009	10375	29	13	3.4	5	0	4	31%
2010	98550	33	15	0.4	4	0	1	7%
Average	28871	31.4	19.8	4.1	6.2	0	2.6	14%

Table 4.10 – SR 115 Crash History

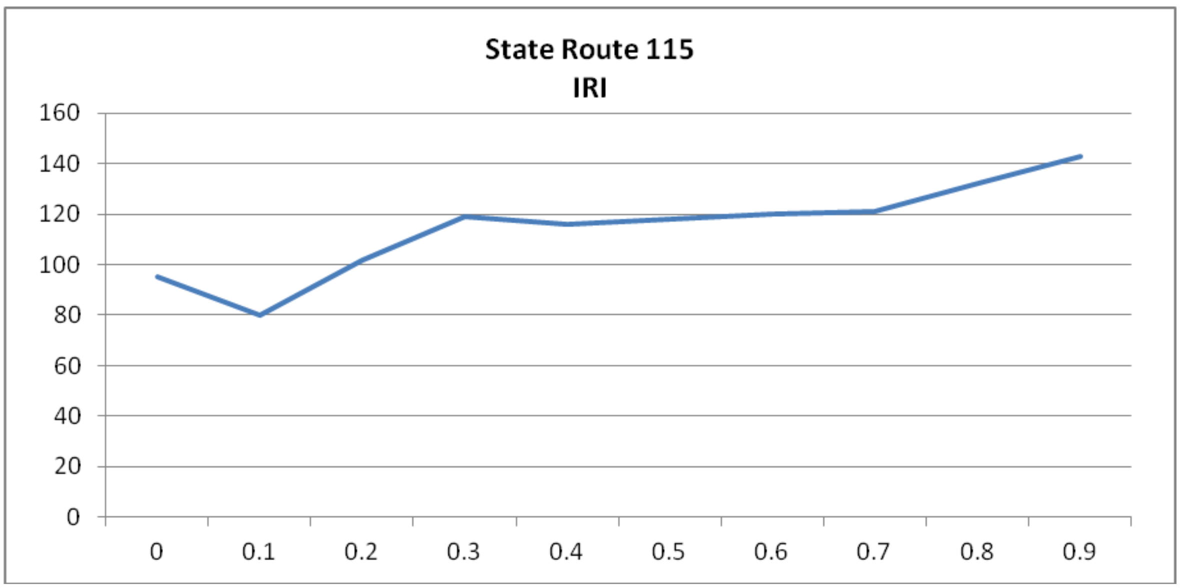


Figure 4.8C – SR 115 Pavement Roughness

Pavement Condition and Safety Analysis:

- This section of SR115 has skid numbers that are below standard from milepost 0.0 to 0.6.
- These levels have been present since 2006.
- The number of crashes remains low even though the skid numbers have been low for some time.
- However the percentage of injury crashes and wet weather crashes is a concern.
- The pavement roughness is “fair”.
- This section has some minor patching and wheel-path cracking.
- The priority of this section is high and should be addressed within the next few years.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

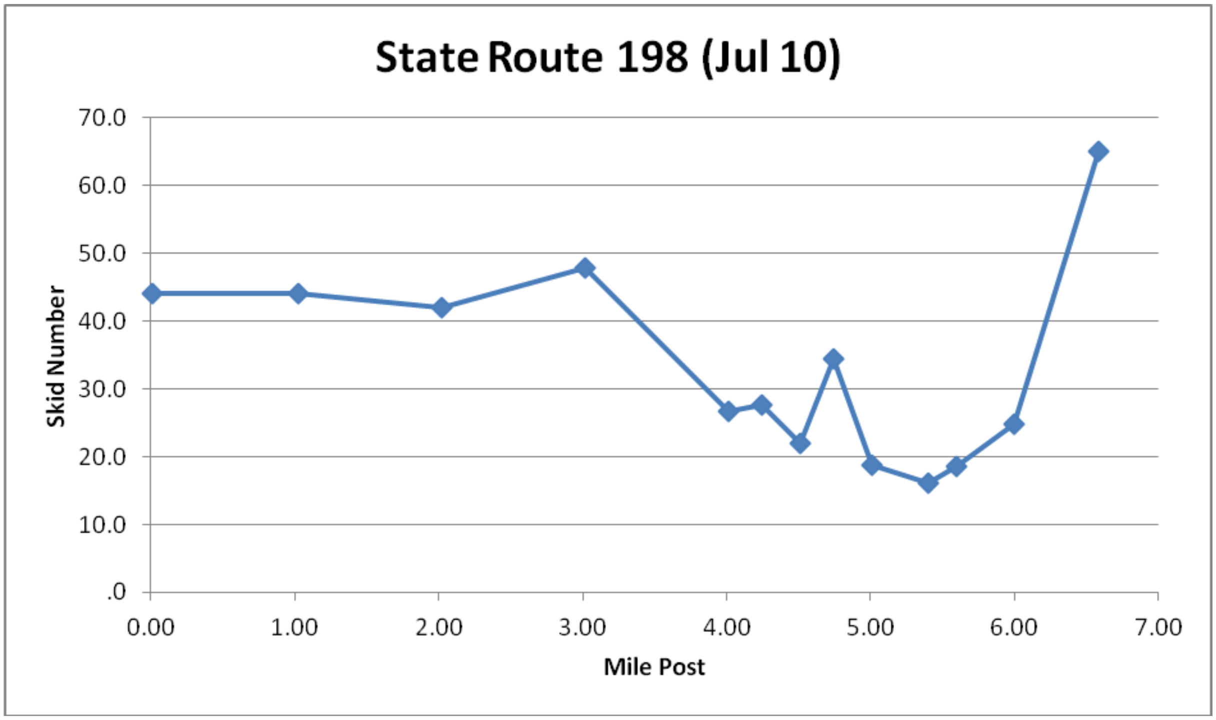


Figure 4.9A – SR 198 Skid Numbers

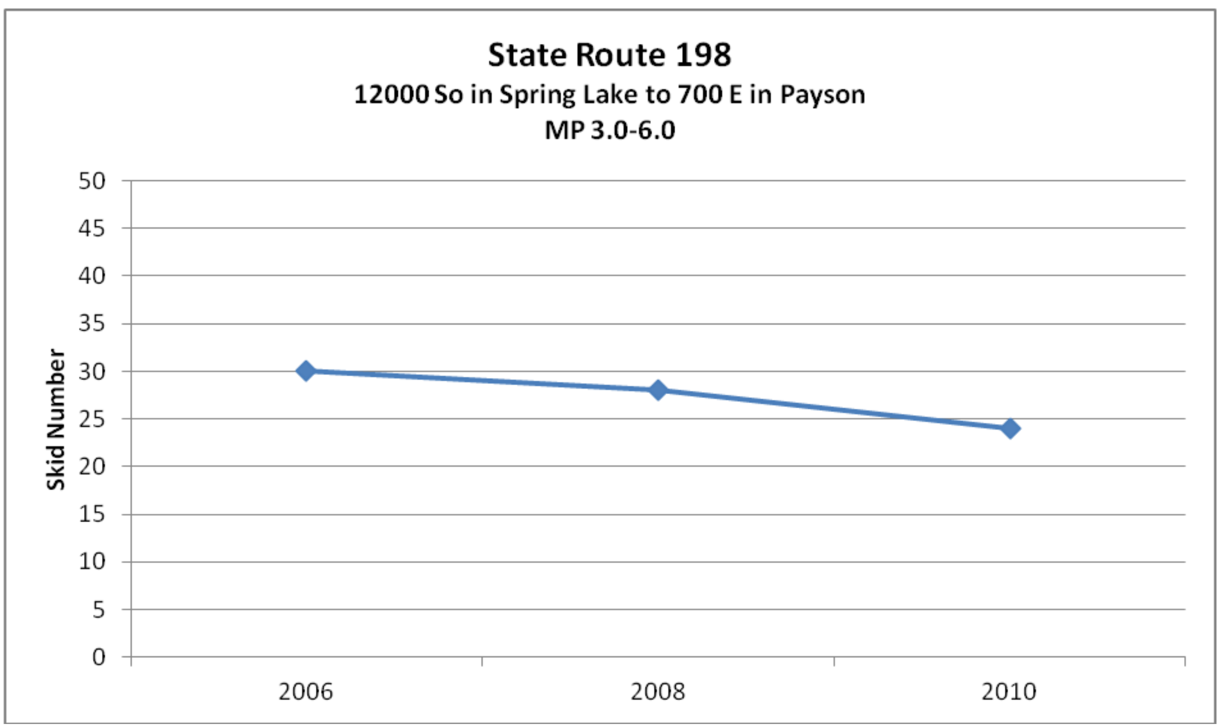


Figure 4.9B – SR 189 Skid Number History

State Route 198 Milepost 3.0 - 6.0								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	13710	30	65	4.3	24	1	11	17%
2007	13900	30	100	6.6	29	0	14	14%
2008	13220	28	72	5.0	25	0	8	11%
2009	12950	28	88	6.2	49	0	18	20%
2010	12510	24	74	5.4	25	0	11	15%
Average	13258	28	79.8	5.5	30.4	0.2	12.4	15%

Table 4.11 – SR 198 Crash History

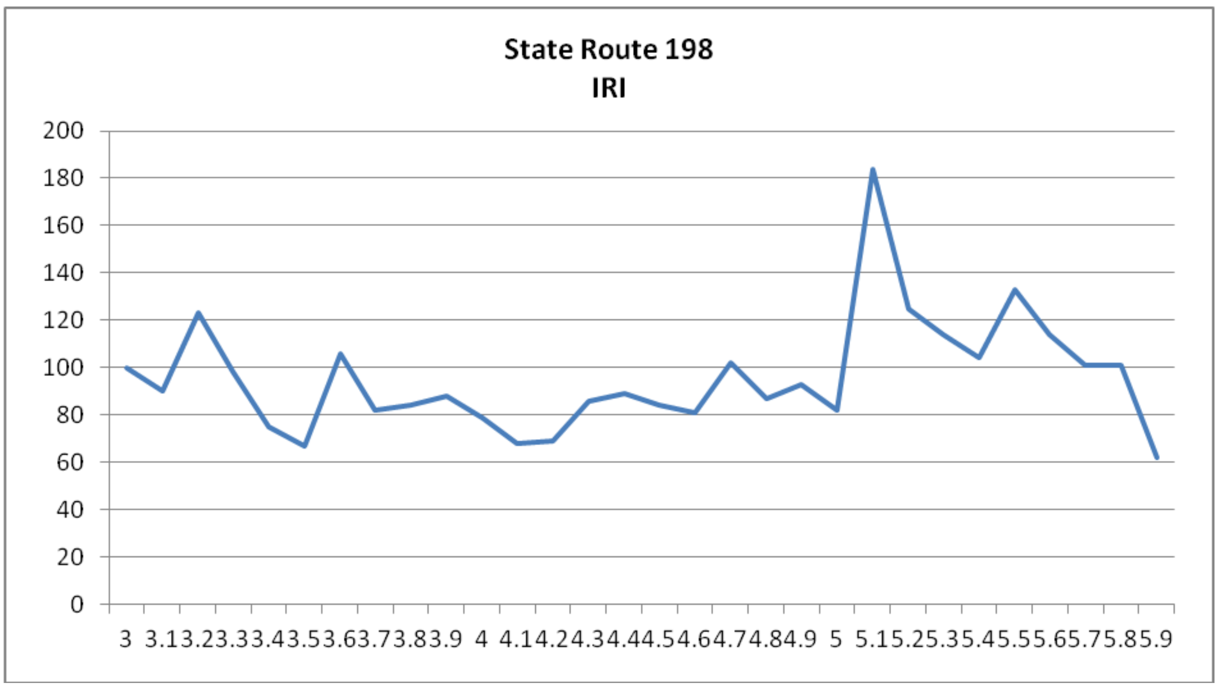


Figure 4.9C – SR 189 Pavement Roughness

Pavement Condition and Safety Analysis:

- This section on SR198 has very low skid numbers from milepost 4 to 6. Some of these areas have skid numbers nearly as low as those measured on ice.
- The skid numbers have been low for a number of years, and have dropped over time.
- The number of crashes and the accident rate are significant.
- The number of crashes with injuries is a concern. One fatality was reported in the last five years.
- The number of wet weather related crashes is substantial.
- There are areas with significant patching on this section.
- This section has excessive wheel-path cracking.
- The priority of this section is very high and should be addressed ASAP.
- A priority swap with another section may be warranted.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Some pavement distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- ASAP/Possibly swap with another section in the rehabilitation program

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

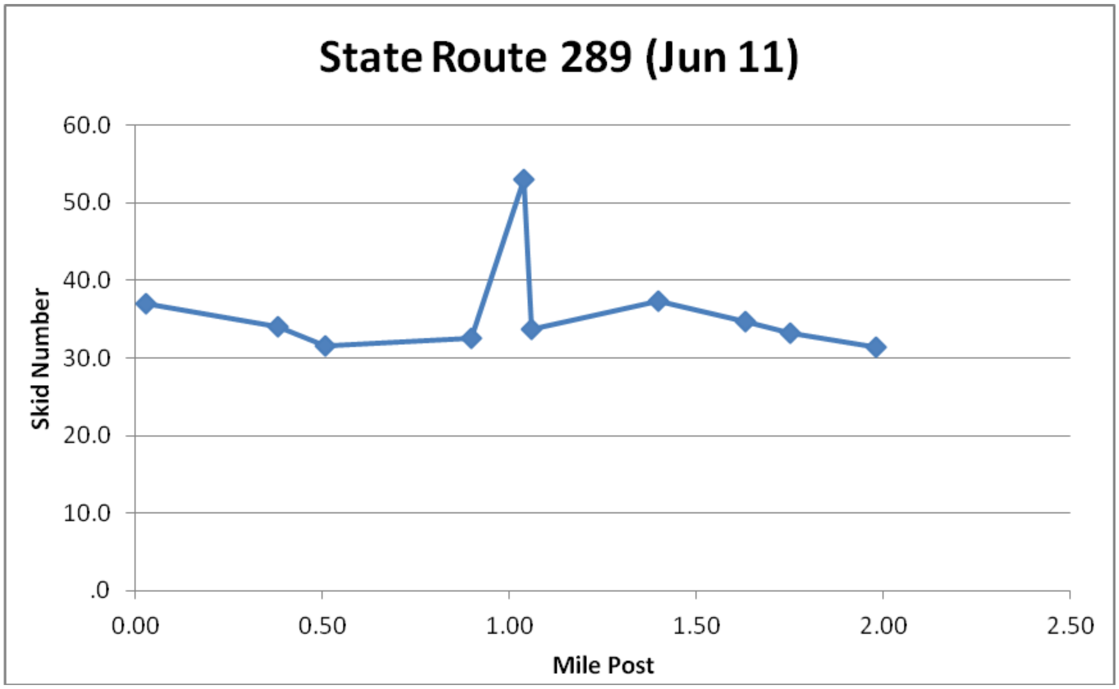


Figure 4.10A – SR 289 Skid Numbers

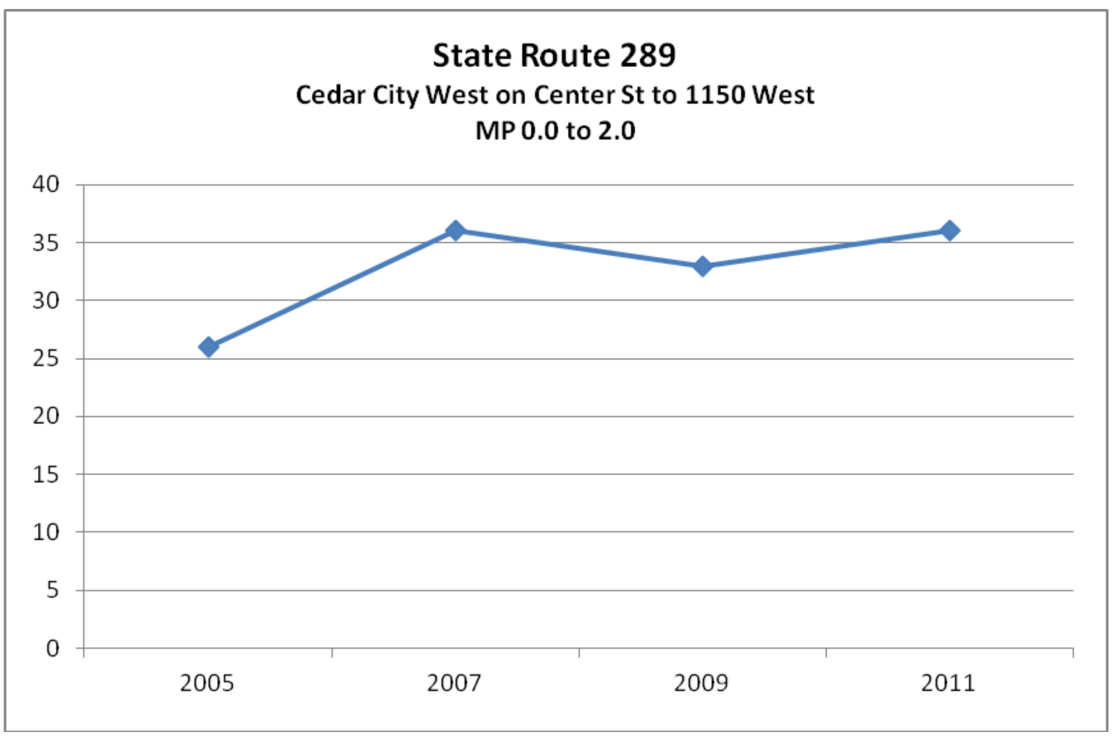


Figure 4.10B – SR 289 Skid Number History

State Route 289 Milepost 0.0 - 2.0								
Year	AADT	Skid No.	Total Crashes	Crash Rate (#/MVMT)	Injury Crashes	Fatal Crashes	Wet Weather Crashes	% Wet Weather Crashes
2006	5415	26	30	7.6	7	0	2	7%
2007	5491	36	42	10.5	8	0	3	7%
2008	5042	36	27	7.3	9	0	1	4%
2009	5010	33	17	4.6	5	0	0	0%
2010	4695	33	20	5.8	7	0	2	10%
Average	5131	32.8	27.2	7.2	7.2	0	1.6	6%

Table 4.12 – SR 289 Crash History

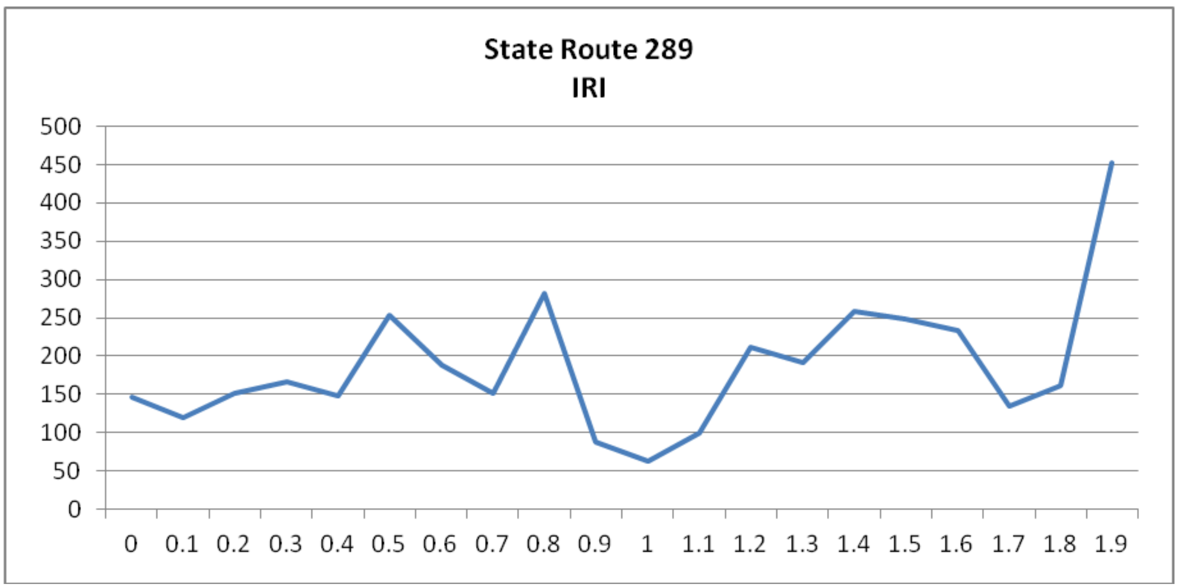


Figure 4.10C – SR 289 Pavement Roughness

Pavement Condition and Safety Analysis:

- Most of this section of SR289 has low skid numbers.
- The skid numbers have been low for a number of years.
- The number of crashes on this section is low, but the crash rate is significant.
- The number of crashes with injuries is a concern.
- The number of wet weather related crashes is not an issue.
- There are some areas with “poor” ride quality.
- The priority of this section is moderate and should be addressed in the next few years.
- “Slippery When Wet” signs should be posted until the work can be done.

Possible Correction Strategies (check all that apply):

- Chip seal/Open-graded surface course
- Some pavement distress correction should be considered prior to resurfacing

Strategy Timing (check one):

- Schedule new surface within 2 or 3 years.

Region Approval and Work Order:

- Recommended strategy:
- Approved timing:

Feedback Information:

- Skid Numbers: Date tested:
- Crashes per Year: Date:

5.0 SEMI-ANNUAL INSPECTION CRASH ANALYSIS PROGRAM

Maintenance forces conduct an inspection of all highway sections on a semi-annual basis. These inspections are used to establish needs for the section and schedule work during the next six to twelve months. This is an ideal time to review the number, type and severity of crashes occurring on the section to aid in strategy selection and programming resources.

Care should be taken to determine if the observed crash clusters exceed what is "expected" for that location and crash type. Clusters naturally occur at intersections and other areas of conflict. Crash cluster areas should be included for action only if they are considered to be significantly above the "expected" level.

Maintenance activities programmed during the semi-annual inspections can result in a significant reduction in the number and severity of crashes in the corridors reviewed. Knowledge that the crashes are occurring is the first step in taking action to reduce any problems or contributing factors at these sites.

The following processes are recommended to provide crash data for use in decision-making at semi-annual inspections:

1. Prepare tables including key crash types that could be related to maintenance activities using the most current crash data over the last 3 to 5 years
2. Distribute the tables for use during semi-annual inspections electronically, in hard copy or in other forms as needed
3. Use surveys on a regular basis to accumulate feedback on the data needed, formats used, and information timing

Some personnel attending semi-annual inspections have utilized crash data in the past. This has been inconsistent around the state, however, and the data distributed at these meetings have often varied from region to region and from one review to the next in crash type and formats used.

5.1 Data Needs

Very specific information is needed for use at semi-annual inspections to select the best strategy for reducing the crashes in a highway corridor. The type of crashes should lead the decision-maker to program activities that will have a direct influence on the numbers and severity of these crashes.

It is tempting to only list problem areas when distributing crash data for use at semi-annual inspections. Similar formats should be used even when the number of crashes is low. This provides consistency to end-users and may be useful where recent activities require feedback on effectiveness.

The following crash types and contributing circumstances are suggested for use at semi-annual inspections:

Crash Type:	**Wild animal/Motor-vehicle crashes**
Probable cause(s):	Deer fence breaches, insufficient escape ramps, new fencing needed, separated grade crossing needed
Crash Type:	**Domestic animal/Motor-vehicle crashes**
Probable cause(s):	Ranch fence breaches, gates left open, open range issues
Crash Type:	**Pedestrian/Motor-vehicle crashes**
Probable cause(s):	Lack of sidewalks, deficient crosswalks, narrow shoulders, significant run-off-the-road accidents, separated grade crossing needed
Crash Type:	**Bicycle/Motor-vehicle crashes**
Probable cause(s):	Narrow shoulders, lack of bicycle lanes, debris on pavement, poor rumble strip location
Crash Type:	**Snow & ice related crashes**
Probable cause(s):	Geometrics such as steep grades, curves, intersections, etc, traffic conflicts, insufficient plow passes related to storm intensity, significant delay after storm onset, inadequate forecasting or RWIS information,

unsuitable material used for conditions, inappropriate strategy used for conditions, transition area between station boundaries

Crash Type: **Wet weather related crashes**

Probable cause(s): Low skid numbers, drainage problems, debris on pavement

Crash Type: **Obscured vision related crashes due to trees and weeds**

Probable cause(s): Lack of tree trimming, lack of weed mowing, inadequate sight distance

Crash Type: **Total crashes, crash rate and severity**

Probable cause(s): Various: Excessive conflicts, sight distance issues, geometric deficiencies, edge drop-off, inadequate signing, poor pavement marking, poor delineators, inadequate sight distance, barrier needs, pavement deficiencies, etc.

In high crash areas care should be taken to ensure that all safety related issues are addressed, such as adherence to the MUTCD, good surface skid resistance, adequate clear zone, visible traffic control devises, functioning barrier systems, etc.

5.2 Seasonal Data Issues

The data included should be appropriate for the upcoming season if possible. The information provided should be timely to allow maintenance forces to respond to the safety issue during the next six month period.

The spring inspection should emphasize information related to issues such as delineation improvements, tree trimming, weed mowing, skid number deficiencies, drainage problems, fence maintenance, etc. Data distributed at the fall inspection should be winter related, such as information associated with snow and ice related crashes.

5.3 Deliverables of the Program

The following should be supplied for use at semi-annual inspections:

- Crash data tables should be distributed for each section of highway
- Maps and bar charts are useful at many locations
- Instructions on how to interpret and utilize the information will be required
- A survey for use in program feedback and enhancement should be distributed

5.4 Stakeholders

The success of this program will require coordination from Area Supervisors, Station Foreman, the Region Maintenance Engineer, the Central Division of Traffic & Safety, and the Region Safety Coordinators. The Crash Studies Engineer will have a key role in supplying the required information.

5.5 Resource Needs

The cost of this program can be maintained at a low level by using standard report software that generates the needed crash data tables from UDOT's crash data system. This software should be managed by the Division of Traffic & Safety.

In this way the needed data can be quickly disseminated to the appropriate personnel in a timely manner for use at the semi-annual inspections. The formats recommended by the region experts should be utilized when possible.

It is estimated that about 60 person-hours will be needed to generate and distribute the needed data tables each year. The annual cost of this program is about $5,000 to $7,000. Some resources may be required initially to draft the software needed to access the crash data file.

5.6 Legal Considerations

It is useful to show that UDOT managers consider and review safety issues on each section of highway every six months. This can have a profound impact during legal challenges where deficiencies in the highway system is claimed to contribute to a severe crash.

For this reason it is recommended that formal notes and action items be recorded at each semi-annual inspection, and a list of who was in attendance. Traffic and Safety personnel should take the lead on this to accumulate the information for future use.

5.7 Program Implementation

UDOT should establish a formal policy to distribute key crash data for use during semi-annual inspections. The lead on this would be best accomplished by experts within the Division of Traffic & Safety. Software will be needed to supply the information to maintenance personnel.

Surveys conducted for the end-users of this program indicate that the information should be distributed in the form of tables showing route and milepost, maps with clusters labeled by crash type, and bar charts identifying crash cluster locations. The uPlan system would be an ideal way to distribute these deliverables for use at the semi-annual inspections.

5.8 Program Feedback

Surveys should be conducted on a regular basis to accumulate feedback on the data needed, which formats should be used, and information timing. The surveys can identify problems with the data that may need attention. Also it will be useful to compile success stories for use by other region personnel.

5.9 Area Supervisor Survey

Feedback on the need and importance of crash data to UDOT's Area Supervisors was accumulated through a survey conducted via email and telephone. Useful information of this issue was compiled and reported as follows:

- All Area Supervisors (16) responded to the survey in support for the use of crash data to fine-tune and enhance specific maintenance programs.
- All but one have used some crash data in the past and find it to be useful.
- About half of the Areas Supervisors believe that a review of selected crash data can reduce the need for some activities based on the lack of safety concerns in some corridors. The others indicated that it may be possible under some circumstances.
- Most Area Supervisors indicated that the use of snow and ice related crash data is an effective way to improve snow removal plans in the regions.
- A majority of the Area Supervisors support a program to analyze sections with low skid numbers using wet weather crashes and other crash data. Some believe that the pavement management personnel in their region should take the lead on this program.
- The most suggested formats for disseminating the data are maps with clusters shown, tables with data by route and milepost, and bar charts showing crash clusters.

The results of the survey concerning the use of crash data by Area Supervisors is shown in Table 5.1.

Table 5.1 Crash Data Use
Area Supervisor Survey Results

Question	Yes	No	Possibly
1- Do you believe that selected crash data can be used to improve the programs that you manage?	16	-0-	-0-
2- Are you currently using crash data to make decisions?	15	1	
3- Do you believe that low numbers of crashes can be used to reduce inspections and/or activities?	8	1	7
4- Do you believe that the location of snow & ice related crash clusters can be used to improve snow removal plans at UDOT?	16	-0-	
5- Do you support the concept of using wet weather related crash data and other crash data to make better decisions on highway sections with low skid numbers?	13	-0-	3
6- Which of the following do you recommend for use in evaluating crash data:			
-Table showing crashes by route and milepost	11		
-Map with locations of crashes	13		
-Bar charts showing cluster locations	5		
-Other (ProjectWise)	1		

The usefulness of the crash types were rated by the Area Supervisors as shown in Table 5.2.

Table 5.2 Data Type Usefulness
Area Supervisor Survey Results

Crash Type	Very Useful	Possibly Useful	Not Useful
Snow & ice related crashes	11	4	1
Wet weather related crashes	8	8	-0-
Wild animal/vehicle collisions	13	3	-0-
Domestic animal/vehicle collisions	10	6	-0-
Obscured vision related crashes	12	4	-0-
Work zone related crashes	14	2	-0-
Accident rate	7	8	1
Fatal crashes	12	4	-0-
Injury crashes	12	4	-0-

Based on the results of the Area Supervisor survey there is positive support for this program. Maintenance personnel utilize crash data on occasion, and would like to see more information available for use.

5.10 Example of Crash Data Sheet

The information shown in Table 5.2 is an example of crash data provided at semi-annual inspections.

Table 5.3 Semi-Annual Inspection Crash Data Sheet

Route	Milepoint	Total Accid	Accident Rate	Injury Accid	Fatal Accid	Wild Animal	Domestic Animal	Ped Accid	Bicycle Accid	Snow & Ice	Percent Snow & Ice	Wet Weather	Percent Wet Weather	Obscured Weeds Trees
084	50.00 - 51.00	37	2.7	5	2	4	0	0	0	18	49 %	3	8 %	0
084	51.00 - 52.00	19	1.3	4	1	0	0	0	0	10	53 %	3	16 %	0
084	52.00 - 53.00	64	4.2	24	0	3	0	0	0	31	48 %	7	11 %	0
084	53.00 - 54.00	30	2.0	8	0	1	2	0	0	15	50 %	7	23 %	0
084	54.00 - 55.00	22	1.4	4	0	7	0	0	0	6	27 %	0	0 %	0
084	55.00 - 56.00	16	1.2	4	0	6	0	0	0	2	13 %	0	0 %	0
084	56.00 - 57.00	3	0.2	1	0	1	0	0	0	1	33 %	0	0 %	0
084	57.00 - 58.00	16	1.2	2	1	1	0	0	0	5	31 %	0	0 %	0
084	58.00 - 59.00	10	0.7	1	0	2	0	0	0	4	40 %	0	0 %	0
084	59.00 - 60.00	11	0.8	0	0	3	0	0	0	2	18 %	1	9 %	0
084	60.00 - 61.00	5	0.4	1	0	2	0	0	0	0	0 %	0	0 %	0
084	61.00 - 62.00	4	0.3	2	0	1	0	0	0	1	25 %	0	0 %	0
084	62.00 - 63.00	5	0.4	3	0	2	0	0	0	0	0 %	0	0 %	0
084	63.00 - 64.00	4	0.3	1	0	0	0	0	0	2	50 %	0	0 %	0
084	64.00 - 65.00	13	1.0	1	0	8	0	0	0	1	8 %	1	8 %	0
084	65.00 - 66.00	12	0.9	2	0	2	2	0	0	3	25 %	1	8 %	0
084	66.00 - 67.00	4	0.4	2	0	1	0	0	0	1	25 %	0	0 %	0
084	67.00 - 68.00	10	0.9	2	0	2	0	0	0	4	40 %	1	10 %	0
084	68.00 - 69.00	19	1.7	3	0	2	0	0	0	13	68 %	2	11 %	0
084	69.00 - 70.00	26	2.3	3	0	0	0	0	0	21	81 %	2	8 %	0
084	70.00 - 71.00	15	1.3	6	1	0	0	0	0	9	60 %	1	7 %	0
084	71.00 - 72.00	13	1.2	5	0	0	0	0	0	6	46 %	2	15 %	0
084	72.00 - 73.00	14	1.3	1	0	1	0	0	0	9	64 %	0	0 %	0

CONFIDENTIAL: This information is protected under 23 USC 409.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The programs proposed in this study address only a small slice of safety issues facing UDOT and ultimately the traveling public. However the effective execution of these programs can prevent a significant number of crashes on Utah's highways. The major conclusions and recommendations from this study are listed as follows:

1- The highway maintenance programs supported by the Utah Department of Transportation have a direct and profound impact on the safety of Utah's highways. These activities include pavement repairs, snow removal, deer fence maintenance, pavement marking replacement, sign maintenance, and many others. There is no doubt that the excellent work by UDOT maintenance forces have prevented countless crashes and saved many lives.

2- Many of the activities conducted by UDOT maintenance personnel can be made more effective and efficient by identifying where certain types of crashes are occurring on Utah highway corridors. This can be achieved by utilizing procedures to identify crash cluster locations for certain types of crashes and executing strategies to reduce these incidents.

3- Feedback on specific actions is very important for each program. Data in the impacted corridors should be reviewed to determine if the action taken has been successful in reducing the number and/or severity of the crashes occurring at the location.

4- All maintenance managers should be made aware of the potential of utilizing crash data and their obligation to apply it to improve decision-making. This objective should be promoted at both the region maintenance and central maintenance levels, and supported by the Division of Traffic and Safety.

5- Keeping formal information related to each program and the actions taken are crucial for dealing with litigation taken against UDOT. All data, recommendations, action items programmed, and feedback information are needed to address legal disputes.

The following conclusions and recommendations are provided related to each of the four programs proposed:

6.1 Snow & Ice Crash Cluster Reduction Program

6- The snow and ice related crashes analyzed in this study indicate that UDOT maintenance forces are performing in a very effective way to minimize these types of crashes. The procedures and policies currently being used in the snow removal plans are successful in most corridors. UDOT has successfully implemented innovative and progressive methods to enhance their snow removal and anti-icing processes.

7- The program outlined in this report to use snow and ice related crashes to enhance snow removal plans should be adopted. Use of this information has been shown to reduce these types of crashes when applied in conjunction with standard snow removal methods and equipment. The estimated cost for this program is $3,000 to $5,000 per year.

6.2 Wild Animal Fence Evaluation Program

8- The wild animal fence evaluation program should be adopted as described in this report. The information shown in Table 3.1 should be developed on a semi-annual basis for use in fence maintenance activities, review of gate violations, placement of new deer escape ramps, and other fence enhancements as needed.

9- The use of carcass removal data managed by Department of Wildland Resources at Utah State University should be used in this program. It is recommended that this group be contracted to publish the information in Table 3.1. Carcass removal information is more accurate in terms of both numbers and locations than the UDOT crash data since formal crash reports are not filed for many wild animal hits. The use of animal species information gathered under this program may also be useful in selecting a more appropriate strategy as well. The annual cost of this program is estimated at $3,000 to $5,000.

6.3 Low Skid Number Correction Program

10- The skid correction program developed in this study should be adopted by UDOT. The steps outlined in Table 4.1 should be formalized and embedded into UDOT's current operations. The estimate cost of the program is $3,000 to $4,000 per site, and $12,000 to $20,000 each year for the program. This program should be managed in-house.

11- UDOT should adopt the "Skid Correction User's Manual" published under this contract as the process used to address pavement sections with unacceptable skid numbers. The manual describes in detail the steps needed to develop a strategy for each section identified, a timetable for each action, and the personnel responsible for each activity.

12- Procedures should be continued for gathering the skid numbers using the Locked-Wheel Trailer to provide accurate data and precise location information. When a skid number below 35 is observed the test vehicle speed should be reduced to 40 mph and tests should be gathered on a 0.2 mile interval. This should be continued until the skid numbers are observed to be above 40.

13- Special skid testing requests should become common at UDOT. A policy should be promoted to encourage managers and experts within the department to request this information when certain conditions are observed as follows: pavement sections experiencing surface bleeding, chip seal failures, and sections with loss of surface texture.

14- Analysis is needed to identify and address sections of highway with significant wet weather crashes. These are sections with more than 30% of the crashes occurring during wet surface conditions. This study should be done annually and is separate from the programs outlined in this report.

6.4 Semi-Annual Inspection Crash Analysis Program Recommendations

15- Surveys indicate that maintenance managers and experts could use certain crash information to aid in decision-making related to the programs that they oversee. A large majority of Area Supervisors support the use of crash data to aid in decision-making.

16- Tables, maps and bar charts containing pertinent crash information should be distributed to the region offices for use at semi-annual inspections. The information disseminated should be pertinent to the type of activities assigned to maintenance personnel as described in this program description. The annual estimated cost of this program is $5,000 to $7,000. The deliverables of this program could be created in-house or outsourced.

17- Reports should be posted from each semi-annual inspection to show that UDOT managers consider and review safety issues on each section of highway every six months. This can have a profound impact during legal challenges where deficiencies in the highway system are claimed to contribute to a severe crash.

7.0 IMPLEMENTATION

The implementation of the programs outlined in this report will require careful but minor changes to UDOT's operations. Each stakeholder must remain in tune with the other key partners to keep the information flowing across division and region lines.

Complexity is the enemy of safety; whether it is too many signs along a route, confusing pavement markings, too much multitasking by drivers behind the wheel, or information overload in manager decision-making. Over complicating decision-making can result in poor decisions, or the lack of any action at all. These programs should be kept as simple as possible while still delivering the needed results. Simplicity will aid in keeping the costs low and effectiveness up.

Each program should be led by a Program Manager. This person will be required to dedicate no more than 2 or 3% of their annual workload to keep the program active. The tasks of each program should be part of the Program Manager's Annual Work Plan.

The following steps should be undertaken to complete the implementation process:

1- A formal presentation should be given to selected UDOT maintenance and safety personnel to fully explain the concepts described in this report and foster an open discussion about their use.

2- A PowerPoint presentation will be delivered to UDOT managers for future use in implementing these concepts, and to aid in training of managers and experts as needed.

3- The crash clusters identified through these programs could be added to each region's safety improvement process. This is currently accomplished through the Highway Safety Improvement Program (HSIP) and the Spot Safety Improvement Program (SSIP). Each region staff is required to prepare a plan to reduce the crashes at these locations.

4- The main goal of the snow and ice cluster reduction program should be to implement a strategy into the snow removal plan for each section to eliminate or reduce the observed cluster. This could be accomplished by including tasks into the performance plan of each of the program stakeholders.

5- The snow and ice related crash clusters could be identified each year by outsourcing the process to a university expert or to a knowledgeable consulting firm. The decisions related to selecting an appropriate strategy should be completed in-house with UDOT oversight.

6- A “Wild Animal Fence Evaluation Maintenance Activity Standard” should be drafted and approved using the tasks outlined in this report. This will ensure that the process will receive formal deliverables within UDOT guidelines, and that the tasks and goals will be included in the performance plans of maintenance personnel.

7- The “Skid Correction User’s Manual” is a useful tool in the implementation process for this program. It should be adopted as the guidelines used in the program.

8- The tasks outlined in the skid correction process should be entered into the performance plans of the key stakeholders listed in the process. This includes the Pavement Condition Engineer in the Planning Statistics Section, the Crash Studies Engineer in the Traffic and Safety Division, Region Operations Engineer, the Region Materials Engineer, and the Region Traffic and Safety Engineer.

9- UDOT should distribute key crash data for use during semi-annual inspections. This could be best accomplished by experts within the Division of Traffic & Safety. Software to create annual reports should be generated to supply the information to maintenance personnel.

10- Personnel within UDOT that are involved with litigation against the department should be trained on how to access the information delivered by these programs. The data along with the actions taken can be very useful in showing that UDOT managers responded appropriately to safety issues.

11- Top management personnel should take the lead on ensuring that information is acquired at semi-annual inspections are filed for use in legal challenges against the department.

REFERENCES

1- Kononov, J., & Allery, B. (2007). Level of Service of Safety: Conceptual Blueprint and Analytical Framework. *Transportation Research Record* , 57-66

2- Highway Safety Improvement Program Manual, (2011), UDOT

3- Spot Safety Improvement Program Manual, (2011), UDOT

4- Cramer, Patricia, (2012). USU Ecologist Leading Efforts to Stop Wildlife-Vehicle Collisions

5- Anderson, Douglas I., P.E., (2012) Skid Correction User's Manual

6- Kuttesch, J.S., (2005) Qualifying the Relationship between Skid Resistance and Wet Weather Accidents for Virginia Data, Virginia Department of Transportation

Appendix A

Maintenance Safety Program Templates

Figure A1- Snow & Ice Crash Cluster Reduction

-Template-

Section Information:

Route No._____ [and Route No. _______ if at intersection]

Milepoint____________ to____________ [Milepoint____________ to____________]

Region _______ Station No.___________

Snow & ice related crashes:

Single vehicle_________%

Multiple vehicle_______%

Average per year	Year	
	2011	_______
	2010	_______
	2009	_______
	2008	_______
	2007	_______

Severity of snow & ice related crashes:

01_____	_______%
02_____	_______%
03_____	_______%
04_____	_______%
05_____	_______%

Intersection information (if applicable):

Leg A_________

Leg B_________

Leg C_________

Leg D_________

Possible Correction Strategies:

Snow & ice related crash clusters may be reduced through one or a combination of the following steps:

- Increase the frequency of plow passes related to storm intensity
- Reduce delays after storm onset
- Improve forecasting, now-casting or RWIS information
- Modify the material used for conditions
- Modify the strategy used for conditions
- Improve transition areas between station boundaries

Other factors may be contributing to the snow and ice related crashes such as:

- Geometrics such as steep grades, curves, intersections, etc
- Congested areas
- Sections with traffic conflicts, such as driveways or turning movements
- Traffic generators such as schools, taverns, senior centers, malls, etc
- Areas where drivers tend to speed due to or travel faster than conditions would allow

Note: Care should be taken to determine if the observed snow and ice related crash clusters are at acceptable levels or are higher than expected. High traffic areas and/or intersections may result in significant numbers of observed accidents but are at levels that would be considered normal.

Figure A2- Wild Animal Fence Inspection

-Template-

Section Information:

Route No._____ Region _______Station No.___________

Milepoint____________to____________

Average wild animal related crashes:

2011 _______

2010 _______

2009 _______

2008 _______

2007 _______

Severity of wild animal related crashes:

01_____ _______%

02_____ _______%

03_____ _______%

04_____ _______%

05_____ _______%

Bar chart:

Figure A3- Low Skid Correction Program

-Template-

Section Information:

Route No.____________ Region _______Station No.___________

Milepoint____________to____________

Skid Number History:

Year	Average	Minimum
2011	_______	_______
2010	_______	_______
2009	_______	_______
2008	_______	_______
2007	_______	_______

Skid Number Graph:

Crash History:

Average crashes per year	_______	Average wet weather	_______	_______%
2011	_______		_______	
2010	_______		_______	
2009	_______		_______	
2008	_______		_______	
2007	_______		_______	
Accident Rate	_______	Expected AR	_______	

Crashes per Year Graph:

Severity of crashes:

	01_____	_______%
	02_____	_______%
	03_____	_______%
	04_____	_______%
	05_____	_______%

Possible Correction Strategies (check all that apply):

- Post "Slippery When Wet" signs
- Chip seal
- Open-graded surface course
- Plant mix seal coat
- Overlay
- Treat with blotter sand to correct rejuvenator or flush seal
- Mill surface to correct bleeding
- Diamond grinding (concrete)

Strategy Timing (check one):

- ASAP
- Swap with another section
- Next Rehab Cycle

Region Approval and Work Order:

Recommended strategy:

Approved timing:

Feedback Information:

Skid Numbers: Date tested:

Crashes per Year: Date:

Appendix B

Snow & Ice Related Crashes

Statistical Analysis and Section List

Tables B1, B2, B3 and B4 have been constructed for freeway and non-freeway routes. They list the route, starting and ending mileposts, crash counts, predicted mean, standard deviation, and mean plus one and a half standard deviation. Locations that fell into this category but had a crash count of 3 or less were not included due to the low crash observations.

Bar charts are also provided to illustrate the snow and ice related crashes occurring in these sections and their magnitude relative to the areas nearby.

Table B1- Freeway Snow & Ice Crash Data Statistics

Freeway Negative Binomial						
Number of Observations = 955						
LR Chi2(7) = 669.49						
Prob > Chi2 = 0.0000						
Pseudo R2 = 0.1451						
Dispersion = Mean						
Log Likelihood = -1973.2301						
Variable	**Coefficient**	**Std. Error**	**z**	**P>|z|**	**[95% Confidence Interval]**	
LN_AADT	0.9628043	0.059127	16.28	0.000	0.8469181	1.07869
Rural	-0.3483408	0.130529	-2.67	0.008	-0.6041735	-0.092508
Constant	-8.200475	0.666259	-13.3	0.000	-9.506318	-6.894631
LN_LEN	1 (Offset)					
Alpha	0.7378755	0.06294			0.6242764	0.8721461

Note- Road segments with 3 or less crashes that were 1.5 standard deviations above the expected mean were not considered for improvements due to the low crash observations.

Table B2- Snow & Ice Crash Freeway Section Analysis

Site Number	Route	Start_MP	End_MP	AADT	Crash_Count	Mean	STD	Mean+1.5STD
1	15	29	30	21472	7	2.03	2.76	6.17
2	15	37	38	20823	7	1.97	2.69	6.01
3	15	42	43	20995	8	1.99	2.71	6.05
4	15	44	45	21195	7	2.01	2.73	6.10
5	15	46	47	21195	7	2.01	2.73	6.10
6	15	47	48	21195	9	2.01	2.73	6.10
7	15	50	51	21195	7	2.01	2.73	6.10
8	15	93	94	16327	6	1.57	2.22	4.91
9	15	124	125	16302	10	1.57	2.22	4.90
10	15	125	126	16302	11	1.57	2.22	4.90
11	15	134	135	12470	4	1.23	1.81	3.94
12	15	135	136	11483	5	1.14	1.70	3.68
13	15	140	141	11488	8	1.14	1.70	3.68
14	15	141	142	11488	6	1.14	1.70	3.68
15	15	216	217	13655	6	1.33	1.93	4.24
16	15	217	218	13655	7	1.33	1.93	4.24
17	15	219	220	13655	6	1.33	1.93	4.24
18	15	221	222	13655	5	1.33	1.93	4.24
19	15	225	226	15628	9	1.51	2.15	4.73
20	15	242	243	26418	8	2.46	3.27	7.36
21	15	244	245	26728	8	2.49	3.30	7.43
22	15	250	251	35078	12	3.20	4.13	9.40
23	15	255	256	47173	14	4.21	5.32	12.19
24	15	257	258	47173	32	4.21	5.32	12.19
25	15	259	260	79035	20	6.80	8.34	19.31
26	15	291	292	132795	33	11.01	13.24	30.87
27	15	293	294	142223	34	11.73	14.08	32.86
28	15	297	298	196465	62	15.84	18.86	44.13
29	15	299	300	170673	52	13.90	16.60	38.80
30	15	300	301	170673	57	13.90	16.60	38.80
31	15	306	307	226828	53	18.10	21.49	50.34
32	15	308	309	125773	30	10.47	12.61	29.39
33	15	324	325	126997	32	10.56	12.72	29.65
34	15	329	330	105233	27	8.87	10.75	25.00
35	15	332	333	91018	23	7.75	9.45	21.93
36	15	333	334	94895	26	8.06	9.80	22.77
37	15	334	335	94895	28	8.06	9.80	22.77
38	15	335	336	104752	32	8.84	10.71	24.90
39	15	338	339	101520	43	8.58	10.41	24.20

Site Number	Route	Start_MP	End_MP	AADT	Crash_Count	Mean	STD	Mean+1.5STD
40	15	339	340	89917	32	7.67	9.35	21.69
41	15	343	344	84270	24	7.22	8.82	20.46
42	15	349	350	49148	24	4.38	5.51	12.64
43	15	353	354	42195	13	3.80	4.83	11.05
44	15	354	355	42195	17	3.80	4.83	11.05
45	15	355	356	42195	13	3.80	4.83	11.05
46	15	387	388	9830	5	0.98	1.51	3.25
47	15	390	391	9830	4	0.98	1.51	3.25
48	70	6	7	5385	9	0.56	1.00	2.06
49	70	7	8	5385	4	0.56	1.00	2.06
50	70	11	12	5378	5	0.56	0.99	2.05
51	70	12	13	5378	5	0.56	0.99	2.05
52	70	23	24	5390	4	0.56	1.00	2.06
53	70	35	36	7498	4	0.76	1.25	2.64
54	70	68	69	8588	9	0.87	1.37	2.93
55	70	81	82	6188	6	0.64	1.09	2.28
56	70	83	84	6188	7	0.64	1.09	2.28
57	70	84	85	6188	7	0.64	1.09	2.28
58	70	85	86	6188	7	0.64	1.09	2.28
59	70	141	142	4398	7	0.47	0.87	1.77
60	80	95	96	13828	5	1.35	1.95	4.28
61	80	98	99	13828	16	1.35	1.95	4.28
62	80	101	102	34355	16	3.14	4.06	9.23
63	80	106	107	21275	8	2.01	2.74	6.12
64	80	108	109	21275	7	2.01	2.74	6.12
65	80	111	112	21275	12	2.01	2.74	6.12
66	80	114	115	39625	14	3.58	4.58	10.46
67	80	115	116	55193	24	4.87	6.09	14.01
68	80	116	117	57840	19	5.09	6.34	14.60
69	80	118	119	57843	15	5.09	6.34	14.61
70	80	122	123	57843	33	5.09	6.34	14.61
71	80	127	128	33700	18	3.08	4.00	9.08
72	80	133	134	47995	14	4.28	5.40	12.38
73	80	139	140	45963	14	4.11	5.20	11.91
74	80	148	149	15507	7	1.50	2.13	4.70
75	80	149	150	15507	12	1.50	2.13	4.70
76	80	150	151	15507	8	1.50	2.13	4.70
77	80	151	152	15358	5	1.49	2.12	4.66
78	80	191	192	13205	5	1.29	1.89	4.12
79	84	22	23	8185	7	0.83	1.33	2.82

Site Number	Route	Start_MP	End_MP	AADT	Crash_Count	Mean	STD	Mean+1.5STD
80	84	28	29	8102	5	0.82	1.32	2.80
81	84	30	31	8102	4	0.82	1.32	2.80
82	84	81	82	10152	9	1.01	1.55	3.34
83	84	87	88	14513	5	1.41	2.03	4.45
84	84	89	90	15082	16	1.46	2.09	4.59
85	84	90	91	15082	14	1.46	2.09	4.59
86	84	91	92	15082	11	1.46	2.09	4.59
87	84	104	105	9708	6	0.97	1.50	3.22
88	84	106	107	9708	4	0.97	1.50	3.22
89	84	107	108	10052	25	1.00	1.54	3.31
90	84	108	109	10052	6	1.00	1.54	3.31
91	84	109	110	9890	9	0.99	1.52	3.27
92	84	111	112	9890	6	0.99	1.52	3.27
93	201	1	2	14197	6	1.38	1.99	4.37
94	201	3	4	13770	5	1.34	1.95	4.27
95	201	5	6	14802	5	1.44	2.06	4.52
96	201	16	17	85318	23	7.30	8.92	20.69
97	215	0	1	16345	17	1.58	2.22	4.91
98	215	6	7	65388	32	5.71	7.06	16.29
99	215	7	8	66718	18	5.81	7.18	16.59
100	215	13	14	104022	27	8.78	10.64	24.74
101	215	17	18	100970	33	8.54	10.36	24.08
102	215	19	20	94920	24	8.06	9.81	22.77
103	215	20	21	73603	20	6.37	7.83	18.11
104	215	21	22	72680	35	6.29	7.74	17.91
105	215	22	23	72680	33	6.29	7.74	17.91
106	215	23	24	59905	16	5.26	6.54	15.07

Table B3- Non-Freeway Snow & Ice Crash Data Statistics

Non-Freeway Negative Binomial						
Number of Observations = 3556						
LR Chi2(7) = 682.02						
Prob > Chi2 = 0.0000						
Pseudo R2 = 0.0815						
Dispersion = Mean						
Log Likelihood = -3844.1718						
Variable	**Coefficient**	**Std. Error**	**z**	**P>|z|**	**[95% Confidence Interval]**	
LN_AADT	0.7161285	0.0277539	25.80	0.000	0.6617319	0.7705252
Constant	-6.268237	0.2365585	-26.50	0.000	-6.731883	-5.804591
LN_LEN	1 (Offset)					
Alpha	2.17468	0.1140176			1.962309	2.410036

Note- The rows highlighted in red are locations where there were problems with the crash data. The row highlighted in green may or may not have problems in the crash data (all the crashes are at milepost 0.00).

CONFIDENTIAL: This information is protected under 23 USC 409.

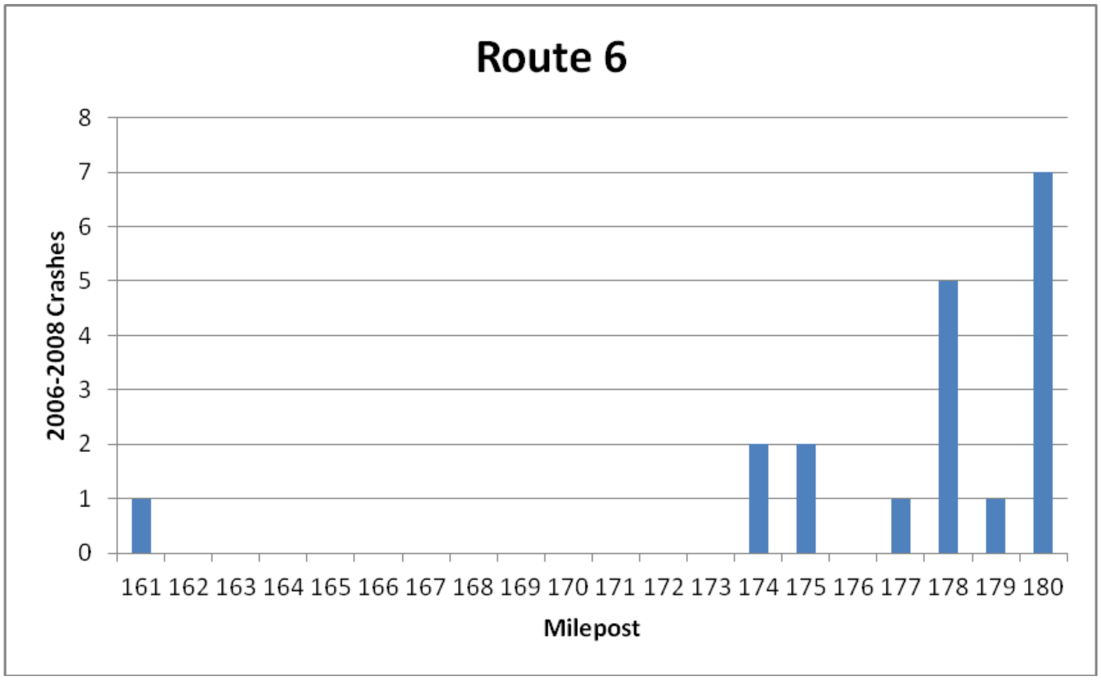
Table B4- Snow & Ice Crash Non-Freeway Section Analysis

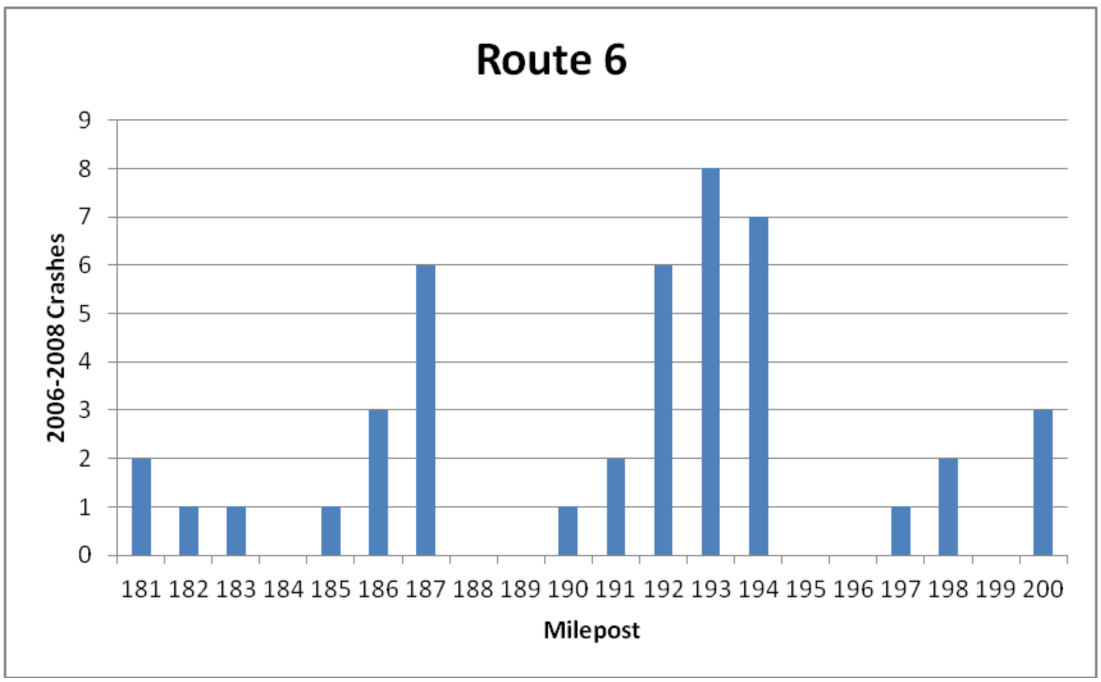
Site Number	Route	Start_MP	End_MP	AADT	Crash_Count	Mean	STD	Mean+1.5STD
1	6	177	178	13445	5	1.72	1.75	4.34
2	6	179	180	9358	7	1.32	1.46	3.51
3	6	186	187	9358	6	1.32	1.46	3.51
4	6	191	192	6937	6	1.07	1.26	2.96
5	6	192	193	6937	8	1.07	1.26	2.96
6	6	193	194	6937	7	1.07	1.26	2.96
7	6	203	204	6747	4	1.05	1.25	2.91
8	6	206	207	6747	4	1.05	1.25	2.91
9	6	208	209	6747	4	1.05	1.25	2.91
10	6	210	211	6747	8	1.05	1.25	2.91
11	6	211	212	6723	6	1.04	1.24	2.91
12	6	222	223	6333	5	1.00	1.21	2.81
13	10	6	7	1288	6	0.32	0.61	1.23
14	26	0	1	28663	7	2.95	2.64	6.90
15	26	1	2	35003	9	3.40	2.95	7.84
16	30	102	103	6658	4	1.04	1.24	2.89
17	37	11	12	6945	4	1.07	1.26	2.96
18	39	4	5	16225	6	1.96	1.93	4.86
19	39	9	10	8045	5	1.19	1.35	3.22
20	40	0	1	24655	9	2.65	2.42	6.28
21	40	3	4	24605	11	2.64	2.42	6.27
22	40	4	5	24605	13	2.64	2.42	6.27
23	40	5	6	19807	6	2.26	2.15	5.49
24	40	6	7	19807	13	2.26	2.15	5.49
25	40	7	8	19807	8	2.26	2.15	5.49
26	40	9	10	18355	7	2.14	2.06	5.24
27	40	10	11	18355	14	2.14	2.06	5.24
28	40	11	12	18355	10	2.14	2.06	5.24
29	40	32	33	4472	4	0.78	1.03	2.32
30	40	33	34	4472	5	0.78	1.03	2.32
31	40	35	36	4472	4	0.78	1.03	2.32
32	40	51	52	4122	4	0.74	0.99	2.22
33	40	95	96	5245	5	0.87	1.11	2.53
34	40	138	139	6793	4	1.05	1.25	2.93
35	40	139	140	6793	6	1.05	1.25	2.93
36	48	6	7	4903	4	0.83	1.07	2.44
37	51	0	1	6822	5	1.06	1.25	2.93

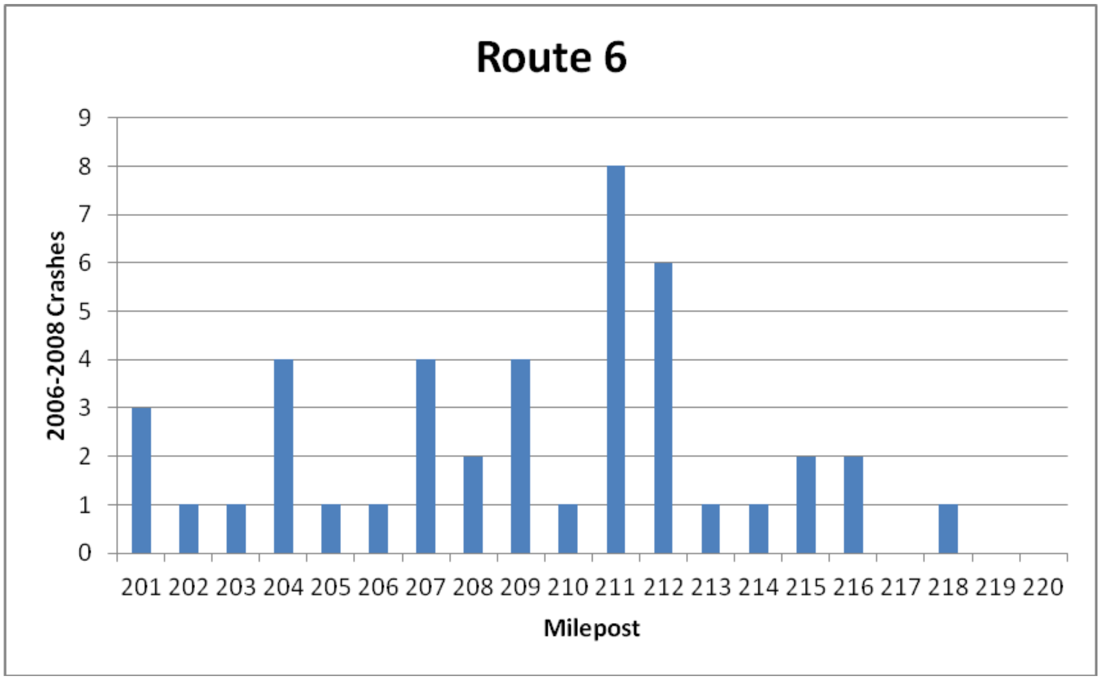
38	68	35	36	15588	7	1.91	1.89	4.74
39	68	45	46	18170	7	2.13	2.05	5.21
40	68	48	49	28833	7	2.96	2.65	6.93
41	68	49	50	36497	9	3.51	3.03	8.05
42	75	0	1	11785	6	1.56	1.64	4.02
43	77	7	8	5198	7	0.87	1.10	2.52
44	77	8	9	19742	12	2.26	2.15	5.48
45	89	0	1	3360	130	0.64	0.91	1.99
46	89	97	98	1442	5	0.35	0.63	1.30
47	89	99	100	1442	6	0.35	0.63	1.30
48	89	102	103	1442	4	0.35	0.63	1.30
49	89	336	337	30988	10	3.12	2.76	7.25
50	89	338	339	40822	10	3.80	3.23	8.65
51	89	370	371	36558	9	3.51	3.03	8.06
52	89	395	396	17183	9	2.04	1.99	5.03
53	89	406	407	49315	26	4.35	3.61	9.77
54	89	407	408	39142	11	3.69	3.15	8.42
55	89	411	412	22333	6	2.47	2.29	5.91
56	89	476	477	5690	7	0.93	1.15	2.65
57	89	486	487	2843	5	0.56	0.84	1.83
58	89	492	493	1920	5	0.43	0.71	1.50
59	91	5	6	16862	9	2.02	1.97	4.97
60	91	10	11	15278	9	1.88	1.87	4.69
61	91	11	12	15278	11	1.88	1.87	4.69
62	91	12	13	15278	5	1.88	1.87	4.69
63	91	13	14	15278	8	1.88	1.87	4.69
64	91	14	15	15278	10	1.88	1.87	4.69
65	91	27	28	39630	9	3.72	3.18	8.48
66	92	0	1	20482	6	2.32	2.19	5.60
67	92	2	3	18897	7	2.19	2.10	5.33
68	96	0	1	427	8	0.14	0.39	0.73
69	99	0	1	4618	127	0.80	1.04	2.36
70	101	5	6	3392	5	0.64	0.91	2.00
71	111	4	5	7460	7	1.12	1.31	3.08
72	111	5	6	7460	4	1.12	1.31	3.08
73	114	3	4	10495	4	1.44	1.54	3.75
74	130	1	2	13650	6	1.73	1.77	4.38
75	132	36	37	4090	4	0.73	0.99	2.21
76	132	39	40	4090	4	0.73	0.99	2.21
77	132	40	41	3268	4	0.62	0.90	1.97
78	154	8	9	32478	26	3.23	2.83	7.47

79	154	9	10	38163	23	3.62	3.11	8.28
80	154	10	11	38995	11	3.68	3.15	8.40
81	154	13	14	47595	10	4.24	3.54	9.55
82	154	22	23	33082	12	3.27	2.86	7.56
83	154	23	24	33077	8	3.27	2.86	7.56
84	158	3	4	6205	4	0.99	1.20	2.78
85	165	10	11	17915	7	2.11	2.04	5.16
86	171	3	4	15657	5	1.91	1.90	4.76
87	189	3	4	34435	10	3.36	2.93	7.75
88	189	8	9	16477	16	1.98	1.95	4.91
89	189	9	10	16477	10	1.98	1.95	4.91
90	189	10	11	16477	18	1.98	1.95	4.91
91	189	11	12	16477	20	1.98	1.95	4.91
92	189	12	13	12340	29	1.61	1.68	4.13
93	189	13	14	12340	34	1.61	1.68	4.13
94	189	14	15	12340	22	1.61	1.68	4.13
95	189	15	16	9727	12	1.36	1.49	3.59
96	189	17	18	9727	6	1.36	1.49	3.59
97	189	18	19	9727	5	1.36	1.49	3.59
98	189	24	25	9872	5	1.37	1.50	3.62
99	190	3	4	4288	5	0.76	1.01	2.27
100	190	4	5	4288	29	0.76	1.01	2.27
101	190	6	7	2792	17	0.56	0.84	1.81
102	193	0	1	22185	10	2.46	2.29	5.88
103	210	4	5	5500	7	0.90	1.13	2.60
104	210	7	8	5500	5	0.90	1.13	2.60
105	210	8	9	5500	5	0.90	1.13	2.60
106	222	0	1	3270	4	0.62	0.90	1.97
107	224	4	5	2925	7	0.58	0.85	1.85
108	224	5	6	22655	8	2.49	2.31	5.96
109	224	8	9	27707	9	2.88	2.59	6.76
110	235	0	1	25753	7	2.73	2.48	6.46
111	248	4	5	9205	8	1.31	1.45	3.48
112	248	5	6	5893	4	0.95	1.17	2.70
113	248	7	8	5893	5	0.95	1.17	2.70
114	273	1	2	15963	8	1.94	1.92	4.81
115	273	2	3	15963	6	1.94	1.92	4.81
116	289	1	1.92	4880	5	0.83	1.07	2.44

Snow & Ice Related Crash Bar Charts



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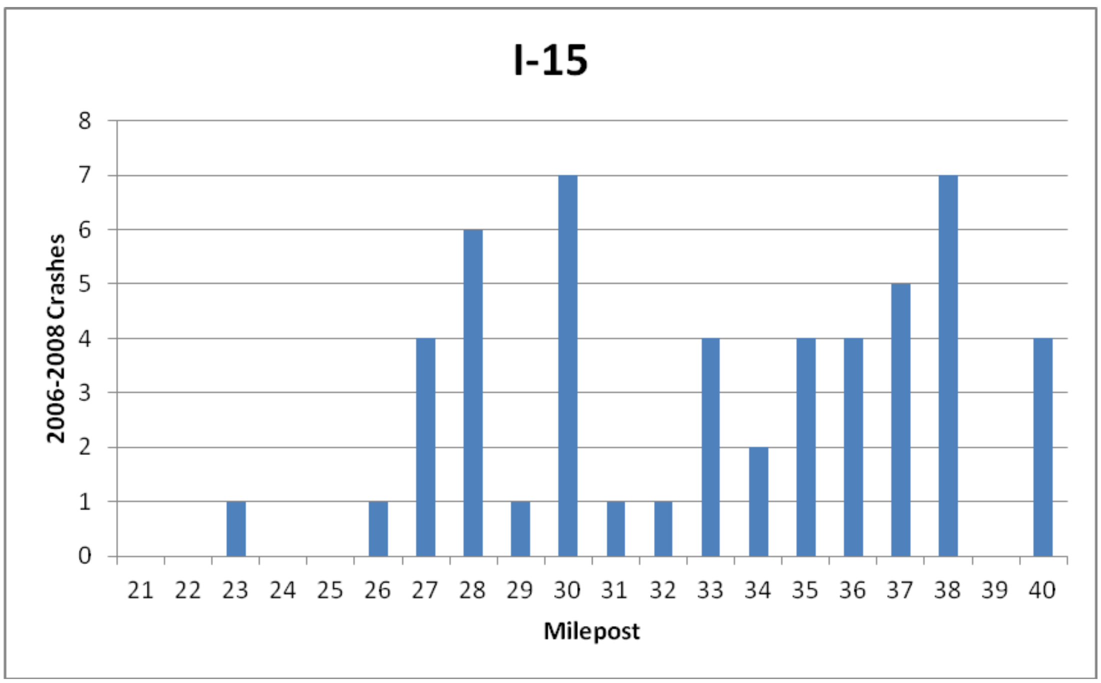
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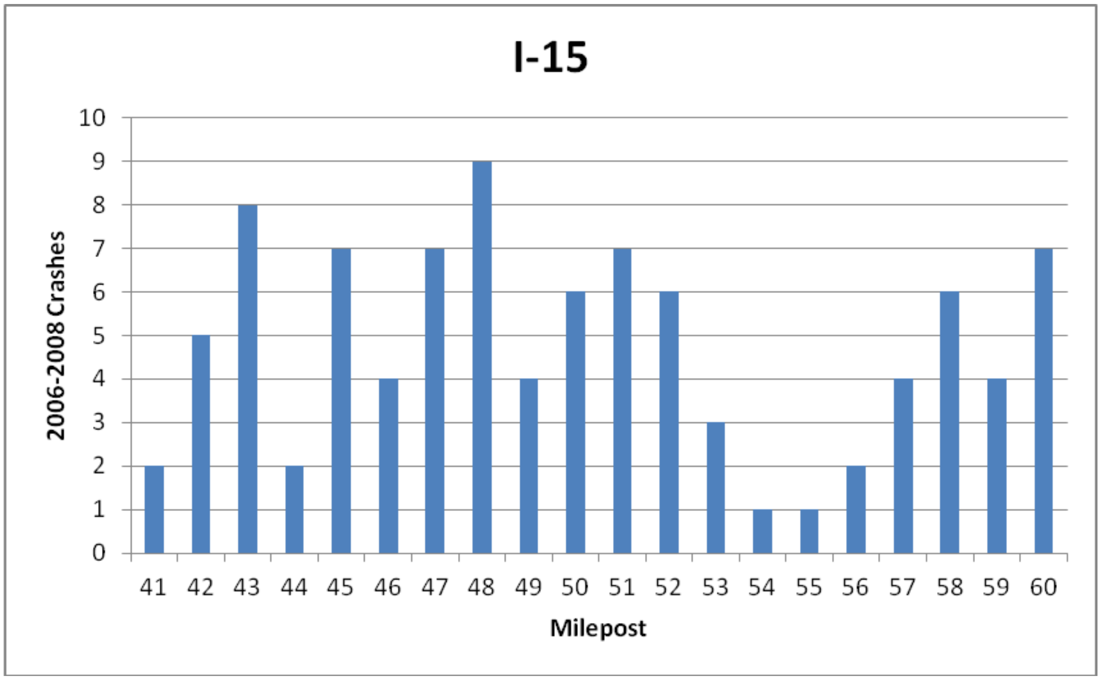
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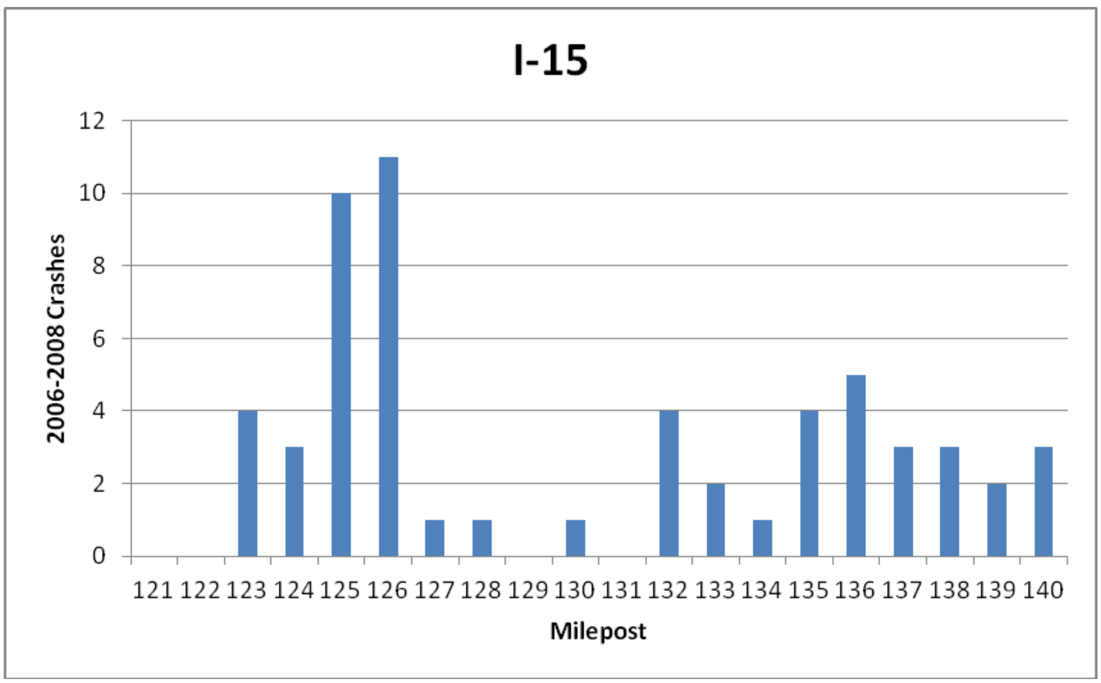
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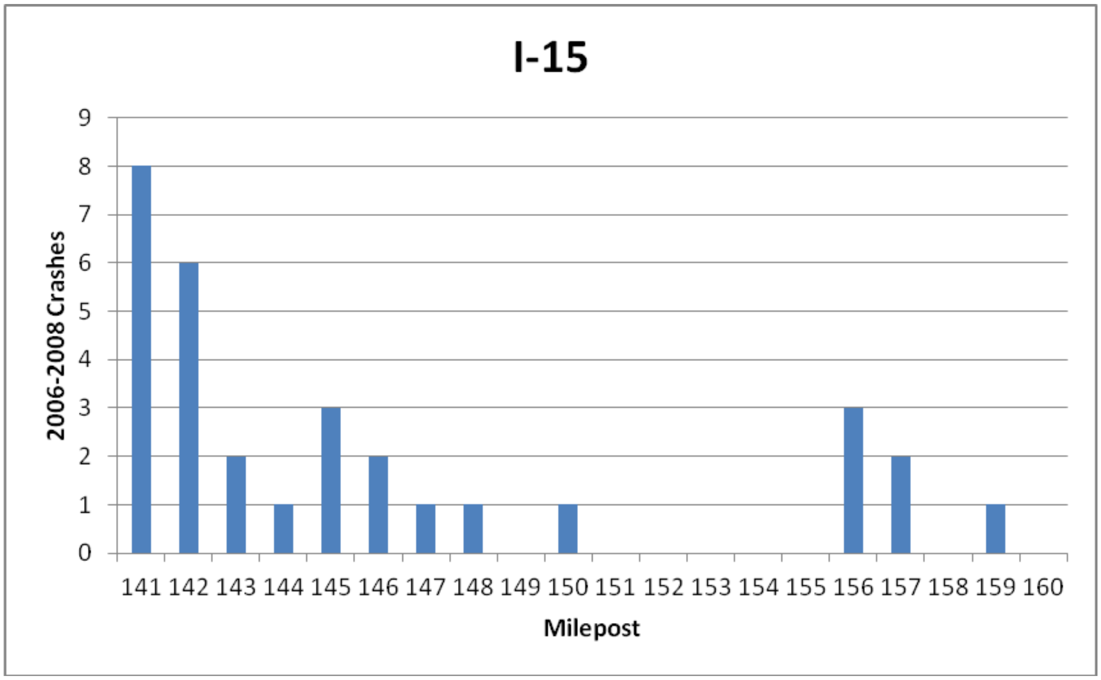
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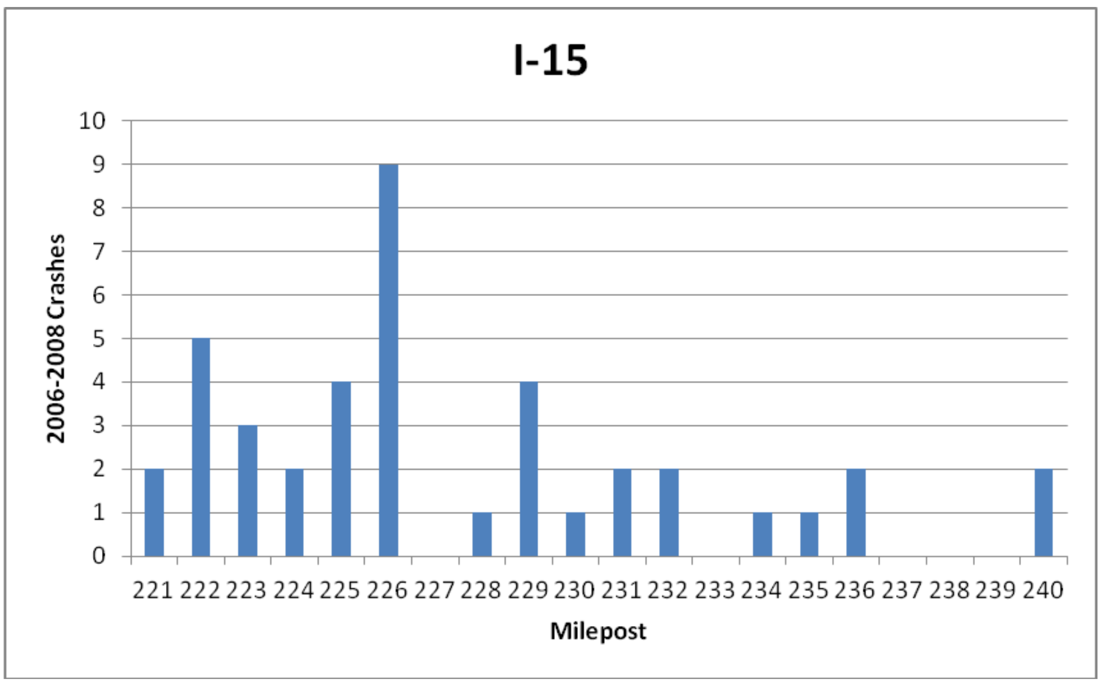
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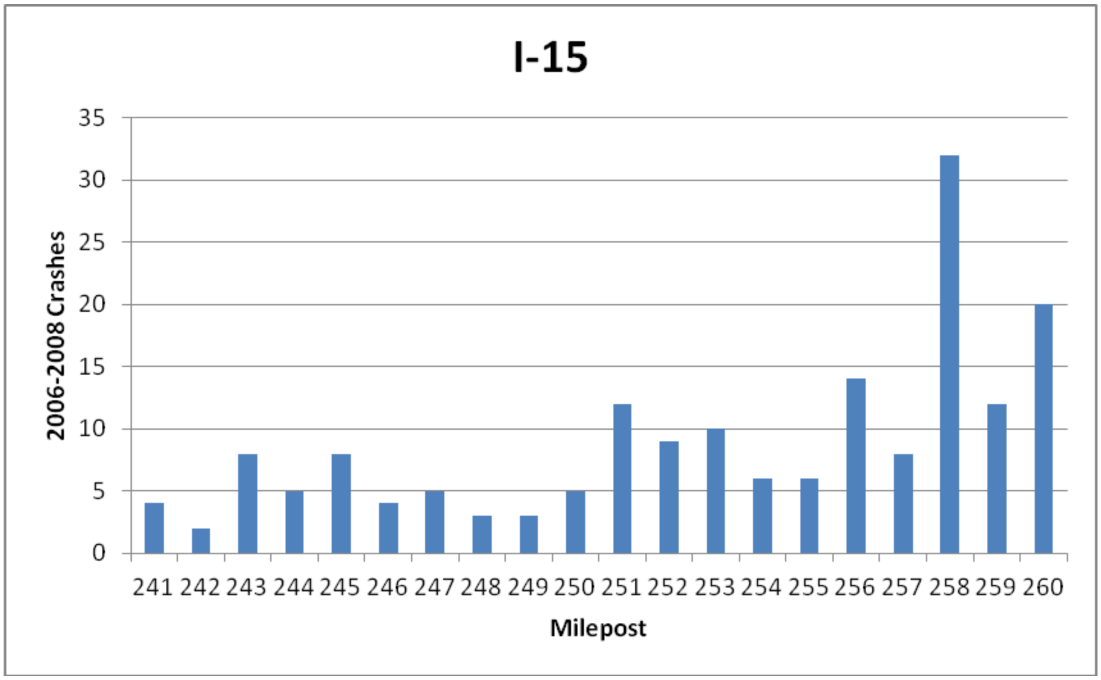
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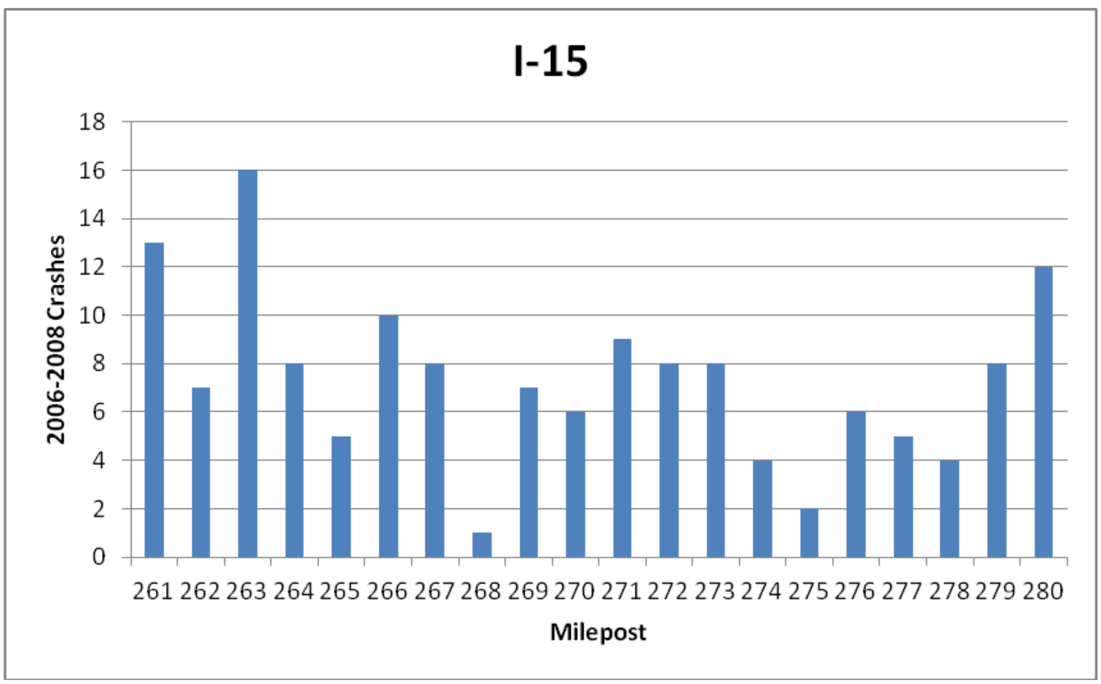
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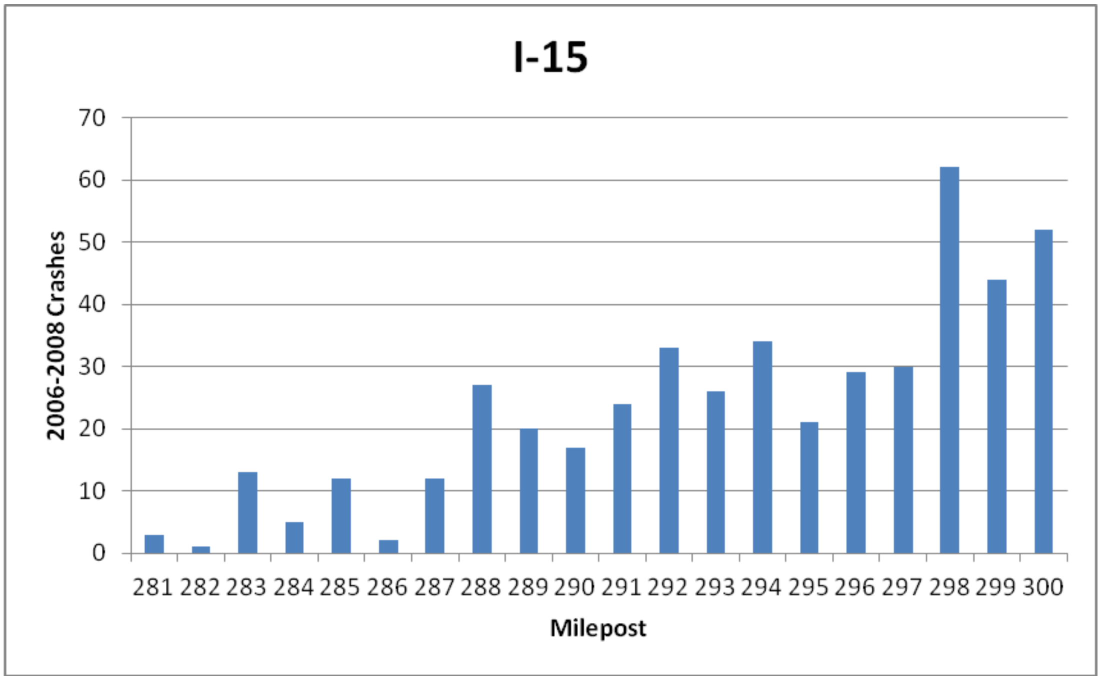
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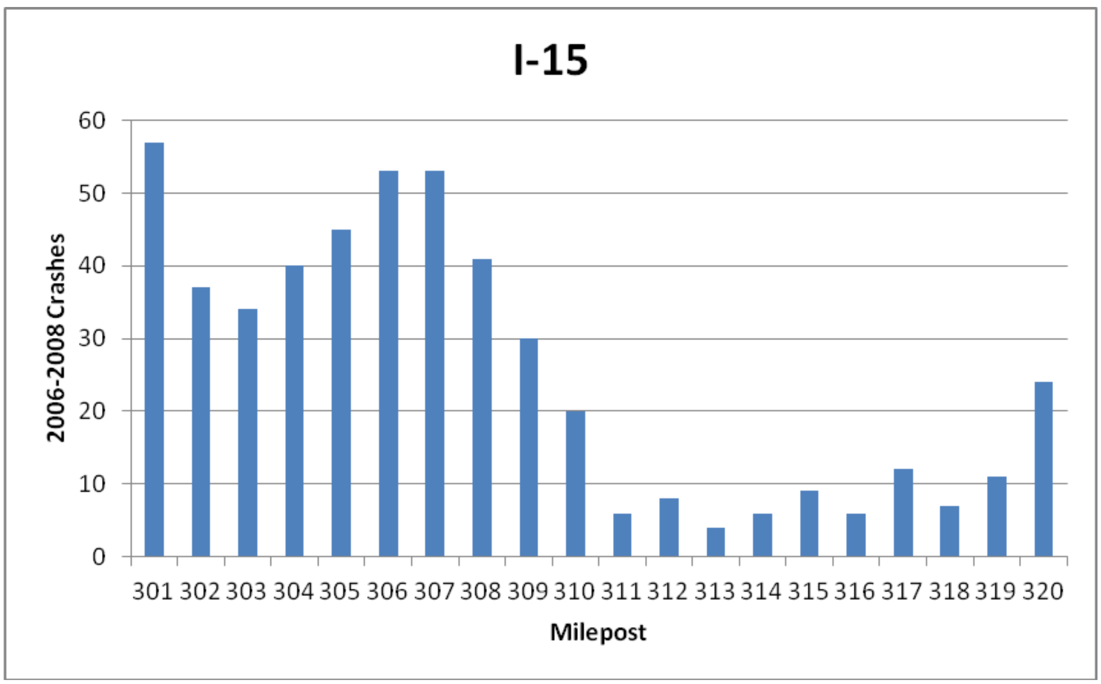
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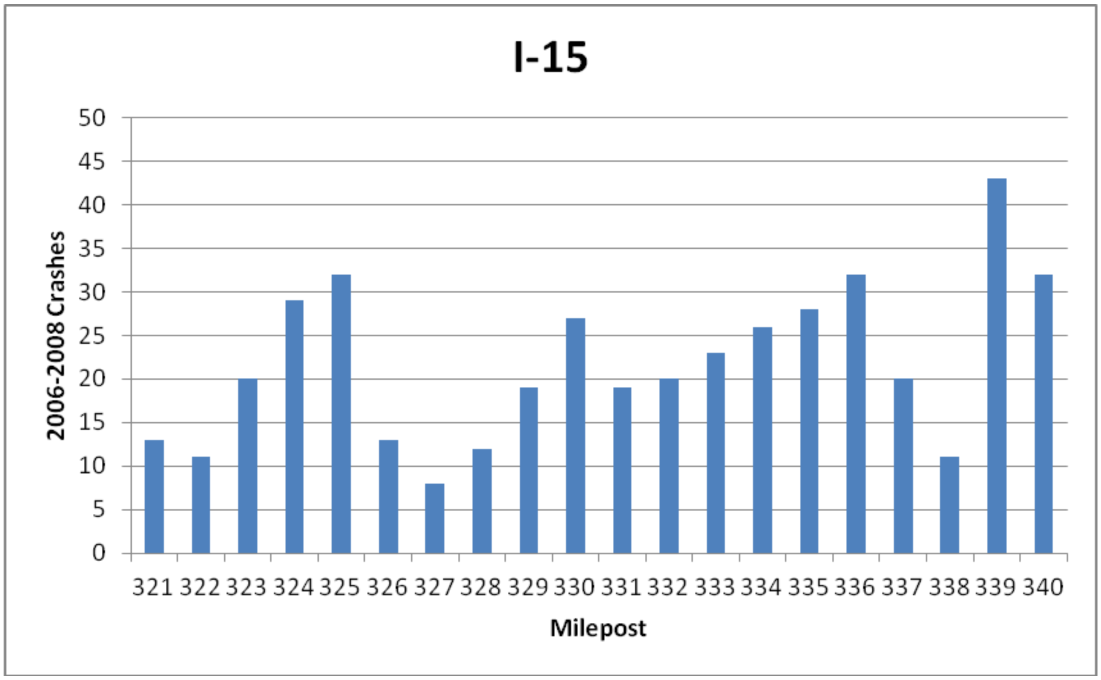
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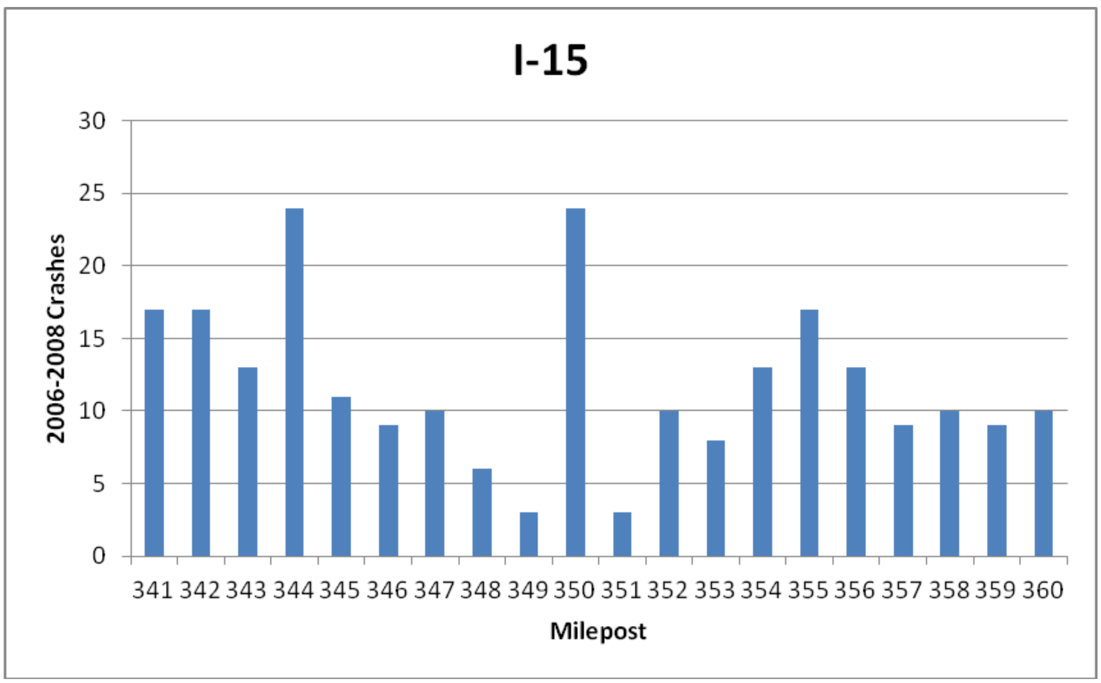
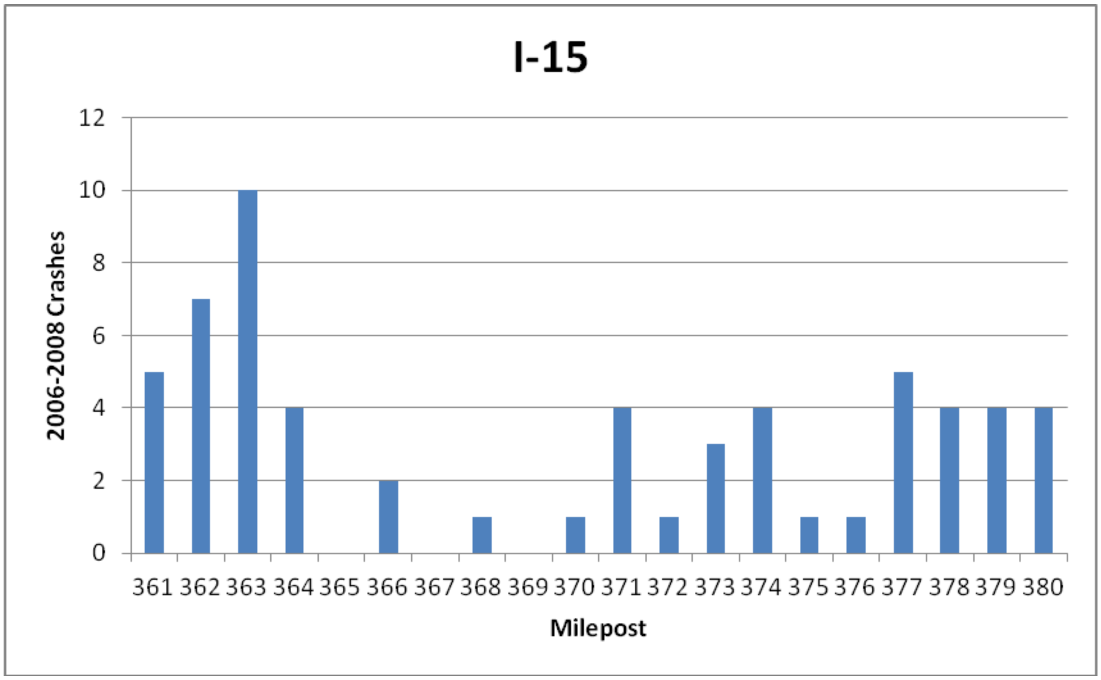
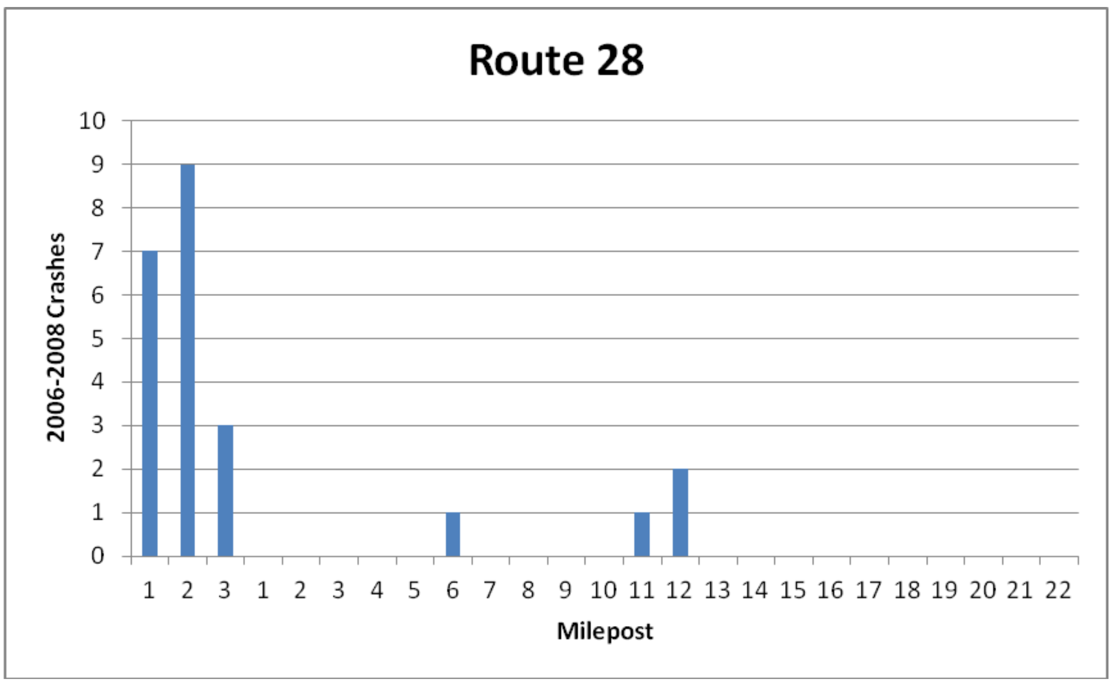

I-15
30
25
20
15
10
5
0
2006-2008 Crashes
341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360
Milepost


I-15
2006-2008 Crashes
0
2
4
6
8
10
12
361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380
Milepost


Route 28
2006-2008 Crashes
0
1
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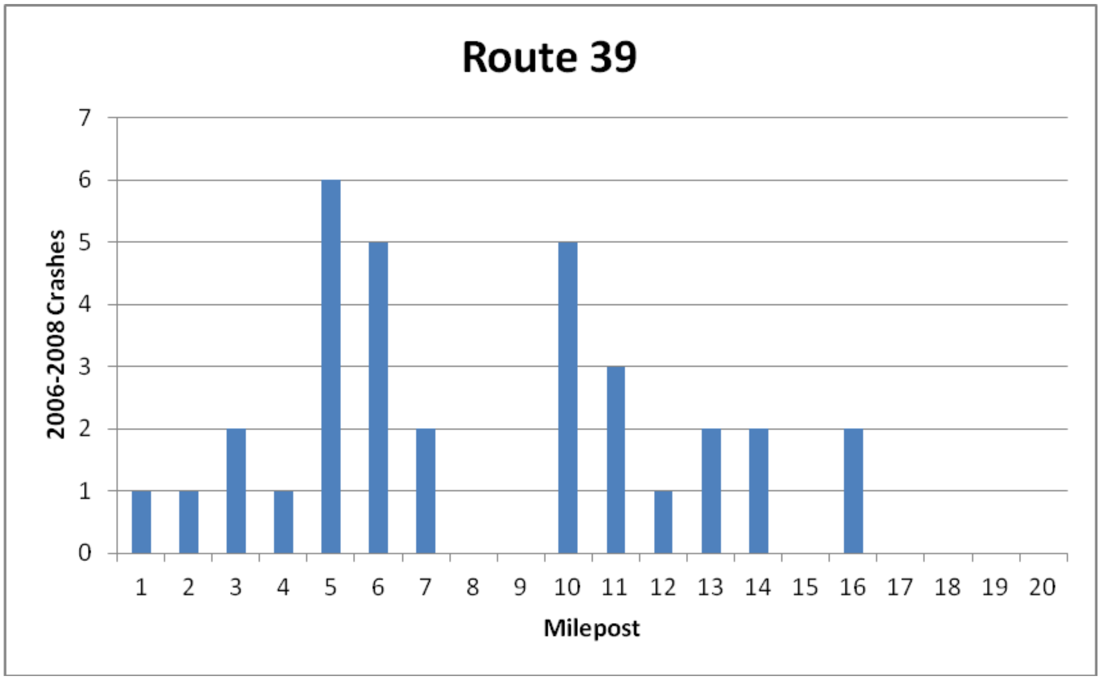
6
7
8
9
10
1 2 3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Milepost


Route 39
7
6
5
4
3
2
1
0
2006-2008 Crashes
1
2
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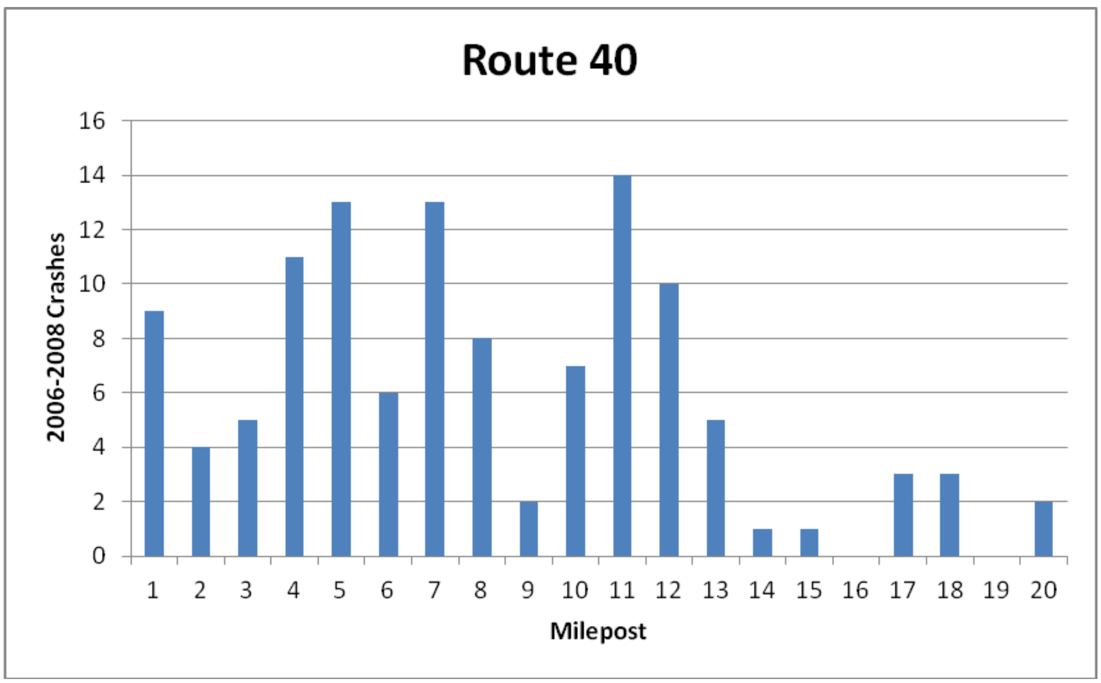
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Milepost


Route 40
16
14
12
10
8
6
4
2
0
2006-2008 Crashes
1
2
3
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6
7
8
9
10
11
12
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14
15
16
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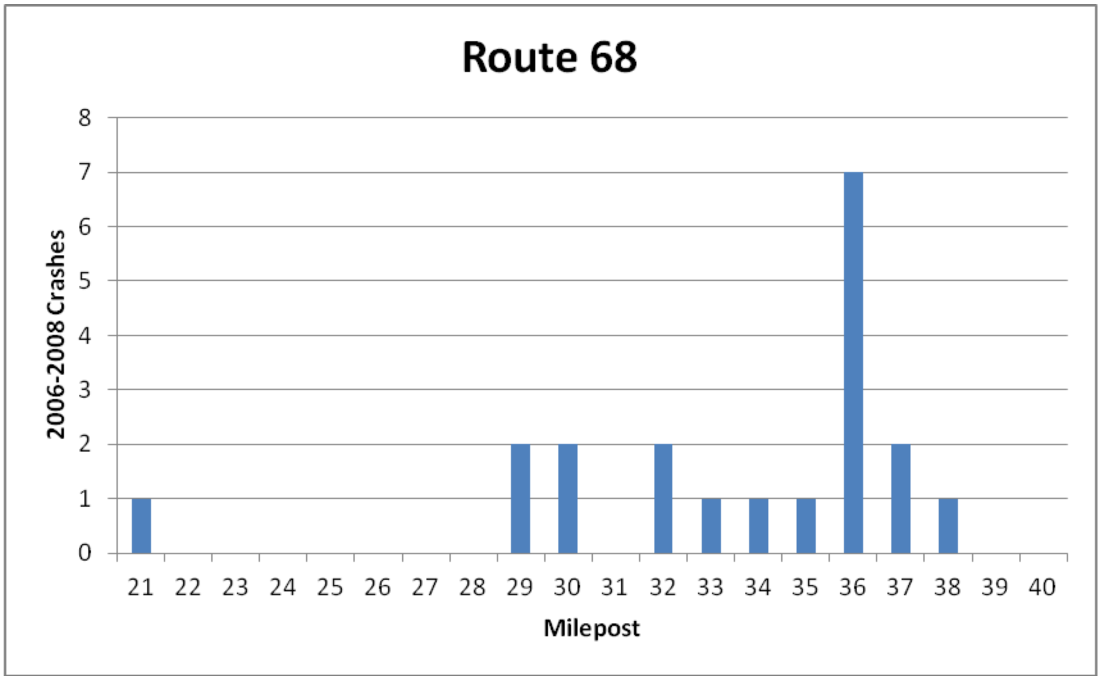
18
19
20
Milepost


Route 68
2006-2008 Crashes
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2
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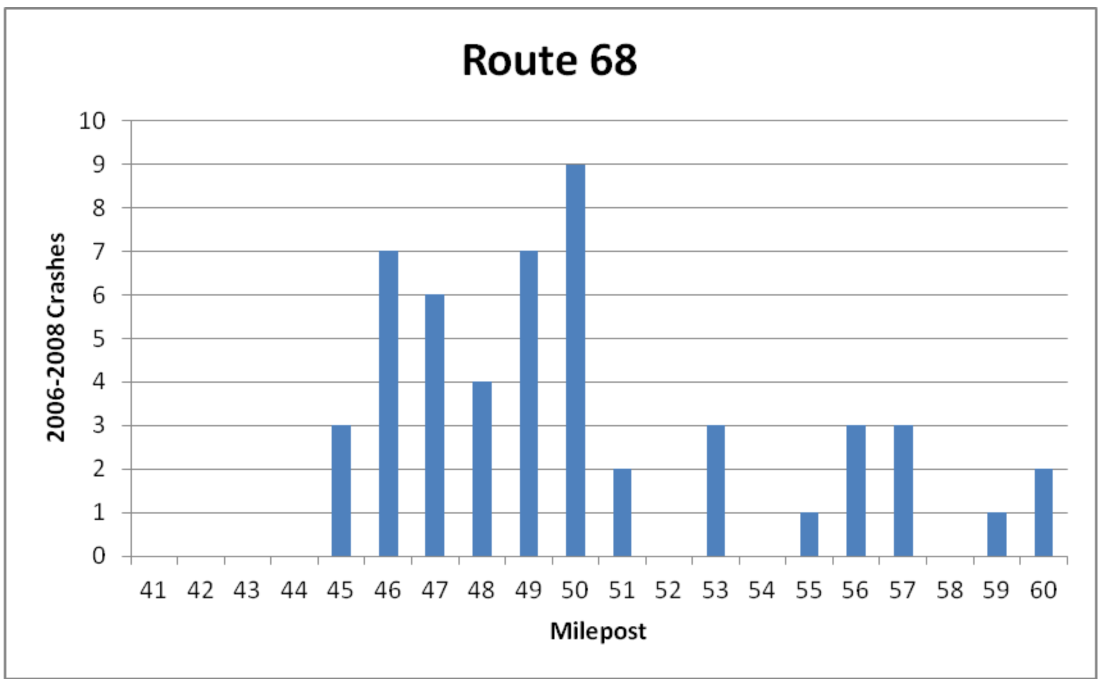
4
5
6
7
8
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Milepost


Route 68
2006-2008 Crashes
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2
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4
5
6
7
8
9
10
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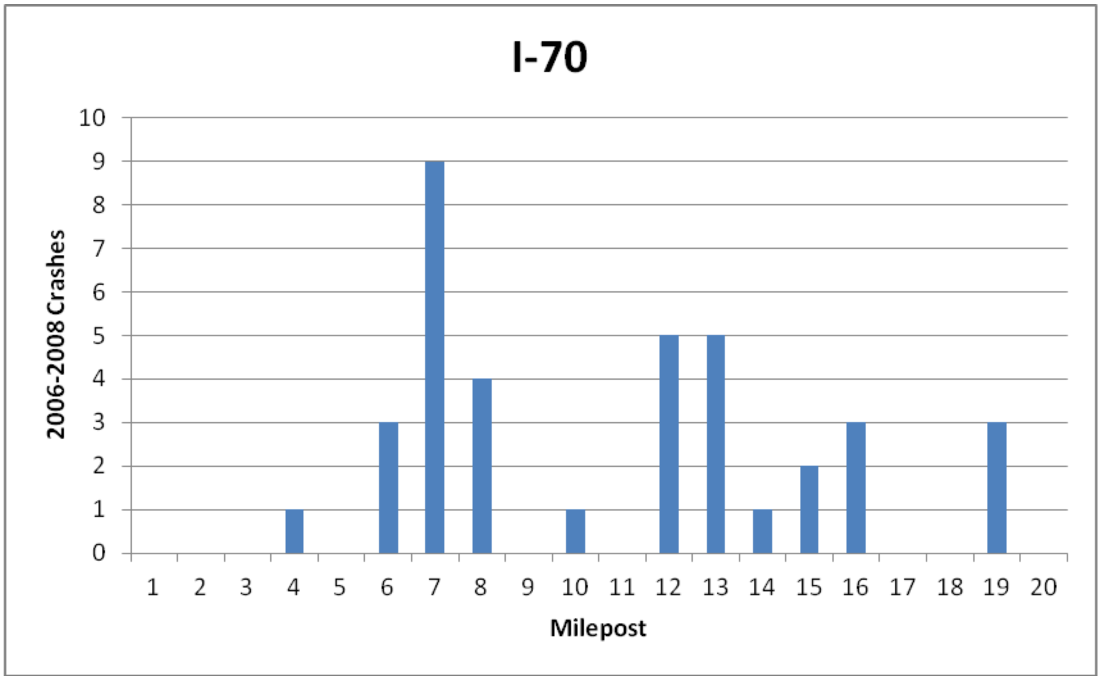
Milepost


I-70
2006-2008 Crashes
Milepost
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2
3
4
5
6
7
8
9
10
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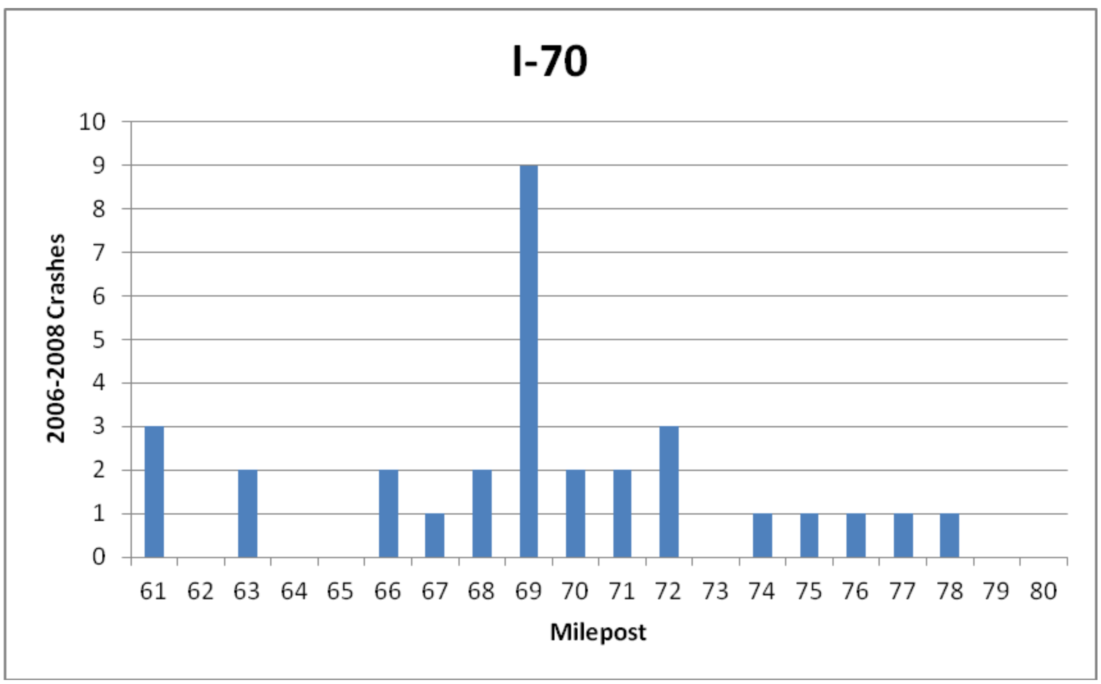
I-70
2006-2008 Crashes
Milepost
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6
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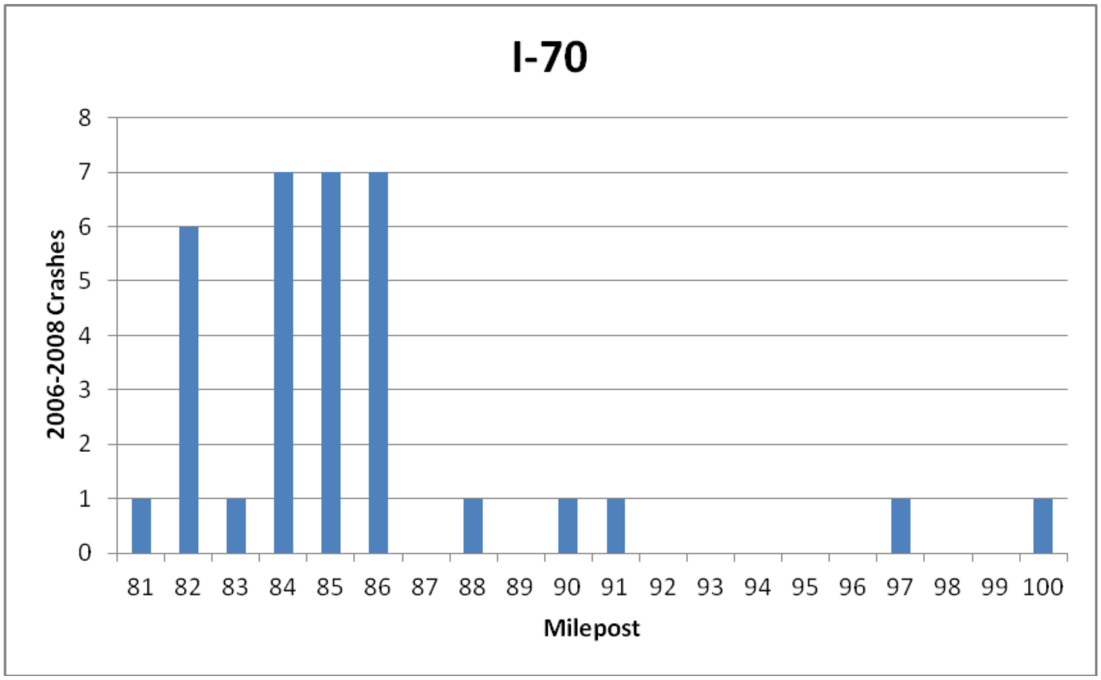
10
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80


I-70
8
7
6
5
4
3
2
1
0
2006-2008 Crashes
81
82
83
84
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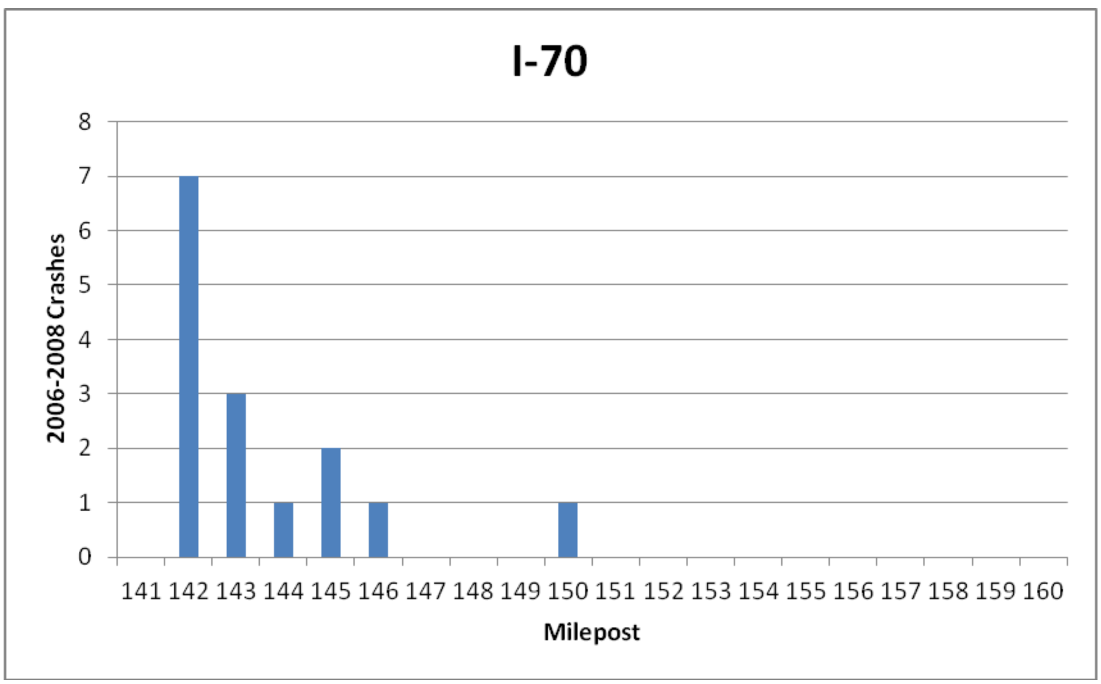
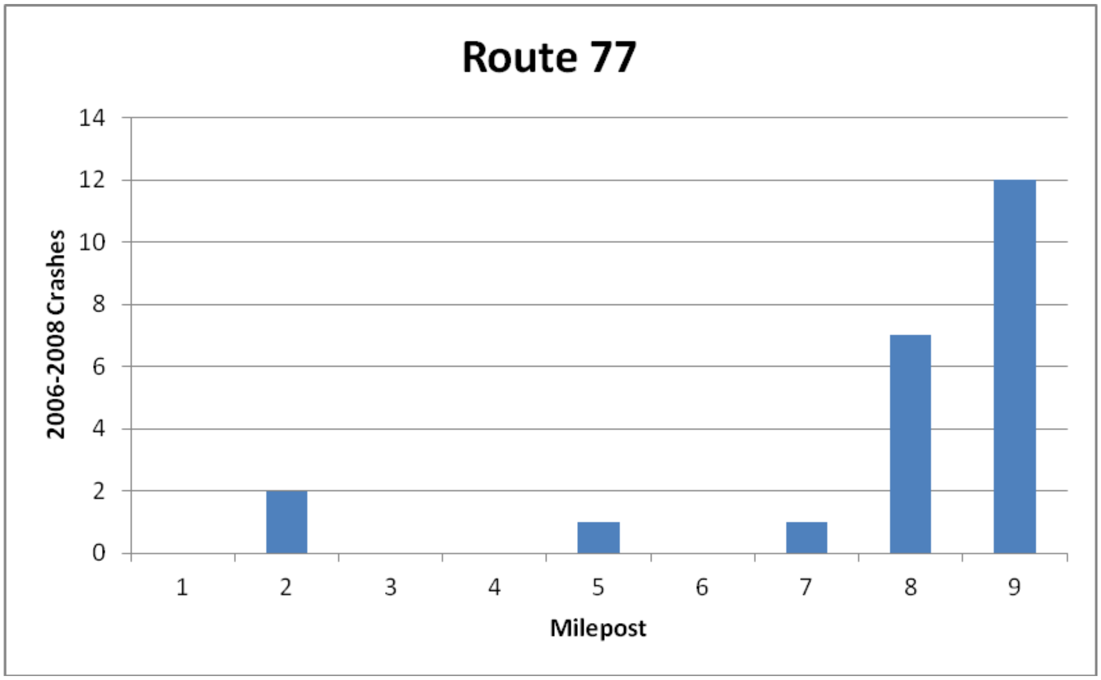
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
Milepost


I-70
8
7
6
5
4
3
2
1
0
2006-2008 Crashes
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
Milepost


Route 77
2006-2008 Crashes
14
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10
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6
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2
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1
2
3
4
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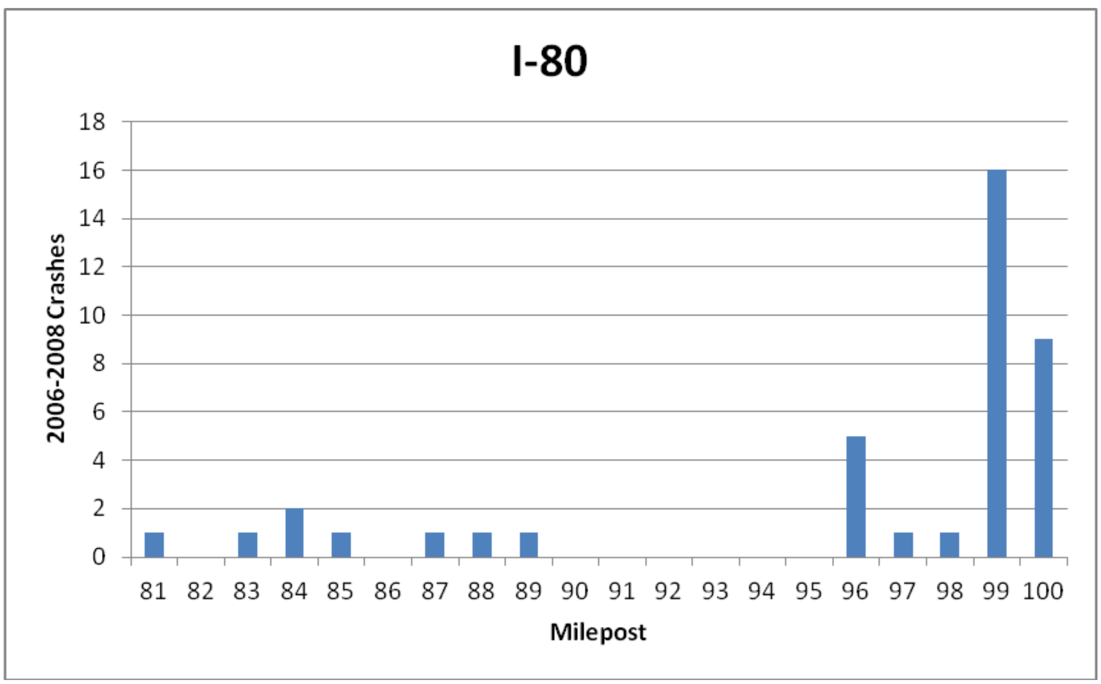
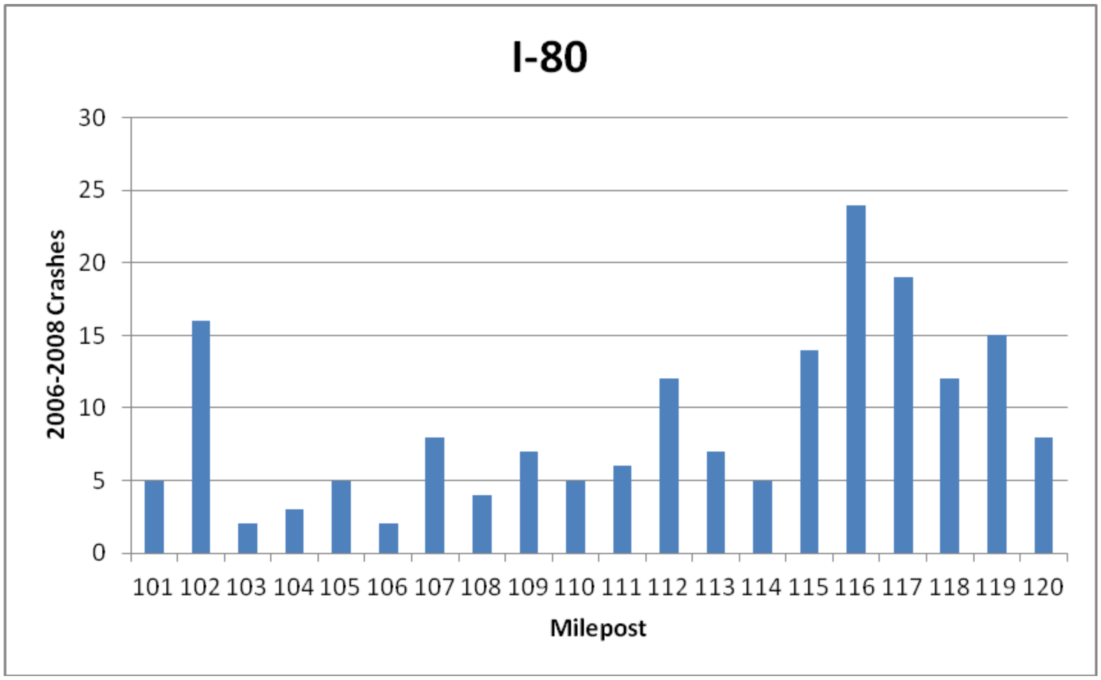
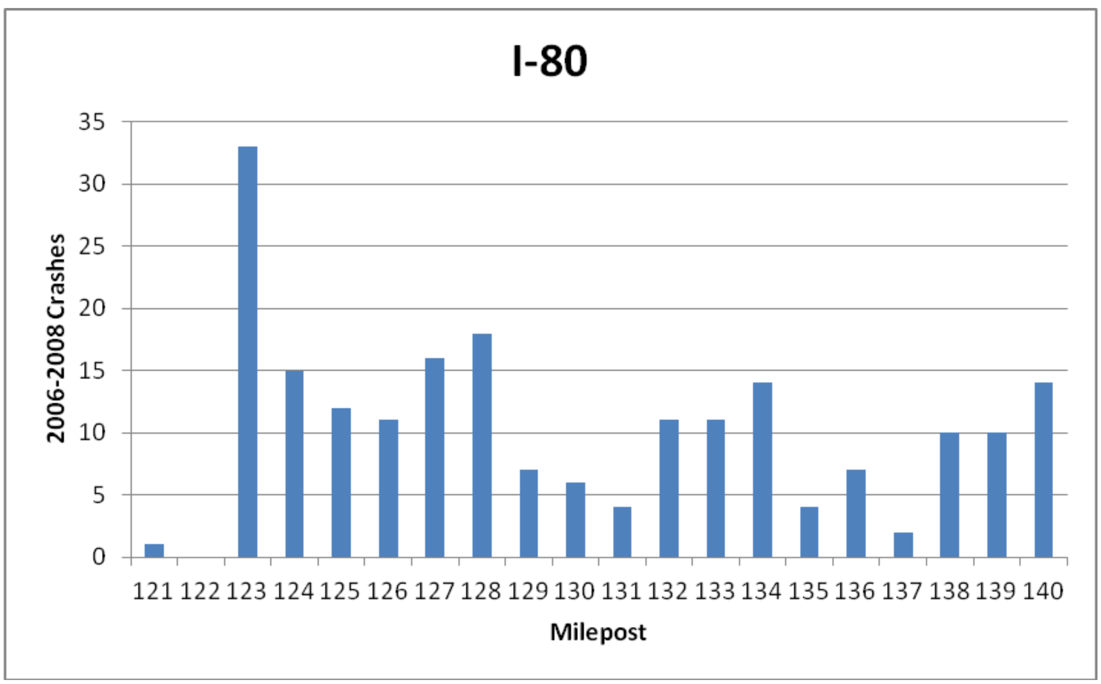
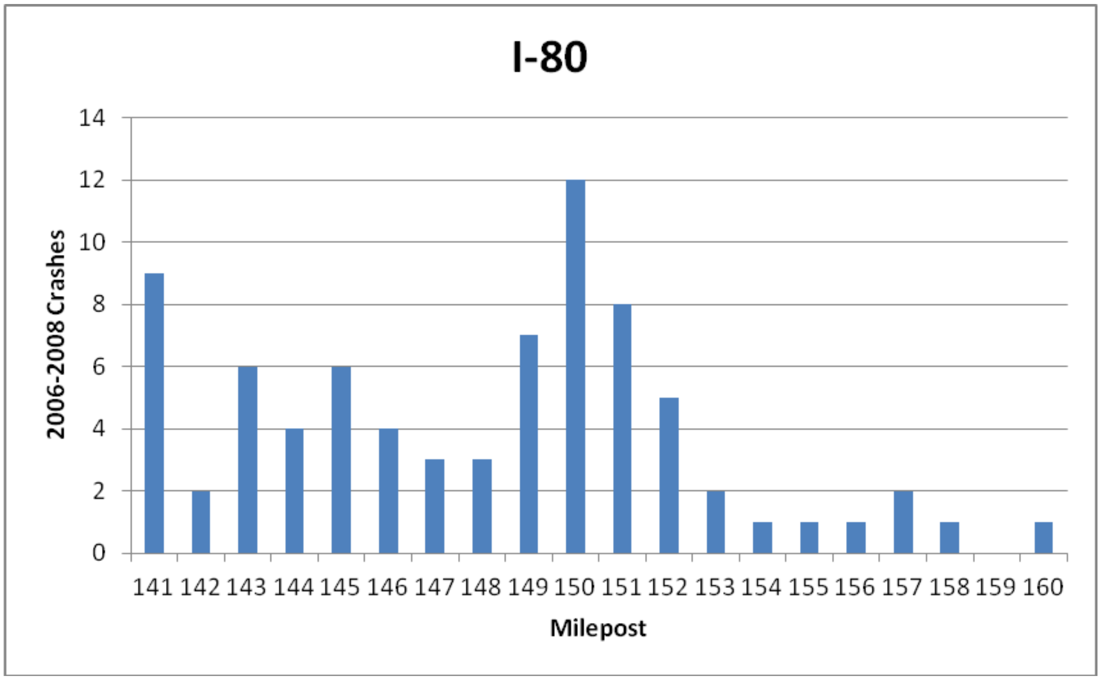
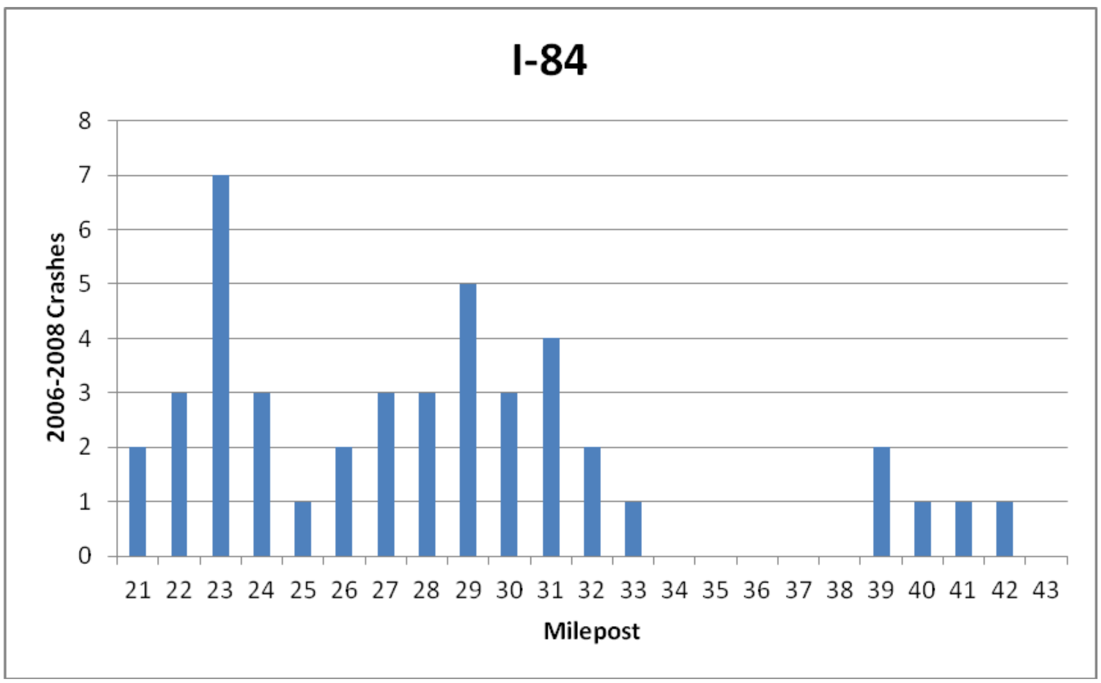
7
8
9
Milepost

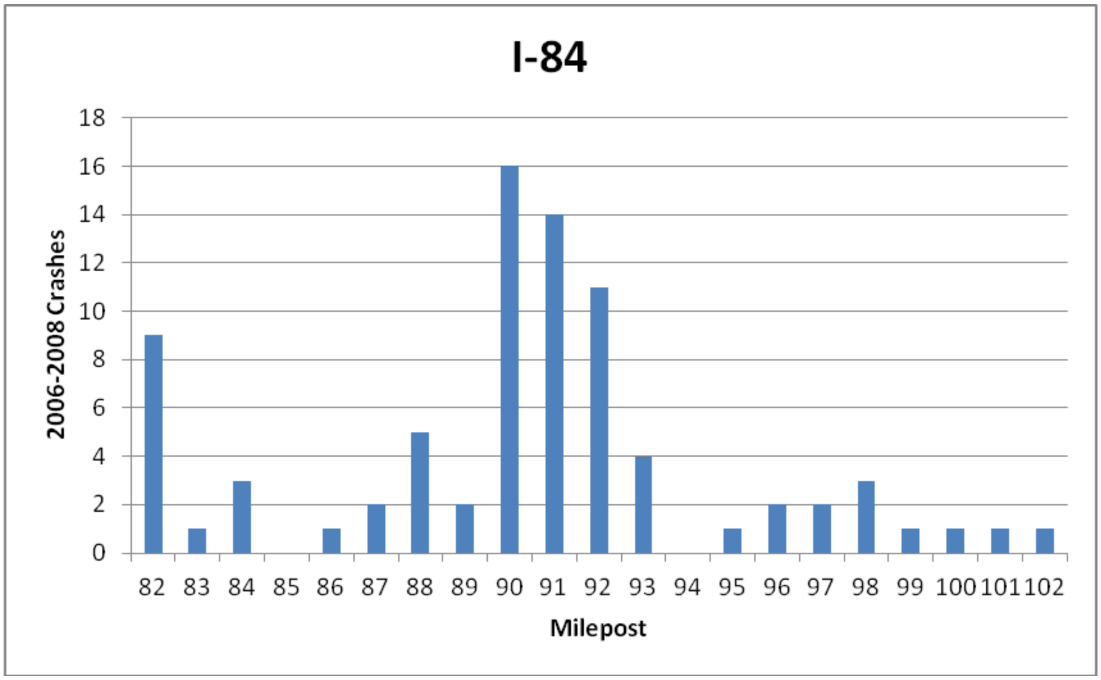

I-80
2006-2008 Crashes
18
16
14
12
10
8
6
4
2
0
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
Milepost


I-80
2006-2008 Crashes
0
5
10
15
20
25
30
101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
Milepost

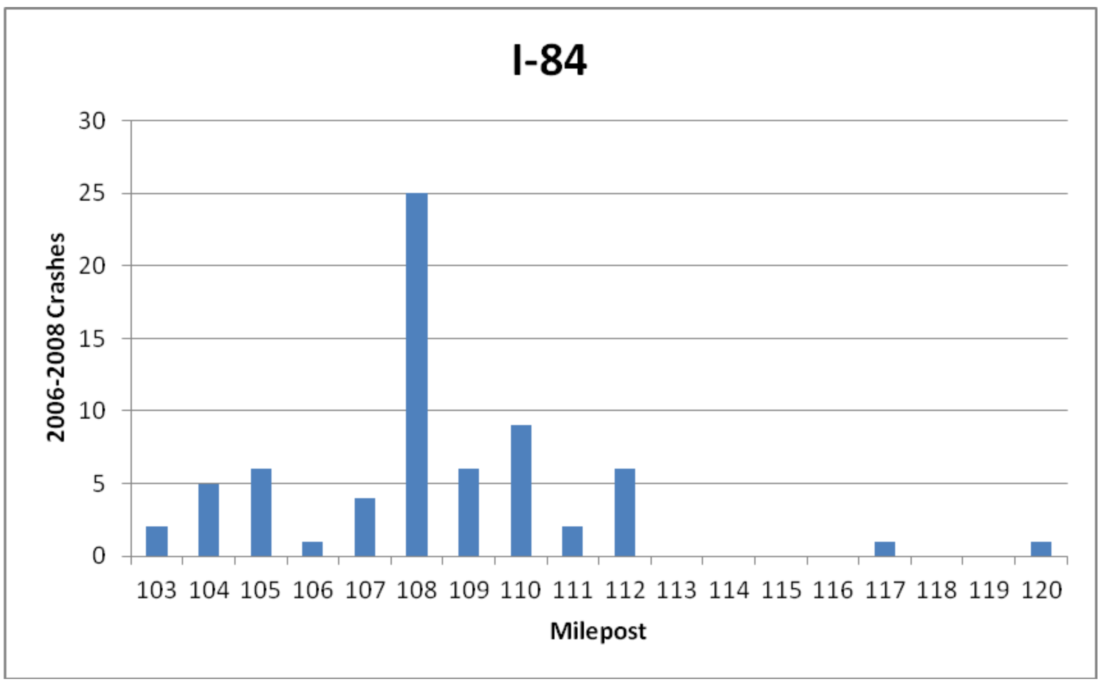

I-80
2006-2008 Crashes
0
5
10
15
20
25
30
35
121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140
Milepost


I-80
2006-2008 Crashes
0
2
4
6
8
10
12
14
141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160
Milepost

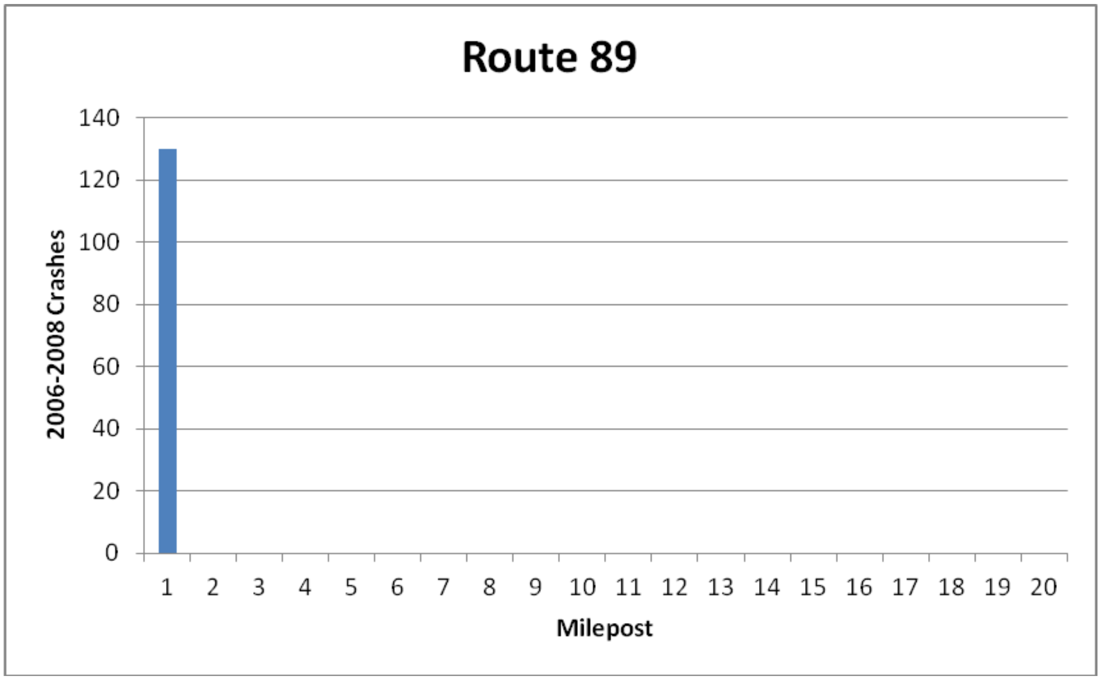

I-84
2006-2008 Crashes
0
1
2
3
4
5
6
7
8
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
Milepost

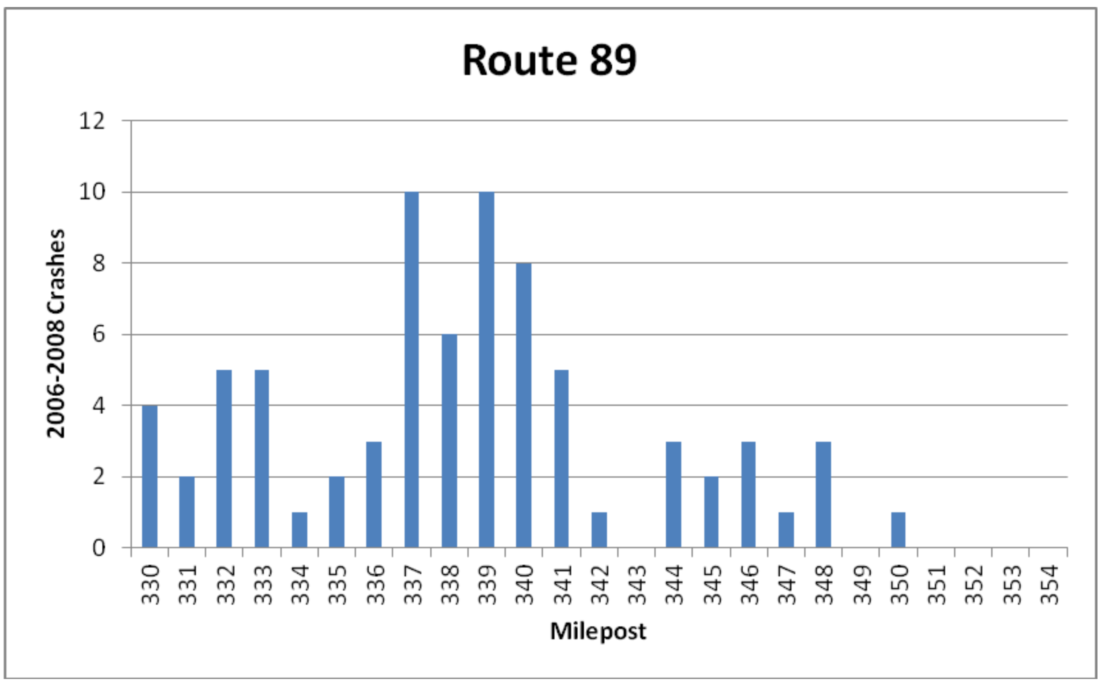


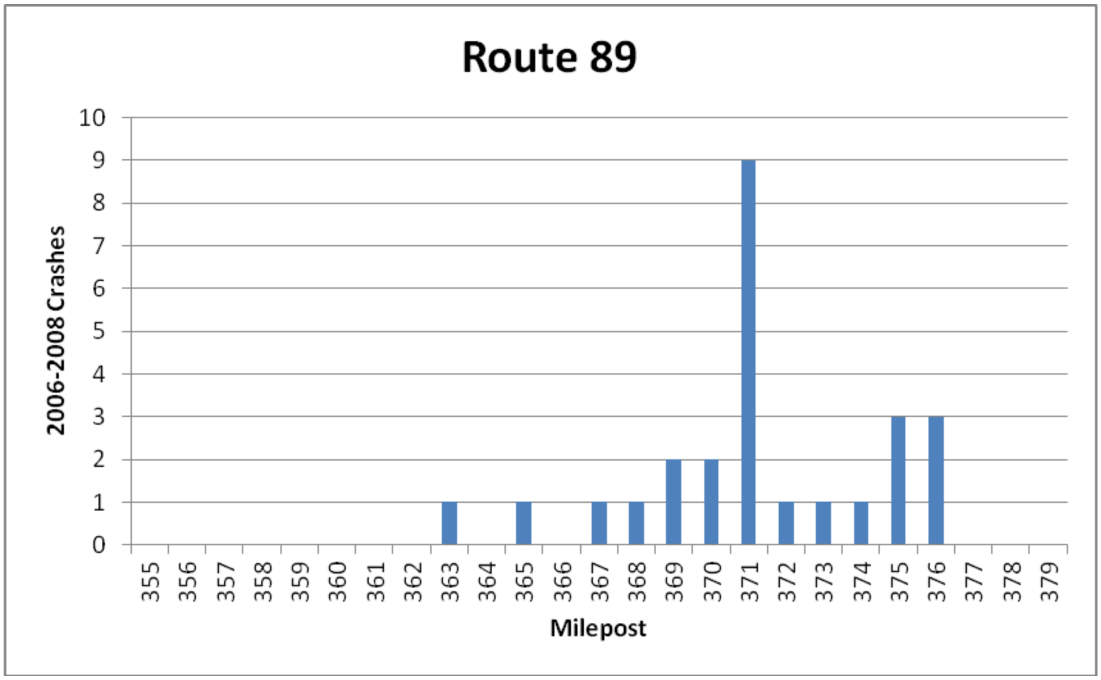
I-84
2006-2008 Crashes
0
2
4
6
8
10
12
14
16
18
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102
Milepost



I-84
2006-2008 Crashes
0
5
10
15
20
25
30
103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
Milepost


Route 89
140
120
100
80
60
40
20
0
2006-2008 Crashes
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Milepost


Route 89
12
10
8
6
4
2
0
2006-2008 Crashes
330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354
Milepost


Route 89
2006-2008 Crashes
Milepost
0
1
2
3
4
5
6
7
8
9
10
355
356
357
358
359
360
361
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363
364
365
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369
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371
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376
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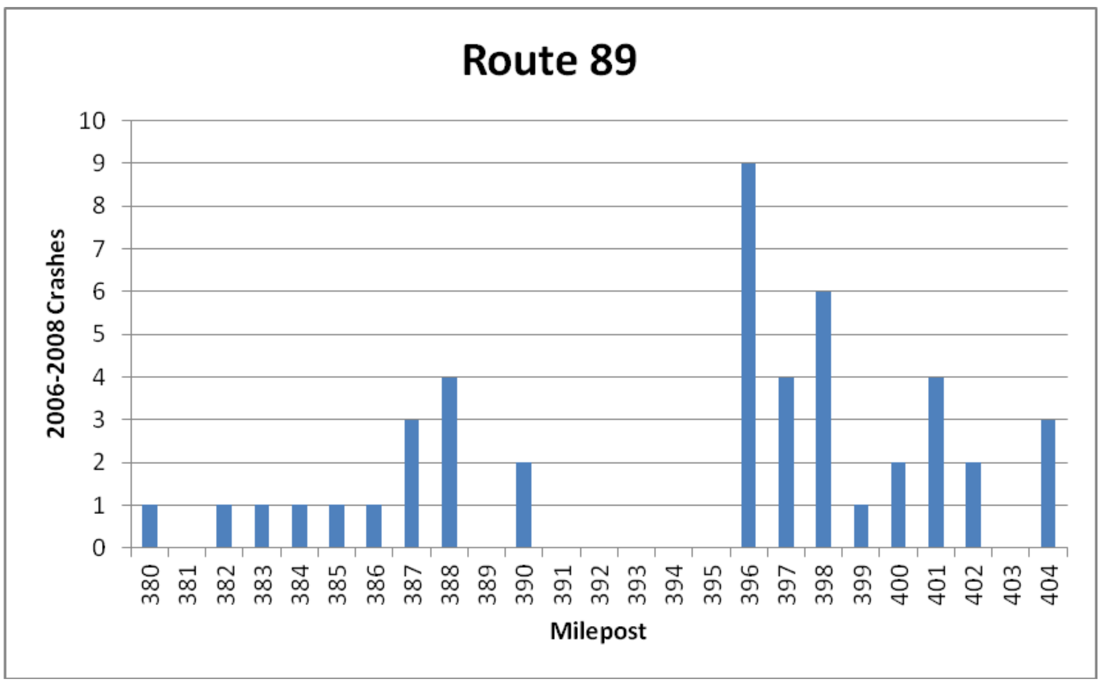
378
379


Route 89
2006-2008 Crashes
Milepost
0
1
2
3
4
5
6
7
8
9
10
380
381
382
383
384
385
386
387
388
389
390
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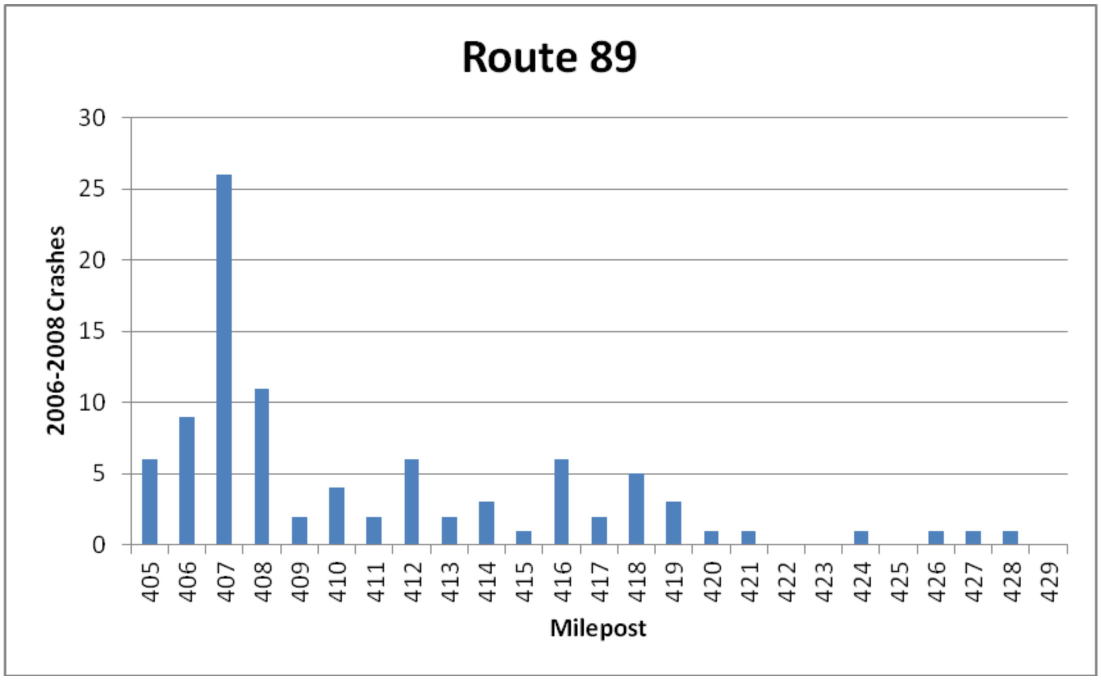
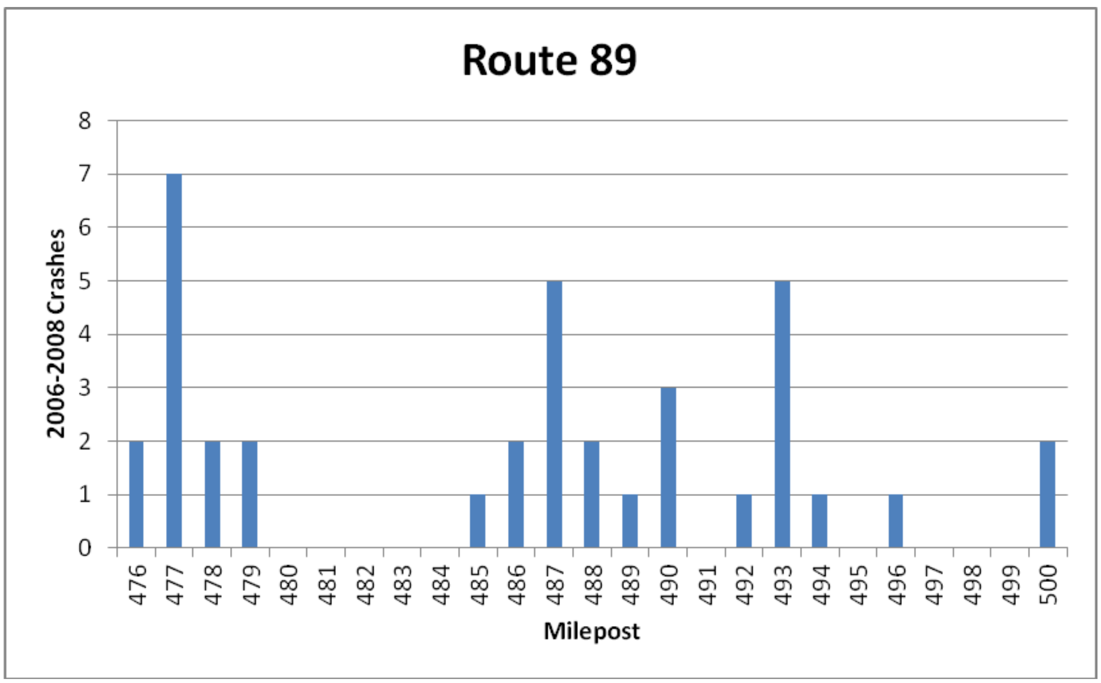
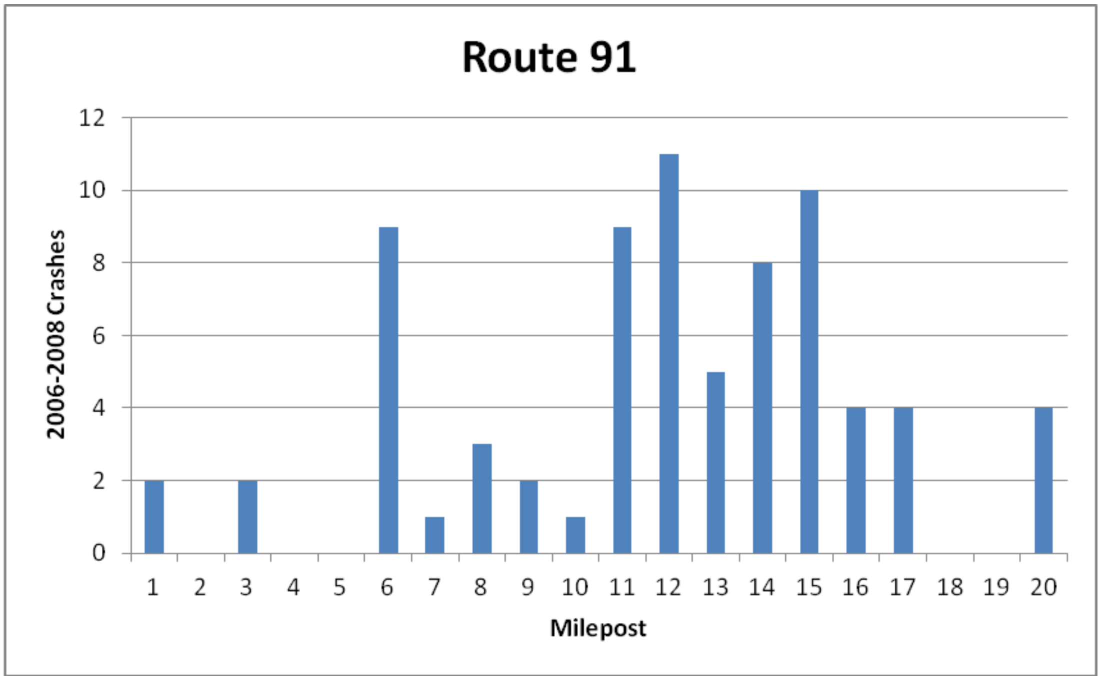
393
394
395
396
397
398
399
400
401
402
403
404



Route 89
2006-2008 Crashes
30
25
20
15
10
5
0
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
Milepost



Route 89
2006-2008 Crashes
8
7
6
5
4
3
2
1
0
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
Milepost


Route 91
12
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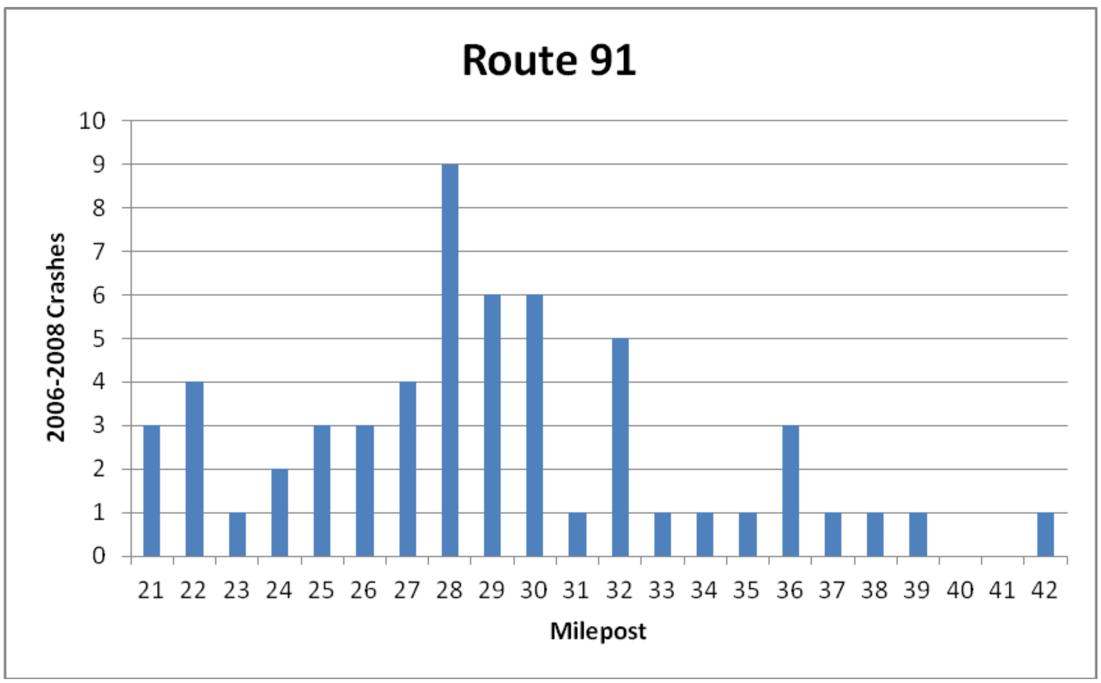
8
6
4
2
0
2006-2008 Crashes
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Milepost


Route 91
10
9
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5
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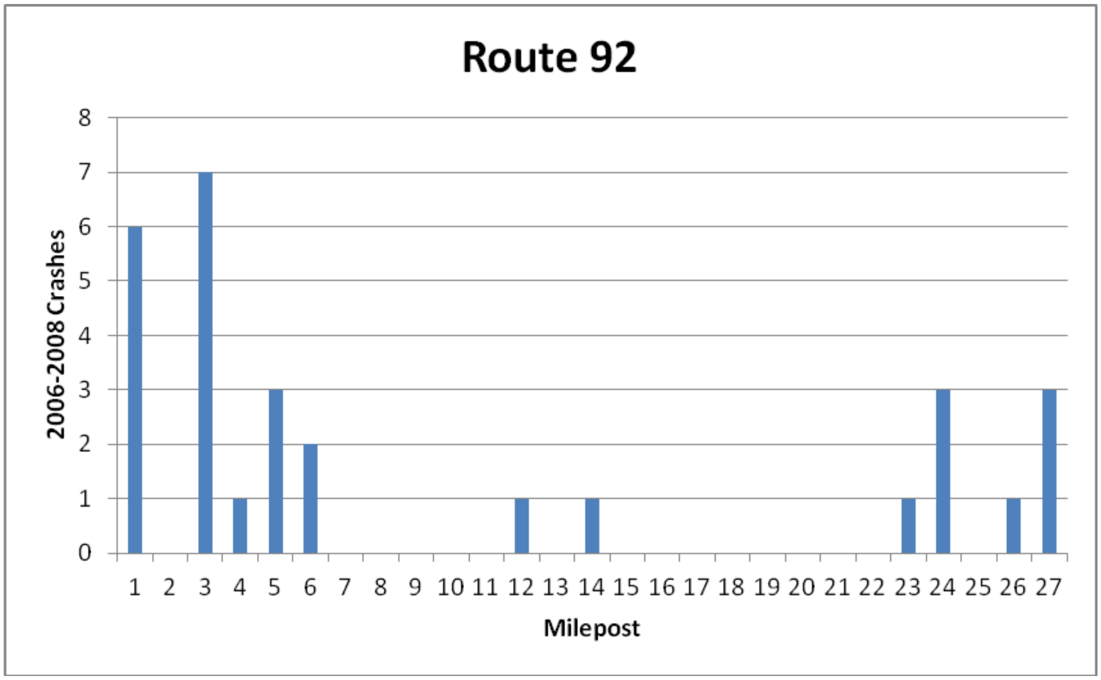
3
2
1
0
2006-2008 Crashes
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
Milepost


Route 92
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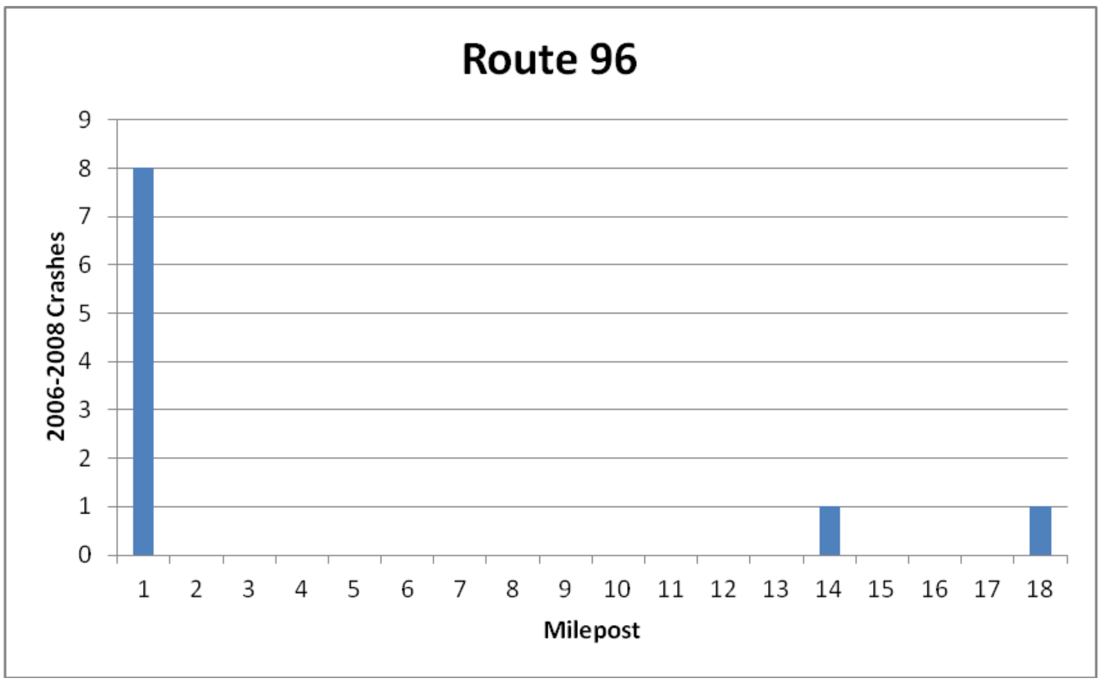
2006-2008 Crashes
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Milepost


Route 96
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2006-2008 Crashes
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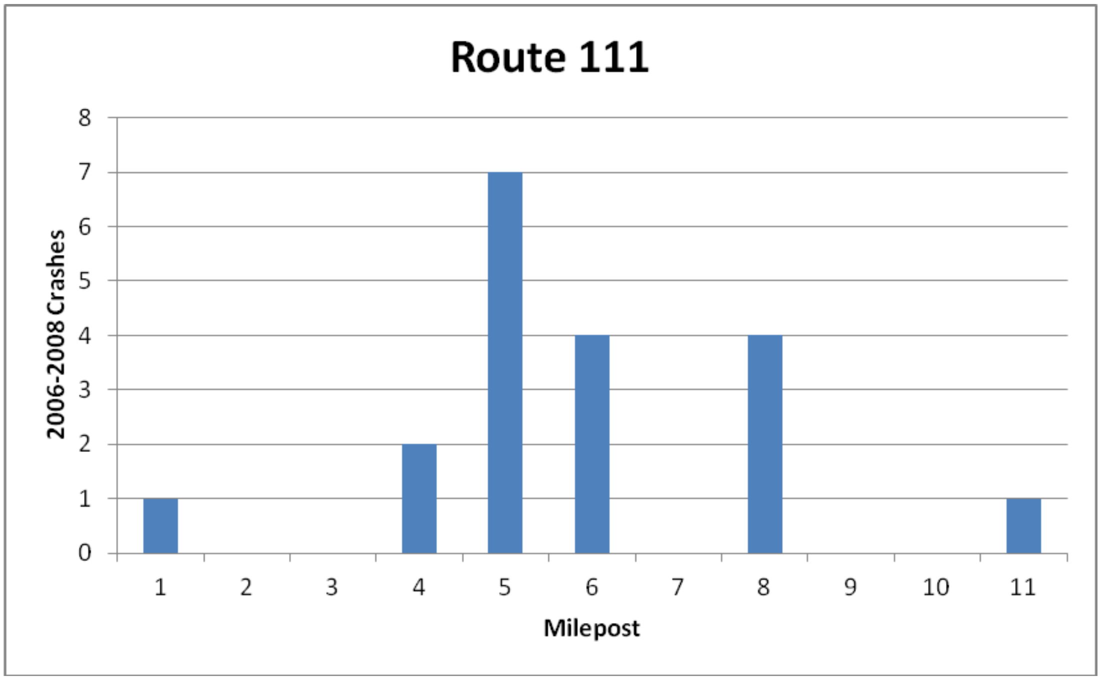
Route 111
2006-2008 Crashes
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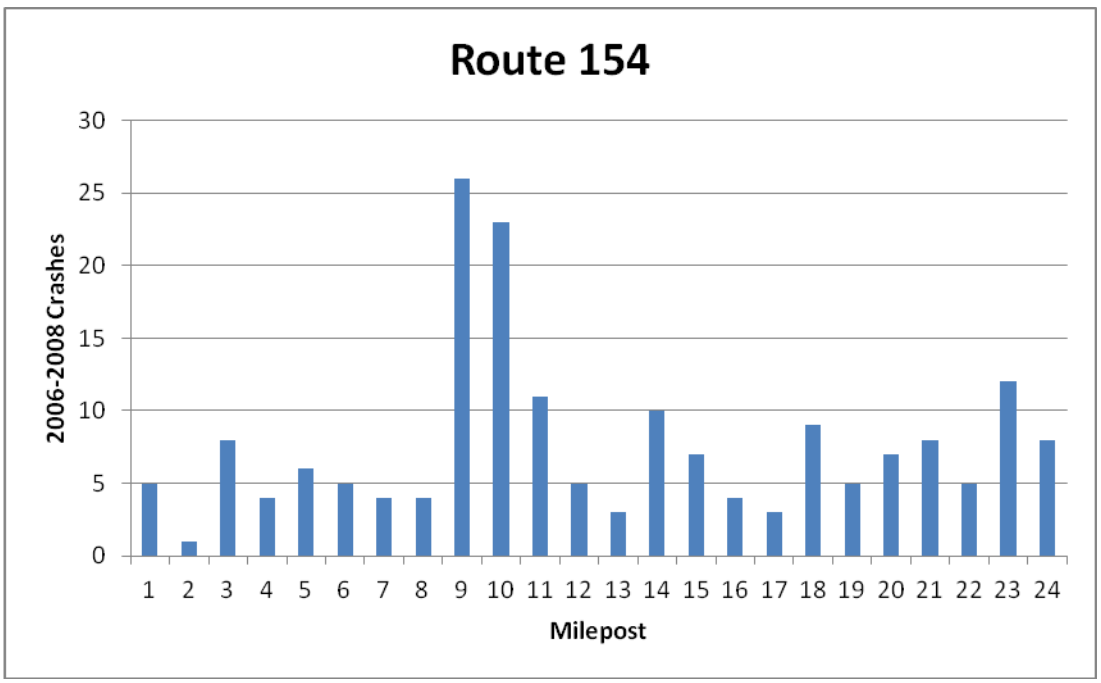
8
1 2 3 4 5 6 7 8 9 10 11
Milepost


Route 154
2006-2008 Crashes
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5
10
15
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25
30
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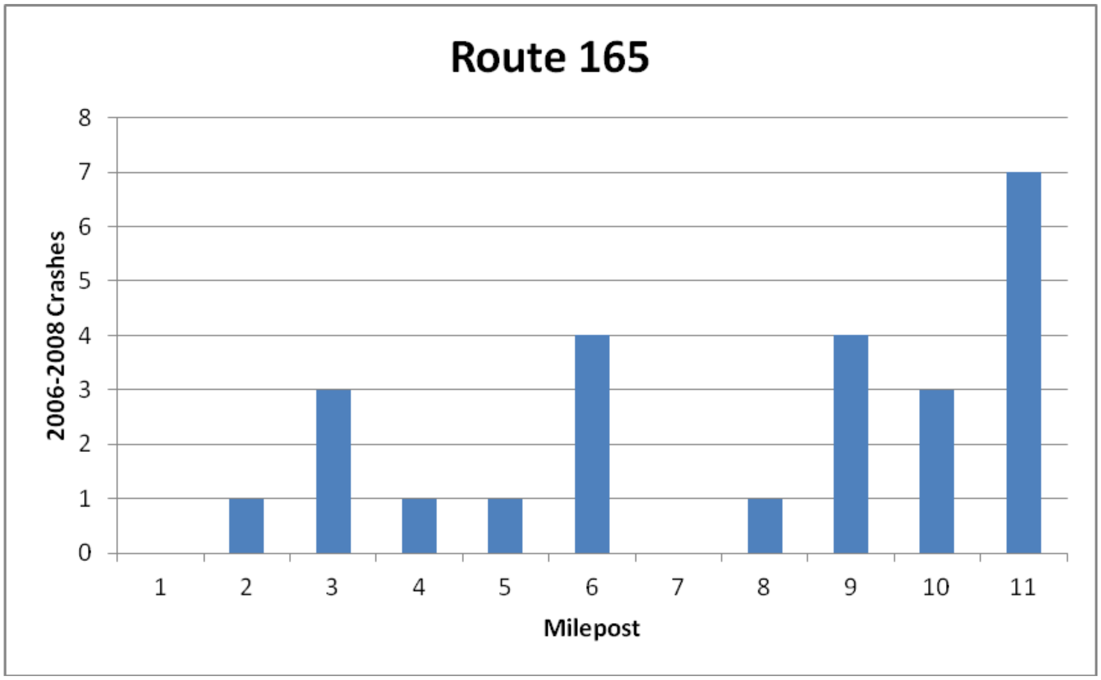
Milepost


Route 165
2006-2008 Crashes
0
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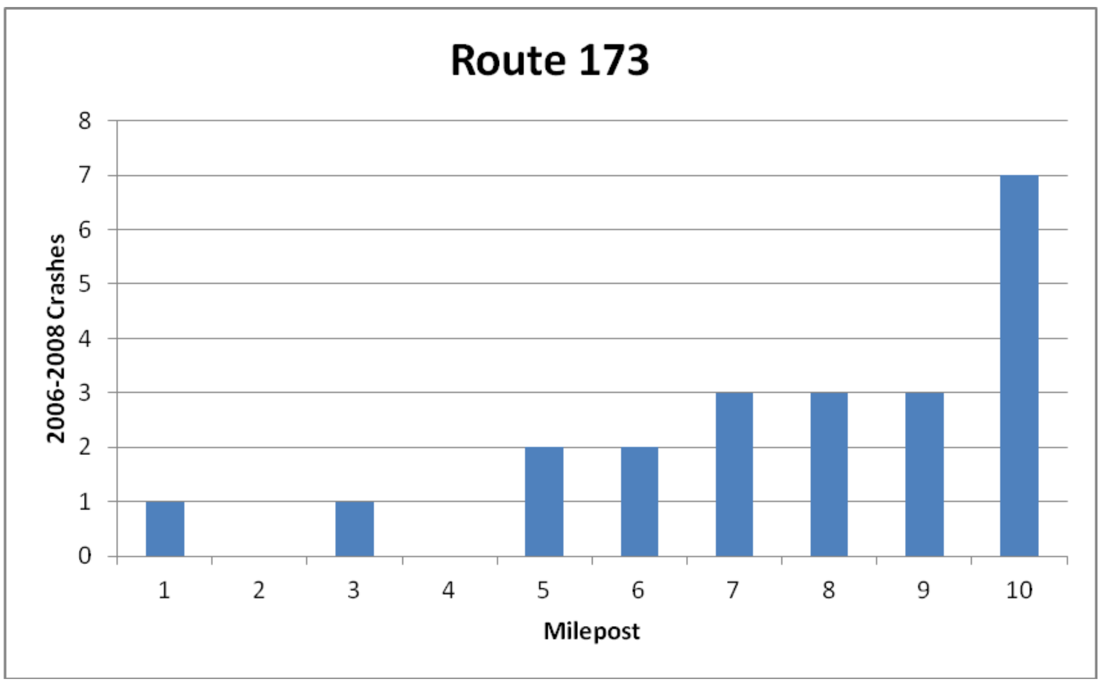
3
4
5
6
7
8
1 2 3 4 5 6 7 8 9 10 11
Milepost


Route 173
2006-2008 Crashes
0
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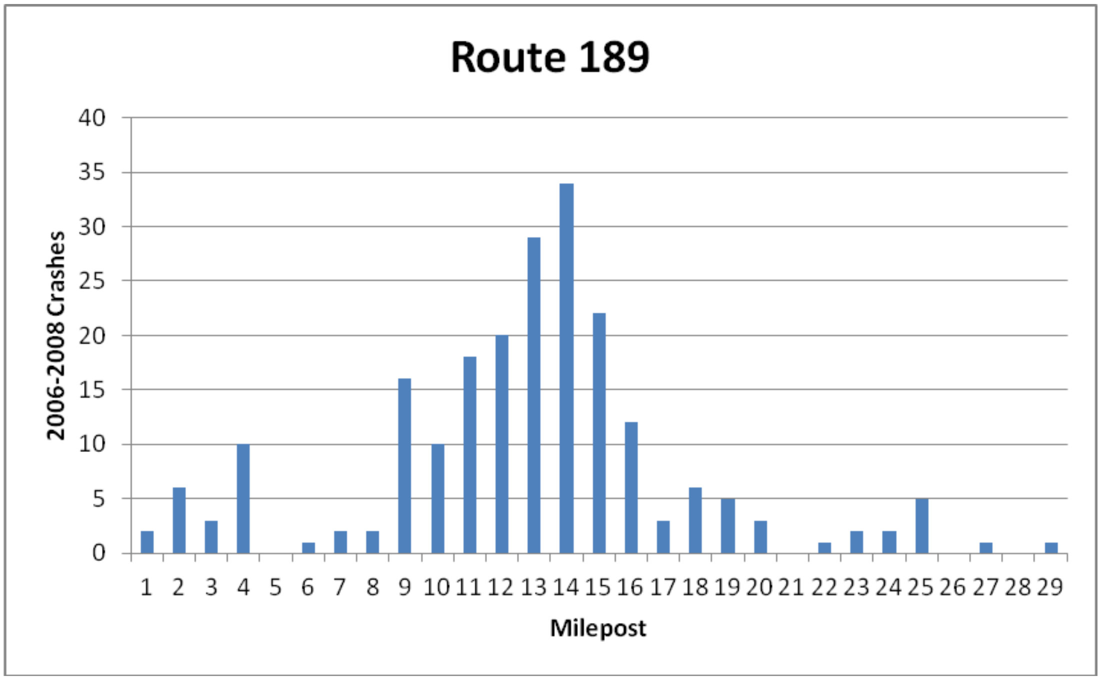
6
7
8
1 2 3 4 5 6 7 8 9 10
Milepost


Route 189
40
35
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15
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5
0
2006-2008 Crashes
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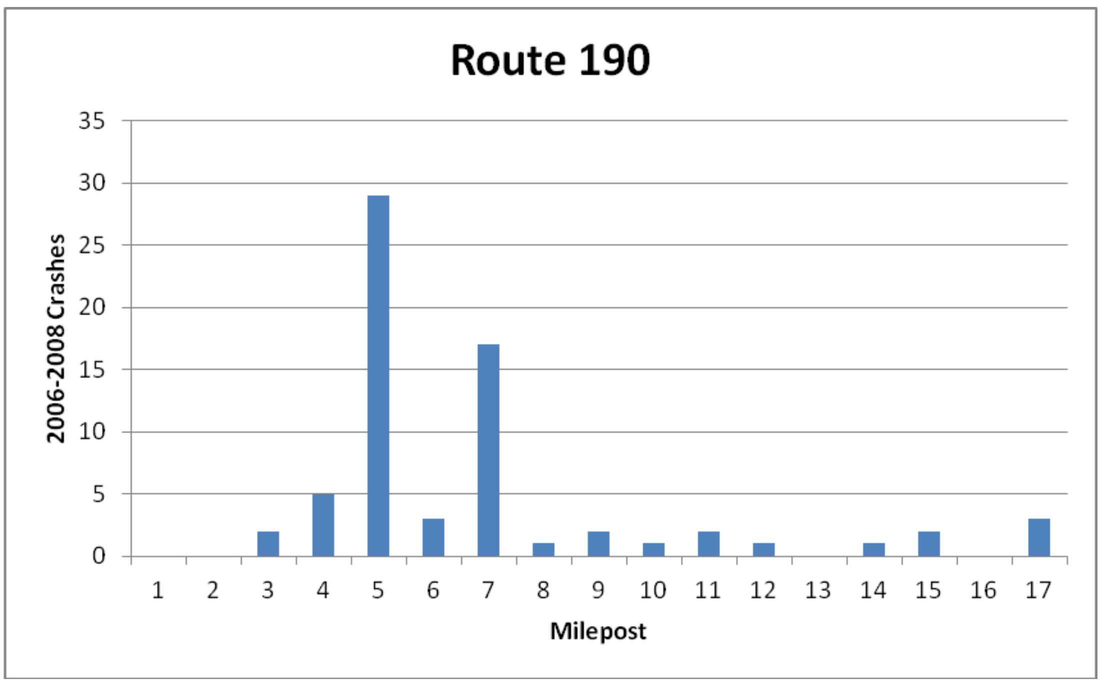
Milepost


Route 190
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20
15
10
5
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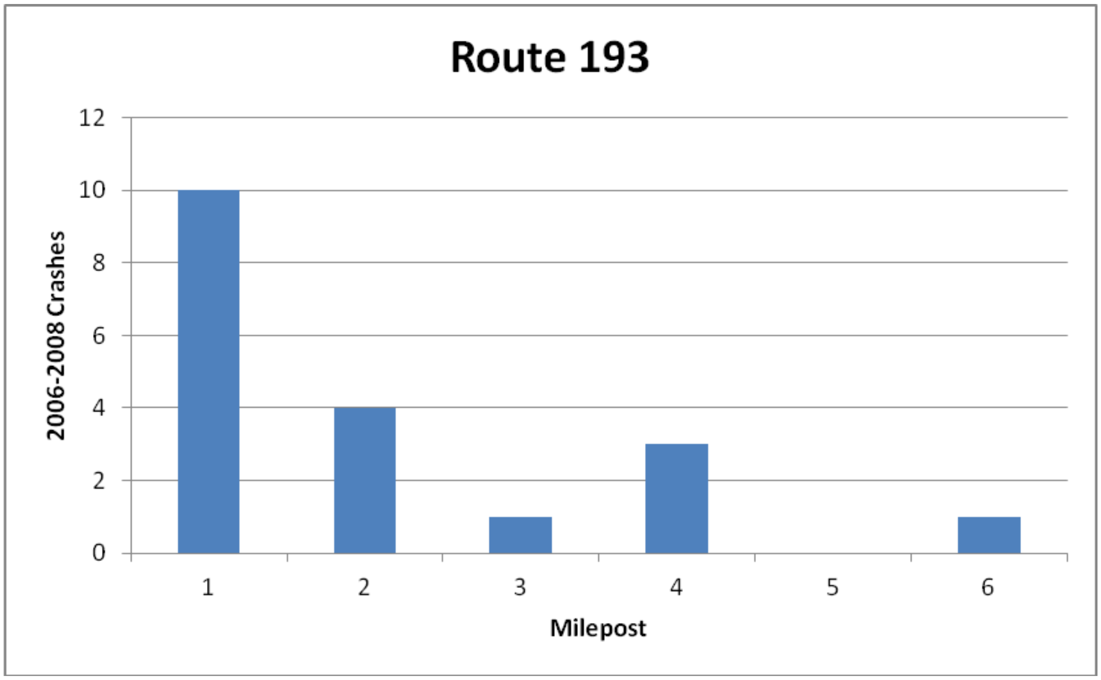
2006-2008 Crashes
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Milepost


Route 193
2006-2008 Crashes
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10
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4
2
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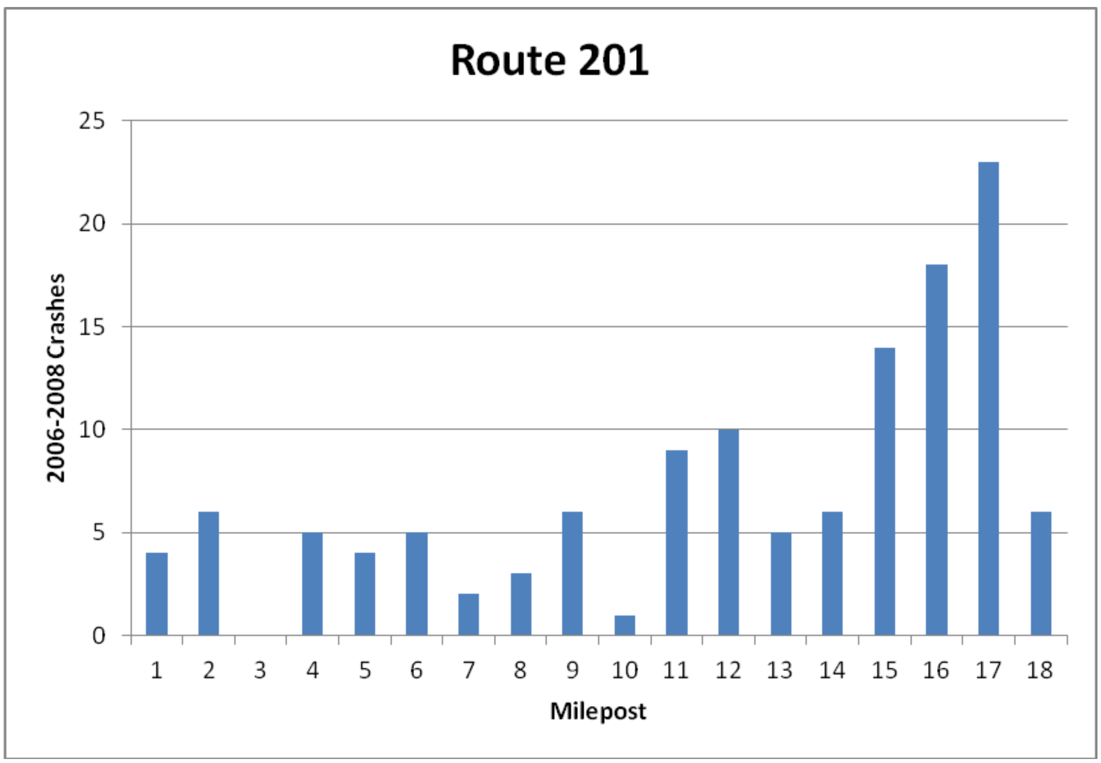
1
2
3
4
5
6
Milepost


Route 201
2006-2008 Crashes
25
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10
5
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6
7
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9
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12
13
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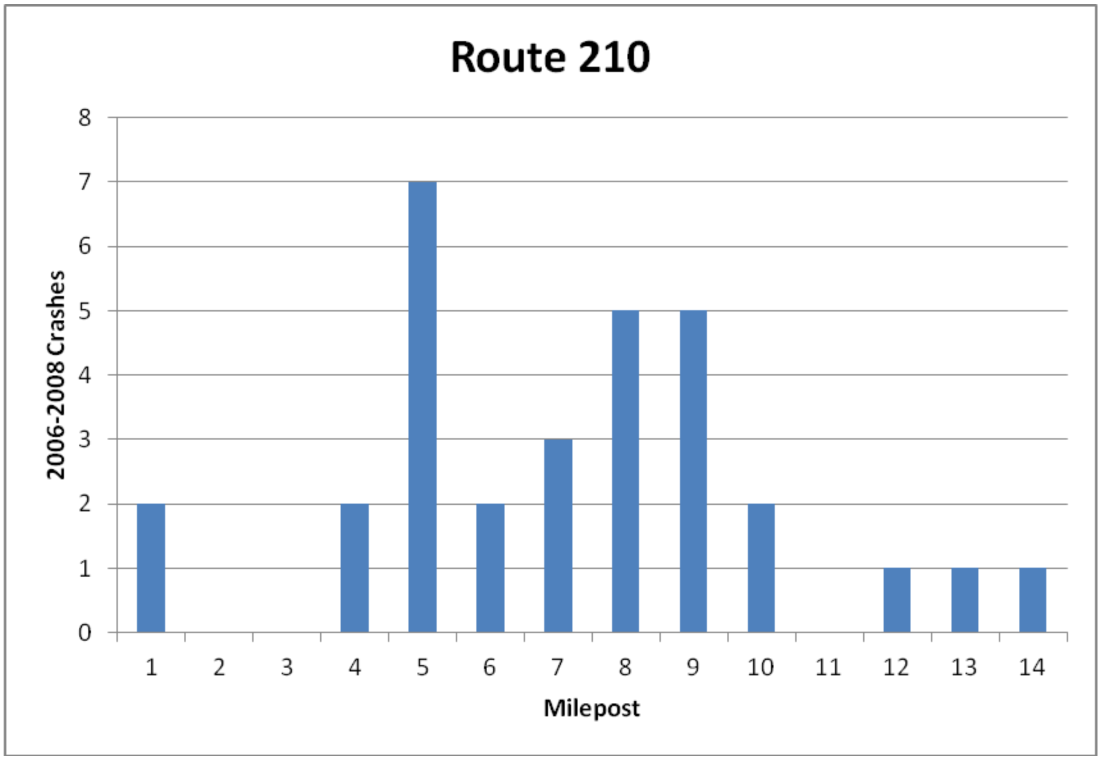
15
16
17
18
Milepost


Route 210
2006-2008 Crashes
8
7
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5
4
3
2
1
0
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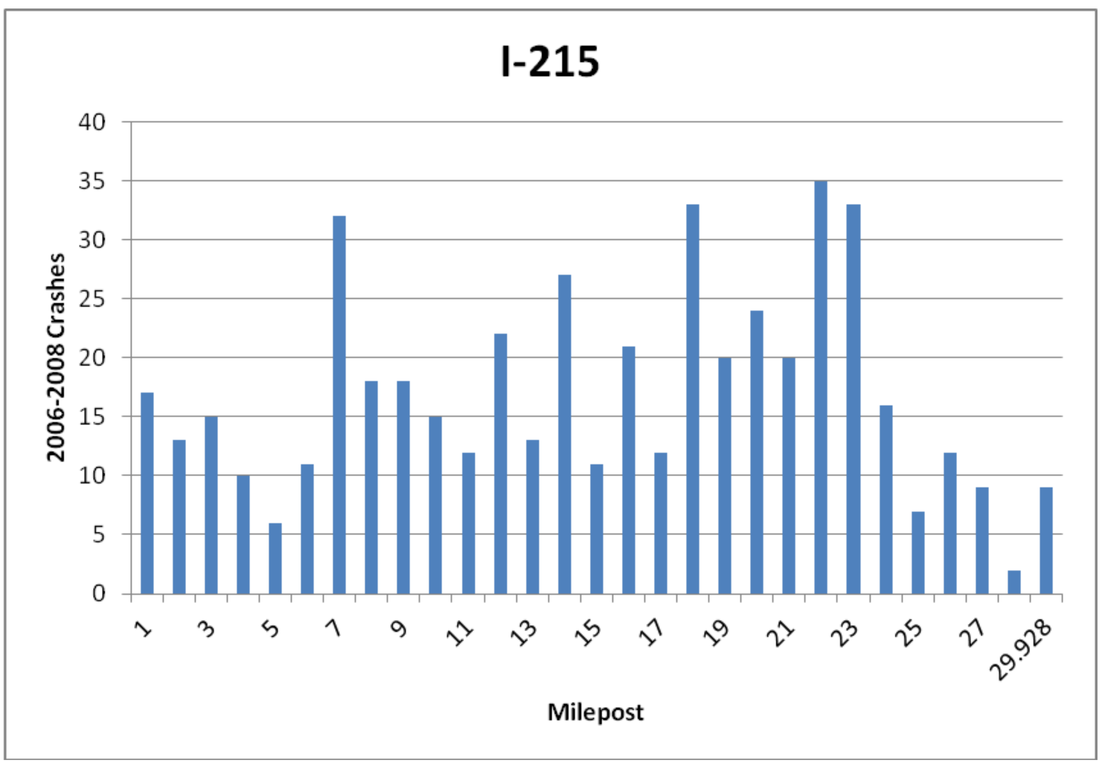
Milepost


I-215
2006-2008 Crashes
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25
20
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10
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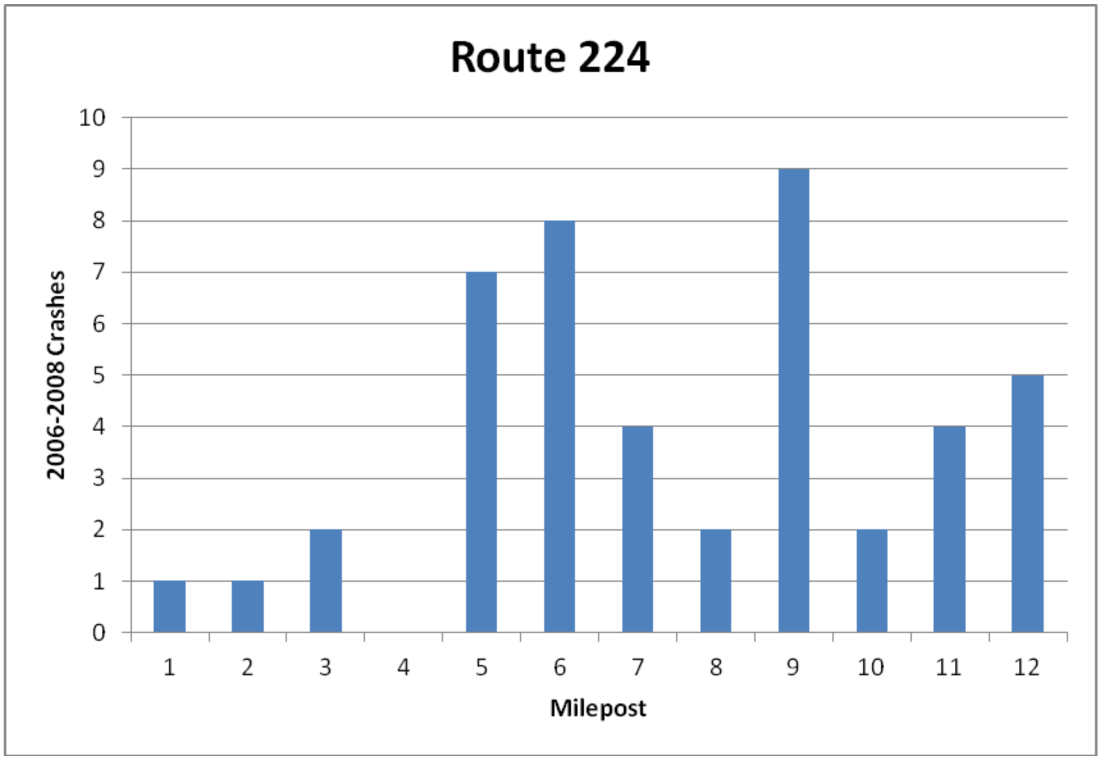
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29.928
Milepost


Route 224
2006-2008 Crashes
10
9
8
7
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1
0
1
2
3
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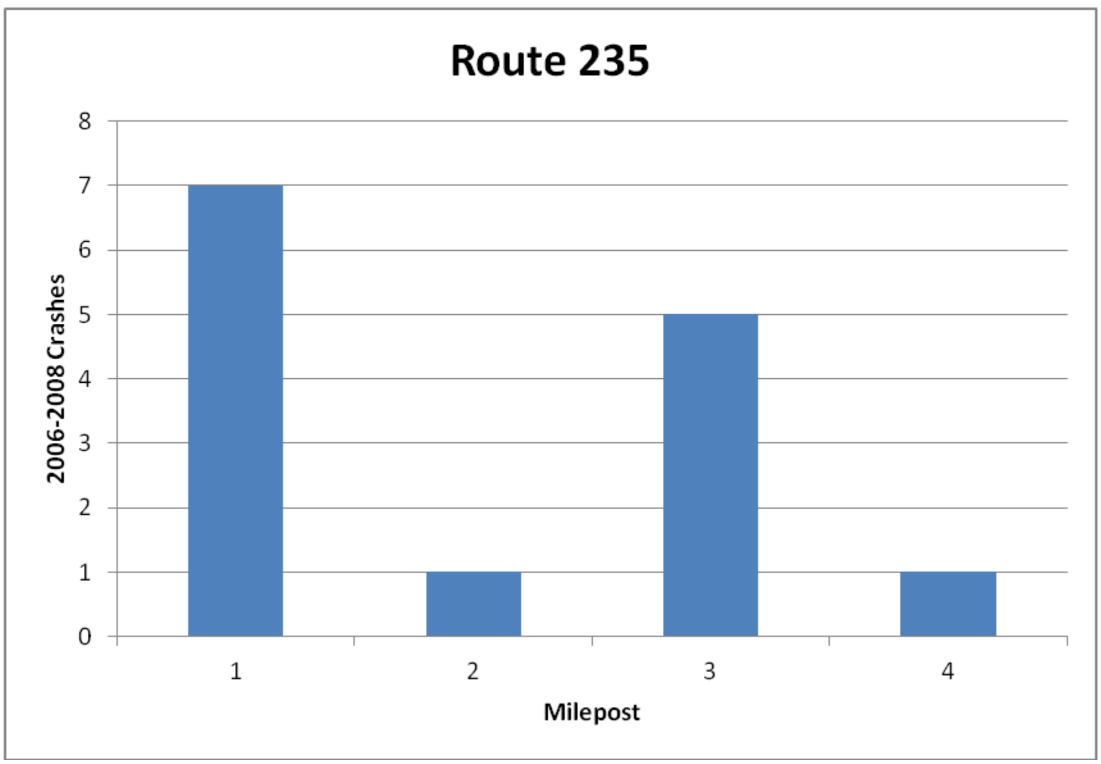
5
6
7
8
9
10
11
12
Milepost


Route 235
2006-2008 Crashes
8
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1
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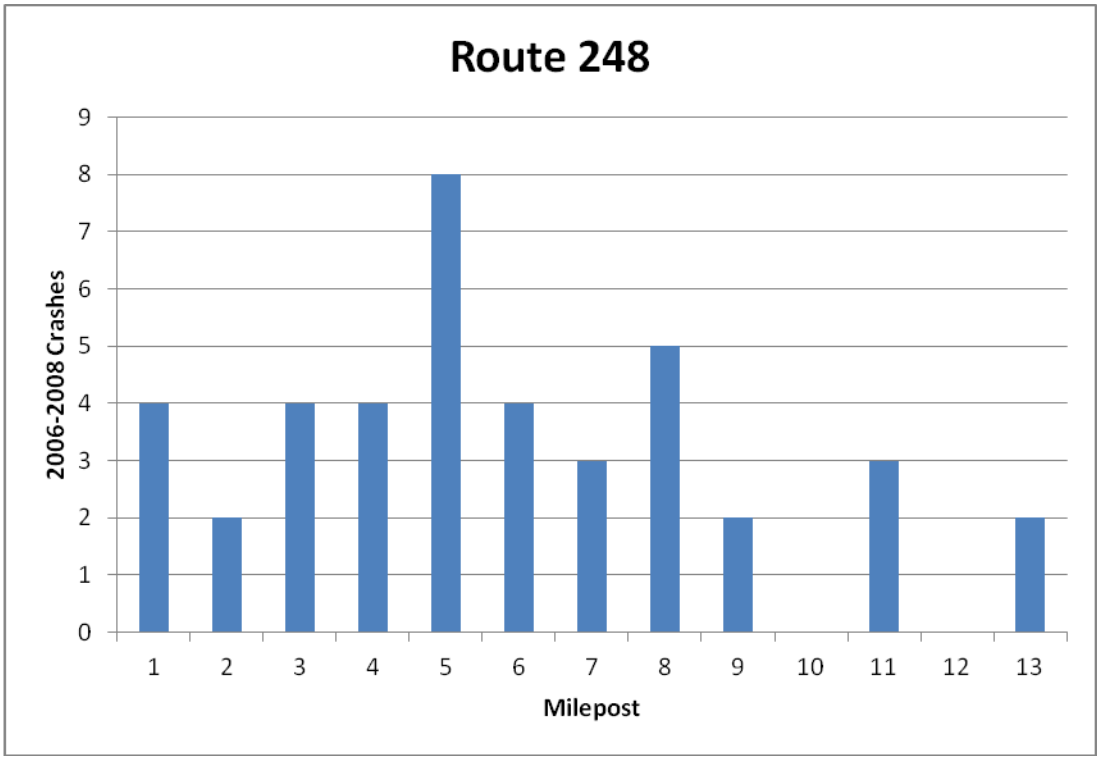
3
4
Milepost


Route 248
2006-2008 Crashes
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4
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6
7
8
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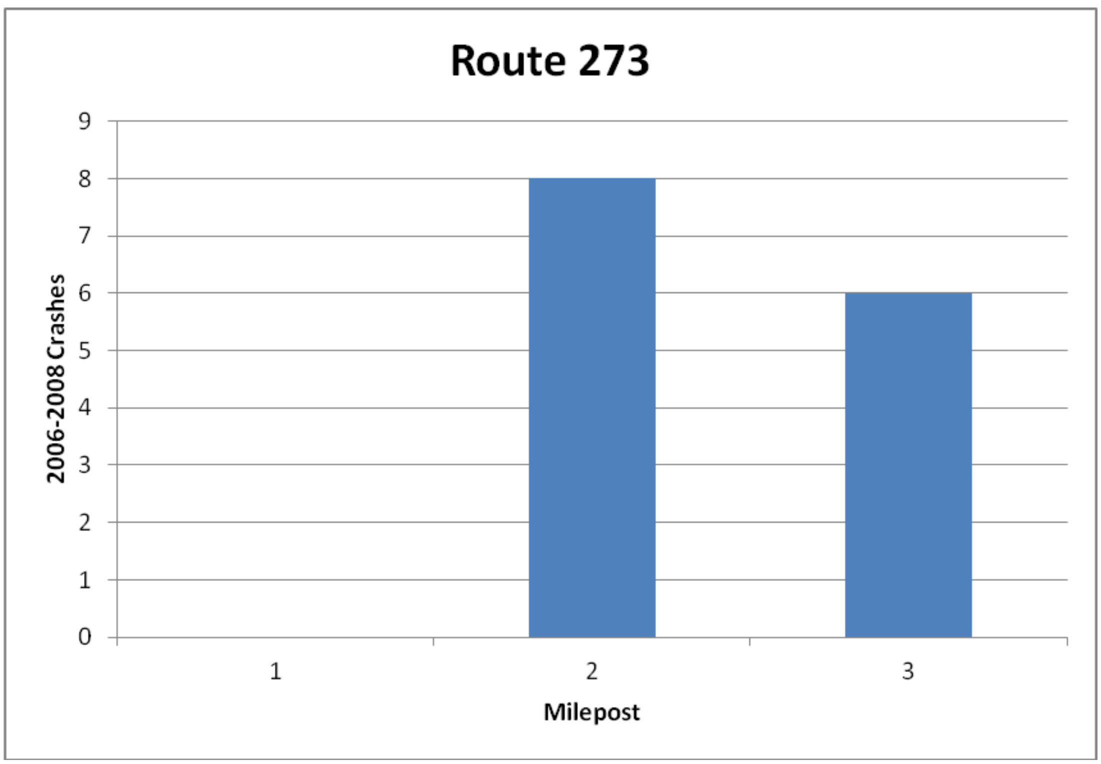
10
11
12
13
Milepost


Route 273
2006-2008 Crashes
9
8
7
6
5
4
3
2
1
0
1
2
3
Milepost

Appendix C

Table C1- Possible Uses of Crash Data by Region and Division Personnel

Snow & ice removal plans	Pavement marking plans
Loose chip related	Railroad crossing failures
Sign management	Wild animal hits
Rejuvenation related	Domestic animal hits
Pot holes hit	Edge drop-off problems
Rut related	Traffic control evaluation
Tree and grass related	Deer fence location & maintenance
Glare screen maintenance	RWIS needs
Fog mitigation	Worker related crashes
Construction zone crashes	Construction zone speed criteria

Table C2- Examples of Performance Measures for UDOT Regions and Divisions

Maintenance/Operations:	Measures	Possible Action
Deer Fence (existing)	-Deer hits per year -Severe deer related crashes	-Conduct fence maintenance
Deer Fence (new)	-Deer hit clusters -Severe deer related crashes	-Recommend new fence
Snow Removal	-Snow & ice crash clusters -Severe snow & ice crashes	-Modify snow removal plan
Slippery Pavement	-Number of crashes per year -Crash rate -% Wet weather crashes -Number severe crashes	-Post “Slippery When Wet” sign -Resurface early -Resurface as scheduled