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OREGON DEPARTMENT OF TRANSPORTATION

Evaluation of Region 2 Incident Response Program Using Archived Data

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Research Report PSU-CE-TRG-01-01

June 30, 2001

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ACKNOWLEDGEMENTS

This project has been made possible by the efforts of many individuals. The research team is grateful to the Project Manager, Martin G. Klug, and the Technical Advisory Committee: Galen McGill, Dan Dollar and Becky Knudson. In addition, Sylvia Vogel, Tim Thex, Jennifer Campbell and Mark Willis assisted in obtaining data. Richard Peek generously provided the CAD data in various formats. Dan Dollar provided Incident Response background information and cost data. Finally, Bill Williams and Kevin Kinney arranged valuable field reconnaissance.

Robert Bertini served as Principal Investigator. Sutti Tantiyanugulchai and Edward Anderson were responsible for database development and data processing. Roger Lindgren assisted with the literature review. Monica Leal assisted with preparation of data summaries and graphics.

EXECUTIVE SUMMARY

Introduction

Incidents are defined as accidents, breakdowns and other random events that occur on our highway system. It is well known that incidents contribute to approximately 50 percent of the congestion delay on the nation's highways, lead to major road closures and adversely affect the safety of our transportation network. Further, incidents increase drivers' exposure to hazardous conditions and are known to lead to secondary accidents as well. In Oregon, outside of the Portland metropolitan area, maintenance personnel typically managed incidents on an as-needed or reactive basis. Knowing that incidents do not only occur during the hours when maintenance personnel are working, overtime charges are necessary for response to major incidents on weekends and overnight. In recent years, growth in traffic volumes and tightening maintenance budgets have led to the need for more proactive operations management strategies. During this same period, more and more diversion of maintenance resources has led to increased overtime costs and increasingly negative effects on maintenance productivity.

As a proactive means of addressing these issues, since 1995 the Oregon Department of Transportation (ODOT) has deployed one of the first incident management programs outside of a major urban area. Incident management is a proven strategy for reducing the duration of incidents' impact on traffic flow, and provides *eyes and ears* to the highway system. The Region 2 Incident Response (IR) Program is a tool used to assist disabled vehicles along freeway and highway corridors. The Region 2 IR program's continuously patrolling vehicles provide complimentary services such as: changing a flat tire, refilling a radiator, providing fuel, and giving directions. The IR vehicles work with local private towing firms to remove stalled vehicles from the roadway. The work accomplished by the IR team helps relieve non-recurrent congestion through quick incident detection, verification, response, and removal/clean up. This effort in turn can reduce delay, fuel consumption, accident exposure, air pollution and environmental impacts of incidents that occur, as well as improve agency resource allocation. In addition, the IR team can notify the proper authorities, through the traffic operations center, of other types of roadway problems which currently or in the future will impact traffic flow.

The Region 2 IR program has evolved over the past six years and is one of the first documented rural incident management programs in the nation. The IR program is administered by ODOT in cooperation with the Oregon State Police and many other local agencies. This report presents the results of an analysis of this program for two representative corridors along Interstate 5 and Highway 18 during the period 1995 – 2000.

Benefits of Incident Response

For the purposes of this study, in addition to the costs of implementing the IR program, a number of prospective IR benefits were identified. Some of the benefits accrue to the general public, including:

- Reduced delay
- Reduced fuel consumption
- Improved air quality
- Improved safety and security (avoided accidents and secondary accidents and an improved feeling of security on the transportation system)
- Improved flow of commerce
- Reduced harm to wildlife, soil and water quality

Other IR benefits include those that accrue to ODOT and other agencies, including:

- Reduced maintenance crew cost
- Value of extra maintenance performed
- Increased recovery of Charges Against Others (CAO) from motorists' insurance companies
- Awareness of potentially hazardous items requiring maintenance
- Improved de-icing information
- Improved public relations and good will.

Research Objectives

This research included a statistical analysis of archived incident data (available since 1995), estimation of reductions in fuel consumption and delay, calculation of program costs and development of a decision-making tool for design/expansion of IR on future corridors. As shown in Figure 1, the project concentrated on two corridors using archived CAD data for Highway 18 (McMinnville to Lincoln City) and Interstate 5 within the Lane County limits in the Eugene area. These two distinct corridors were selected carefully in collaboration with the Technical Advisory Committee. Highway 18, between McMinnville and Lincoln City, is a rural highway characterized by heavy weekend/recreational traffic, has no parallel detour routes, is a major truck route to the Oregon coast, and thus imposes an economic impact if the highway is closed for any period of time. In addition, there are few existing emergency response resources immediately adjacent to the highway. Interstate 5 within Lane County in the Eugene area is a more typical commute corridor with available nearby emergency resources.

Figure 1 – Study Sites

The methodology consisted of a quantitative analysis of archived incident data during two distinct phases since the IR program's inception. As shown in Figure 2, *Phase 1* covers the period between February 1995–March 1997 and *Phase 2* covers the period from March 1997-December 2000. Figure E2 also shows the total amount of IR resources deployed. As shown, during Phase 1 on Highway 18, IR personnel invested approximately 36 hours per month, while during Phase 2 (continuing today), there is one full-time IR staff member deployed (173 hours per month). Figure E2 also indicates that the staffing level has increased over time on Interstate 5. It should be noted that it has not been possible to conduct a true "before and after" study, since it is the IR staff themselves who are the roving data collectors. Thus, the numbers of reported incidents (as opposed to the actual number of incidents—impossible to determine) has increased because the IR personnel are physically monitoring the status of the roadways.

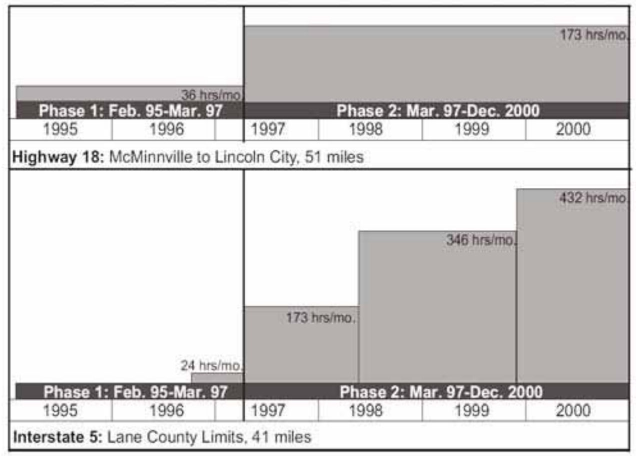

Figure 2 – Incident Response Staffing

This analysis has been used to characterize the benefits of the IR program, and is contrasted with the costs of administering and operating the program. Quantitative comparison of potential benefits has included consideration of possible reductions in accidents, traffic congestion, pollution and requirements for ODOT and law enforcement resources. The evaluation of these benefits aims to provide threshold levels of inputs (e.g., traffic volumes, number of incidents, etc.) that would indicate that an IR program should be created or expanded for a particular route. In addition, qualitative benefits derived as a result of the IR program were also identified. Although these benefits are not directly measurable, their presence increases the value of the IR program making it more cost effective than that actually presented.

Data Analysis

As shown in Figure 3, incident data collected by ODOT's Region 2 CAD included 15 fields of data for both roadways over the study period, including details regarding the incident type, location, time reported, time cleared and other remarks. It should be noted that there are many incidents that are never reported, and in particular, before the implementation of the IR program, there were fewer reported incidents. Now, IR personnel report incident data via radio, and so in addition to the improvement in reporting frequency, there have been improvements in reporting accuracy and timeliness due to the presence of the IR program itself. In addition, since 1995, the prevalence of cellular phones had increased the public reporting rate. Therefore, the reported incident frequency tracks with increases in IR coverage.

ID	Identification number (not used)
CAD_NUM	Incident number
CALL	Call type
DATE	Date
UNIT	Unit responding
TIME_RCVD	Time call received
CLEAR	Time call cleared
LOCATION	Location (highway number, etc.)
REMARKS	Remarks
REMARKS2	Additional Remarks
ARRIVED	Time arrived (*added January 1999*)
DISPO	Disposition code
CA	Command area
COUNTY	County
DISP_RMKS	Disposition remarks

Figure 3 – CAD Data Sample

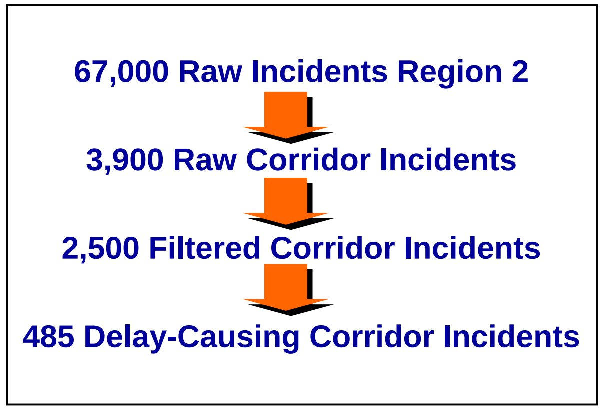

Figure 4 – Data Processing

As shown in Figure 4, these raw CAD data were expanded into a database describing the incidents for Highway 18 and Interstate 5. The database includes information on more than 67,000 unfiltered (raw, may include duplications, errors, etc.) incidents. These raw data were subsequently filtered to isolate 3,900 reported incidents in the study corridors. These raw corridor incidents were further filtered to remove duplicate incidents, and were reviewed for consistency, resulting in 2,500 incidents to be analyzed. Finally, each incident was analyzed carefully in terms of its severity, duration, timing and location to determine whether it actually caused delay to the motoring public. This resulted in the consideration of a total of 485 delay-causing incidents along the study corridors.

Study Findings

The following information was determined from our review and analysis of the Region 2 IR program for the period 1995 - 2000. First, as shown in Figure 5, considering all 67,000 reported incidents in Region 2 during the period 1995 – 2000, it is clear that the majority of incidents are classified as HAZARDS (34%), followed by ACCIDENTS (15%) and

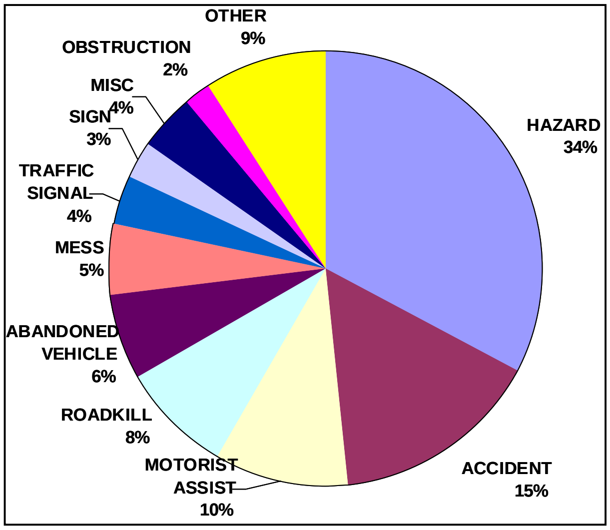

Figure 5 – Incident Characteristics

MOTORIST ASSIST (10%). Nearly 60% of all incidents fall under these major categories. As an example, Figure 6 shows a histogram of incidents by type on Highway 18 alone. This figure indicates that the incidents in the

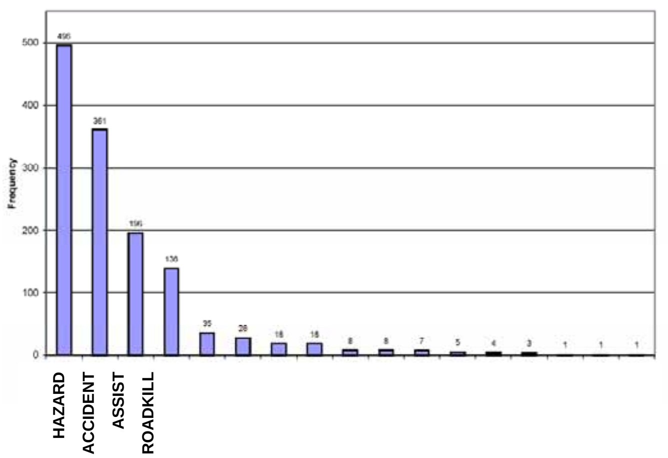

Figure 6 – Highway 18 Incidents

categories of HAZARD, ACCIDENT, MOTORIST ASSIST and ROADKILL account for nearly all of the incidents that occurred on Highway 18. Figure 7 displays the top four incident types (HAZARD, ACCIDENT, MOTORIST ASSIST and ROADKILL) by milepost location. As shown, it is possible to identify mileposts 1, 24 and 53 as the higher incident locations. This information can be useful when planning incident response staffing as well as when planning safety and other roadway improvements.

A series of analyses was also conducted with respect to incident duration. As shown in Figure 8, an incident usually occurs some time before it is actually reported. Also, an incident may actually be cleared several minutes before this clearance is reported to dispatch. However, an incident's impact can be felt for a

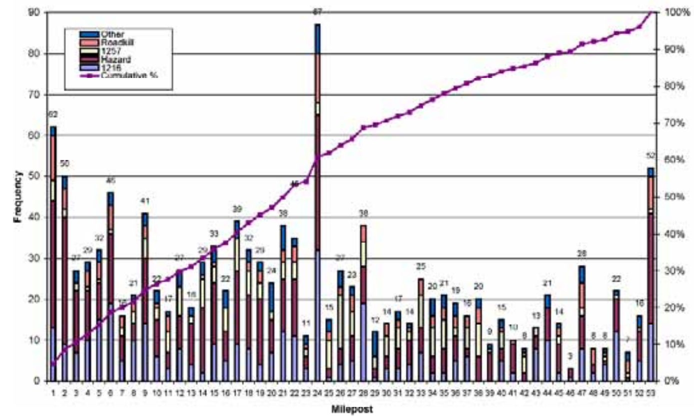

Figure 7 – Highway 18 Incident Locations

long time after it is actually cleared from the roadway. Figure 8 also indicates that it is the motivation of an incident response program to minimize the time between actual incident occurrence and clearance

Once the incidents' actual durations are estimated, they can be plotted in the form of a histogram, as shown in Figure 8. This figure

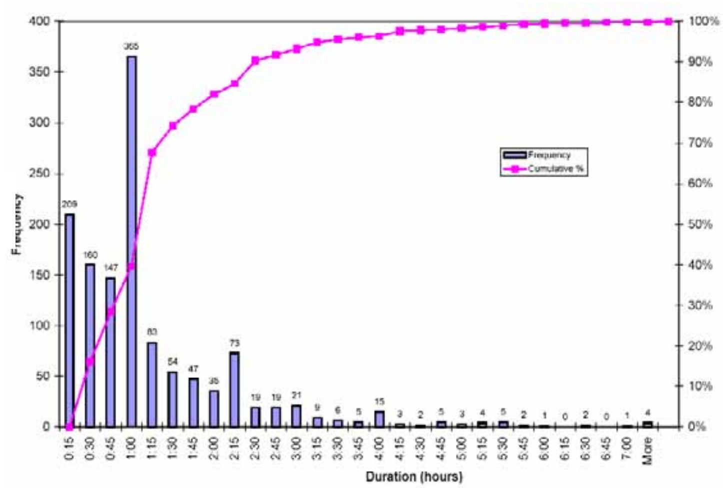

Figure 8 – Incident Durations

shows the distribution of incident durations on Highway 18 between 1995-2000. As shown, the majority of the incidents had durations between 45 minutes and one hour. The primary benefit of an IR program is to decrease

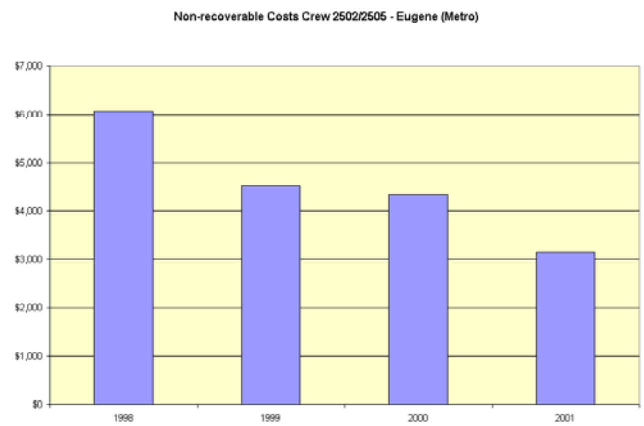

Figure 9 – Non-recoverable Costs

the duration of incidents, thus reducing the impact of the incidents on driver delay.

Some additional analysis was performed in order to assess the impact of IR on ODOT's maintenance productivity. As one indicator, Figure 9 demonstrates that the non-recoverable costs in the Eugene metro area have been declining. This decline can be attributed to better incident reporting.

Finally, ODOT has provided some additional

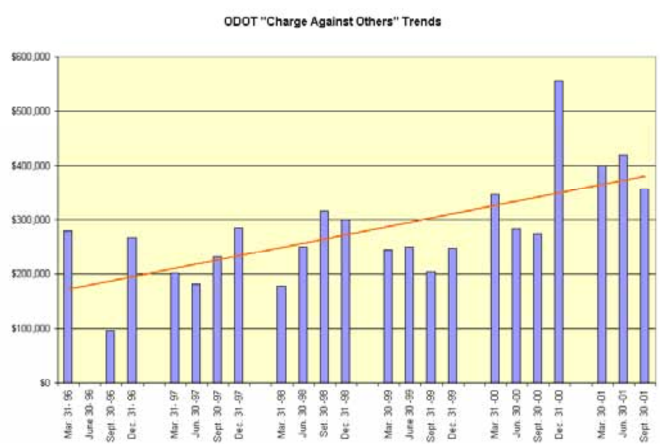

Figure 10 – Charge Against Others

data regarding their efforts to recover costs incurred during accidents that damage state property. Figure 10 shows that along Highway 18, this type of cost recovery has been increasing, likely due to the presence of the IR personnel who serve as additional witnesses to such damage.

Summary of Results

The tabulated results shown below summarize the findings of this research.

	Highway 18	Interstate 5

Roadway Characteristics: The average daily traffic on both routes has increased substantially since 1995, with no increases in capacity. As on most highways throughout Oregon, this emphasizes the need to focus attention on development of new operational strategies.

Length (miles)	51	41
Average Daily Traffic – 1995	8,600	33,000
Average Daily Traffic – 2000	11,400	40,000
Average Daily Traffic Increase 1995 - 2000	+33%	+21%
Capacity Increases 1995 - 2000	0%	0%

IR Program Characteristics: The IR program handles more than 30 major assists per month. One major finding of this research was that 70-75% of the delay-causing incidents were accidents. This indicates that for future planning purposes accident statistics may help determine routes that would be candidates for new or expanded IR programs. It is important to recognize, however, that the number of accidents reported to the state by motorists is much smaller than the actual number of accidents that occur.

Total Number of Incidents Reported by IR	1,815	2,018
Average Assists per Month (total)	36	35
Average Assists per Mile (total)	31	39
Percent Delay Causing that are Accidents	75%	70%

Accident Characteristics (ODOT statewide data): Based on statewide accident data, it is shown that the accident rate has decreased on Highway 18 over the period that the IR program has been in effect.

Accident rate expressed in number per million vehicle-miles traveled		
Accident Rate – 1995 (pre-IR)	0.72	0.12
Accident Rate – 1999 (post-IR)	0.63	0.19
Accident Rate Reduction	-13%	+58%

Average Duration of Incident (hours): Another major finding of this research is that the duration of delay-causing incidents has dropped substantially with the implementation of the IR program. This drop in duration was approximately 30% on Highway 18 and almost 15% on Interstate 5.

Delay-Causing Phase 1 (pre-IR)	2.07	1.10
Delay-Causing Phase 2 (post-IR)	1.42	0.95
Delay-Causing Incident Duration Reduction	-31%	-14%

	Highway 18	Interstate 5

Average Delay per Incident (vehicle-hours): Along with the reduction in mean incident duration has followed the reduction in delay imposed on other motorists. The average delay per incident has dropped 66% on Highway 18 and 36% on Interstate 5.

	Highway 18	Interstate 5
Delay-Causing Phase 1 (pre-IR)	3,572	1,907
Delay-Causing Phase 2 (post-IR)	1,227	1,224
Delay-Causing Incident Delay Reduction	-66%	-36%

Average Cost of Fuel and Person's Time Loss per Incident: When delay is reduced, so is fuel consumption and the value of drivers' time.

	Highway 18	Interstate 5
Delay-Causing Phase 1 (pre-IR)	$63,800	$34,100
Delay-Causing Phase 2 (post-IR)	$21,900	$21,900
Cost Reduction	-66%	-36%

Total Return on Program Investment: Based on reductions in delay and fuel consumption, the IR program in Region 2 has provided a total return on investment of $885,000 on Highway 18 and $1,010,000 on Interstate 5.

	Highway 18	Interstate 5
a. Total Program Cost (1995 – 2000)	$240,000	$400,000
b. Total Delay & Fuel Costs (1995 – 2000)	$3,700,000	$9,400,000
c. Total Delay & Fuel Savings (1997-2000)	$1,125,000	$1,410,000
d. Total Return (1995 – 2000) [c-a]	$885,000	$1,010,000

Year 2000 Maintenance Staffing Estimates: A more detailed analysis for the year 2000 was conducted considering the reduction in agency costs. As shown below, nonrecoverable crew costs declined while charge against others revenue increased. It was estimated that maintenance staff costs plus overtime resulted in additional labor and equipment savings. Finally, the value of the extra maintenance that was performed while personnel were not diverted to incident response was also included. As shown, without considering delay or fuel, the IR program on Highway 18 is justified based on agency costs alone.

	Highway 18	Interstate 5
Decline in Nonrecoverable Crew Costs	--	$3,000
CAO Revenue (2000)	$10,000	
Maintenance Staff Costs Saved (2000)	$62,000	$50,000
Value of Extra Maintenance Done (2000)	$19,000	$19,000
Subtotal	**$91,000**	**$72,000**
Cost of IR Program (2000)	($71,000)	($126,000)
Delay and Fuel Savings (2000)	$230,000	$333,090
Annual Return (2000)	**$250,000**	**$279,090**

As mentioned previously, the majority of the delay causing incidents (approximately 75%) along Highway 18 and (approximately 70%) along I-5 are 1216 – Motor Vehicle Crashes. This suggests that a review of the reported accident (1216) data from the CAD system alone may suffice when considering the potential use of or the expansion of an existing IR program. Since the effectiveness of an IR program is a function of the roadway length, ADT, and the accident rate, the results of the Highway 18 analysis were used to derive a simple procedure in order to consider the viability of future IR programs. By modeling the roadway length, ADT, and the accident rate, this report attempted to estimate the delay on similar facilities under different scenarios. The results of this will not necessarily provide a definitive answer as to whether an IR program will provide immediate returns, but whether the roadway under consideration should be given additional review when considering future IR programs.

Recommendations

The results of this study indicate ODOT's Region 2 IR program is beneficial and exceptionally cost effective. Recommendations are made not on the general operation of the IR program but on the reporting/record keeping portion. These recommendations are made to facilitate faster, more precise review of this and other IR programs. These recommendations include: 1) additional fields for more incident and roadway characteristics, 2) using standard terminology when reporting incidents, 3) implementing AVL to measure time on specific routes, and 4) more detailed designations in the HAZARD category, since nearly one third of the incidents were reported as HAZARD.

1.0 INTRODUCTION

1.1 Background

Incident management is a critical public safety and traffic management technique designed to: decrease emergency vehicle response times; reduce incident duration, severity, and associated congestion (delay), fuel consumption and emissions; prevent secondary accidents[1]; improve safety for emergency and Department of Transportation (ODOT)[2] personnel; and allow ODOT to ensure that roadway facilities are in safe conditions before they are opened to traffic.

Incident management programs give ODOT the chance to be proactive rather than reactive, and are usually the first and only opportunity for direct contact between ODOT personnel and highway users. These programs are also very popular with the public, and provide a heightened sense of safety and security for motorists on the highway system. Thus, incident management programs can provide enhanced customer satisfaction, and improved user perceptions.

ODOT currently operates dedicated Incident Response (IR) teams in Regions 1 and 2. IR vehicles patrol the Interstate and state highways, assisting state and local police forces and individual motorists during a wide variety of traffic events. In areas not covered by IR teams, maintenance workers are dispatched on an incident-by-incident basis. At some point, as traffic volumes continue to increase, IR tasks become frequent enough to warrant expansion of existing programs and creation of dedicated IR teams in Regions 3, 4 and 5.

As with any investment decision, it is important to include some form of evaluation as part of a continuous improvement process. It is believed that a qualitative and quantitative analysis of the incident management programs in Oregon will lead to a better understanding of their costs and benefits, and thus their effectiveness in meeting their objectives. It is also anticipated that this greater understanding may also lead to improvements in making decisions about where and when to deploy and/or expand such programs, and how to prioritize resources.

1.2 The Region 2 Incident Response Program

Recognizing that incidents account for more than fifty percent of congestion delay on the highways, ODOT has established the IR program to reduce congestion on the state highways. This is the first rural incident management program in the nation. The program was conceived in response to experiences with very long roadway closure times, and the program reduces road closure time by assisting disabled vehicles, responding to crashes, hazardous material spills and any incident that blocks a highway lane or causes a hazard to the safety of the traveling public. In addition, the program reduces the length of time that motorists are exposed to hazardous situations by targeting stranded motorists and stalled vehicles as well as attempting to reduce secondary accidents. The program has been designed recognizing that when the normal flow of

[1] Secondary accidents are those that occur as a result of the hazardous, queued conditions that result when a primary accident occurs. Secondary accidents classically occur when an unsuspecting motorist reaches the back of the queue and when rubbernecking occurs while passing an accident or incident scene.
[2] Acronyms and abbreviations shall be defined once.

traffic is impeded, goods and services are delayed from reaching their destinations, which can cause a notable economic impact on the state.

The Region 2 IR program is the first known rural incident management program, and is designed to reduce in-lane traffic flow impacts by an average of approximately 15 minutes. The Region 2 program has evolved over the past six years and presently includes services such as:

- Initiation of measures to reduce traffic congestion and delay.
- Providing support to law enforcement and other emergency agencies.
- Assisting in clearing stalled vehicles from travel lanes.
- Provide stranded motorists with minor mechanical assistance, including:
    - Changing flat tires.
    - Fuel, coolant, etc.
    - Jump start weak batteries.
    - Provide travel information and road conditions.

In addition, the incident responders provide assisted motorists with mail-back surveys. As an indication of the immense popularity and success of the program, only one out of thousands of surveys has ever indicated a negative response.

1.3 Objectives of the Study

The objectives of this study have been to perform a qualitative and quantitative analysis of the benefits and costs of the ODOT Incident Response (IR) program in Region 2, with a focus on Highway 18 (Districts 3 and 4) and I-5 in the Eugene area (District 5), as shown in Figure 1. The research has focused on developing a method that can be used for future evaluations and updates. This research has been conducted under a rapid two-month time frame.

This research provides estimates of the benefits and costs of incident response programs within ODOT Region 2. The research primarily used existing archived data sources, which also demonstrates the value of the data collection and management systems already in place. The research results will enable better decision-making on resource allocation within ODOT. The framework developed in this research will be relevant for future and ongoing evaluations of existing programs and will contribute toward future expansions and modifications of incident management efforts throughout the state.

1.4 Organization of the Report

The report has been organized as follows. Section 2 describes the research approach including the procedures used to estimate the selected measures used to calculate the benefits of the IR program. Section 3 describes data collection and processing. Section 4 presents the analysis of the incident data, and Section 5 presents the evaluation of the incident response program for the two selected corridors. Finally, Section 6 summarizes the study findings and includes suggestions for future research.

Appendix A documents the value of travel time assumed for automobiles, light trucks, and heavy trucks in Oregon. Appendix B presents vehicle occupancy rates for the State of Oregon. Appendix C shows the 1999 average daily traffic (ADT) volumes by milepost for Highway 18 (Salmon River Highway Number 39). Appendix D shows the 1999 ADT volumes by milepost for Interstate 5. Appendix E is a summary of typical Highway 18 incident entries describing traffic conditions.

2.0 METHODOLOGY

This research has been based primarily on a statistical analysis of Oregon State Police (OSP) computer aided dispatch (CAD) data from Highway 18 (McMinnville to Lincoln City) and Interstate 5 within the Lane County limits in the Eugene area. In general, to the extent possible, the methodology consisted of a statistical analysis of incident data both "before" and "after" the IR program was initiated. This analysis has been used to characterize the benefits of the IR program, and is contrasted with the costs of the program. Field reconnaissance was also conducted along both corridors.

Quantitative comparison of potential benefits has included consideration of possible reductions in accidents, traffic congestion, pollution and requirements for ODOT and law enforcement resources. For potential benefits such as improved customer satisfaction, a brief review of customer surveys was also included. The evaluation of these benefits aims to provide threshold levels of inputs (e.g., traffic volumes, number of incidents, etc.) that would indicate that an IR program should be created or expanded for a particular route.

Other data sources have include the Oregon Department of Motor Vehicles, ODOT's Transportation Systems Monitoring Unit, crash data from ODOT's Crash Analysis & Reporting Unit, and ODOT's Integrated Transportation Information System (ITIS).

2.1 Literature and Peer State Review

The research team conducted a review of the rural incident management literature, and incident management programs in selected peer states were reviewed, with a focus on non-urban applications. In order to accomplish this, a Transportation Research Information Service (TRIS) search was conducted. The National Transportation Library (NTL) and the Institute of Transportation Studies (ITS) Library and the Partners for Advanced Transit and Highways (PATH) database located at the University of California at Berkeley were also reviewed. The Federal Highway Administration (FHWA) Freeway Management Handbook and results of other incident management evaluations were reviewed.

This review has shown that rural incident management projects exist or are in the planning stages in a number of locations across the country. Among them are:

- Arizona – Rural Incident Management Plan and Statewide Traffic Information Center
  - Streamlining agency authority and responsibility.
  - Expanding freeway service patrols to rural areas.
  - Centralized communications system.

- California Statewide Traffic Incident Information
  - The public is provided near real-time web access to reported traffic incidents throughout the state.

- California-Oregon Advanced Transportation System (COATS) I-5 Incident Management System:

  - Yreka, CA to Medford, OR
  - Includes variable message signs, video detection and call boxes.

- California's Kern County
  - Changeable message signs on busier rural routes.
  - Automated computer program provides support to dispatchers for more uniform agency response.
  - Highway advisory radio.

- California's Sutter County
  - Automatic detection of low visibility situations and traffic flow.
  - Early warning to drivers to reduce impact of detected incidents.

- California's TransCal Intelligent Transportation Systems (ITS) Rural Field Operational Test
  - Interregional Traveler Information System.
  - Will disseminate customized traveler via personal digital assistants (PDAs) and other in-vehicle communication systems.
  - Goal is to mitigate the impact of highway incidents.

- California Gateway Counties Rural ITS (RITS)
  - Counties in northeast CA.
  - Coordination of communication system allows for faster response by agencies.

- Colorado Rural ITS Program (RITS)
  - Changeable message signs on busier rural routes.
  - Roadway weather advisory systems.
  - Roadside emergency call box system for driver reporting of incidents.

- Florida's Wireless Phone Surcharge Program
  - Florida cell phone users pay a surcharge to pay for a system that will enhance the ability of incident responders to pinpoint the location of callers.

- Florida's Daytona Area Smart Highways (DASH)
  - Loop detection used to locate incidents and send responders.
  - Being expanded from urban to more rural areas.

- I-95 Corridor Coalition
  - Member agencies provide primarily an urban freeway incident management system, but many are expanding the coverage to rural applications.
  - Pennsylvania Turnpike Commission uses a computer-aided-dispatch system.

- Minnesota's Advanced Rural Transportation Information and Coordination (ARTIC)
  - Seven county area in northwest MN.
  - Integrated agency communication system allowing for faster incident response.

- Minnesota's Rural Coordinate Addressing System
  - Blue Earth County MN.
  - Global Positioning System (GPS) used to map the rural roads in the county.
  - GIS mapping system aids in sending out responders to highway incidents.

- New Jersey SR55 Surveillance and Delay Advisory System (SDAS)
  - Weigh-in-motion devices and video monitoring allow for speed and incident detection.

- North Carolina Transportation Incident Management System
  - Most verified traffic incidents are automatically sent to a publicly accessible web site to aid motorists in route selection.
  - Incidents are assigned a severity ranging from minor to severe depending on the potential for flow reduction.

- Pennsylvania's North Central Rural ITS program:
  - Starting with a mapping project to identify locations of all roads.
  - Next planned step is improved wireless communication system.

- Pennsylvania Rural Interstate ITS
  - Instituted SmartTraveler (phone and internet based information system).
  - Installed variable message signs, motorist call boxes.
  - Plans for 24/7 statewide operations center.

- Wisconsin I-90/94 Incident Management System
  - Centered on freeway safety patrols.

2.2 Selection of Test Sites

As shown in Figure 1, the corridors selected for analysis were along Highway 18 and Interstate 5. These two corridors were selected in cooperation with the Technical Advisory Committee for the following reasons: 1) the traffic volumes are high enough to warrant an IR responder and 2) although limited, “before” the IR and “after the IR” incident data was available. In addition, the Highway 18 corridor includes the Safety Corridor between Grand Ronde (MP 20.7) and Sheridan (MP 38.4)

Each corridor was analyzed from the inception of the CAD system (early 1995) through the end of 2000. It is very important to point out that incidents were not previously being reported. When deployed, the IR personnel became the “eyes and ears” of the highways, so we are not surprised that the number of reported incidents increased as the number of staff hours deployed. The history of the IR staffing level[3] is shown in Figure 2. As shown, the level of effort has increased since the program’s inception. Each route’s length and IR staffing levels during different phases and periods are listed in Tables 1 and 2. Since the implementation of the IR

[3] Source: Dan Dollar

program has occurred in phases, the phases and periods in Tables 1 and 2 were established for each corridor to better estimate the costs associated with the IR program during these times. For Highway 18, phase 1 represents part time (or limited) IR while phase 2 represents full time IR. For Interstate 5, phase 1 represents part time (no or limited) IR while phase 2 represents full time IR. The different periods represent changes in staffing levels that were accounted for in the costs portion of this report.

TABLE 1 – Staffing Levels for Highway 18

Highway 18 · McMinnville to Lincoln City · P.M. –0.22 to 51.23 · Length: 51.5 miles		
Phase 1:	**26 months**	**February 1995 – March 1997** *(part-time IR, 36 hours/month)*
Phase 2:	**46 months**	**March 1997 – December 2000** *(1 person, 4 days/week, Friday – Monday, 10 hours/day)*

TABLE 2 - Staffing Levels for Interstate 5

Interstate 5 · P.M. 168.01 to 209.06 · Lane County Limits · Length: 41 miles		
Phase 1	**26 Months**	**February 1995 – March 1997**
	Period 1:	February 1995 – September 1996 *(none)*
	Period 2:	September 1996 – March 1997 *(part-time IR, 24 hours/month)*
Phase 2	**46 months**	**March 1997 – December 2000**
	Period 3:	March 1997 – April 1999 *(1 person, full time, 10 a.m. – 7 p.m., Monday-Friday)*
	Period 4:	April 1999 – November 2000 *(2 people, full time, 6 a.m.–2 p.m. & 10 a.m.–7 p.m., Monday – Friday)*
	Period 5:	November 2000 – December 2000 *(2.5 people, 6 a.m.–2 p.m., 10 a.m.–7 p.m. and 2 p.m.–6:30 p.m., Monday – Friday)*

2.3 Measures of Effectiveness

Benefits of the Region 2 IR program included consideration of improvements in safety, traffic congestion/delay, fuel consumption, air quality, customer satisfaction, community event coordination, police support, motorist assistance, prevented collisions, and increased capacity. The incremental reduction in incident duration and response time due to presence of IR program has been estimated. The ODOT Policy Section provided data related to calculation of delay costs (see Appendix A).

2.4 Estimation of Incident Delay

A simple deterministic queueing model was used to estimate incident delay.[4] Figure 3 shows a hypothetical curve of cumulative vehicle arrivals and departures versus time during an incident. This input-output diagram is also called a queueing diagram. The line with slope *V* is the cumulative number of vehicles that want to pass the incident, also referred to as demand. The assumed capacity of the roadway (when an incident is not present) is shown by the line with slope *C*, the maximum slope on the figure. When an incident occurs, the model predicts that the roadway capacity will be (instantaneously) reduced to slope *Ci* for the assumed duration of the incident, *t*. Vehicles begin to queue behind the incident, such that the number of vehicles in the queue at any time is the vertical distance between line *V* and line C_i. The magnitude of C_i depends on the severity, location and type of incident, and can range between zero (in which case the line would be horizontal) and *C*. Once the incident has been cleared, after *t* minutes, the model predicts that the resulting queue will discharge at the capacity of the roadway, *C*, until the queue has dissipated. According to the model, the total vehicular delay, *D* (in vehicle-hours) caused by an incident is represented by the shaded area in Figure 3. The equation for the area is:

$$D = \frac{t^2 (V - C_i)(C - C_i)}{2(C - V)} \text{ in vehicle-hours} \quad (1)$$

The procedures for estimating *t*, *V*, *C*, and C_i will be described in Section 4.

2.5 Estimation of Fuel Consumption

Fuel costs were estimated using the following simple General Motors model[5].

$$E = k_5 * L + k_6 * T \quad (2)$$

Where: E = additional fuel consumed per vehicle
k_5 = 90 ml/km = 0.03826 gallons per mile
L = distance traveled in queue
k_6 = 0.44 ml/sec = 0.4184 gallons per hour
T = travel time in queue

This model estimates the additional fuel consumed by vehicles moving slowly in traffic (average speed under 40 mph) such as in a queue. For the purpose of this report, it was assumed that vehicles average approximately 10 mph throughout the queue and that the cost of fuel is $1.65 per gallon. Therefore, Equation 2 can be simplified to:

E = $1.32 per hour per vehicle (3)

As will be seen later (Figures 31 through 38), the additional fuel costs are small compared to delay costs.

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[4] Skabardonis, et al., 1998, and other standard transportation references.
[5] Daganzo and Newell.

3.0 DATA COLLECTION AND PROCESSING

3.1 Test Site Characteristics

The research team became familiar with the characteristics of the corridors (Highway 18 and I-5) in close cooperation with ODOT staff. The research team rode along with IR staff for several hours to become familiar with the existing scope and operating conditions of IR services.

Highway 18 Ride Along Notes
Several observations of importance were made during the Highway 18 ride along:

- Responder carries booms, pads and absorbent materials for spills threatening streams and wildlife. Some unquantified benefit in minimizing damage to environment and wildlife and saving major cleanup costs.
- Chain saw for downed trees allows responder to rapidly clear fallen branches in order to open roadway quickly. This is particularly important in the Van Duzer Corridor where trees are growing at the edge of the roadway.
- Responder maintains good relations with tow companies and OSP.
- Responder fills out weekly incident logs (not analyzed in this study) manually. If these were computerized they may serve as a further source of data for future/continuing performance measurement.
- Responder carries gasoline, as well as bottled water for people involved in breakdowns or crashes; also stuffed animals for children seem to be calming factors.

I-5 Ride Along Notes
Several observations of importance were made during the Interstate 5 ride along:

- Carries the same materials as Highway 18 to handle situation such as oil spills, crashes and breakdowns.
- Responder fills out personal incident records on a small notepad, which he later inputs to his personal computer as a reference/record.
- Carries feedback postcards to give to assisted commuters but it seemed to him that there was a low response rate.
- Carries a hazardous material handbook as a reference for potential hazardous material spill situations.
- Receives potential incident information from many sources such as the fire department, OSP, commercial radio traffic reports and ODOT dispatchers.
- It appears that the fire department is often the first to report an incident. They often know first and following with OSP, ODOT, and radio traffic reports respectively.

3.2 CAD Incident Data

CAD data were obtained from the inception of the system in October 1995 through December, 2000. The research team developed a statistical database format for storing relevant incident data, so that the same format can be used for future analyses. By becoming familiar with each corridor and CAD incident category, much was learned about how incidents are logged.

For the period between October 19, 1995 to December 31, 2000 a total of 67,631 incidents were reported in Region 2:

Year	**Incidents Reported**
1995	1,777 (partial year)
1996	8,883
1997	11,603
1998	15,329
1999	15,351
2000	14,688
TOTAL	67,631

The CAD data provided included 15 fields:

ID	Identification number (not used)
CAD_NUM	Incident number
CALL	Call type
DATE	Date
UNIT	Unit responding
TIME_RCVD	Time call received
CLEAR	Time call cleared
LOCATION	Location (highway number, etc.)
REMARKS	Remarks
REMARKS2	Additional Remarks
ARRIVED	Time arrived (*added January 1999*)
DISPO	Disposition code
CA	Command area
COUNTY	County
DISP_RMKS	Disposition remarks

The occasional notes in the REMARKS and REMARKS2 fields were not always consistent and sometimes it was difficult to determine to what extent the IR was involved versus the OSP. Incidents were grouped into six categories according to severity, potential to cause lane blockage and potential to require IR assistance (agreed upon at meeting on May 10, 2001 - based on list provided by ODOT):

1. Accidents

1216	Motor vehicle crash
1216A	Fatality

2. Breakdowns

1235	Abandoned vehicle
1257	Motorist assist (person with vehicle)

3. Maintenance

HAZARD	Hazards (e.g. tire casing, rock slide)
HWYBLOCK	Highway blockage, unknown reason
HWYOBST	Highway obstruction (not used)
SIGN	Damage to sign
VANDAL	Vandalism reports

4. Miscellaneous - with potential to cause vehicle delay

FIRE	Reports of fires along roads or structures
HZSPILL	Hazard material spill or leak
LIVESTK	Livestock loose on roadway
MISC1	Miscellaneous type call when nothing else applies
OERS	Used by OSP when no Emergency Mgmt call taker on duty
OPASS	Overpass: person throwing things from over crossing
RDKILL	Road kill (not blocking travel lanes; if blocking then hazard)
TRKINSP	Truck inspection
TSIGNAL	Traffic signal problems
WWAY	Wrong way driver

5. Travel Time and/or Response to an Incident - with no potential to cause vehicle delay

1231	Intoxicated driver
AGASST	Assist other agency
BACKUP	Assist other agency (higher priority than AGASST)
BLOOD	Emergency relay of blood products
CHKAREA	Request to check an area for person, vehicle, etc.
DRIVING	Driving complaints
TRAFFIC	Traffic complaint
TRAVEL	Travel status, used to track travel time

6. Other - with no potential to cause vehicle delay

AIRACC	Airplane crash
AIRPLANE	Incident involving aircraft
ALARM	Audible or silent
ANGLING	Fishing complaint
ANIMAL	Calls about non game domestic animals
ARREST	Arrest made for crime
ARSON	Arson investigation
ASSAULT	Assault, any degree or complaint
ATL	Attempt to locate
BICYCLE	Complaints about bicyclists
BOAT	Boating complaints
BOLO	Be on look out (usually for criminal purposes)

BOMB	Bomb squad calls
BURG	Burglary
BURNING	Burning complaints, e.g. smoke from fields causing traffic probs.
CAD	Computer Aided Dispatch
CASES	Used to get a list of numbers for an incident
COMM	Communications problems
CRIME	Used for getting CAD number for crimes not listed in CAD codes
DEATH	Death investigation, not homicide
DISTURB	Disturbance calls, fights or other problems
DOMEST	Family disturbance type problems
DRUG	Drug seizures or complaints about sale of manufacture of drugs
FOLLOW	Follow up report on prior incident
FOUNDPR	Found property
GAME	Non specific complaint for game officers
H/R-STOP	High risk stop
INFORM	Caller wants to leave information about prior call or crime
LITTER	Littering or dumping complaint
LSTPROP	Lost property
MEDICAL	Medical aid call, request for ambulance
MESS	Message call
OUTSERV	Out of service
PRKCMPL	Parking complaint
PUBREL	Public relations call
PURSUIT	Police pursuit
RECVEH	Recovered stolen vehicle
RDW	Road and weather report
REDDI	Report every drunk driver immediately – 800 number to OSP
RTCNTCT	Routine contact—vehicle or person contact
SELFINIT	Self initiated call by dispatcher
SPCL01	Special operation
SUICIDE	Suicide - investigation
SUSPACT	Suspicious activity
SUSPERS	Suspicious person
SUSPVEH	Suspicious vehicle
TEST	Test entry used for training
THEFT	Theft complaint
TOW	Request for tow truck not associated with other call
TRAINING	Training entry
TRNSPORT	Transportation of inmates
TRSPASS	Trespass complaint
WARRANT	Served warrants—tracking device
WELCHK	Welfare check
WINTER	Winter—used to track snow plow or sanding requests

Incident categories 1 through 4 were defined as potentially delay-causing incidents.

3.3 Supplemental Data

The CAD data was augmented with data from the ODOT Transportation Systems Monitoring Unit (Oregon State Highway Transportation Volume Tables), and data on reported crashes obtained from the ODOT Crash Analysis & Reporting Unit's *State Highway Crash Rate Tables*. The Crash Analysis & Reporting Unit compiles data from individual driver and police crash reports submitted to ODOT. Legally reportable crashes are those involving death, bodily injury or damage to any one person's property in excess of $1,000.

Information was also obtained from ODOT's Integrated Transportation Information System (ITIS) on cross section attributes (e.g., number of lanes, lane width, shoulder width, climbing/passing lanes), pavement condition and treatments, roadside conditions (side slopes, obstacles), characteristics of medians (width, turn lanes, guard rails/restrictions), horizontal and vertical curves, and posted speeds.

The CAD data only include data on accidents where ODOT's IR responders were involved. Therefore, more crashes will be contained in the Figure 4 compares the crash data from CAD with the crash data from the ODOT Crash Analysis & Reporting Unit for each year by milepost. Figure 5 compares the crash data from CAD with the crash data from the ODOT Crash Analysis & Reporting Unit for each year by phase. As shown, generally fewer accidents show up in the CAD system; this is likely due to the presence of the IR staff only on weekends. Similar information is conveyed in Figures 6 and 7 for I-5.

3.4 Database Development

The 15 field Region 2 CAD data provided by ODOT was expanded to include other fields for analysis. Some of these added fields included: 1) day of week, 2) mile post, 3) revised duration, 4) ADT, 5) roadway capacity reduction factor, 6) reported duration, and 7) revised duration.

For better future analysis of these two corridors other corridor, recommendations of fields to add and what information to provide in existing fields is given later on in this report.

4.0 ANALYSIS OF THE INCIDENT DATA

4.1 Region 2 Incident Statistics

The 67,631 reported incidents are shown in Figure 8 as a pie chart giving a visual picture of the distribution of recorded incident types for the entire region. Recalling the incident categories defined in Section 3.2), the total number of recorded incidents in categories 1 through 5 reached 60,974. A total of 59,238 recorded incidents fell into incident categories 1 through 4 (potentially delay-causing). It is recognized that some incidents were not reported, some were duplicates, and some did not require IR assistance.

Figure 9 is an incident tree using the topology defined earlier to document the distribution of incident types. Note that many incidents are not reported, and about 13 percent of the incident types are characterized as having little potential to cause delay (categories 5 and 6). The incident quantities listed in Figures 8 and 9 should be described as "raw," since the data presented had not yet been filtered. Figure 10 presents a histogram illustrating the number of observations of each incident type. The four categories containing more than 5,000 observations include: HAZARD, 1216, 1257 AND RDKILL. From Figure 10, one can observe that nearly one third of the incidents were reported as HAZARD. Thus, for the future it might be prudent to create more detailed designations for this category in order to allow more informative analysis. Finally, Figure 11 shows a histogram depicting the distribution of "raw" incident durations. As shown, nearly 25 percent of all reported incidents had durations less than 15 minutes. On the other hand, almost ten percent of incidents had reported durations greater than seven hours. Through the filtering process (described later) it was determined that many of these very long incidents were actually maintenance reminders. This would lead to a recommendation that a field be added to the CAD system for the time that the IR personnel leave the site of an incident. Also it will be recommended that a means of providing a maintenance "flag" be developed that will avoid the tracking of such long incident durations.

4.2 Initial Data Analysis

Incidents were extracted from the overall database for just the study corridors. At this stage it was observed that a variety of labels are given for the highway location. Thus, in the data sorting procedure, several search terms were used for each corridor:

- Interstate 5: "I 5", "I5"
- Highway 18: "SR 18", "18 SR", "HWY 18"

The overall database was sorted for incidents on each corridor. The next step was to insert a field for milepost. Some incidents had the milepost in the location field; others had it embedded in one of the remarks fields. Other incidents used landmarks to identify an approximate crossroad or relationship to a city or other landmark. Through a series of database queries, a milepost value was generated for each incident. One noted recommendation would be to standardize the method for identifying an incident's location. A separate field for just the route number where the incident is located would be preferred, with a second, separate, field for the milepost, and a third field for a cross road or crossing highway number.

Additional fields were added to facilitate data filtering and calculations. For example, a separate field was created for day of the week. Also the number of lanes (according to milepost) was added as a separate field based on the supplemental cross sectional data provided by ODOT.

Figure 12 is an incident tree, which tabulates the "raw" count (under the vertical column entitled RAW) of each type of incident on Highway 18. Note that a total of 1,815 incidents were reported on Highway 18 (1,807 for categories 1 through 5) from 1995-2000. Similarly, Figure 13 is an incident tree for the I-5 study corridor, where a total of 2,018 incidents were reported on I-5 in Lane County (1,808 for categories 1 through 5) between 1995-2000. Incidents for Highway 18 were divided into two phases (1995-1997 and 1997-2000) and I-5 incidents were divided into 5 phases (see Tables 1 and 2) based on changes in IR staffing levels.

4.3 Incident Filtering Process

Figures 12 and 13 also tabulate "filtered" incident data (column entitled FILTERED) for Highway 18 and I-5 respectively. To obtain the filtered totals, incidents out of milepost ranges were eliminated and duplicate incidents were eliminated. Incidents in category 6 were eliminated, as were incidents in other categories (1 through 5) that were determined to be non-delay-causing based on their type, location and/or description. As shown in Figures 12 and 13, on Highway 18, 1,323 incidents were left (73%) and for I-5 about 1,186 incidents (68%) were left.

The next several sections describe how additional data were added for each reported incident to facilitate the delay calculations.

4.3.1 Calculating ADT and Hourly Volume

The ADT was retrieved from the ODOT traffic volume data by milepost, see Appendices C and D. The ADT was converted to hourly volumes using a conversion ratio derived from hourly data from Automatic Traffic Recorders (ATRs) located near Valley Junction on Highway 18 and using the ATR at Bond Butte located about 11 miles north of the Lane County line on I-5. It is recognized that the use of these conversion factors introduce some errors, but in general it was assumed that the overall hourly patterns would be similar in the study corridors.

Figure 14 shows the ADT data from all weekend days in 2000 for the Valley Junction ATR, where the mean was 21,993 vehicles per day. Weekend days were chosen since the IR program is in effect on weekends. Figure 15 shows the directional ADT conversion factors for Highway 18. To obtain this graph, the mean hourly volumes for all weekend days in 2000 were divided by the mean ADT. The conversion factors shown were used to convert the ADT to estimate the hourly volume at the time each incident occurred.

Similarly, Figure 16 shows the ADT data from all weekdays in 2000 for the Bond Butte ATR, where the mean was 35,713 vehicles per day. Figure 17 shows the directional ADT conversion factors for I-5. To obtain this graph, the mean hourly volumes for all weekdays in 2000 were divided by the mean ADT. The conversion factors shown were used to estimate the hourly volume at the time each incident occurred.

4.3.2 Capacity Reduction During Incident

We also estimated the resulting roadway capacity C_i, which is a function of the type of incident, the severity reported, the number of vehicles involved, whether there was a fatality involved and the roadway characteristics, such as, the location of the incident (blocking a lane or on the shoulder) and whether there is room for other vehicles to pass (in the median or on the shoulder or in adjacent lanes).

For Highway 18, the capacity reduction was estimated based on the description of the incident and the roadway cross-section information at the location of the incident.

For I-5, Table 3 provides a summary of the estimated reduction in capacity versus the location of an incident on a freeway. Note that the loss of capacity is likely to be greater than simply the proportion of the original capacity that is blocked. For example, if one lane is blocked on a two-lane freeway, the available capacity of the freeway is approximately 35% of the original capacity even though only 50% of the lanes are blocked. The rubbernecking factor is also responsible for a reduction in capacity in the direction of travel opposite to that in which the accident occurred. The methodology works with the full speed-flow curve (for the undersaturated part of the relationship), but in many of the cases described above, only the effect on capacity has been identified by research reported to date. The literature does not describe the effect of the factor (incident, construction) on speeds and hence on the speed-flow curve.

TABLE 3: Proportion of Freeway Segment Capacity Available under Incident Conditions[6]

Number of Freeway Lanes in Direction	Shoulder Disablement	Shoulder Accident	Lanes Blocked		
			One	Two	Three
2	0.95	0.81	0.35	0.00	N/A
3	0.99	0.83	0.49	0.17	0.00
4	0.99	0.85	0.58	0.25	0.13
5	0.99	0.87	0.65	0.40	0.20
6	0.99	0.89	0.71	0.50	0.25
7	0.99	0.91	0.75	0.57	0.36
8	0.99	0.93	0.78	0.63	0.41

4.3.3 Incident Duration

Key time points during an incident's duration are depicted in Figure 18. The actual duration of an incident is usually unknown, since there is some lag time between the occurrence of an

[6] *Highway Capacity Manual.*

incident and the initial incident report. An incident report may come from a myriad of sources including a 911 call, a cellular 911 call, observation by OSP, IR or local law enforcement. The CAD database included three incident time fields:

1) Time call received, t_{CR}
2) Time call cleared, t_{CC}
3) Time IR arrived, t_A (for incidents after January, 1999).

The best estimate of an incident duration is the time it was cleared minus the time it was first reported. From these three time fields, two incident durations were calculated:

1) Reported Duration = $t_{CC} - t_{CR}$
2) Field Duration = $t_{CC} - t_A$

The Field Duration represents an estimate of the amount of time the IR spent on the scene. The CAD database contained values of t_{CC} that led to very long Reported Durations (sometimes more than 24 hours). For example, one accident involving a fatality involved may have had a reported duration of 30 minutes while a second incident such as a vehicle off the road may have had a reported duration of 10 hours and yet a third incident involving a roadkill or a downed tree may have had a reported duration of more than 20 hours. Therefore, a fourth incident time field called t_C was estimated after studying each incident's Reported Duration and evaluating whether it seemed reasonable based on all other reported information. Using the above examples, depending on what information was provided in the REMARKS and REMARKS2 fields, the Revised Duration for the accident with a fatality would have been increased to three hours while the revised duration for the incident with the vehicle off the road would have been reduced to one hour. Finally, using the value of t_C a third duration was calculated:

3) Revised Duration $t = t_C - t_{CR}$

In most cases, no adjustment in duration was made so that, in general, the Revised Duration equals the Reported Duration. The Revised Duration, t, was used in the delay formula to calculate the delay attributable to each incident.

4.4 Incident Delay and Fuel Consumption

Next for each remaining incident with revised duration (an example of a revised duration would include what appears to be a minor accident from the remarks, with a reported duration of 7 hours, the duration affecting traffic flow would be reduced to 2 hours), vehicular delay (D, in vehicle-hours) was estimated using the deterministic queueing model. The delay caused by the incident, the shaded area in Figure 3 was estimated using the highway capacity, demand and actual hourly flow estimated during the incident. Because of the assumptions involved in this analysis, there were times that apparently serious incidents were not determined to actually cause vehicular delay according to the model. This might have been due to a low demand volume at the time of the incident combined with a low capacity impact factor. After this analysis, smaller numbers of actual delay-causing incidents remained. The parameters used for estimating incident delay are listed below for each corridor.

Highway 18

The values used to estimate delay for Highway 18 were as follows:

- *V* = volume – from ADT data, see Appendix C.
- *C* = 2,800 passenger cars per hour (pc/h) for both directions of travel.[7]
- R_f = roadway capacity reduction factor – subjective factor based on reported incident type, severity, location and other characteristics.
- *t* = incident duration from CAD incident log.

Interstate 5

The values used to estimate delay for Interstate 5 were as follows:

- *V* = volume – from ADT data, see Appendix D.
- *C* = 1,800 passenger cars per hour per lane (pc/h/ln), with a 0.6 directional distribution.[8]
- R_f = roadway capacity reduction factor – factor selected from Table 3 based on reported incident type, severity, location and other characteristics.
- *t* = incident duration from CAD incident log.

4.4.1 Filtered Incident Statistics

Subsequent to the incident filtering process, adjustment to incident durations, and determination of actual delay-causing incidents, it is possible to examine some frequency statistics for each corridor (1995-2000). After the incident filtering process, a total of 1,317 incidents remained for Highway 18 and 1,186 incidents remained for I-5.

Figure 19 is an incident frequency histogram for Highway 18's filtered incidents. As shown, more than one-third of the incidents were HAZARDS. The next largest category was the accident category followed by 1257 and roadkill. Only a few filtered incidents fell into other categories. Figure 20 is a filtered incident duration histogram, showing that on Highway 18 the largest number of incidents had durations between 45 minutes and one hour. Finally, Figure 21 shows incident frequency by milepost. The bottom bar shows the number of accidents, the second bar shows the number of hazards, the third bar shows the number of motorist assists, the fourth bar shows the roadkill incidents and the top bar includes the total number of all other categories. Using this visual tool, it is clear where the largest numbers have occurred and may be a useful tool for designing IR patrol beats (focusing on the eastern half of the corridor, as is currently done), and perhaps for considering engineering and safety improvements to the roadway.

Figure 22 is an incident frequency histogram for I-5's filtered incidents. As shown, nearly one-half of the incidents were HAZARDS. The next largest category was the accident category

[7] *Highway Capacity Manual*
[8] *Highway Capacity Manual*

followed by roadkill. Only a few filtered incidents fell into other categories. Figure 23 is a filtered incident duration histogram, showing that on I-5 the largest number of incidents had durations between 45 minutes and one hour. Finally, Figure 24 shows incident frequency by milepost. The bottom bar shows the number of accidents, the second bar shows the number of hazards, the third bar shows the number of roadkill incidents, the fourth bar shows the motorist assists and the top bar includes the total number of all other categories. Using this visual tool, it is clear where the largest numbers have occurred and may be a useful tool for designing IR patrol beats, and perhaps for considering engineering and safety improvements to the roadway.

4.4.2 Highway 18 Delay and Fuel Consumption

Figure 25 shows the results for Highway 18. Looking down the center of the figure, one can observe the results of the incident filtering process. Starting with all 67,631 incidents for the entire study period (1995-2000), filtering for Highway 18 led to an analysis of 1,807 potentially delay causing incidents. After filtering, as described above, a total of 1,317 incidents remained.

After the delay calculations, it was shown that 132 of the filtered incidents resulted in actual vehicular delay. For Phase 1 (February 1995 – March 1997, limited IR deployed), turning to the left side of the figure, one can see that the 373 potentially delay-causing incidents had a mean duration of 3.27 hours. After filtering the mean (μ) duration of the 253 incidents was also 3.27 hours, but the standard deviation (σ) was lower (1.74 hours). The 28 incidents that were actually delay-causing in our model had a mean duration of 2.07 hours and a mean resulting delay of 3,572 vehicle-hours per incident. The total delay caused by these 28 incidents was estimated to be 100,000 vehicle-hours. Using an average vehicle occupancy factor of 1.53 (source: ODOT Transportation Systems Monitoring for McMinnville, see Appendix B), the total person delay was estimated to be 153,000 person-hours. Using an average value of time of $17.87 per person-hour (see Appendix A), the total delay cost was estimated to be $2,700,000, or approximately $63,800 per incident.

The fuel costs due to this delay were $132,000. The total dollar cost of delay causing incidents in Phase 1 was $2,832,000.

Looking down the right side of the figure for Phase 2 (April 1997 – December 2000, with IR deployed) one can see that the 1,453 potentially delay-causing incidents had a mean duration of 2.7 hours; this is 34 minutes less than during Phase 1. It is notable that the standard deviation for the Phase 1 and Phase 2 data are nearly identical at 4.21 and 4.31 hours respectively. After filtering, the mean was 0.96 hours, which represents a 2.31-hour reduction. The 104 actual delay-causing incidents had a mean duration of 1.42 hours (a 39 minute reduction) and a mean resulting delay of 1,227 vehicle-hours per incident. The total delay caused by these 104 incidents was estimated to be 127,600 vehicle-hours. Using an average vehicle occupancy factor of 1.53, the total person delay was estimated to be 195,200 person-hours. Using an average value of time of $17.87 per person-hour, the total delay cost was estimated to be $3,500,000, or approximately $21,900 per incident. The fuel costs due to this delay were $168,400. The total dollar cost of delay causing incidents in Phase 2 was $3,668,400.

Phase 2 was further broken down in order to consider the incidents that occurred on days when the IR program is operating (Friday – Monday) in contrast to the days when the IR program is not in place (Tuesday – Thursday). As shown, during Phase 2 without IR (Tuesday – Thursday), there were 67 delay causing incidents resulting in about 70,000 vehicle-hours of delay. The mean duration of these incidents was 1.37 hours, with about 1,046 vehicle-hours of delay attributable to each incident. On days when the IR program is functioning (weekends) there were 37 delay-causing incidents, resulting in 57,500 vehicle-hours of delay, with mean duration of 1.52 hours, and 1,554 vehicle hours of delay attributed to each incident. The mean duration of incidents on weekends was longer than incidents on weekdays, which is consistent with the strategy to deploy the IR program on the weekends.

4.4.3 Interstate 5 Delay and Fuel Consumption

Figure 26 shows the results for Interstate 5. Looking down the center of the figure, one can observe the incident filtering process. Starting with all 67,631 incidents for the entire study period (1995-2000), filtering for Interstate 5 led to an analysis of 1,772 potentially delay causing incidents. After filtering, as described above, a total of 1,186 incidents remained. After the delay calculations, 353 of these incidents resulted in actual vehicular delay. For Phase 1 (February 1995 – February 1997, with minimal IR deployed), turning to the left side of the figure, one can see that the 318 potentially delay-causing incidents had a mean duration of 3.46 hours. After filtering, the mean (μ) duration of the 223 incidents was 1.38 hours. The 67 incidents that were actually delay-causing in our model had a mean duration of 1.10 hours and a mean resulting delay of 1,907 vehicle-hours per incident. The total delay caused by these 67 incidents was estimated to be 128,000 vehicle-hours. Using an average vehicle occupancy factor of 1.43 (source: ODOT Transportation Systems Monitoring for Eugene, see Appendix B), the total person delay was estimated to be 183,000 person-hours. Using an average value of time of $17.87 per person-hour, the total delay cost was estimated to be $3,264,000, or approximately $34,100 per incident. The fuel costs due to this delay were $169,000. The total dollar cost of delay causing incidents in Phase 1 was $3,433,000.

Looking down the right side of the figure for Phase 2 (March 1997 – December 2000, with IR deployed) one can see that the 1,454 potentially delay causing incidents had a mean duration of 2.52 hours; this is 56 minutes less than during Phase 1. It is notable that the standard deviation for the Phase 1 and Phase 2 data are similar at 4.72 and 4.10 hours respectively. After filtering, the mean was 1.15 hours, which represents a 14-minute reduction. The 286 actual delay causing incidents had a mean duration of 0.95 hours (a 9 minute reduction) and a mean resulting delay of 1,224 vehicle-hours per incident. The total delay caused by these 286 incidents was estimated to be about 350,000 vehicle-hours. Using an average vehicle occupancy factor of 1.43, the total person delay was estimated to be 501,000 person-hours. Using an average value of time of $17.87 per person-hour, the total delay cost was estimated to be $8,945,000, or approximately $21,900 per incident. The fuel costs due to this delay were $462,000. The total dollar cost of delay causing incidents in Phase 2 was $9,407,000.

Phase 2 was further broken down (Periods 3, 4, and 5) in order to consider the incidents that occurred on days when the IR program is operating (Monday - Friday) in contrast to the days when the IR program is not in place (Saturday - Sunday). As shown, during Periods 3-5 without

IR (Saturday - Sunday), there were 51 delay causing incidents resulting in about 81,697 vehicle-hours of delay. The mean duration of these incidents was 1.01 hours, with about 1,120 vehicle-hours of delay attributable to each incident. On days when the IR program is functioning (weekdays) there were 235 delay-causing incidents, resulting in 418,857 vehicle-hours of delay, with mean duration of 0.93 hours, and 1,246 vehicle hours of delay attributed to each incident.

4.5 Incident Durations Versus Delay

Figure 27 shows a scatterplot of incident duration versus delay for all delay-causing incidents on Highway 18. A linear regression was performed to establish a best-fit relationship for the data. Because many incidents had short durations and resulting small amounts of delay, Figure 28 uses a log scale on the delay-axis in order to expand the region containing short duration incidents. A log-linear relationship was also estimated (lower R^2 value).

Figure 29 shows a plot of incident duration versus delay for all delay-causing incidents on I-5. A linear regression was performed to establish a best-fit relationship for the data. Because many incidents had short durations and resulting small amounts of delay, Figure 30 uses a log scale on the delay-axis in order to expand the region containing short duration incidents. A log-linear relationship was also estimated (lower R^2 value).

5.0 EVALUATION OF INCIDENT RESPONSE

5.1 Program Benefits

A number of benefits of the IR program have been quantified:

Public Benefits
- Delay (vehicle-hours, person-hours, dollars)
- Fuel Consumption (gallons, dollars)

Agency Benefits
- Maintenance crew costs avoided (dollars)
- Value of extra maintenance performed (dollars)

Some benefits of the IR program are quantifiable but have not been quantified:

- Air quality (tons of emissions)
- Safety (accidents and secondary accidents avoided)
- Opportunity cost of not diverting maintenance personnel

Finally some qualitative benefits of the IR program would be impossible to quantify but should be considered nonetheless:

- Reduce exposure to congestion
- Health care savings due to first aid provided if IR personnel first on scene
- Maintaining flow of commerce to isolated coastal region
- Good will/public relations
- Front line contact with public—may be ODOT's only contact with some people
- Sense of security
- Prevent harm to wildlife, soil and water quality
- Maintenance notes provide early warning about maintenance issues that end up preventing other problems
- Ice notes facilitate effective use of sand resources
- Tree notes
- Burning notes
- Construction area damage to cones etc.

Although the impact of these benefits cannot be quantified, their presence actually reduces the break-even point.

5.2 Delay

From Figure 25, the delay savings for Highway 18 are as follows. For Phase 1 the total delay was estimated to be 100,000 vehicle-hours, the total person delay was estimated to be 153,000 person-hours and the total delay cost was estimated to be $2,700,000, or approximately $63,800 per incident.

For Phase 2 the total delay was estimated to be 127,600 vehicle-hours, the total person delay was estimated to be 195,200 person-hours and the total delay cost was estimated to be $3,500,000, or approximately $21,900 per incident.

From Figure 26, the delay savings for Interstate 5 are as follows. For Phase 1 the total delay was estimated to be 128,000 vehicle-hours, the total person delay was estimated to be 183,000 person-hours and the total delay cost was estimated to be $3,264,000, or approximately $34,100 per incident.

For Phase 2 the total delay was estimated to be about 350,000 vehicle-hours, the total person delay was estimated to be 501,000 person-hours and the total delay cost was estimated to be $8,945,000, or approximately $21,900 per incident.

5.3 Fuel Consumption

For Highway 18, the fuel costs due to the delay in Phase 1 were $132,000 while the fuel costs due to the delay in Phase 2 were $168,400. For Interstate 5, the fuel costs due to the delay in Phase 1 were $169,000 while the fuel costs due to the delay in Phase 2 were $462,000.

5.4 Other Benefits

As listed above, there are numerous other benefits derived from the IR program that have not been quantified due to limitations in the study scope and limitations in data collection feasibility. First, by reducing delay, IR reduces the total exposure of motorists to congestion. Not only is this measurable in terms of delay cost, but also in terms of avoided accidents and pollution.

Often the IR responder is first on the scene after an accident and is able to provide first aid that may save a person’s life or reduce the total health care costs that will be necessary. In addition as the “eyes and ears” of the DOT, the IR staff provide unmeasurable good will and public relations value, since many citizens may never have any other contact with ODOT. The IR program can provide a sense of security and safety for drivers that is also difficult to measure.

In terms of the state’s economy, by reducing congestion and minimizing roadway blockages, freight movement is improved, allowing the flow of commerce to occur unimpeded. This can be especially important for the businesses located in the otherwise isolated coastal region.

In addition, IR responders assist with hazardous materials spills, which prevents harm to wildlife, soil and water quality. The numerous maintenance notes provide early warning about maintenance issues that can end up preventing other problems. During winter months, ice notes facilitate effective use of sand resources, and the many tree and roadkill notes ensure that fallen trees and animals are removed safely and efficiently. Finally with respect to construction areas, the IR staff can monitor the status of cones, barricades and signage to help maintain safety during periods when contractors are not working.

5.5 Incident Response Costs

The costs of the IR programs were estimated to be $36/hour, including labor, overhead, management, vehicles, equipment, fuel, depreciation and expendable items.

5.6 Program Effectiveness in Terms of Public Costs

Figures 31, 32 and 33 address the effectiveness of the IR program on Highway 18. First we assume that the IR responder spends about 75% of his time on Highway 18 (source: Bill Williams). Thus for a 40 hour week, the IR program costs about $4,680 per month. Figure 31 shows the potential delay savings if the incidents in Phase 1 could have been reduced in duration by an IR service. For example, if the average duration were reduced by about 5 minutes, the total savings would be about $150,000 for the 25-month period of Phase 1. A responder would have cost $117,000 for the 25-month period, so this point is referred to as a break-even point. In other words if an IR program had been in place, in order to break-even in terms of quantifiable benefits (delay, fuel) the duration would have needed to be reduced by about four minutes. This seems more than reasonable since as shown in Figure 31, we observed a 39-minute (2.07 hours – 1.42 hours = 0.65 hours) reduction in duration between Phase 1 and Phase 2. Figure 32 shows a similar result for Phase 2, but considers the scenario where the average incident duration would have been *longer* without the presence of IR. Here the break-even point falls at about 7 minutes, while the observed duration reduction was about 33 minutes (2.07 hours – 1.52 hours = 0.55 hours). Finally Figure 33 considers weekday incidents during Phase 2 in order to explore whether a weekday IR service may have been warranted. Although the average incident duration without the IR responder is slightly less than the average incident duration with the IR Responder (1.37 hours verses 1.52 hours), it is not unreasonable to expect that these incidents could have shorter average incident duration with the presence of an IR program. Here the break-even point is at about 7.5 minutes. A possible explanation could be that there may be lower traffic volumes during this time period leading to fewer incidents that need to be attended to by OSP which may allow the OSP quicker response time to incidents.

Figures 34-38 show similar results for I-5. Again, for Phase 1, if we assume that the IR responder spends about 75% of his time on I-5, for a 40-hour week, the IR program costs about $4,680 per month. Figure 34 shows the potential delay savings if the incidents in Phase 1 could have been *reduced* in duration with the presence of an IR provider. For example, if the average incident duration were reduced by about 5 minutes, the total savings would be about $290,000 for the 25-month period of Phase 1. A responder would have cost $104,000 for the 25-month period, so this point is referred to as a break-even point. In other words if an IR program had been in place, in order to break-even the duration would have needed to be reduced by about two minutes. This seems reasonable since, as shown in Figure 26, we observed a 9-minute (1.10 hours – 0.95 hours = 0.15 hours) reduction in duration between Phases 1 and 2. For Phase 2, we assume that the IR responder spends approximately 60% of their time on I-5 during Period 3, 70% of their time during Period 4, and 75% of their time during Period 5 (source: Kevin Kinney). Figure 35 shows the combined total value for all three periods (time and fuel shown separately) if during Phase 2, the average incident duration would have been *longer* during the weekdays without the presence of IR team. Here the break-even point falls just under 2 minutes, while the observed duration reduction was about 10 minutes (1.10 hours – 0.93 hours = 0.17 hours). Figure 36 considers weekend incidents during Phase 2 in order to explore whether a weekend service may be warranted. Here the break-even point is about 4 minutes. Figure 37 shows the individual total loss (time + fuel combined) expected for all three time periods, during Phase 2, if the weekday IR service was not in place resulting in increased incident durations. Finally, Figure 38 shows the break-even points for the three periods, on an average monthly basis during Phase 2, for the three periods if the IR had not been in place. Thus, the break-even points required for Periods 3, 4, and 5 are: 3.2, 3.7 and 5.5 minutes respectively.

5.7 Agency Costs

For the year 2000, some preliminary estimates of the impact on agency costs were explored. The agency benefits manifest themselves in that maintenance crews are not pulled off of their crucial maintenance work to perform incident management tasks, and in particular, are not called from home at high overtime rates.

For Highway 18 (year 2000 only) it is estimated that approximately incident response would have cost approximately $62,000 if maintenance personnel were used, and at the same time about $19,000 worth of maintenance work would not have been completed. This is compared with an annual cost of about $71,000 for the Highway 18 IR program.

For Interstate 5 (year 2000 only) it is estimated that approximately incident response would have cost approximately $50,000 if maintenance personnel were used, and at the same time about $19,000 worth of maintenance work would not have been completed. This is compared with an annual cost of about $126,000 for the Highway 18 IR program.

5.8 Incident Trends

Having the filtered incident data facilitates an analysis of incident trends over time. As an example, Figure 39 compares the Highway 18 observed accident frequency from the CAD data with the accident rates reported by the ODOT Crash Analysis Unit (referred to as ODOT data). The figure displays the cumulative numbers of filtered accidents (1216 and 1216A) between 1995 and 2000 for both data sources. The slopes of the curves are the accident rates, and as shown the accident rate in 1997 surged somewhat. Since 1998 the reported (CAD) rate has paralleled the rate reported by ODOT. The horizontal bars display the annual accident rate (ODOT data per million vehicle miles traveled). As shown, the accident rate in 2000 is about 14% lower than that reported in 1995. Figure 40, similar to Figure 39, shows the annual accident rate for the CAD data. As shown, the rate in 2000 is about 25% lower than the rate reported in 1997.

Figure 41 displays the filtered incident durations over time for Highway 18. The mean duration is shown during Phases 1 and 2, and using linear regression, the duration trend lines are shown. It is clear from the figure that the mean duration is lower during Phase 2 and that the duration trend is also lower during Phase 2.

Figure 42 displays the cumulative incident duration over time for Highway 18. This curve shows that the duration trend is decreasing.

Figure 43 compares the I-5 observed accident frequency from the CAD data with the accident rates reported by the ODOT Crash Analysis Unit. The figure displays the cumulative number of filtered accidents (1216 and 1216A) between 1995 and 2000. The slope of the curve is the accident rate, and as shown the accident rate in 1997 surged somewhat. Since 1998 the reported rate has paralleled the rate reported by ODOT. Figure 43 also shows the annual accident rate (number per million vehicle miles traveled) for 1995 – 1999 using the ODOT crash data. Similar to Figure 43, Figure 44 shows the accident rate as indicated by the CAD data, where an 18% rate reduction is observed.

Figure 45 displays the filtered incident durations over time for I-5. The mean duration is shown during Phases 1 and 2, and using linear regression, the duration trend lines are shown. It is clear from the figure that the mean duration is lower during Phase 2 and that the duration trend is also lower during Phase 2. Also, the duration trend was increasing during Phase 1, and is now decreasing during Phase 2.

5.9 Possible Introduction of Errors

While the use of real data offers immense benefits, its source, manipulation, and interpretation all can introduce potential errors. This is the case with any research project involving the analysis of data. The difference here is that we are actually clearly pointing out where the assumptions were made so that conclusions can be drawn in the context of the degree of precision contained in the report. It is well known that errors can be introduced in all phases of such an analysis including, 1) original CAD entry errors and 2) analysis errors, including assumptions. With respect to assumptions, it is important to note that we cannot be more precise than the data collected. Example sources of potential error encountered in the incident response analysis include:

5.9.1 Potential Data Entry Errors

There appeared to be a wide variation in the clarity of the CAD data. It is possible that during the filtering process some entries were misinterpreted. However, considering the magnitude of incidents analyzed, it is doubtful that errors introduced had much impact on the results. Some specific observations include:

- Unclear, contradictory or miscoded incident locations.
- Duplicate incident entries.
- Incomplete and/or missing incident log entries.
- Inconsistent use of incident categories.
- Not all incidents get reported.
- Some very long durations were observed. It is likely that many of these were maintenance notes left from weekends for Monday morning.
- Some incidents may not have required IR assistance.

5.9.2 Potential Errors in Analysis

The analysis described in this report included numerous assumptions. It is the purpose of this subsection to list these assumptions in one place so that future analyses can take them into account. Possible sources of error in the estimation process included the following:

- Converting ADT to hourly volumes using a conversion ratio derived from hourly data from ATRs located at one point along the corridors.
- Estimating roadway capacity reduction based only upon incident type or one line of remarks.
- Estimating actual roadway closure time based solely on incident type or one line of remarks.
- Reducing the duration of incidents since they seemed exceedingly long when compared with similar incidents.
- Estimating traffic composition.
- Calculating the fuel consumed by all road users using the simplified equation.
- Calculating delay for an incident based on the hourly traffic volume at the start of the incident for an incident that may have a duration of many hours.
- Assuming that traffic demand was constant during entire incident.
- Not considering the costs associated with multi-agency response to an incident.
- Estimating the amount of time the IR team spends on a selected highway.
- Estimating an average roadway capacity versus the specific incident location capacity.
- Using one “average” reduction in roadway capacity over the entire incident duration. In reality, the value of roadway capacity reduction factor changes throughout the duration of the incident. For example, a vehicle initially blocks one lane, the vehicle is moved to the side of the road, a tow truck arrives and hooks up to the vehicle, the vehicle is removed from the scene, and all other parties responding to the incident leave the scene. Each of these incident stages takes differing amounts of time and each has its own effect on capacity reduction.
- Some incidents identified with different identification numbers appeared similar to other reported incidents. In these cases, the similar incidents were individually reviewed. If two different incidents were determined to be the same incident, one was disregarded, usually the second incident. However, when applying duration reductions or road capacity reduction factors, the information from both entries was considered.
- Using different roadway capacity reduction factors methodologies for Highway 18 (subjective factor based on reported incident characteristics) and I-5 (tabulated values from the Highway Capacity Manual).
- No consideration on the roadway capacity reduction created by adverse weather.
- Little consideration on roadway capacity reduction in the opposite direction from rubbernecking.

These potential sources of error are no different than those in all other evaluations of incident management programs. The goal here is to be explicit about the fact that these potential error sources are understood.

6.0 CONCLUSIONS

6.1 Summary of Study Findings

The benefits of the Region 2 incident response program have been described and documented. This analysis has adopted a conservative approach and recognizing that many of the benefits are not quantifiable, it should be emphasized that the program is more beneficial than reported here.

6.2 Planning Tool to Evaluate Expansion of Existing IR Program to Other Highways

The goal in this section is to describe a planning tool to evaluate expansion of the existing IR program. As can be seen from Tables 4 and 5, in general, the majority of the delay causing incidents (approximately 75%) along Highway 18 and (approximately 70%) along I-5 are 1216 – Motor Vehicle Crashes.

The main idea behind the development of the planning tool is to enable ODOT to perform a simple preliminary analysis to consider expanding or introducing an IR program. Figure 46 is a Duration-Delay diagram for two-lane highways with ADT between 9,000 and 15,000. These curves are based on the actual delay-causing accidents on Highway 18 (ADT approximately 12,000). Using basic accident statistics (actual or assumed) Figure 46 will allow one to enter the diagram given a particular ADT and accident duration distribution and predict total delay. For example, consider Highway X of length Y with an ADT of 15,000 and an annual accident distribution as follows:

Highway X Accident Duration	**Number**	**Delay**	**Total Delay**
0-15 min	a	D_a	aD_a
15-30 min	b	D_b	bD_b
30-45 min	c	D_c	cD_c
45-60 min	d	D_d	dD_d
…	…	…	…
	$\Sigma=a+b+c+d+\ldots$		$\Sigma=aD_a+bD_b+cD_c+dD_d+\ldots$

If there were a accidents with durations between 0 and 15 minutes, one enters Figure 46 and reads the delay attributable to each 15-minute accident, D_a. To determine the total delay due to all a accidents with duration between 0 and 15 minutes, one next multiplies $a \times D_a$. These values of total delay are summed for all accident categories to obtain the total delay. Because accidents account for approximately 70% of the delay on Highway 18, we can divide the total delay by 0.70 to obtain a final total. This value is compared to the total potential cost of an incident response program for Highway X for one year (since annual accident statistics have been considered).

TABLE 4 – Percent of Delay by Call Type for Highway 18

Call	Delay (veh-hrs)	Percent of Delay	Number of Calls	Percent of Calls
Phase 1				
1216	49,700	50	15	54
OTHER	50,300	50	13	46
Subtotal	100,000	100	28	100
Phase 2				
1216	120,400	94	84	81
OTHER	7,200	6	20	19
Subtotal	127,600	100	104	100
All Actual Delay				
1216	170,100	75	99	75
OTHER	57,500	25	33	25
Total	227,600	100	132	100

TABLE 5 – Percent of Delay by Call Type for Interstate 5

Call	Delay (veh-hrs)	Percent of Delay	Number of Calls	Percent of Calls
Phase 1				
1216	88,000	68	12	18
OTHER	41,000	32	55	82
Subtotal	128,000	100	67	100
Phase 2				
1216	249,000	71	113	40
OTHER	101,000	29	173	60
Subtotal	350,000	100	286	100
All Actual Delay				
1216	335,000	70	125	35
OTHER	143,000	30	228	65
Total	4778,000	100	353	100

This data confirms that a review of the 1216 incident data or accident statistics may suffice when considering the potential use of or the expansion of an existing IR program. The effectiveness of an IR program is a function of the roadway length, ADT, and the accident rate. Therefore, if we can adjust these factors for different scenarios, we can estimate the delay on similar facilities. The following method may be used to quickly determine if further analysis of the traffic, roadway, and incident characteristics is justified when considering future IR programs. The tasks at hand are divided up into two groups as follows: 1) work required by the ODOT investigation team and 2) work required by this research team.

ODOT Investigation Team

1) Collect the "raw" incident data from the CAD database for the selected road segment. Alternatively use annual accident statistics with an assumed duration distribution.
2) Remove all non-1216 incident data leaving only the 1216 data from the original CAD database.
3) Group the reported accident durations into 15-minute time periods.
4) Adjust the reported incident duration to revised time duration in 15-minute time periods.

Research Team

5) Select the appropriate ADT curve from Figure 46 which best represents the ADT of the new road segment under analysis.
6) For each time period created in step 3, determine the new incident delay using the line selected in step 5. Multiply this delay by the number of incidents in the time period. Sum the delay values for all individual time periods.
7) Repeat step 6 after reducing incident durations between 5 and 30 minutes.
8) Calculate the total delay for all incidents by dividing the estimated delay for 1216 incidents by 0.7 (since it appears from Table 4 that approximately 70% of all delay causing incidents are accidents) for the reductions in incident delay (5, 10, 15, 20, 25 and 30 minutes shorter would be suggested).
9) Convert the three total delay versus to dollar values.
10) Plot these three dollar values versus incident duration reduction (5 to 30 minutes).
11) Determine the cost of the IR program.
12) Locate the break-even point on the graph created in step 10.
13) If the break-even point is small, a more thorough investigation of the roadway and traffic characteristics is recommended to determine if an IR program is warranted.

6.3 Recommendations

To facilitate further research, the following recommendations are made.

- Standardize highway names/identifiers
- Standardize location descriptions.
- Computerize IR weekly reporting sheets (not used in this study).
- AVL to measure time on specific routes.
- From Figure 8, one can observe that nearly one third of the incidents were reported as HAZARD. Thus, for the future it might be prudent to create more detailed designations for this category in order to allow more informative analysis.
- Finally, Figure 11 shows a histogram depicting the distribution of "raw" incident durations. As shown, nearly 25 percent of all reported incidents had durations less than 15 minutes. On the other hand, almost ten percent of incidents had reported durations

greater than seven hours. Through the filtering process it was determined that many of these very long incidents were actually maintenance reminders. This would lead to a recommendation that a field be added to the CAD system for the time that the IR personnel leave the site of an incident.

- Also it will be recommended that a means of providing a maintenance "flag" be developed that will avoid the tracking of such long incident durations.
- One noted recommendation would be to standardize the method for identifying an incident's location. A separate field for the route number where the incident is located would be preferred, with a second, separate, field for the milepost, and a third field for a cross road or highway number.
- Provide more and consistent traffic flow conditions as a result of the incident. Maybe have a standardized selection. State how long traffic was affected.

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APPENDIX A Value of Travel Time Estimate, 1999

	Value of Travel Time Estimates for One Hour of Travel By Cost Category and Vehicle Type for Oregon, 1999			
		Vehicle Class		
		Auto	Light Trucks	Heavy Trucks
	Category	**Average**	**Average**	**Average**
1	1999 Oregon Average Wage	$ 14.84	$ 11.27	$ 15.81
2	1999 Value of Fringe Benefits	$ 5.88	$ 4.47	$ 6.27
3	**1998 Total Compensation**	$ 20.72	$ 15.74	$ 22.08
4	Average Vehicle Occupancy	1.59	1.59	1.2
5	1999 Cost of Employees	$ 32.95	$ 25.02	$ 26.49
6	1999 Freight Inventory Value	$ -	$ 1.82	$ 1.82
7	**Total "On-the-Job" Value**	$ 32.95	$ 26.84	$ 28.31
8	Miles "on-the-job" %	10	31	100
9	Weighted Value	$ 3.29	$ 8.32	$ 28.31
10	**Total "Off-the-Job" Value**	$ 14.28	$ 14.28	$ -
11	Miles "off-the-job" %	90	69	0
12	Weighted Value	$ 12.85	$ 9.85	$ -
13	**Total Weighted Average**	**$ 16.15**	**$ 18.17**	**$ 28.31**

Assuming the following traffic composition, 65 percent passenger cars, 25 percent light trucks, and 10 percent heavy trucks, the average cost per hour is $17.87 per hour.

APPENDIX B Vehicle Occupancy Rates for Oregon

Vehicle Occupancy

The vehicle occupancy statistics shown on this page were derived from 180,725 vehicles that were involved in accidents during the years 1996, 1997, and 1998 in cities with a population over 10,000. The overall average vehicle occupancy per car was 1.51 for this period.

City and Average Occupants per Passenger Vehicle

Albany.............. 1.50	Lebanon............. 1.60
Ashland............. 1.49	McMinnville......... 1.53
Astoria............. 1.54	Medford............. 1.52
Beaverton........... 1.50	Milwaukie........... 1.46
Bend................ 1.48	Newberg............. 1.51
Canby............... 1.54	Ontario............. 1.66
Central Point....... 1.53	Oregon City......... 1.51
Coos Bay............ 1.50	Pendleton........... 1.49
Corvallis........... 1.45	Portland............ 1.42
Dallas.............. 1.52	Redmond............. 1.57
Eugene.............. 1.43	Roseburg............ 1.48
Forest Grove........ 1.56	Salem............... 1.50
Gladstone........... 1.53	Springfield......... 1.53
Grants Pass......... 1.53	The Dalles.......... 1.59
Gresham............. 1.47	Tigard.............. 1.42
Hermiston........... 1.65	Troutdale........... 1.53
Hillsboro........... 1.51	Tualatin............ 1.40
Keizer.............. 1.51	West Linn........... 1.45
Klamath Falls....... 1.54	Wilsonville......... 1.40
LaGrande............ 1.52	Woodburn............ 1.57
Lake Oswego......... 1.41	

APPENDIX C 1999 ADT Highway 18

SALMON RIVER HIGHWAY NO. 39

MP	LOCATION	99 ADT
0.40	0.40 mile east of Oregon Coast Highway (US101)	11300
1.36	0.10 mile east of Alvord Road at Otis	9600
3.96	On Bear Creek Bridge	9200
5.29	0.01 mile west of North Bank Road at Rose Lodge	9100
5.31	0.01 mile east of North Bank Road at Rose Lodge	9900
10.27	Lincoln-Tillamook County Line	9900
14.90	Tillamook-Polk County Line	8900
20.66	0.01 mile west of Fire Hall Road	9800
21.17	0.01 mile west of Grand Ronde Road	11300
21.19	0.01 mile east of Grand Ronde Road	12900
22.96	0.10 mile west of Three Rivers Highway (ORE22)	16700
23.16	0.10 mile east of Three Rivers Highway (ORE22)	19000
23.76	Valley Junction Automatic Recorder, Sta. 27-001, 0.70 mile east of Three Rivers Highway (ORE22)	18500
26.76	0.01 mile west of Willamina-Sheridan Highway (ORE18 Bus.)	18300
27.91	0.03 mile east of connection to Willamina-Salem Highway (ORE22)	8200
29.76	Polk-Yamhill County Line	8300
30.64	0.01 mile east of Harmony Road	8200
32.30	0.30 mile west of Sheridan Interchange (Ballston Road)	8800
32.90	0.30 mile east of Sheridan Interchange (Ballston Road)	8800
34.01	0.10 mile west of Willamina-Sheridan Highway (ORE18 Bus.)	8900
34.21	0.10 mile east of Willamina-Sheridan Highway (ORE18 Bus.)	15000
36.92	0.01 mile west of Bellevue-Hopewell Highway	14700
36.94	0.01 mile east of Bellevue-Hopewell Highway	14800
40.52	0.01 mile east of Delashmutt Lane	15900
43.03	0.01 mile east of Durham Lane	13900
43.76	0.60 mile west of Undercrossing Pacific Highway West (ORE99W)	15400
44.71	0.35 mile east of Pacific Highway West (ORE99W)	9600
46.46	0.20 mile east of McMinnville Spur	14000
48.58	0.01 mile west of Cruickshank Road	11400
48.60	0.01 mile east of Cruickshank Road	10300
49.81	0.10 mile west of Lafayette Highway (ORE233)	10700
49.94	0.03 mile east of Lafayette Highway (ORE233)	11400
51.03	0.20 mile west of Salem-Dayton Highway (ORE221)	11600
52.55	0.10 mile southwest of Pacific Highway West (ORE99W)	11800

APPENDIX D 1999 ADT Interstate 5

PACIFIC HIGHWAY NO. 1

MP	LOCATION	99 ADT
168.01	0.36 mile south of Goshen-Divide Interchange, Lane-Douglas Co. Line.	23700
172.14	0.10 mile south of London Road Interchange.........................	21700
174.64	0.10 mile south of Cottage Grove Interchange.......................	24600
176.46	0.30 mile south of Saginaw Interchange............................	36600
182.53	0.30 mile south of Springfield-Creswell Highway....................	36900
183.13	0.30 mile north of Springfield-Creswell Highway....................	42000
187.83	1.00 mile south of Willamette Highway (ORE58)......................	41600
189.03	0.20 mile south of Bonneville Power Interchange (30th Ave. Conn)....	58700
190.07	0.20 mile south of McVay Highway Connection........................	47900
191.68	0.30 mile south of Judkins Point Interchange.......................	60600
192.15	0.10 mile south of Pacific Highway West (ORE99)....................	67200
193.44	0.50 mile south of Eugene-Springfield Highway (I-105)...............	57200
195.10	0.35 mile south of Belt Line Road Interchange......................	68800
198.85	0.30 mile south of Van Duyn Road Interchange	43900
208.76	0.30 mile south of Diamond Hill Interchange........................	35600

APPENDIX E Highway 18 Incident Entries Describing Traffic Conditions

Initially it was hoped that some detailed traffic congestion or queue length data might have been included in the CAD data. For the Highway 18 corridor, a search was conducted for quantifiable entries describing any form of traffic congestion such as an estimate of the number of cars backed up or an estimation of the travel time between two known points. The Highway 18 data was separated into the following two groups of incidents:

Phase 1: 415 incidents, the following were identified:

There were no entries which gave any quantifiable estimate of traffic conditions; however there were several entries such as:

Incident 95346900	All areas cleared at this time.
Incident 96004346	Accident scene cleared. All traffic lanes open.
Incident 96083339	Accident cleared, traffic moving slowly.
Incident 96188677	Both lanes open. Traffic still backed up.
Incident 96282615	Traffic is moving.
Incident 96262994	Both lanes are open. Traffic slow due to backup.
Incident 96232972	Heavy traffic.
Incident 96083330	Highway department: If unit in area, check for lane blockage and assist with traffic.
Incident 96239542	Need traffic control and will be closing road at this location.
Incident 96183460	Long delays-traffic backed up. Signing would help.
Incident 96141572	Hwy 18 from Dallas to the coast traffic terrible. There are no lanes for passing. Traffic was at a stand still.

Phase 2: 1609 incidents, the following were identified:

Incident 98403800	MP 23 Hwy 18 at Valley Junction, traffic backed up to Grand Rhonde.
Incident 00530393	Jackknifed semi just west of MP 10 with 4-5 cars behind him.
Incident 97191220	Unhappy about long delays on this project. Took 30 minutes to get through today.
Incident 00416596	Traffic backed up to 101/18 … Took 3-5 minutes to get through to Lincoln City. There is not any traffic NB.
Incident 98017044	14” tree across the road, blocked completely. Ambulance caught behind it.

It appears that there are too few existing “traffic conditions” detailed for either (1) prior to the start of the incident response program or (2) after the incident response program started to be used to estimate any benefits which can be attributable to the incident response program.

FIGURE 1: Region 2 Location Map

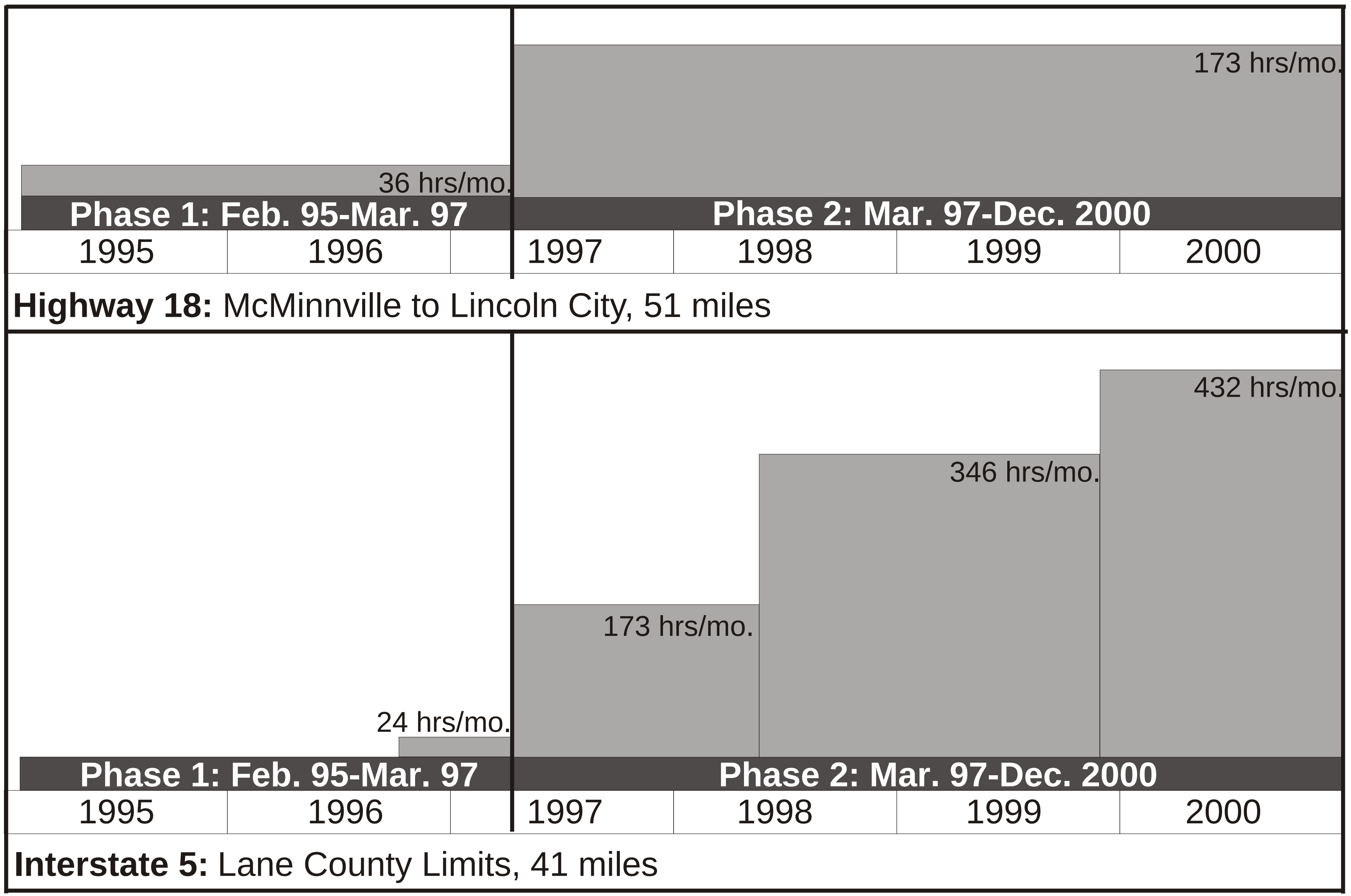


Figure 2: Incident Response Analysis Phases and Staffing Levels

FIGURE 3: Queueing Diagram

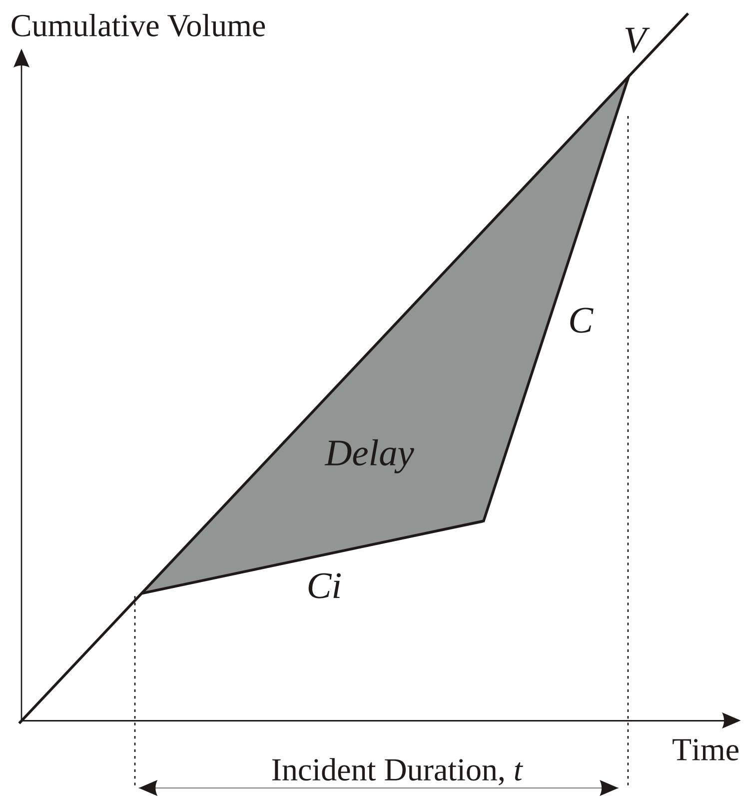


FIGURE 4: Highway 18 Accident Data Comparison, 1995-2000

MILE POST	SECTION DESCRIPTION	MILES	NUMBER OF ACCIDENTS											
			1995		1996		1997			1998		1999		2000	
			Phase 1					Phase 2							
			DATA	ODOT	DATA	ODOT	Data		ODOT	DATA	ODOT	DATA	ODOT	DATA	ODOT
0.22	OREGON COAST HWY 9 TO ALVORD ROAD /OTIS JCT 1	1.48	0	2	0	4	0	3	0	3	3	4	10	3	*
1.26	ALVORD RD TO TILLAMOOK COUNTY	9.01	3	26	1	37	0	25	31	2	26	20	24	14	
10.26	TILLAMOOK COUNTY TO POLK COUNTY	4.64	0	3	7	8	1	6	7	23	6	5	6	5	
14.9	POLK CO TO FIRE HALL RD	5.62	1	11	1	6	1	11	16	1	16	5	13	17	
20.67	FIRE HALL RD TO GRANDE RONDE RD	0.51	0	4	2	4	0	6	3	9	3	2	4	3	
21.18	GRAND RONDE TO THREE RIVERS HWY 32	1.86	0	4	0	5	0	5	3	4	2	2	7	3	
23.04	THREE RIVERS HWY 32 TO S YAMHILL RIVER	0.06	0	1	1	0	1	0	0	1	1	3	2	5	
23.1	S YAMHILL RIVER TO COUNTY ROAD CONNECTION	1.29	0	7	0	4	0	3	6	8	10	2	6	5	
24.4	CO ROAD CONN TO WALLACE BR INTERCHANGE /ORE22	2.77	1	6	0	5	0	5	6	2	5	8	6	4	
27.17	WALLACE BRIDGE INTERCHANGE /ORE22 TO YAMHILL CO	2.59	0	0	1	5	0	2	0	0	2	1	3	1	
29.76	YAMHILL COUNTY TO HARMONY ROAD	0.87	0	1	5	4	1	1	3	2	3	1	1	1	
30.63	HARMONY ROAD TO SHERIDAN	2.05	0	9	1	3	0	1	3	1	4	2	3	0	
32.68	SHERIDAN	0.54	0	0	0	0	0	1	0	2	0	3	2	1	
33.22	SHERIDAN TO JCT WILLAMINA-SHERIDAN HWY 157	0.89	0	3	0	1	0	0	1	2	3	0	2	0	
34.11	HWY 157 TO BELLVUE-HOPEWELL HWY 153	2.82	0	5	0	8	0	3	9	1	8	5	7	2	
36.93	HWY 153 TO OLDSVILLE RD	3.51	0	4	1	8	0	2	4	1	4	1	6	1	
40.44	OLDSVILLE RD TO CONN TO 1W - EBD	3.4	0	5	3	7	0	5	11	2	5	2	7	3	
43.84	CONN TO 1W - EBD TO MCMINNVILLE SPUR	2.42	0	2	3	8	0	1	5	0	2	2	5	3	
46.26	MCMINNVILLE SPUR TO MCMINNVILLE	0.26	0	2	0	2	0	0	0	0	0	0	7	0	
46.42	MCMINNVILLE	2.11	0	6	0	8	0	2	5	2	3	3	6	2	
48.53	MCMINNVILLE TO LAFAYETTE HWY 154	1.38	0	6	1	1	0	2	15	4	6	2	2	2	
49.91	LAFAYETTE HWY 154 TO NBD SALEM-DAYTON HWY 150	1.32	0	1	0	4	2	0	1	3	4	2	1	0	
51.23	SALEM-DAYTON HWY 150 TO JCT HWY 1W /ORE99W	1.42	0	7	0	1	2	0	4	5	1	4	4	1	
52.65			0	0	2	0	2	5	0	1	0	0	0	0	
TOTAL			**5**	**116**	**29**	**133**	**10**	**89**	**133**	**79**	**117**	**79**	**134**	**76**	

* Data from ODOT for 2000 is not yet available

FIGURE 5: Highway 18 Comparison of Accident Data

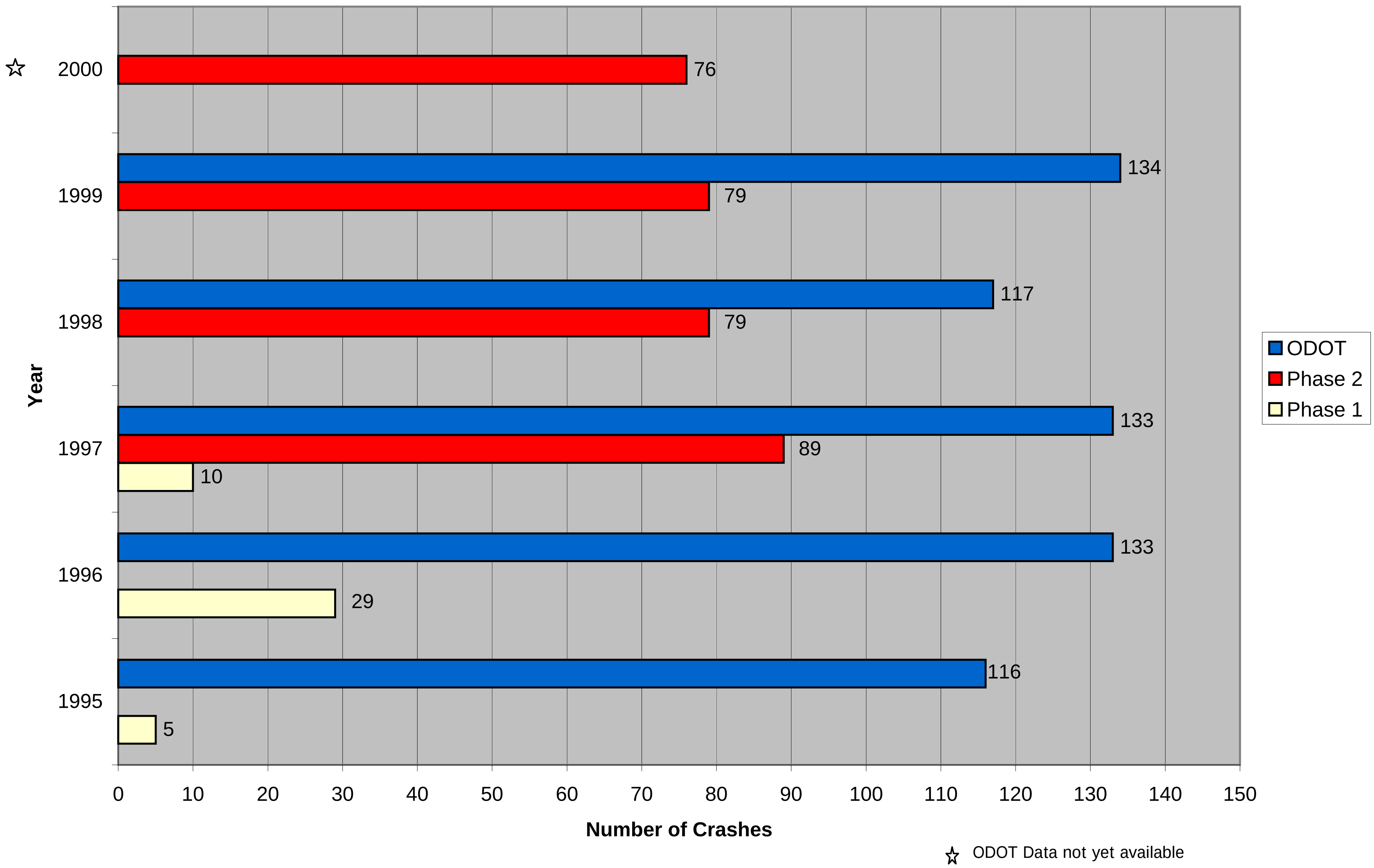


FIGURE 6: Interstate 5 Accident Data Comparison, 1995-2000

MILE POST	SECTION DESCRIPTION	MILES	NUMBER OF ACCIDENTS															
			1995		1996			1997			1998		1999			2000		
			Phase 1					Phase 2										
			Period 1			Period 2		Period 3					Period 4			Period 5		
			Data	ODOT	Data		ODOT	Data		ODOT	Data	ODOT	Data		ODOT	Data		ODOT
168.01	LANE COUNTY TO U-XING MCVAY HWY 226	0.74	0	1	0	0	5	0	0	3	0	2	2	2	1	0	0	*
168.75	DIVIDE INTERCHANGE /ORE99 BUS TO COTTAGE GROVE	4.53	0	8	0	0	10	0	0	7	0	6	0	0	12	0	0	
173.28	COTTAGE GROVE	1.72	1	0	1	1	0	1	5	2	7		3	5		5	4	
175	NCL COTTAGE GROVE TO U-XING SAGINAW E ROAD	1.76	0	2	2	1	10	1	4	2	4	5	0	6	6	7	1	
176.76	U-XING SAGINAW E RD TO CRESWELL	5.87	0	4	0	1	11	1	3	14	1	13	0	3	6	1	0	
182.63	CRESWELL	0.6	1	0	4	1	4	1	5		10	1	2	5	2	11	2	
183.23	CRESWELL TO O-XING WILLAMETTE HWY 18	5.11	0	0	1	0	0	0	1	11	1	14	0	2	19	2	0	
188.34	O-XING HWY 18 TO U-XING 30TH AVE	1.53	0	2	2	0	5	0	7	5	10	5	1	6	5	9	4	
189.87	U-XING 30TH AVE TO MCVAY HWY 225 /ORE231	0.89	0	2	0	0	6	0	1	2	12	7	4	3	5	6	0	
190.76	U-XING MCVAY HWY 225 TO EUGENE	0.94	1	7	0	0	1	0	0	2	1	3	2	2	5	1	0	
191.7	SCL TO U-XING GLENWOOD BLVD	0.28	1	1	0	0	5	0	3	2	5		0	1		1	0	
191.98	JUDKINS PT INTERCHANGE TO JCT PACIFIC HWY WEST	0.29	0	0	0	0	0	0	0	1	0	2	0	0	2	0	0	
192.27	JCT PACIFIC HWY WEST TO WILLAMETTE RIVER BRIDGE	0.48	0	1	0	0	0	0	1	1	4	1	1	0		2	0	
192.75	WILLAMETTE BR TO U-XING EUGENE-SPR HWY 227	1.19	0	0	0	0	0	0	0	2	1	1	0	3	2	1	0	
193.94	U-XING HWY 227 TO BELTLINE ROAD INTERCHANGE	1.51	0	9	0	1	11	1	3	3	5	8	0	1	14	2	0	
195.45	BELTLINE O-XING TO EUGENE-SPRINGFIELD NCL	0.35	0	5	2	1	1	1	4	4	11	5	5	14	3	9	2	
195.8	NCL EUGENE-SPRINGFIELD TO COBURG INT	3.35	0	0	0	0	0	0	0	8	0	8	0	0	10	0	0	
199.15	COBURG INTERCHANGE TO LINN COUNTY	4.4	0	4	2	4	11	4	3	15	9	14	2	3	15	4	0	
203.55	LINN COUNTY TO U-XING DIAMOND HILL DRIVE	5.51	0	0	1	2	0	2	7	2	10	3	0	7	5	5	0	
209.06	DIAMOND HILL TO U-X HALSEY-SWEET HOME HWY 212	7.51	0	11	0	0	10	0	2	10	0	5	0	0	4	1	0	
216.57			0		0	0		0	0		0		0	0		0	0	
TOTAL			**4**	**57**	**15**	**12**	**88**	**12**	**49**	**96**	**91**	**103**	**22**	**63**	**116**	**67**	**13**	

* ODOT data for 2000 is not yet available

FIGURE 7: Interstate 5 Comparison of Accident Data

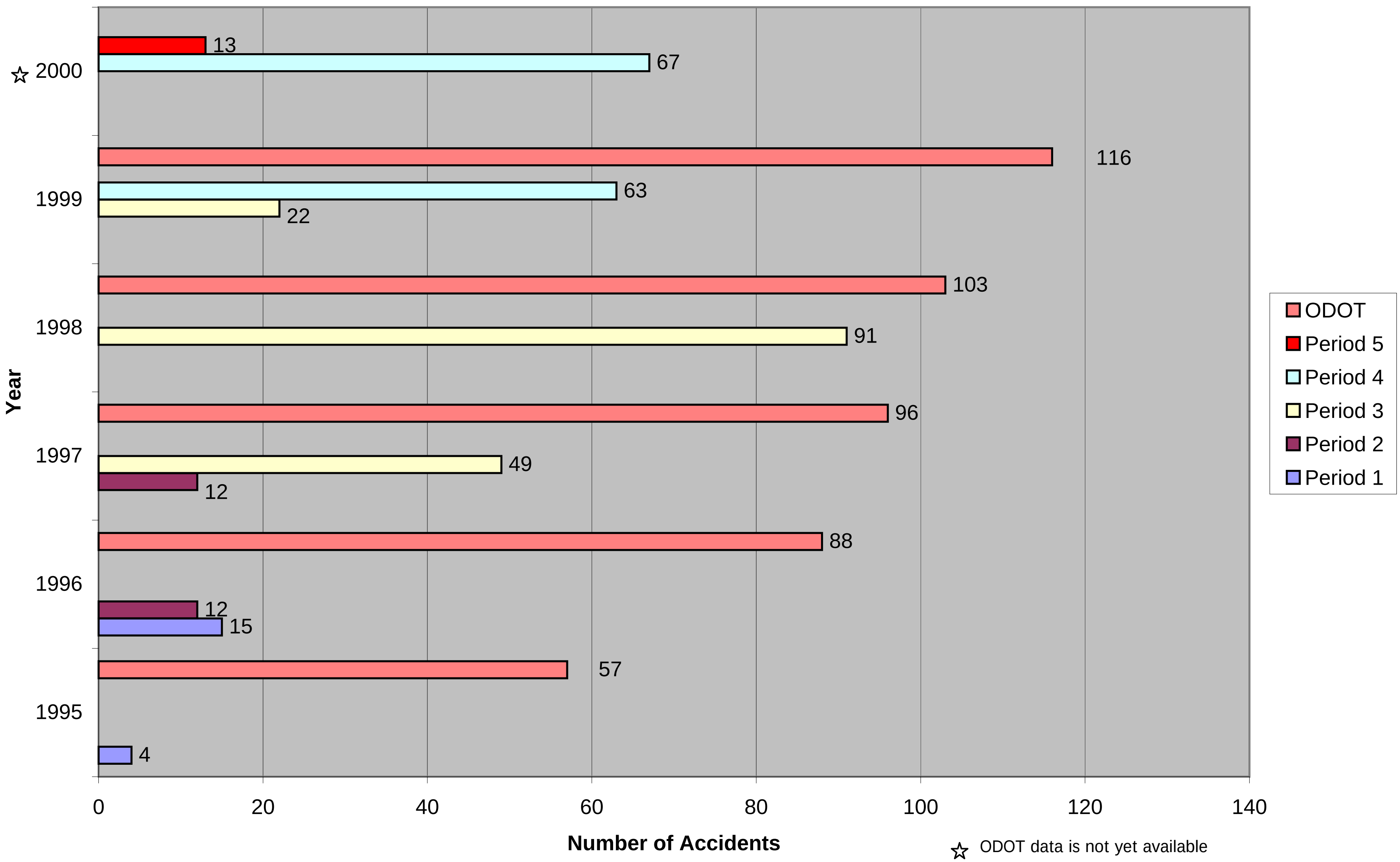


FIGURE 8: Region 2 Incident Frequency, 1995-2000

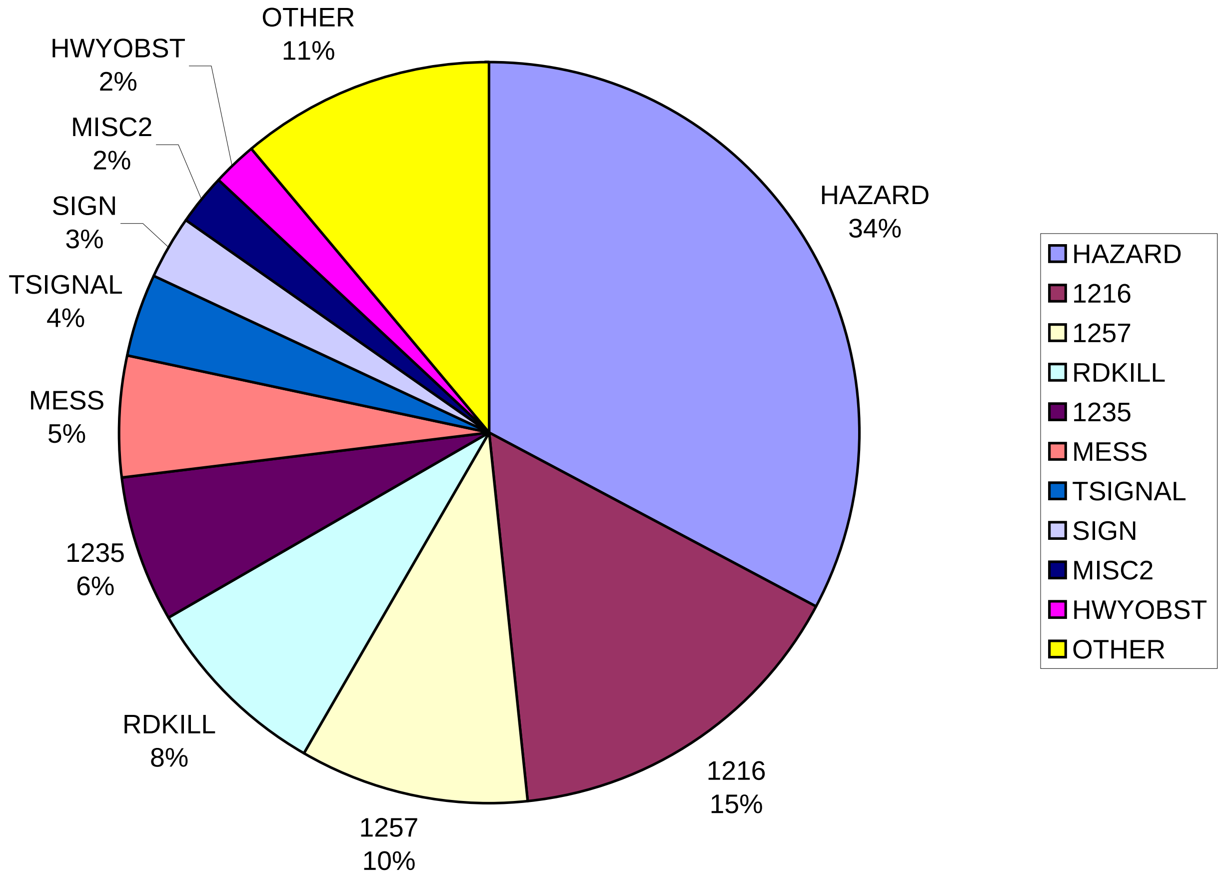


FIGURE 9: Region 2 Incident Tree, All Reported Incidents, 1995-2000

ALL INCIDENTS

REPORTED
TOTAL = 67,631

UNREPORTED INCIDENTS UNKNOWN

GROUP	SUBTOTAL	PERCENT
1 Accidents		
1216 - Crash	10,442	15.44
1216A - Fatality	19	0.03
SUBTOTAL	10,461	15.47
2 Breakdowns		
1235 - Abandoned	4,255	6.29
1257 - Motorist Assist	6,919	10.23
SUBTOTAL	11,174	16.52
3 Hazards/Blocking		
HAZARD	22,173	32.79
HWYBLOCK	28	0.04
HWYOBST	1,275	1.89
SIGN	1,870	2.77
VANDAL	122	0.18
SUBTOTAL	25,468	37.66
4 Potential Delay		
FIRE	566	0.84
HZSPILL	488	0.72
LIVESTK	61	0.09
MISC*	2,846	4.21
OERS	10	0.01
OPASS	7	0.01
RDKILL	5,609	8.29
TRKINSP	1	0.00
TSIGNAL	2,545	3.76
WWAY	2	0.00
SUBTOTAL	12,135	17.94
5 Response/No Delay		
1231	35	0.05
AGASST	609	0.90
BACKUP	2	0.00
BLOOD	1	0.00
CHKAREA	6	0.01
DRIVING	120	0.18
TRAFFIC	463	0.68
TRAVEL	473	0.70
SUBTOTAL	1,709	2.53
6 Misc/No Delay		
ANIMAL	374	0.55
INFORM	266	0.39
LITTER	313	0.46
MESS	3,535	5.23
SELFINIT	753	1.11
TEST	581	0.86
Remaining (<100)	862	1.27
SUBTOTAL	6,684	9.88
TOTAL	67,631	100.00

*includes MISC, MISC0, MISC1 and MISC2

FIGURE 10: Region 2 All Reported Incidents, 1995-2000

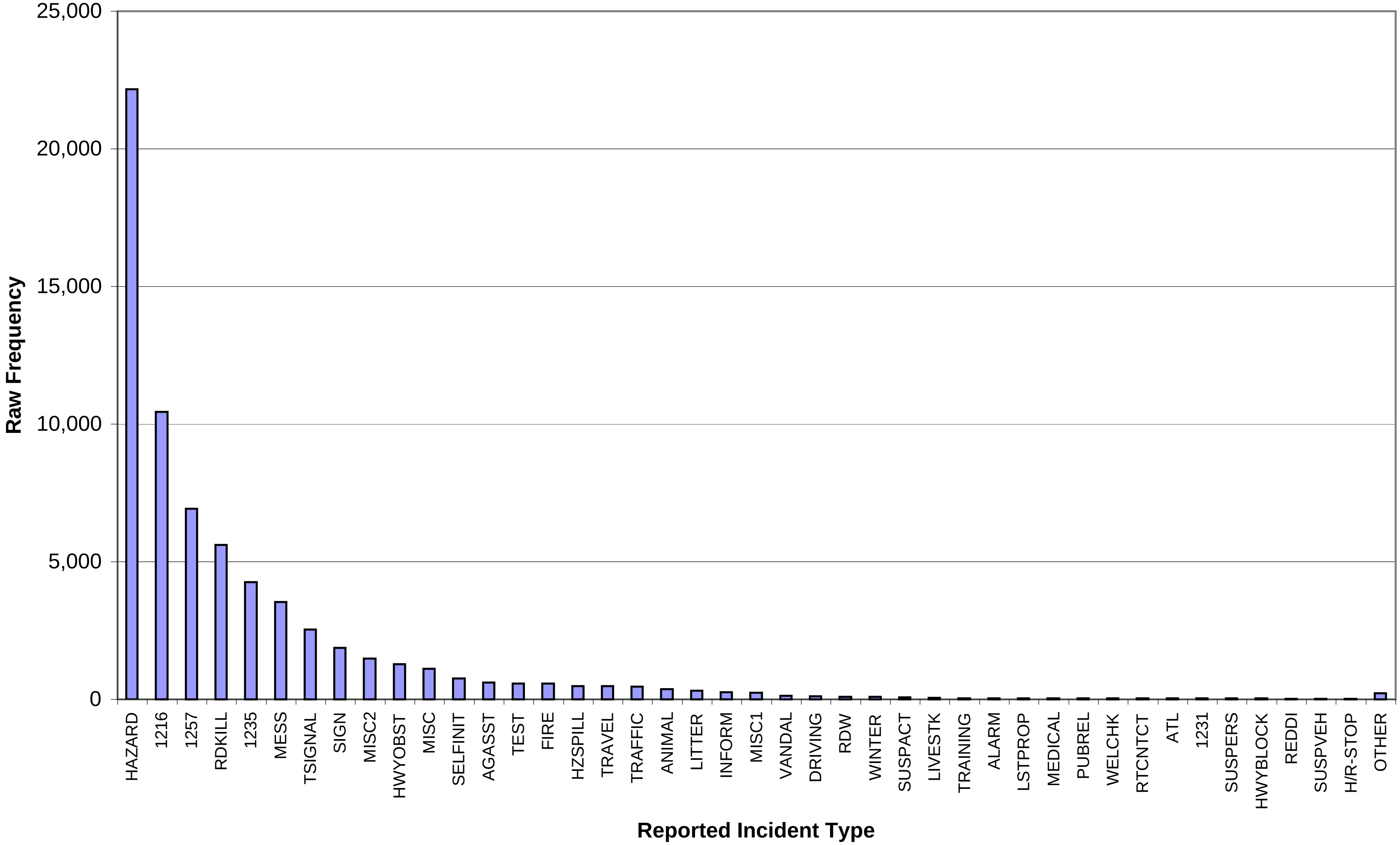


FIGURE 11: Region 2 All Reported Incidents-Duration

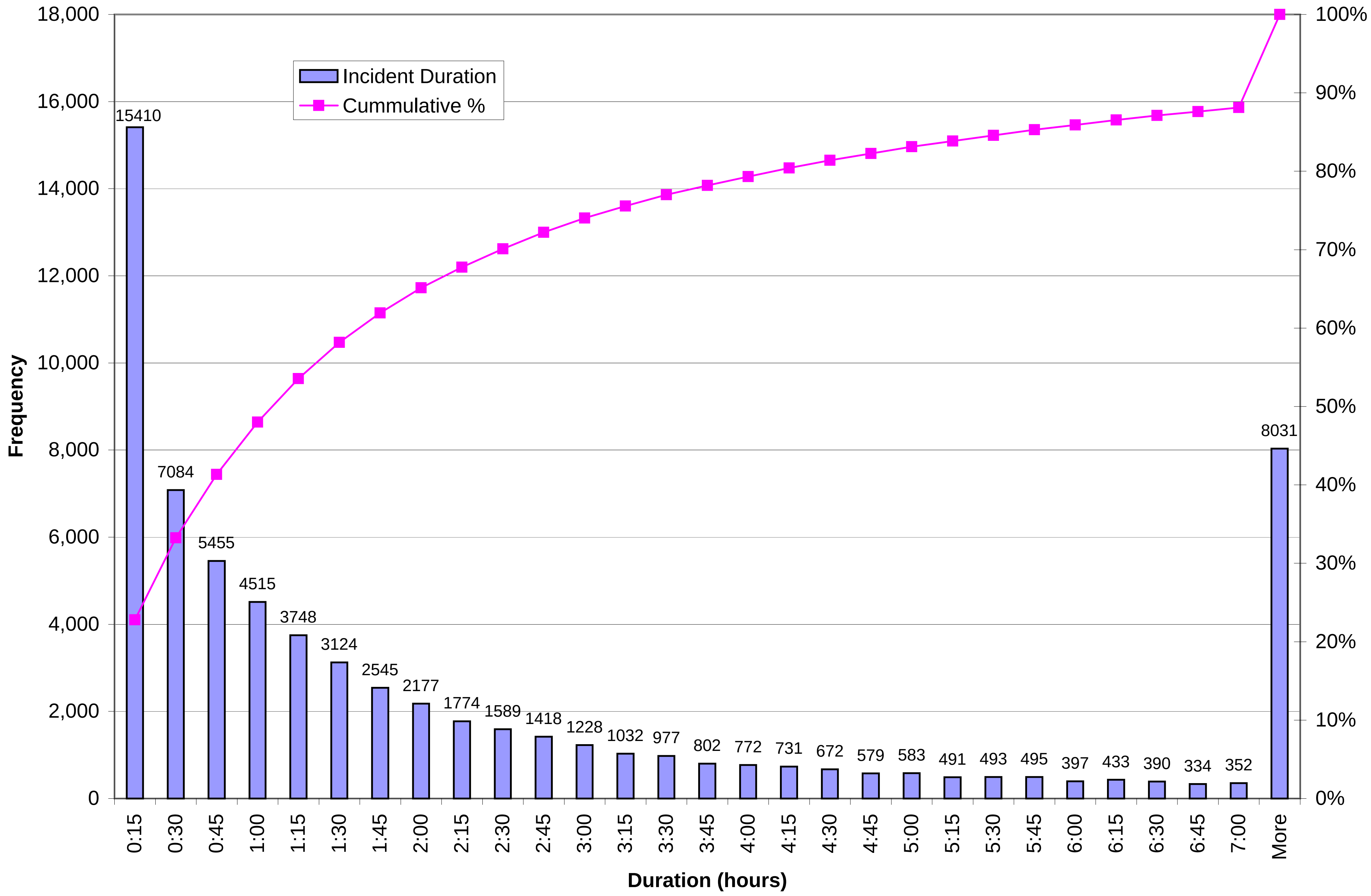


FIGURE 12: Highway 18 Incident Tree, 1995-2000

ALL INCIDENTS

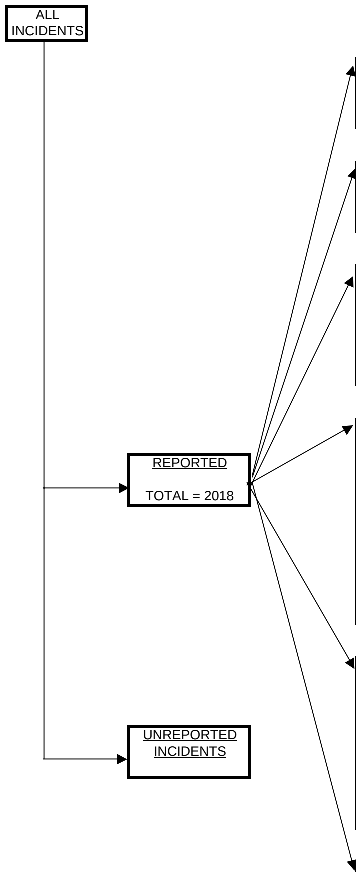
REPORTED TOTAL = 1815

UNREPORTED UNKNOWN

GROUP	RAW	FILTERED	PERCENT
1 Accidents			
1216 - Crash	421	356	26.91
1216A - Fatality	6	6	0.45
SUBTOTAL	427	362	27.36
2 Breakdowns			
1235 - Abandoned	37	34	2.57
1257 - Motorist Assis	206	196	14.81
SUBTOTAL	243	230	17.38
3 Hazards/Blocking			
HAZARD	697	492	37.19
HWYBLOCK			
HWYOBST	49	28	2.12
SIGN	62	18	1.36
VANDAL			
SUBTOTAL	808	538	40.67
4 Potential Delay			
FIRE	12	8	0.60
HZSPILL	15	7	0.53
LIVESTK	4	3	0.23
MISC*	54	18	1.36
OERS			
OPASS			
RDKILL	213	139	10.51
TRKINSP			
TSIGNAL	18	5	0.38
WWAY			
SUBTOTAL	316	180	13.61
5 Response/No Delay			
1231			
AGASST			
BACKUP			
BLOOD			
CHKAREA			
DRIVING			
TRAFFIC	13	7	0.53
TRAVEL			
SUBTOTAL	13	7	0.53
6 Misc/No Delay			
AIRACC			
ALARM			
ANIMAL			
ARSON			
ATL			
BOAT			
BOMB			
BURNING			
CASES			
CRIME			
DISTURB			
DRUG			
FOUNDPR			
H/R-STOP			
LITTER			
MEDICAL			
OUTSERV			
PUBREL			
RECVEH			
REDDI	4	3	0.23
SELFINIT			
SUICIDE			
SUSPERS			
TEST			
TOW			
TRNSPORT			
WARRANT			
WINTER	1	1	0.08
AIRPLANE			
ANGLING			
ARREST			
ASSAULT			
BICYCLE			
BOLO			
BURG			
CAD			
COMM			
DEATH			
DOMEST			
FOLLOW			
GAME			
INFORM			
LSTPROP	1	0	0.00
MESS			
PRKCMPL			
PURSUIT			
RDW			
RTCNTCT			
SPCL01	1	1	0.08
SUSPACT			
SUSPVEH			
THEFT			
TRAINING			
TRSPASS			
WELCHK	1	1	0.08
SUBTOTAL	8	6	0.45
TOTAL	1815	1323	100.00

*includes MISC, MISC0, MISC1 and MISC2

FIGURE 13: Interstate 5 Incident Tree, 1995-2000



GROUP	RAW	FILTERED	PERCENT
1 Accidents			
1216 - Crash	369	310	26.14
1216A - Fatality	3	3	0.25
SUBTOTAL	372	313	26.39
2 Breakdowns			
1235 - Abandoned	50	39	3.29
1257 - Motorist Assist	87	76	6.41
SUBTOTAL	137	115	9.70
3 Hazards/Blocking			
HAZARD	849	553	46.63
HWYBLOCK	1	1	0.08
HWYOBST	18	8	0.67
SIGN	26	9	0.76
VANDAL	4	2	0.17
SUBTOTAL	898	573	48.31
4 Potential Delay			
FIRE	34	27	2.28
HZSPILL	19	8	0.67
LIVESTK	4	0	
MISC*	96	21	1.77
OERS	2	2	0.17
OPASS			
RDKILL	174	118	9.95
TRKINSP			
TSIGNAL	33	2	0.17
WWAY			
SUBTOTAL	362	178	15.01
5 Response/No Delay			
1231	2	2	0.17
AGASST	15	0	
BACKUP			
BLOOD			
CHKAREA			
DRIVING	2	1	0.08
TRAFFIC	20	3	0.25
TRAVEL			
SUBTOTAL	39	6	0.51
6 Misc/No Delay			
AIRACC			
ALARM	1	0	
ANIMAL	21	0	
ARSON			
ATL	1	0	
BOAT			
BOMB			
BURNING			
CASES			
CRIME	1	0	
DISTURB			
DRUG			
FOUNDPR	1	0	
H/R-STOP			
LITTER	8	0	
MEDICAL	2	0	
OUTSERV			
PUBREL	3	0	
RECVEH			
REDDI			
SELFINIT			
SUICIDE			
SUSPERS	1	0	
TEST	15	0	
TOW			
TRNSPORT			
WARRANT			
WINTER	4	0	
AIRPLANE			
ANGLING	1	0	
ARREST			
ASSAULT			
BICYCLE			
BOLO			
BURG			
CAD			
COMM			
DEATH			
DOMEST			
FOLLOW			
GAME			
INFORM	13	0	
LSTPROP	3	0	
MESS	118	0	
PRKCMPL			
PURSUIT			
RDW	3	0	
RTCNTCT			
SPCL01			
SUSPACT	9	0	
SUSPVEH			
THEFT			
TRAINING	1	1	0.08
TRSPASS			
WELCHK	4	0	
SUBTOTAL	210	1	0.08
TOTAL	2018	1,186	100.00

*includes MISC, MISC0, MISC1 and MISC2

FIGURE 14: Highway 18 ADT at Valley Junction ATR (Weekends, 2000)

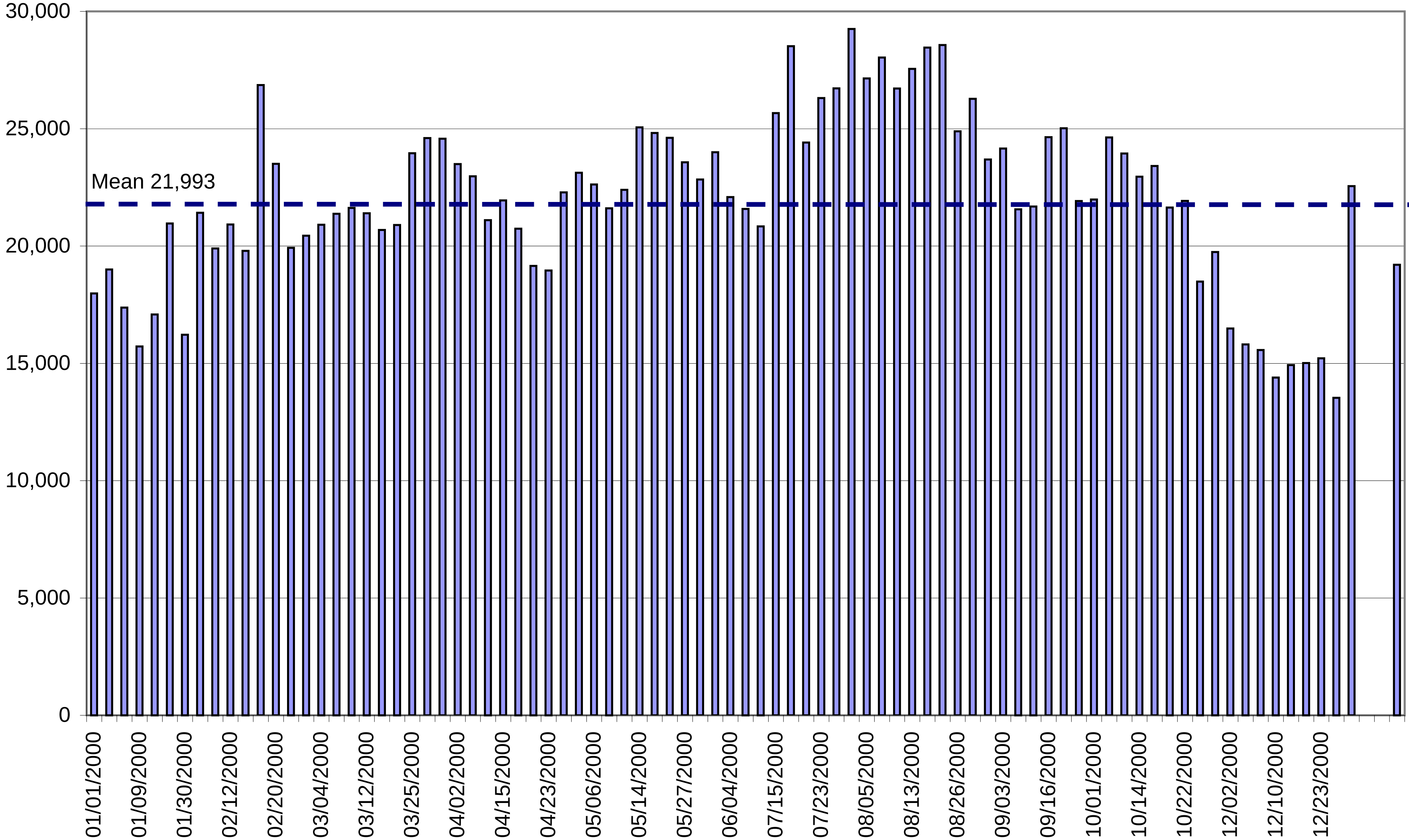


FIGURE 15: Highway 18 Directional ADT Factors (Weekends, 2000)

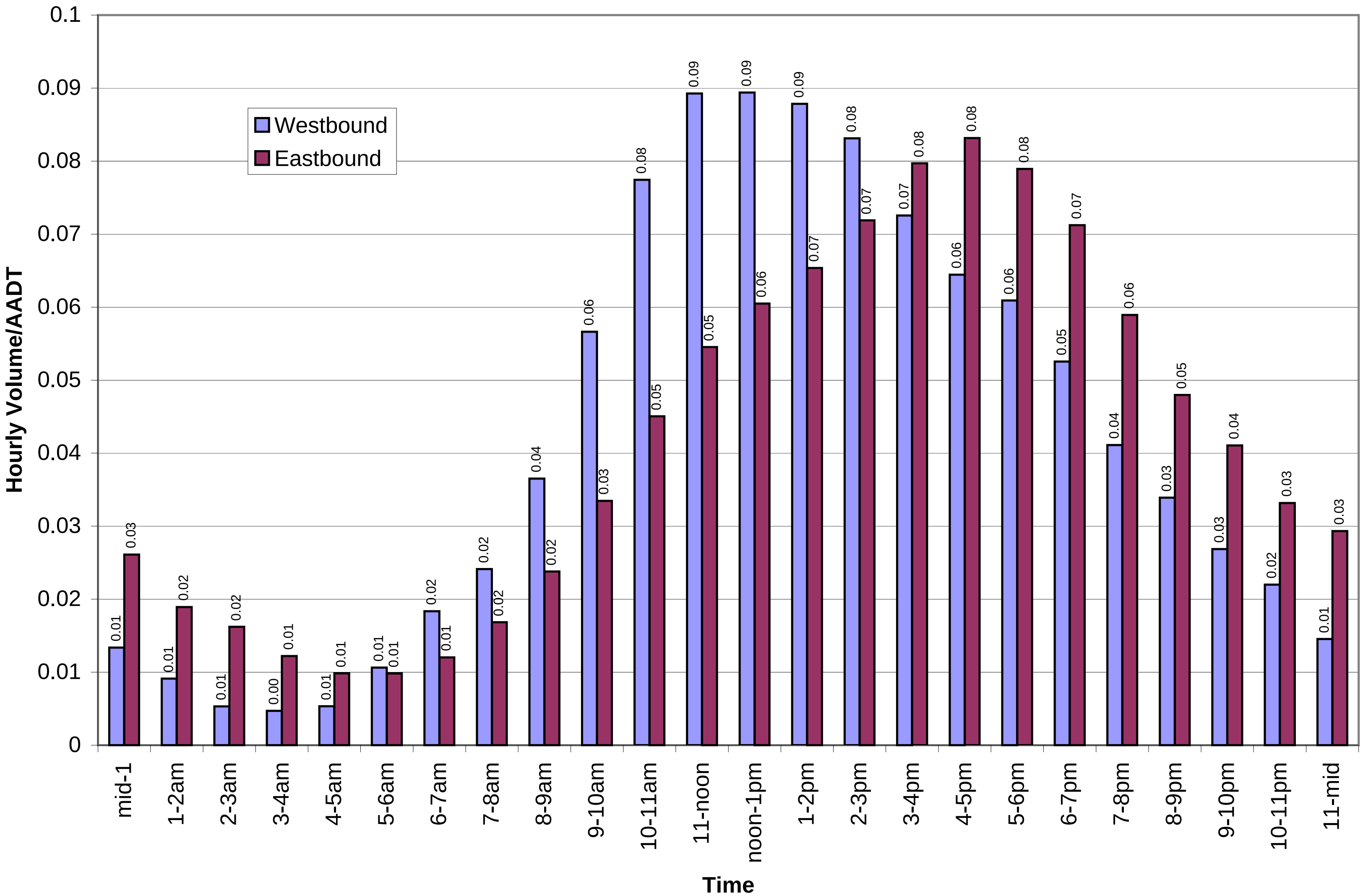


FIGURE 16: Interstate 5 ADT at Bond Butte ATR (Weekdays, 2000)

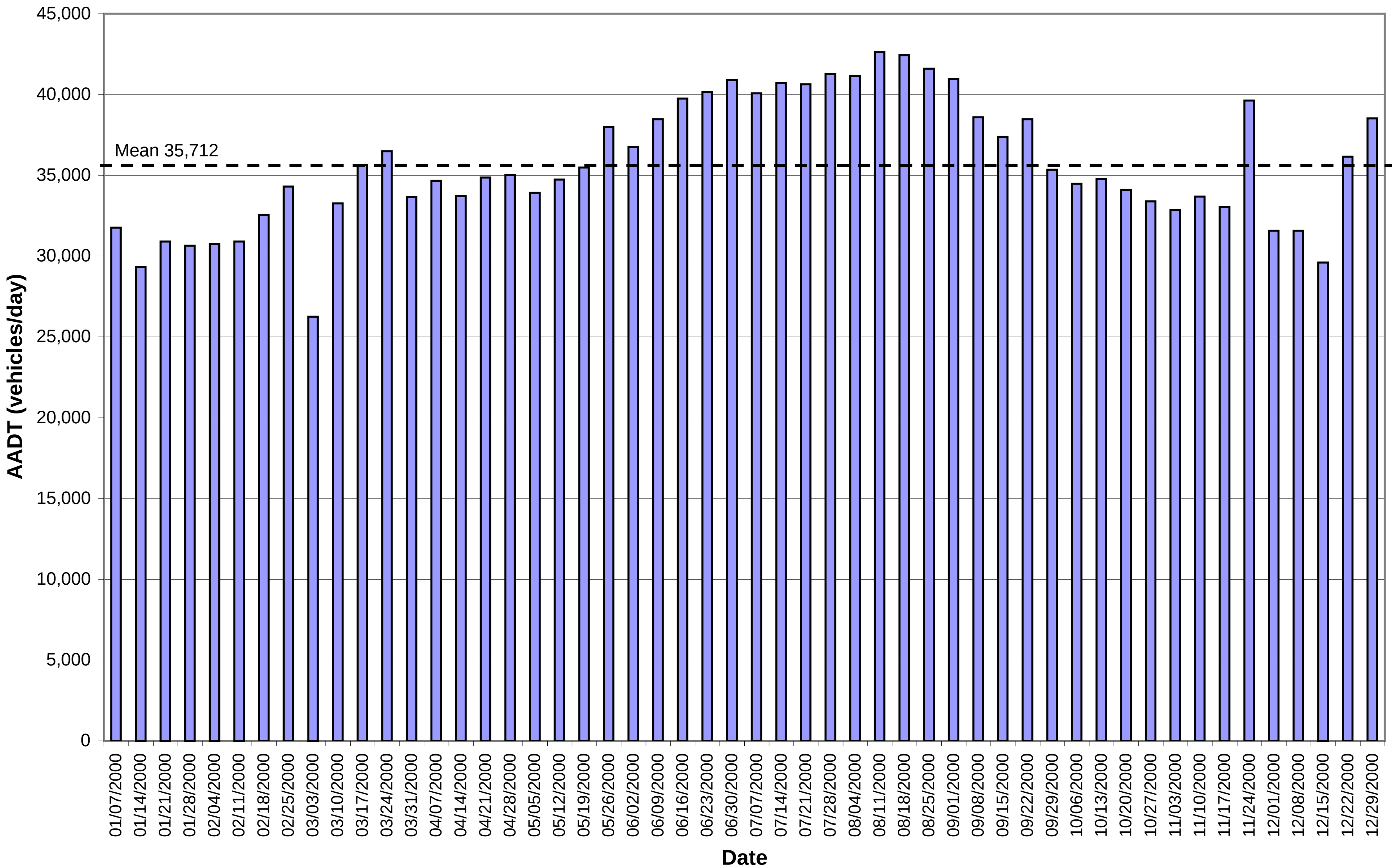


FIGURE 17: Interstate 5 Directional ADT Factors (Weekdays, 2000)

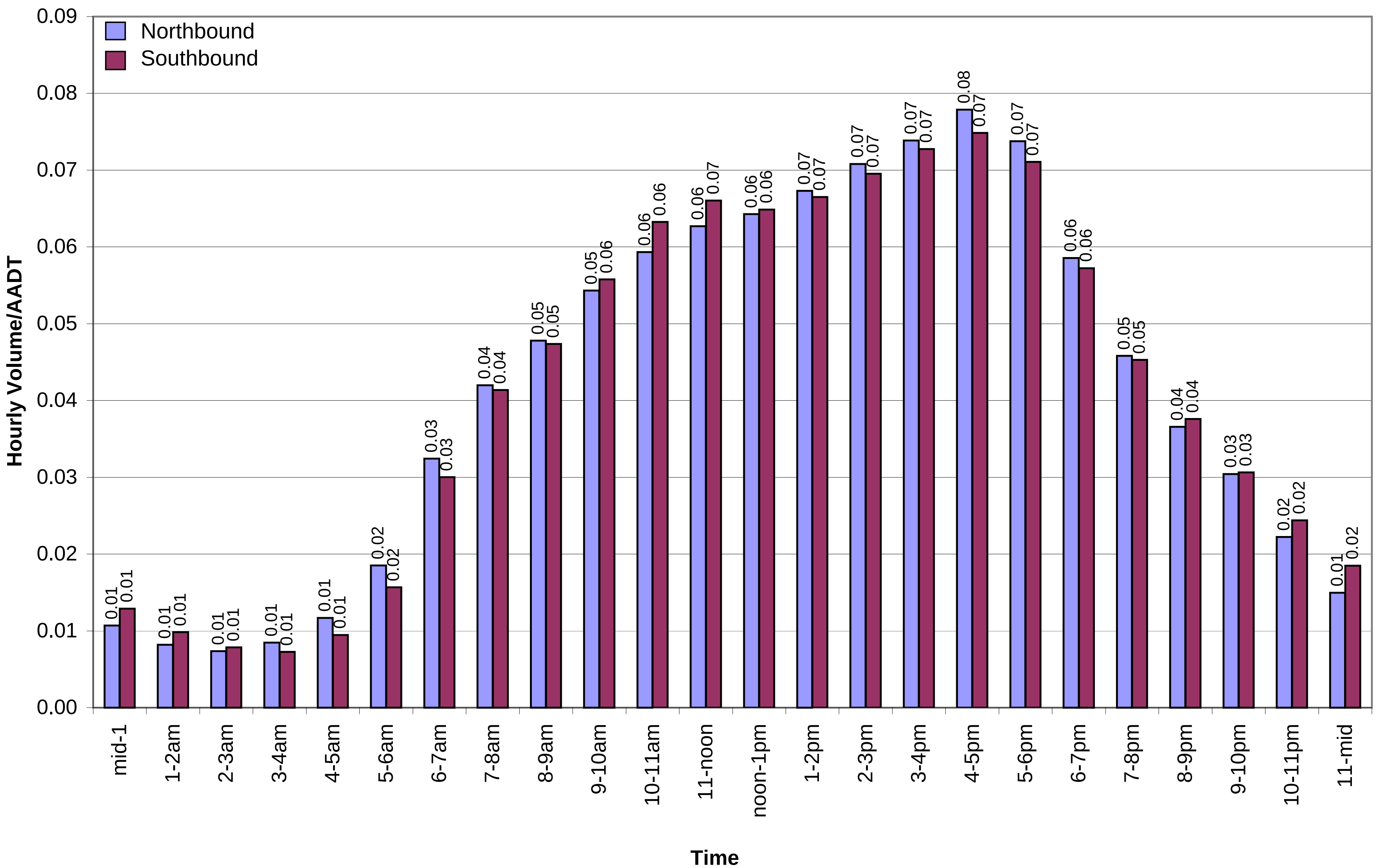
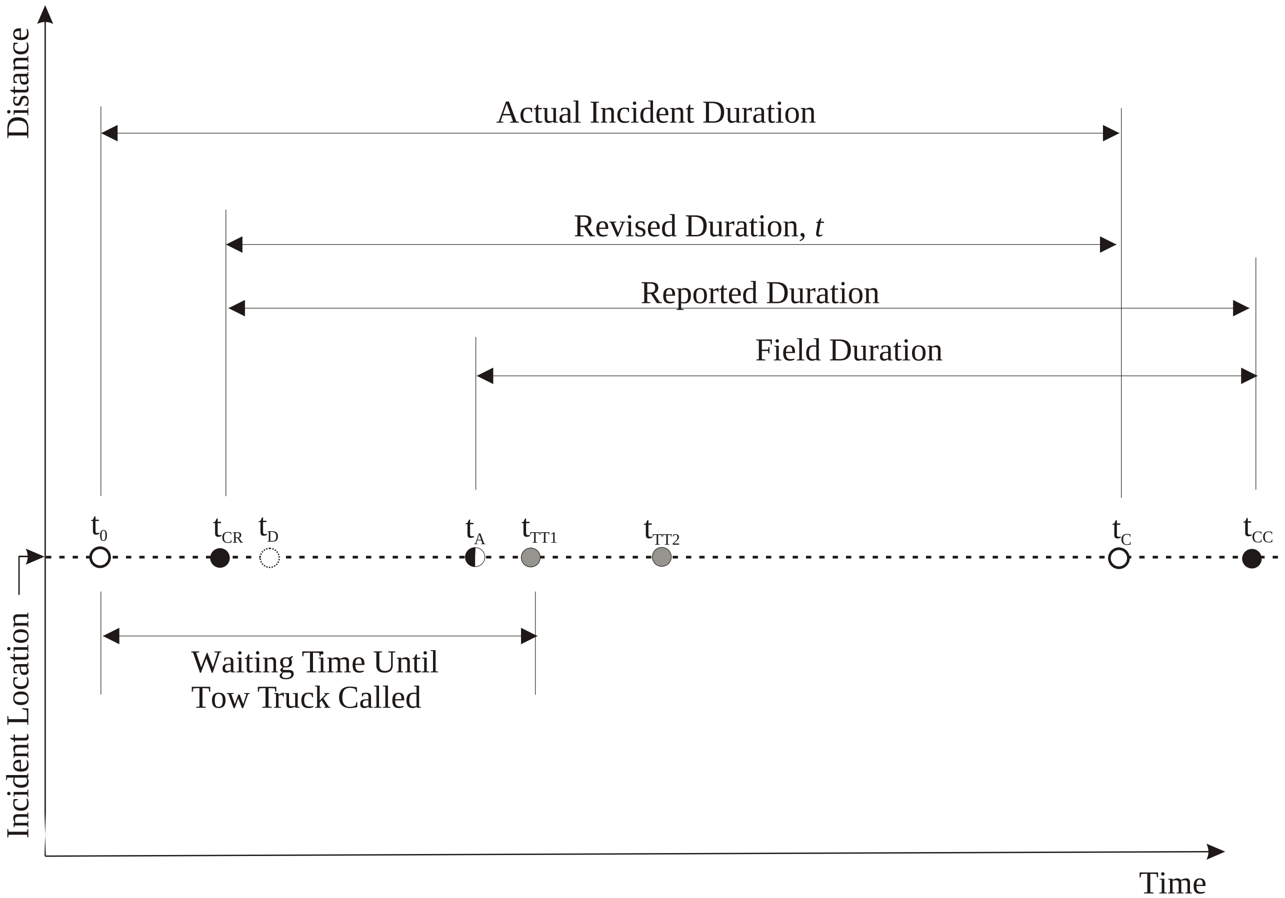


FIGURE 18: Incident Duration



LEGEND

t_0 = Time of incident occurrence (unknown)

t_{CR} = Time call received

t_D = Time IR dispatched

t_A = Time IR arrived

t_{TT1} = Time tow truck called (if applicable)

t_{TT2} = Time tow truck arrived

t_C = Time incident cleared

t_{CC} = Time call cleared (may be same as t_C)

FIGURE 19: Highway 18 All Filtered Incident Frequency, 1995-2000

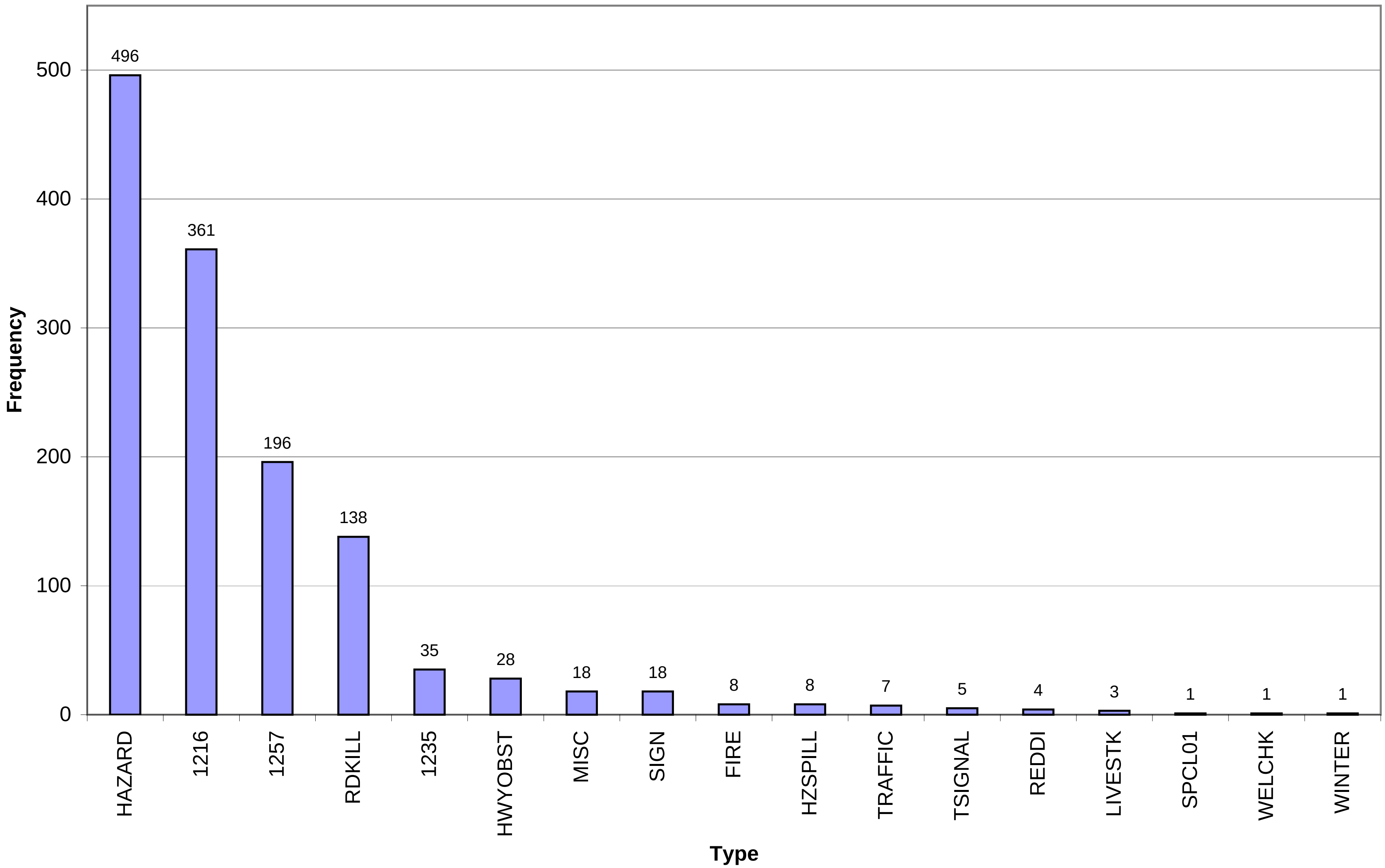


FIGURE 20: Highway 18 All Filtered Incidents, 1995-2000, Duration Histogram

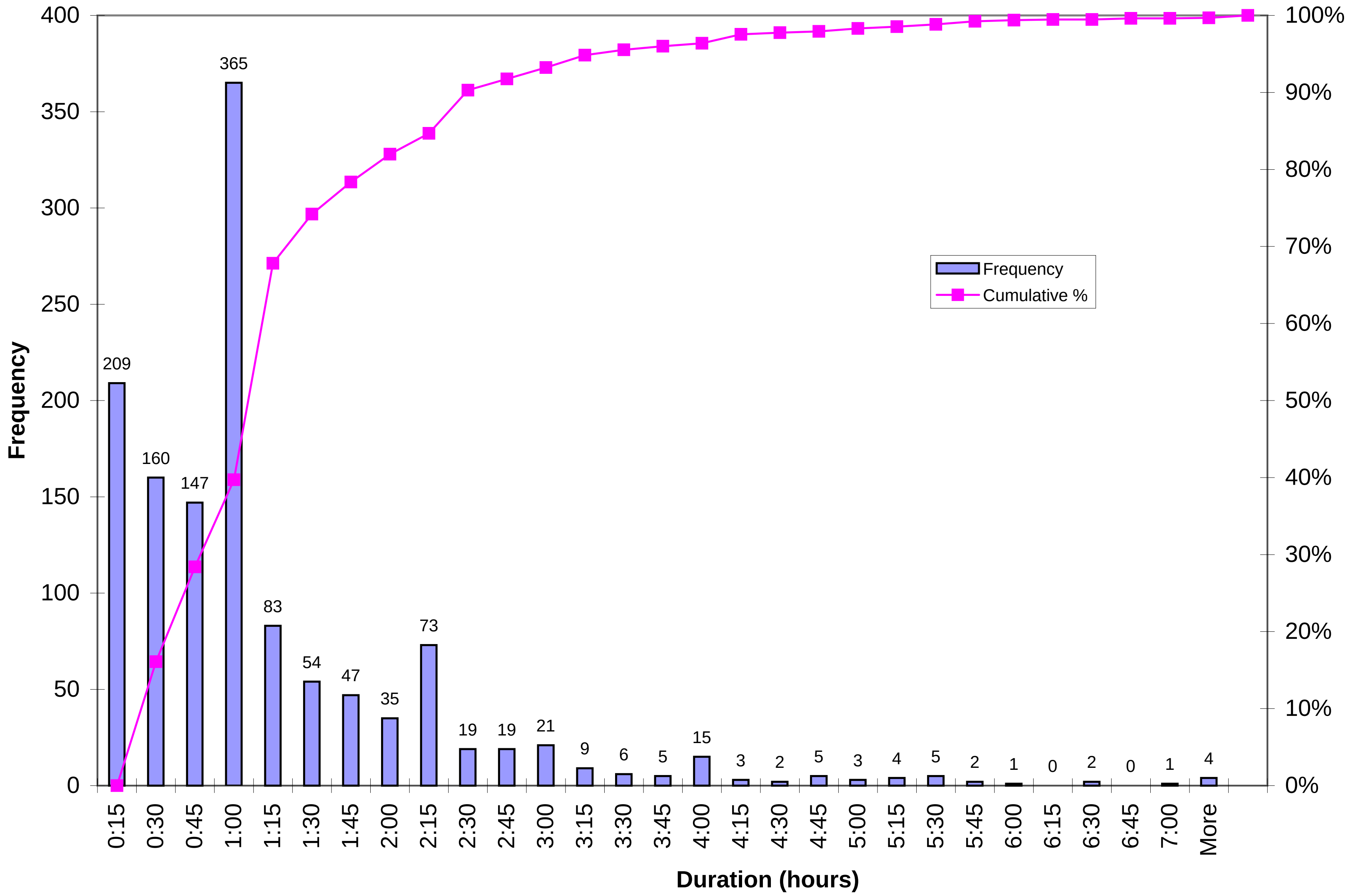


FIGURE 21: Highway 18 All Filtered Incidents, 1995-2000, by Milepost

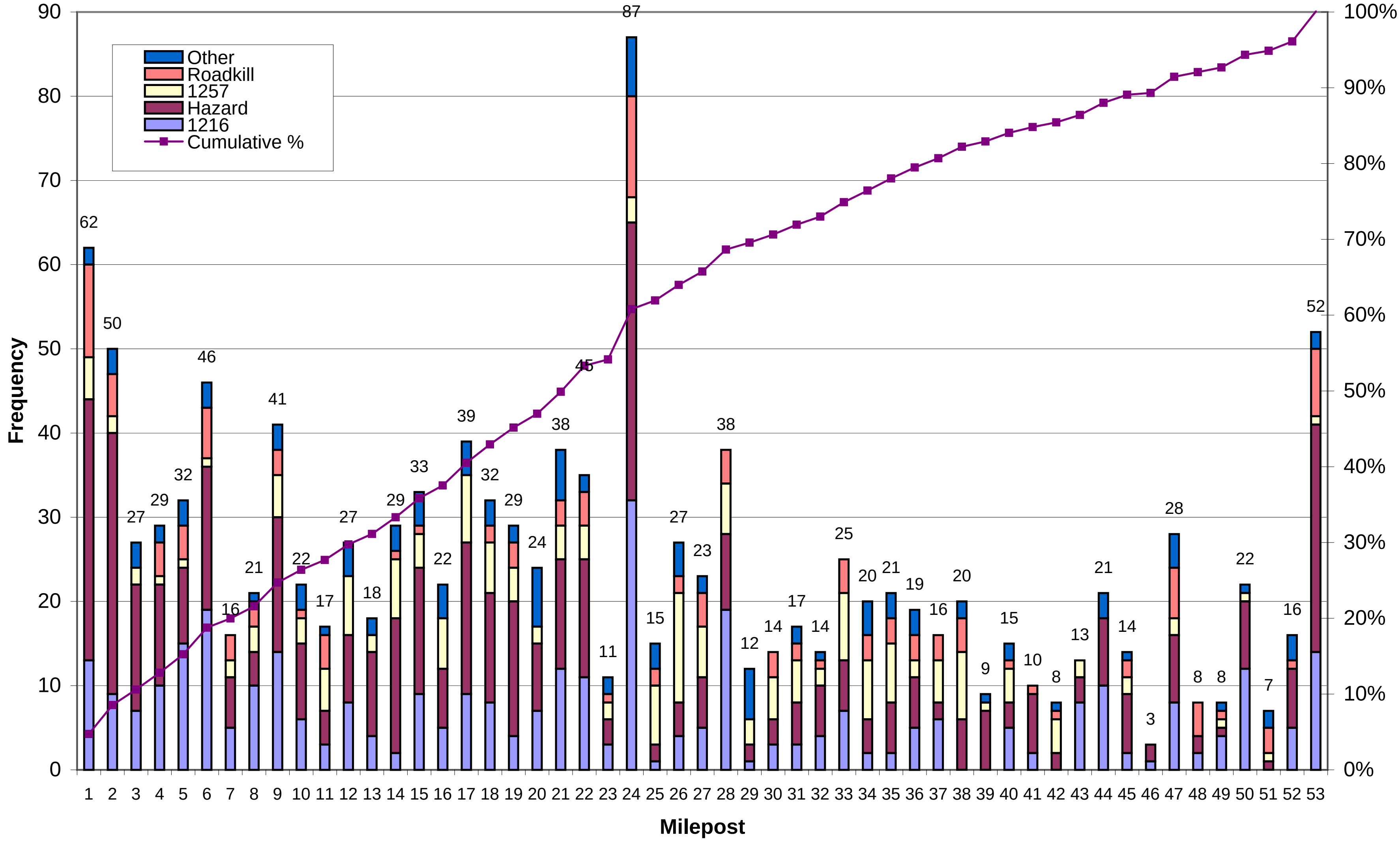


FIGURE 22: Interstate 5 All Filtered Incident Frequency, 1995-2000

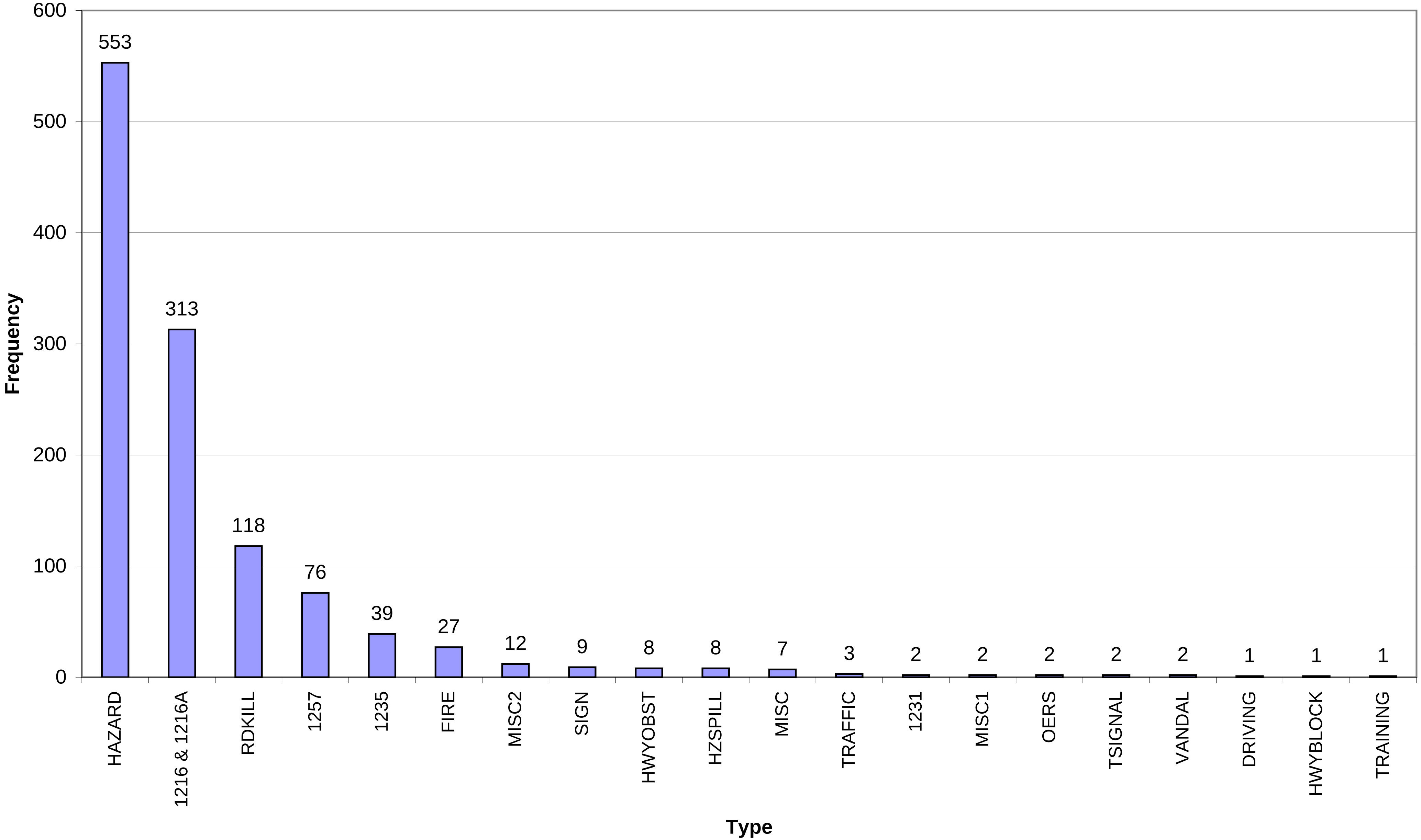


Figure 23: Interstate 5 All Filtered Incidents, 1995-2000, Duration Histogram

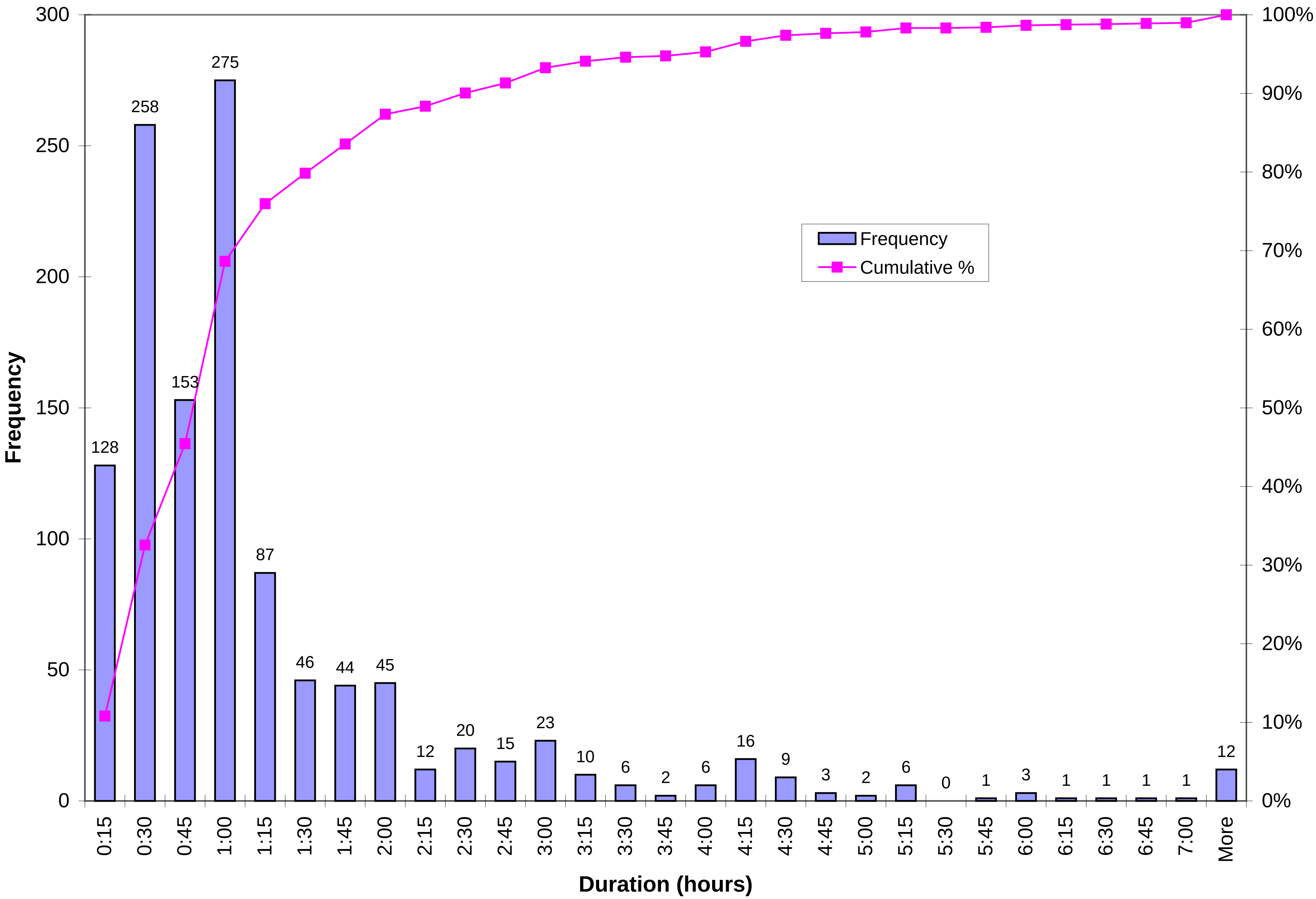


FIGURE 24: Interstate 5 All Filtered Incidents, 1995-2000, by Milepost

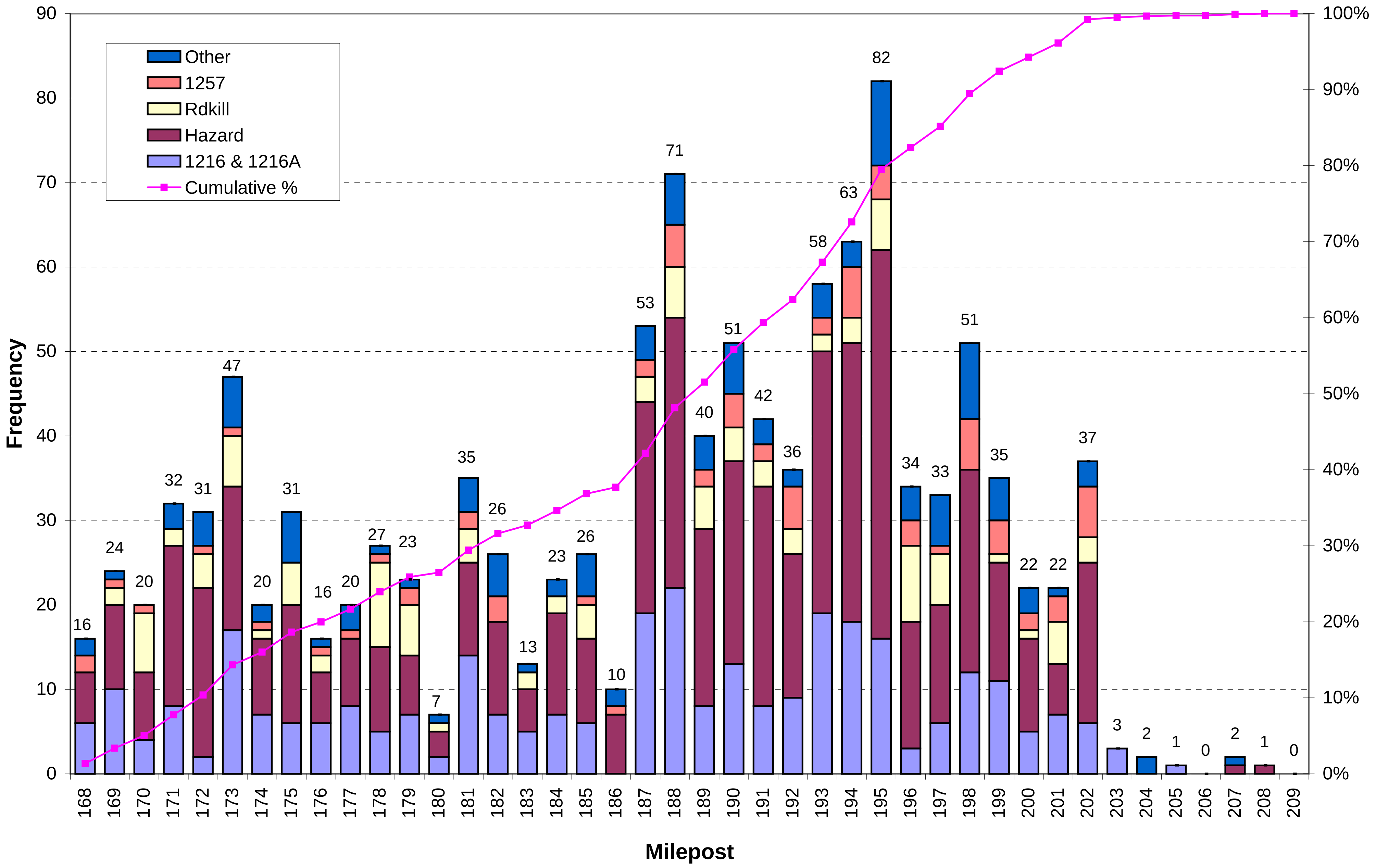
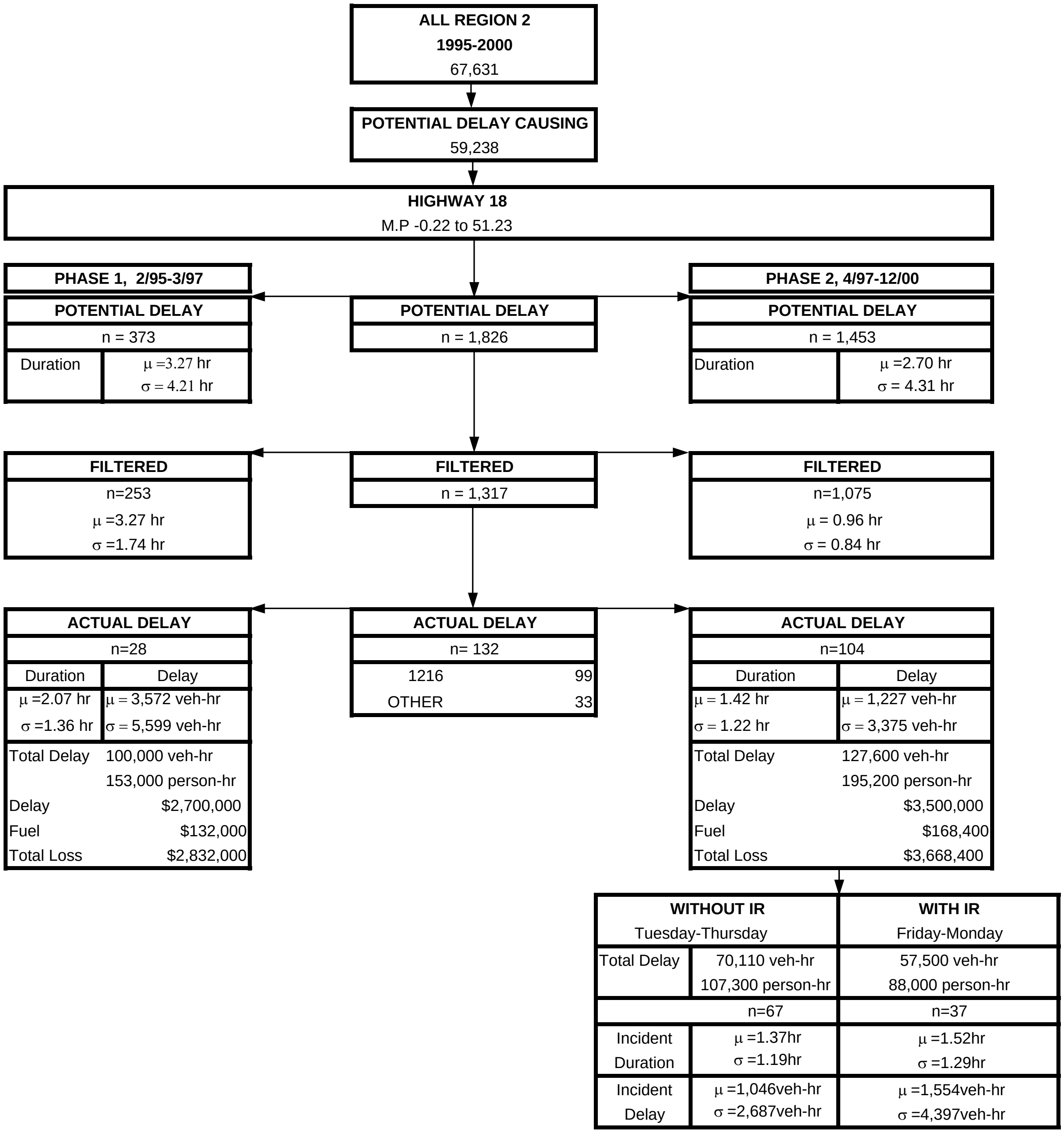
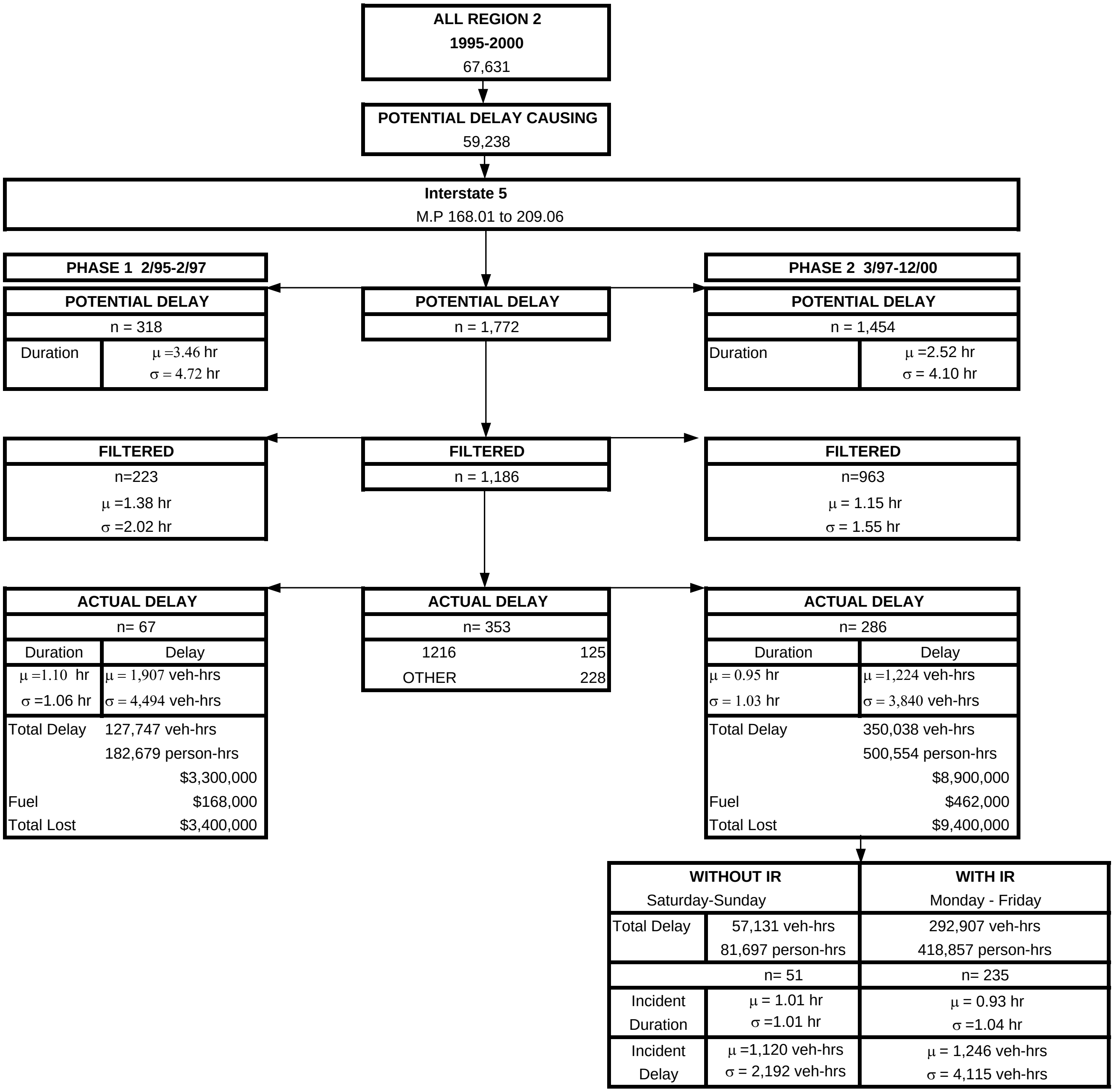


FIGURE 25: Highway 18 Results



Note: μ = mean (average)
σ = standard deviation

FIGURE 26: Interstate 5 Results



Note: μ = mean (average)
σ = standard deviation

FIGURE 27: Highway 18 Duration vs. Delay - Linear Scale

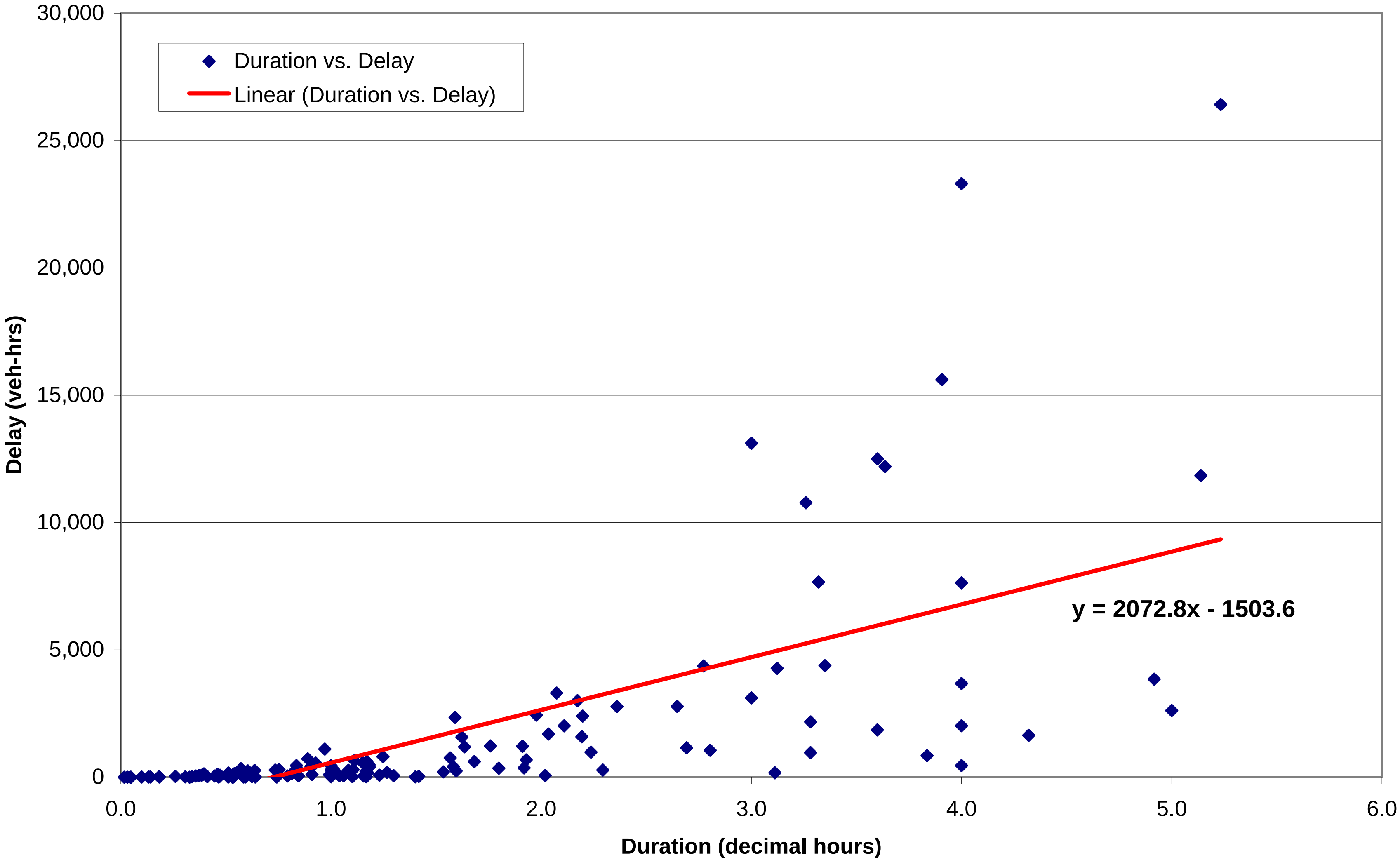


FIGURE 28: Highway 18 Duration vs. Delay - Logarithmic scale

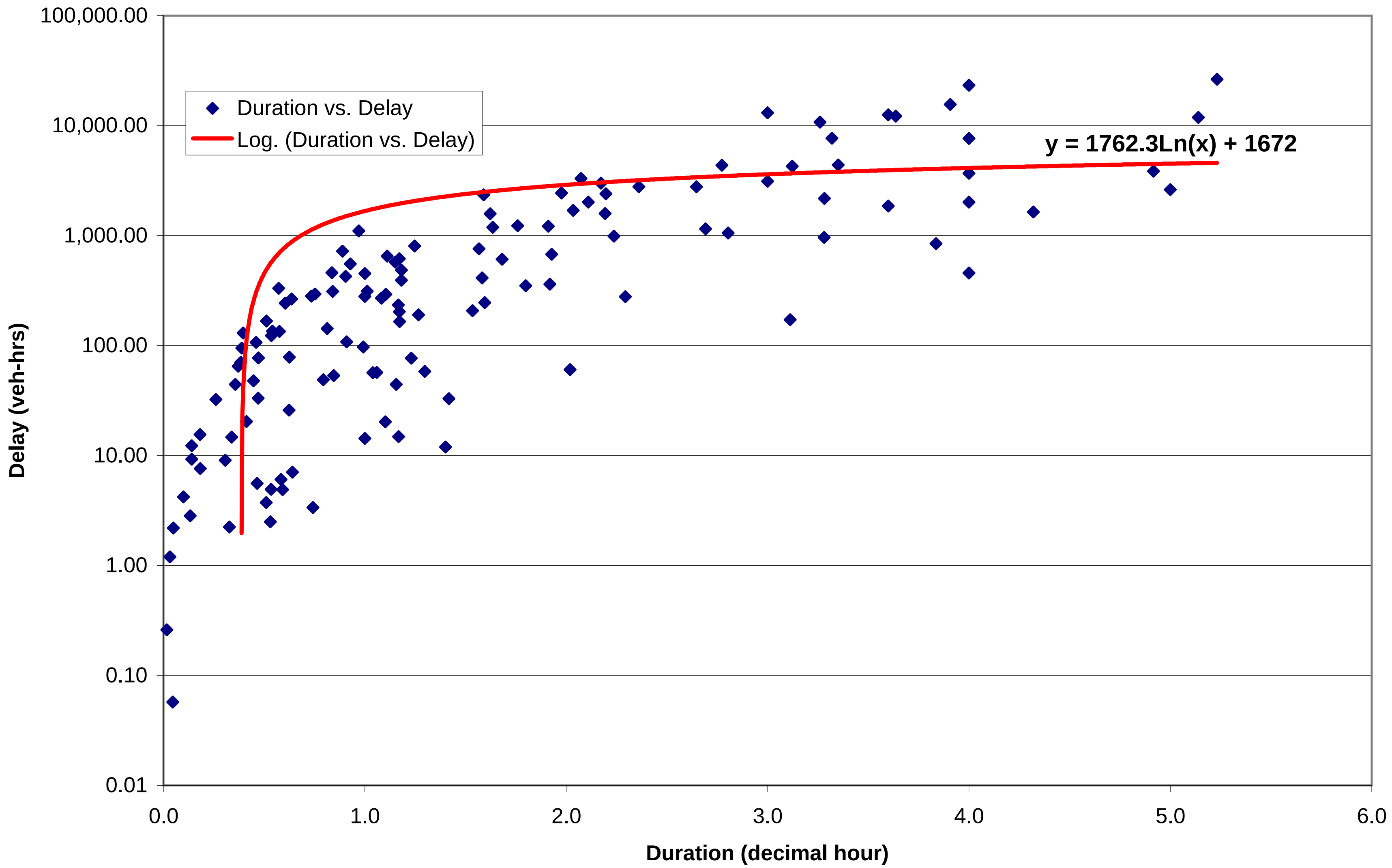


FIGURE 29: Interstate 5 Duration vs. Delay - Linear Scale

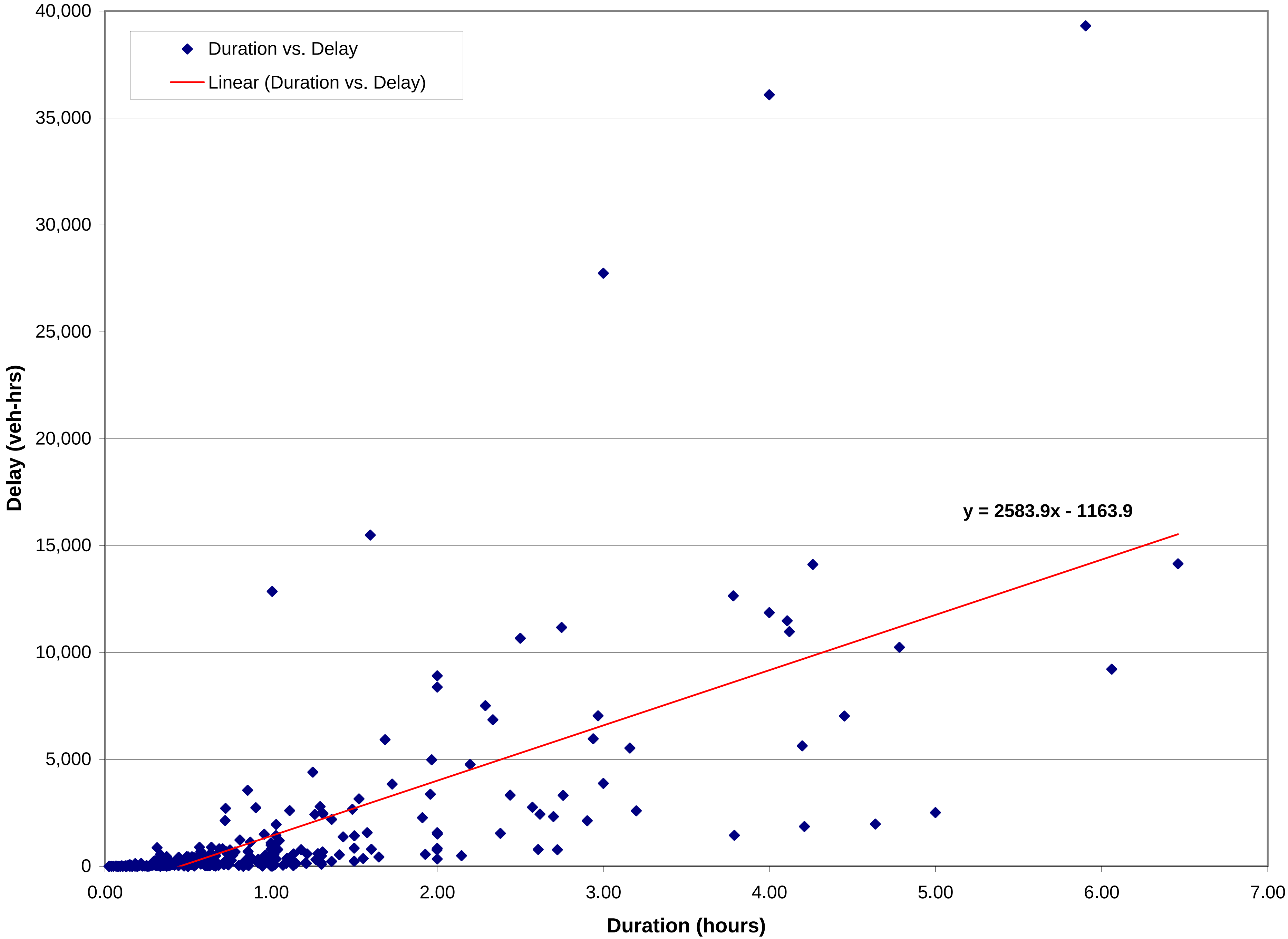


FIGURE 30: Interstate 5 Duration vs. Delay - Logarithmic Scale

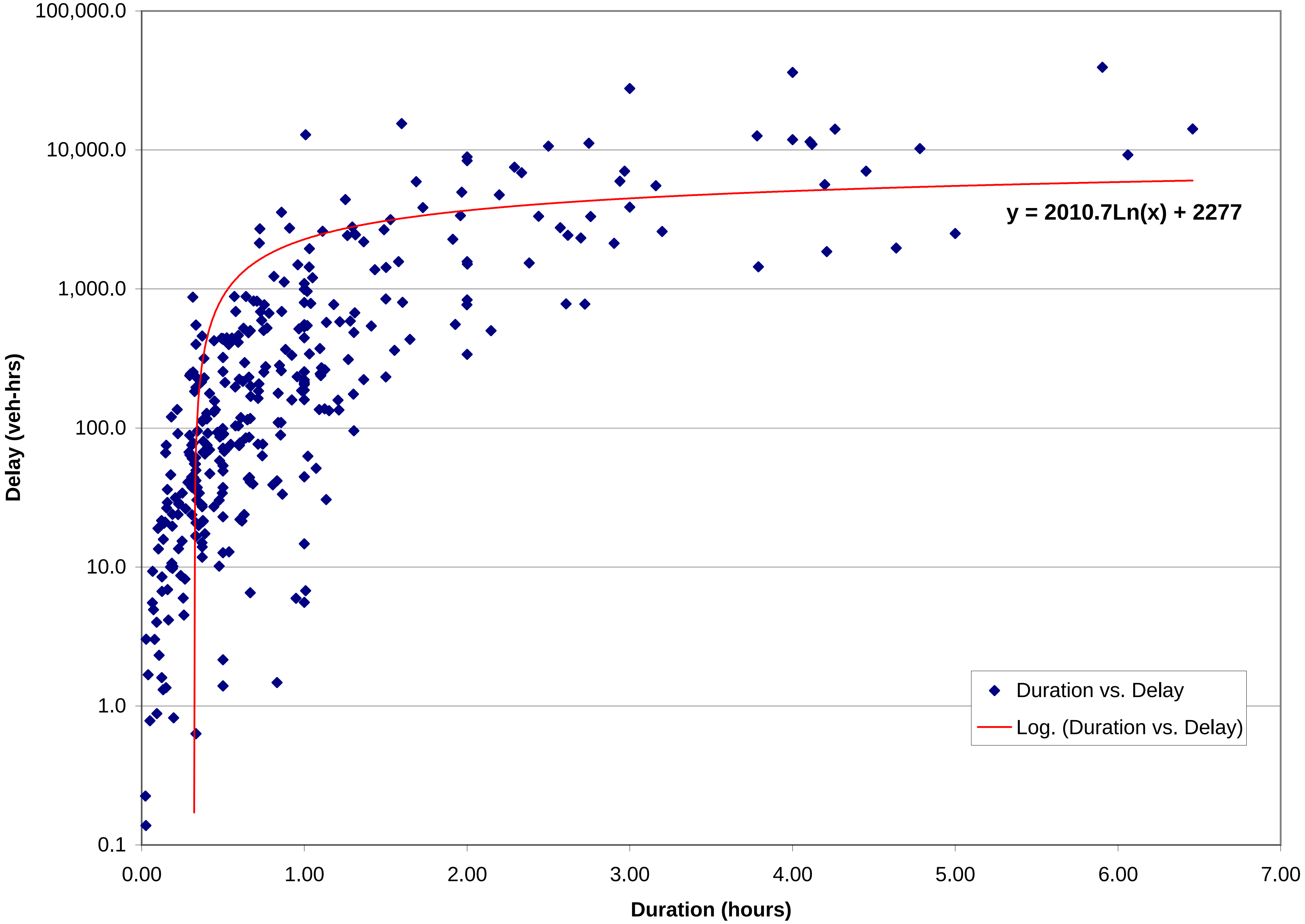


FIGURE 31: Highway 18 Phase 1 IR Deployed and Incident Duration Shorter - Total Savings

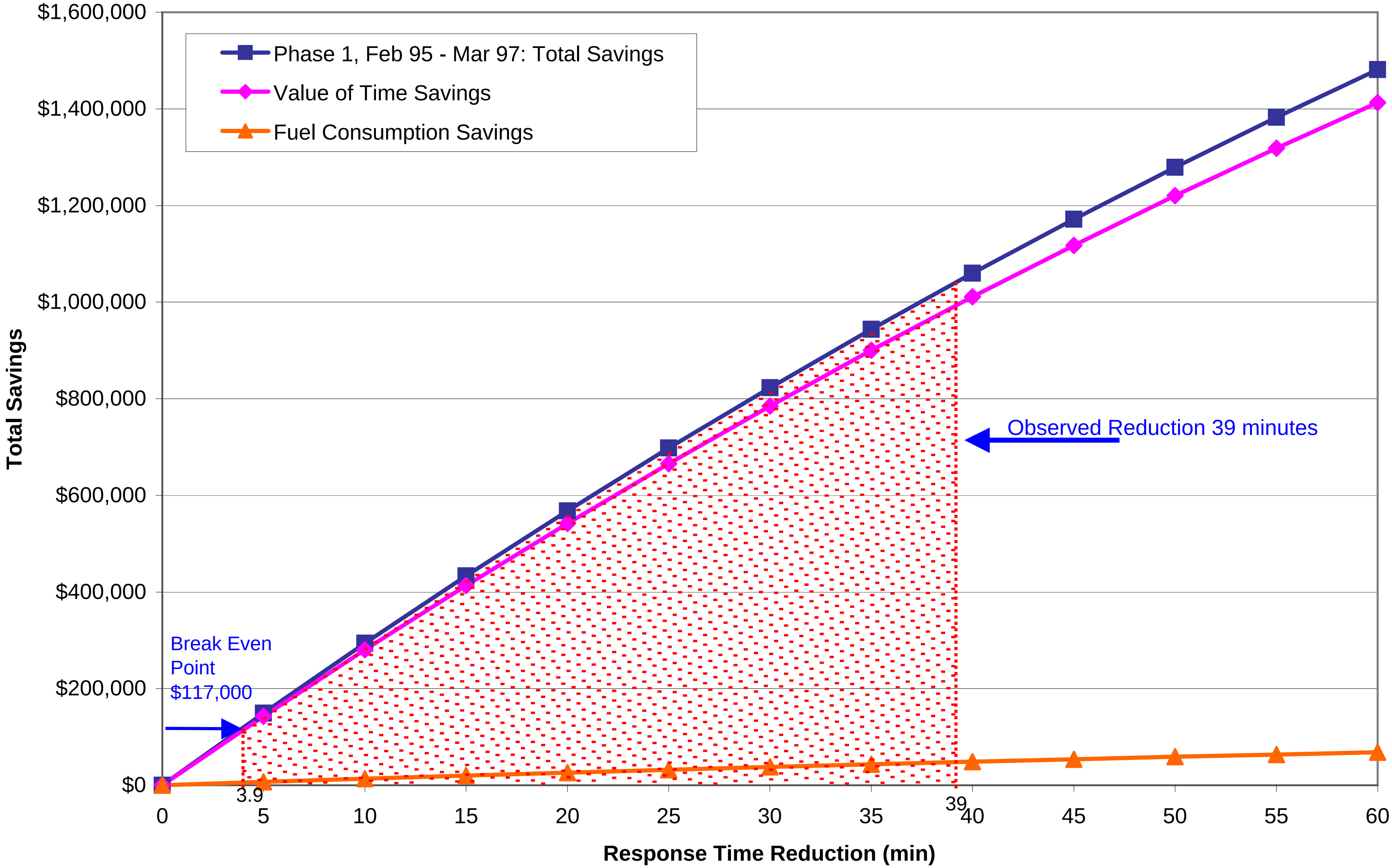


FIGURE 32: Highway 18 Phase 2 IR Not Deployed and Incident Duration Longer-TotalLoss

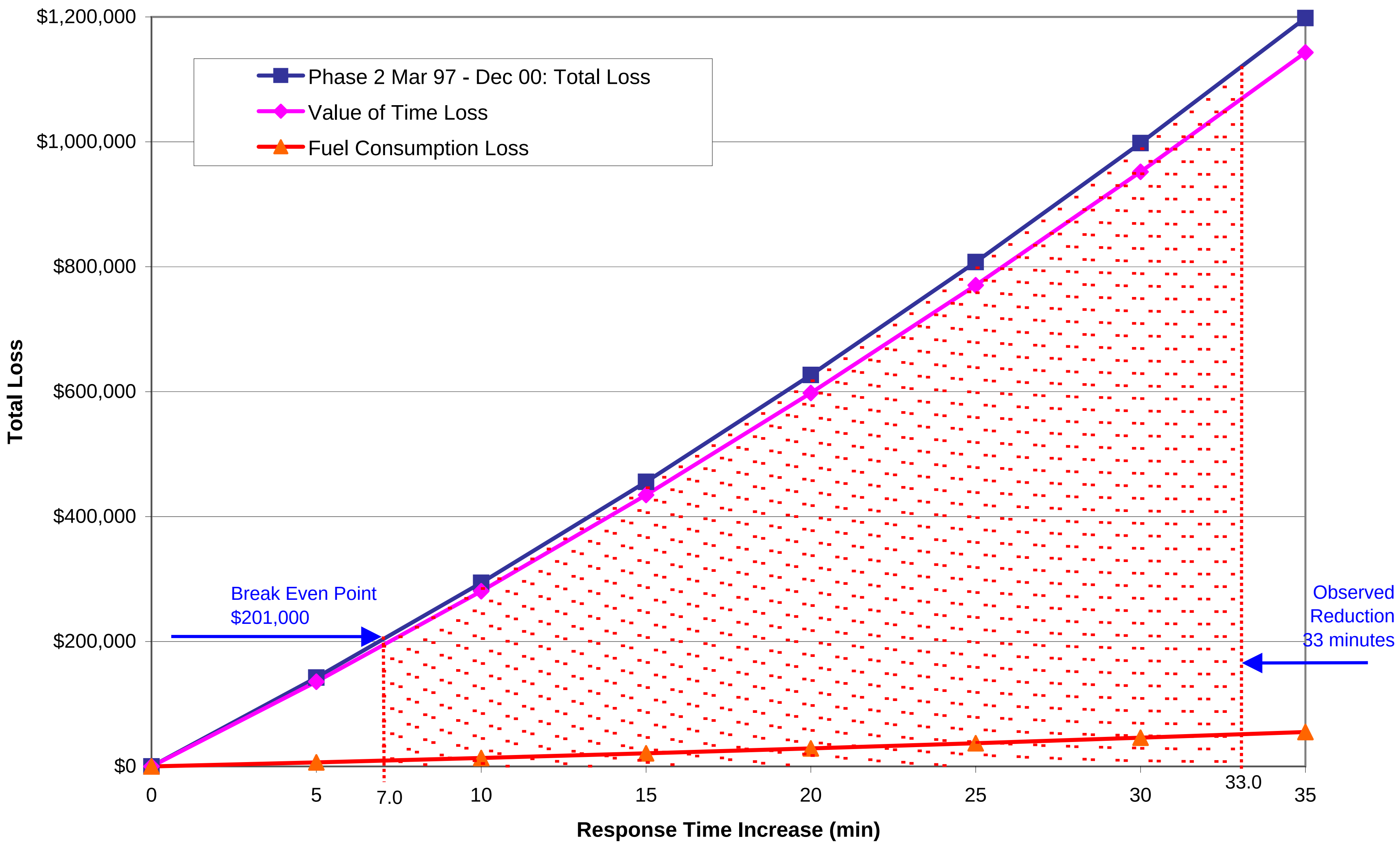


FIGURE 33: Highway 18 Phase 2 IR Deployed (Weekdays: Tue-Thu) and Incident Duration Shorter - Total Savings

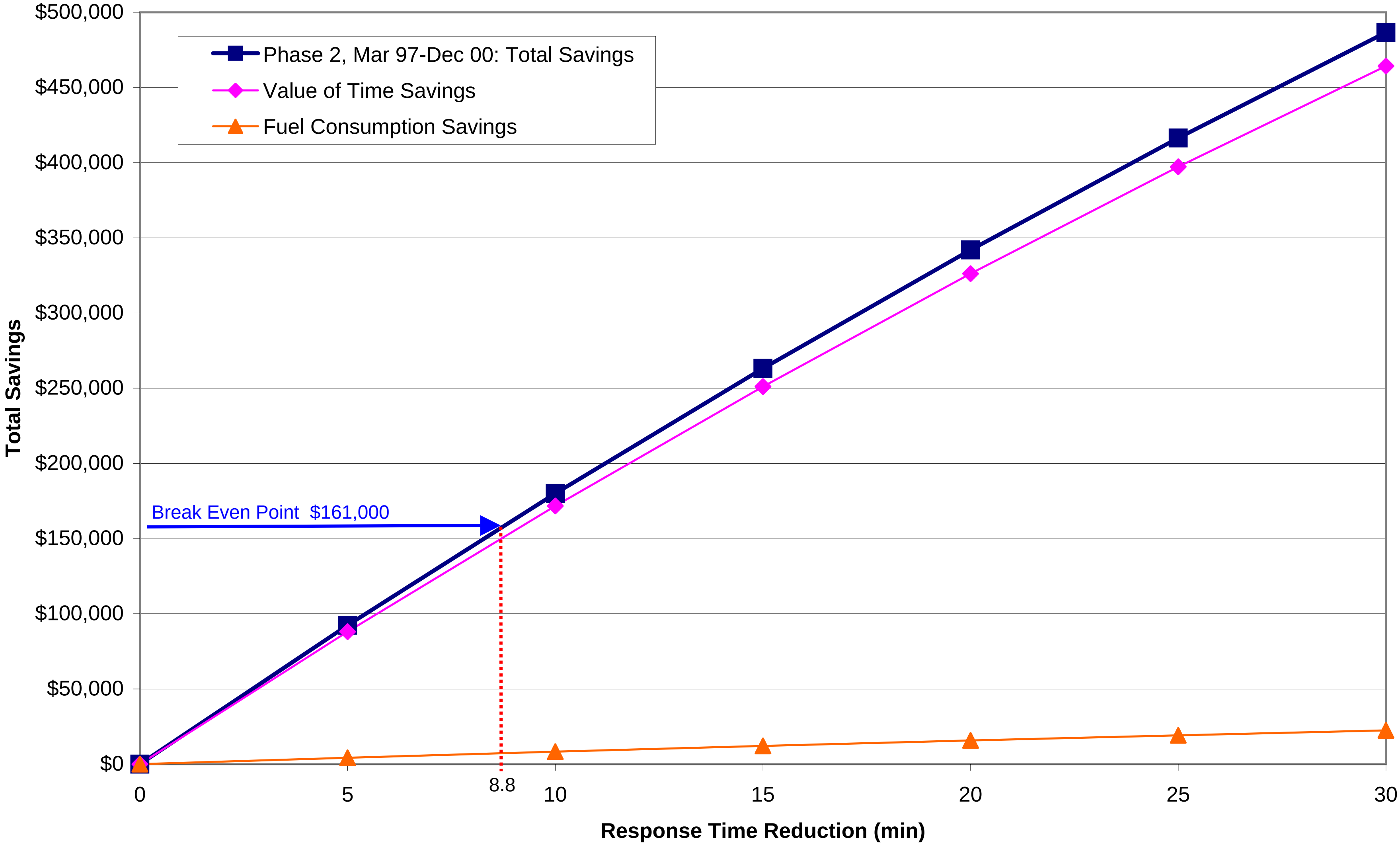


FIGURE 34: Interstate 5 Phase 1 IR Deployed (Weekdays) and Incident Duration Shorter - Total Savings

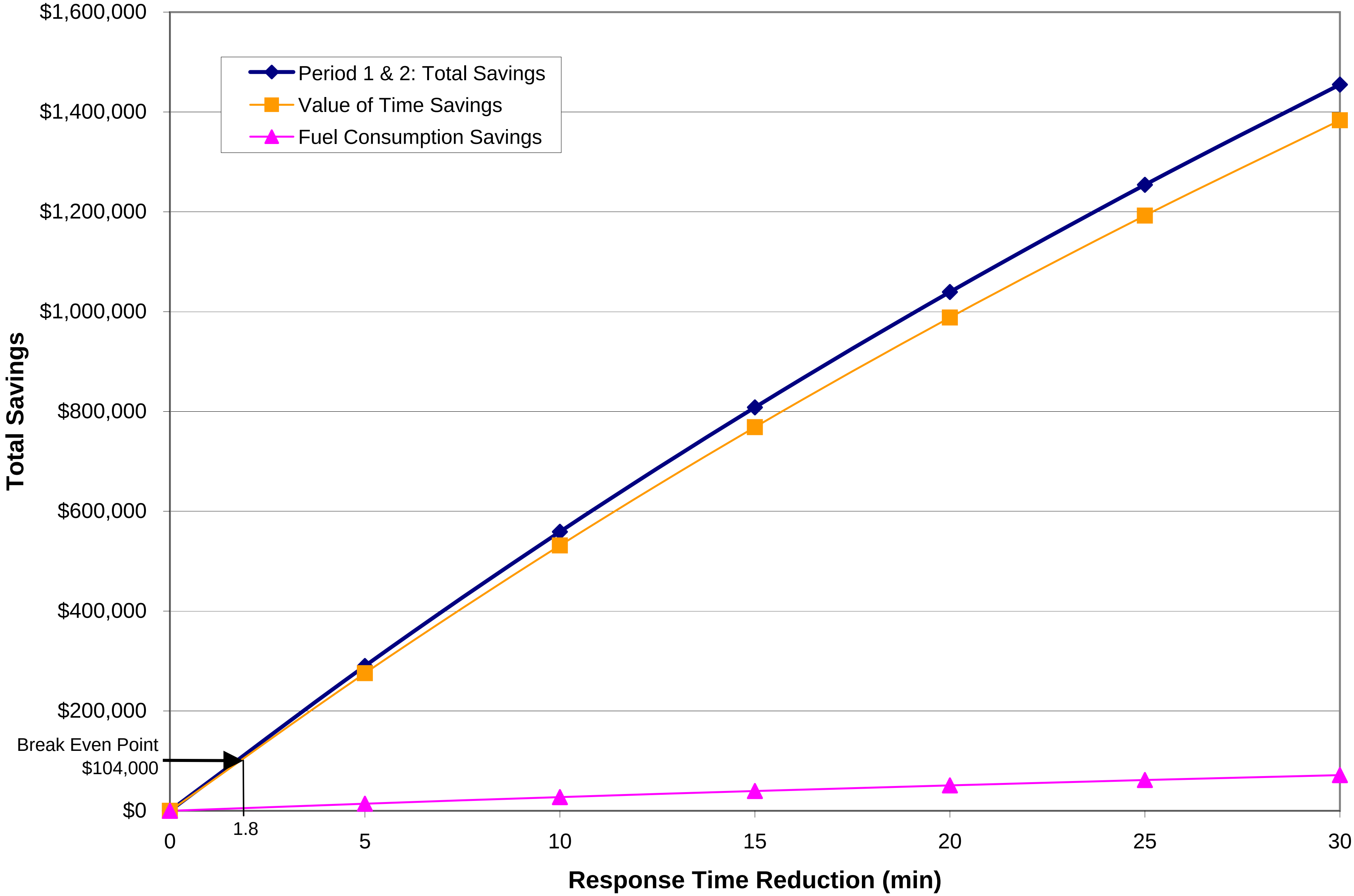


FIGURE 35: Interstate 5 Phase 2 IR Not Deployed (Weekdays) and Incident Duration Longer - Total Loss

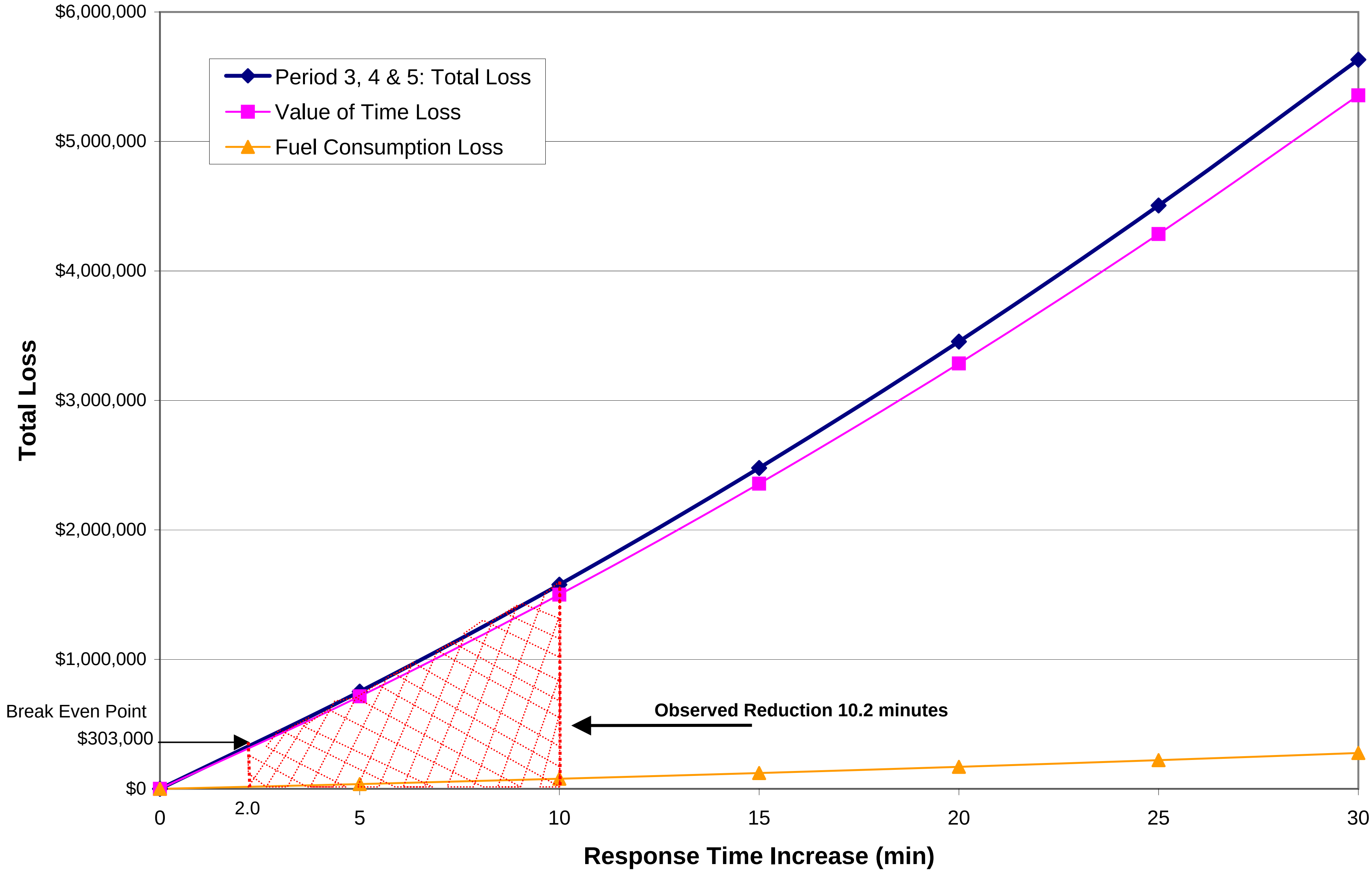


FIGURE 36: Interstate 5 Phase 2 IR Deployed (Weekends) and Incident Duration Shorter - Total Savings

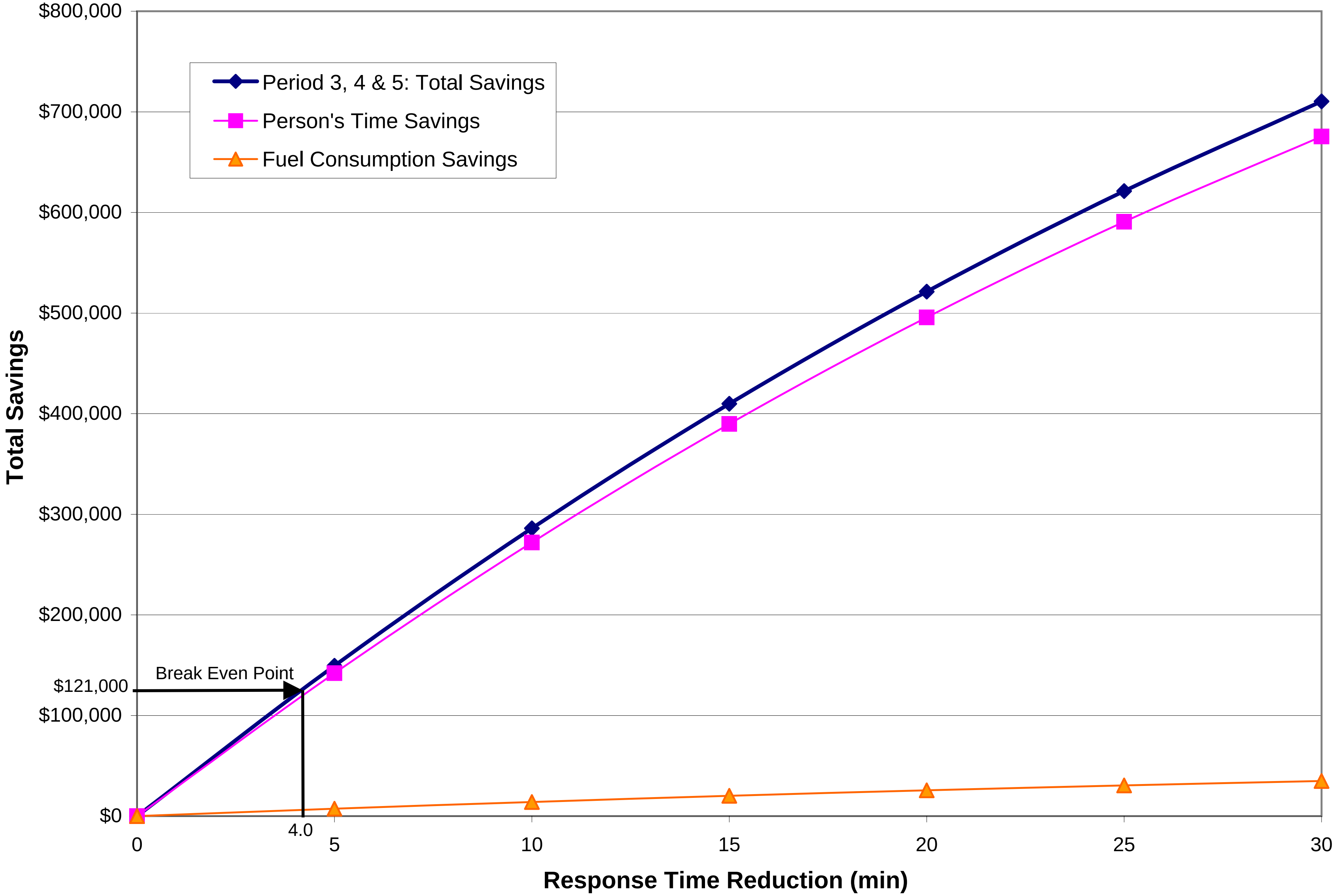


FIGURE 37: Interstate 5 Phase 2 IR Not Deployed (Weekdays) and Incident Duration Longer - Total Loss

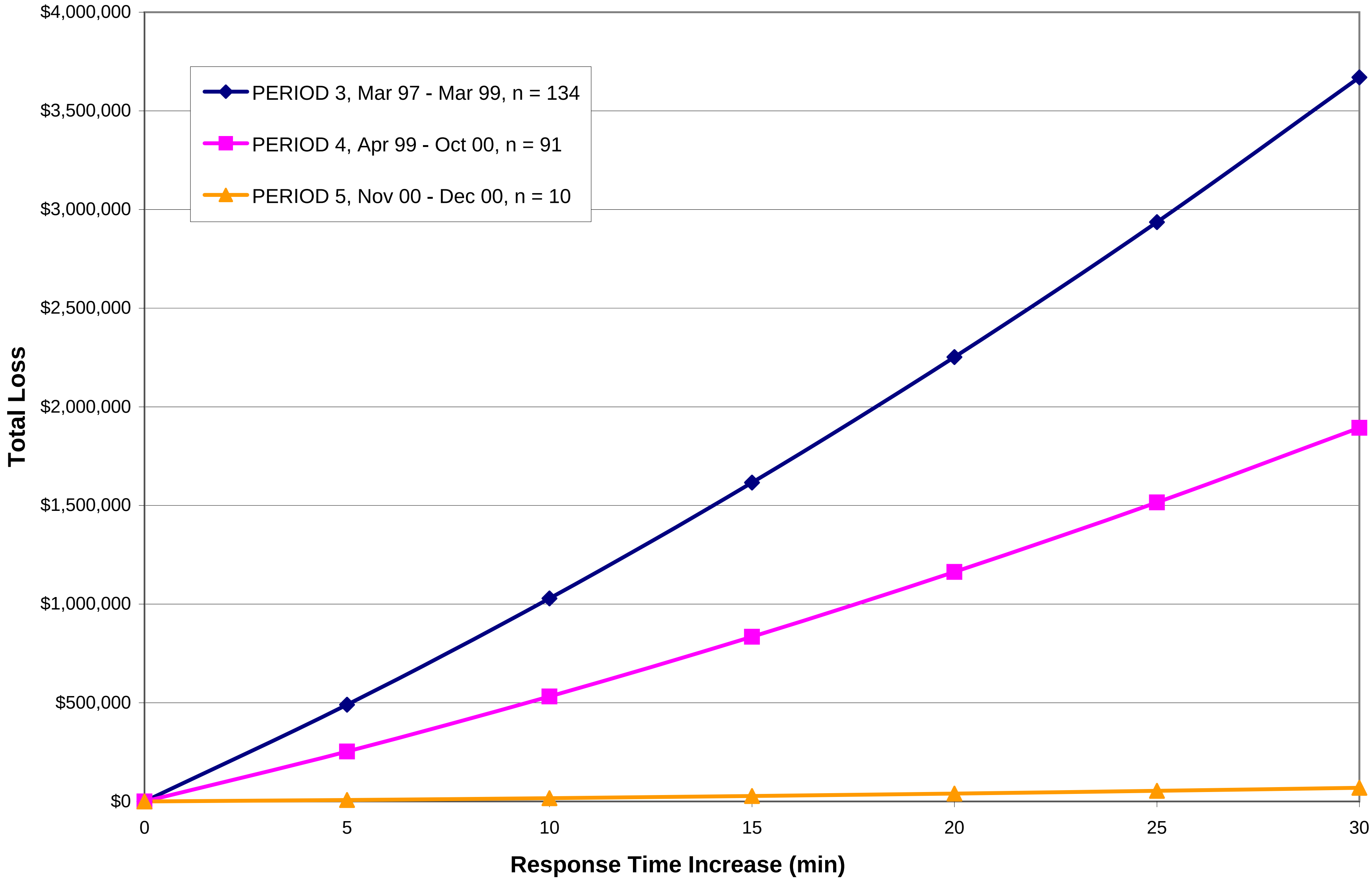


FIGURE 38: Interstate 5 Phase 2 IR Not Deployed and Incident Durations Longer - Average Monthly Loss

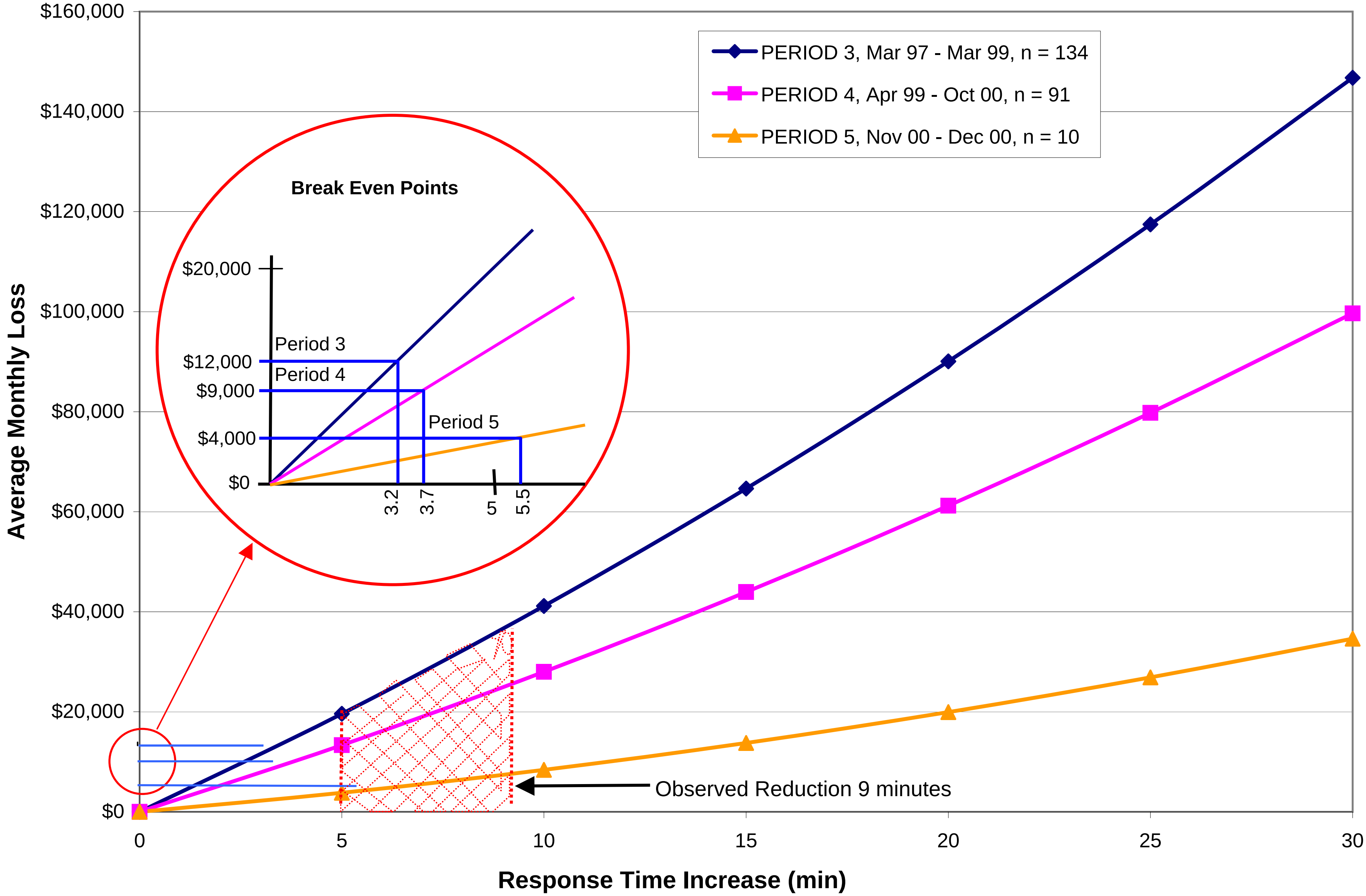


FIGURE 39: Highway 18 Cumulative Accident (1216) Frequency

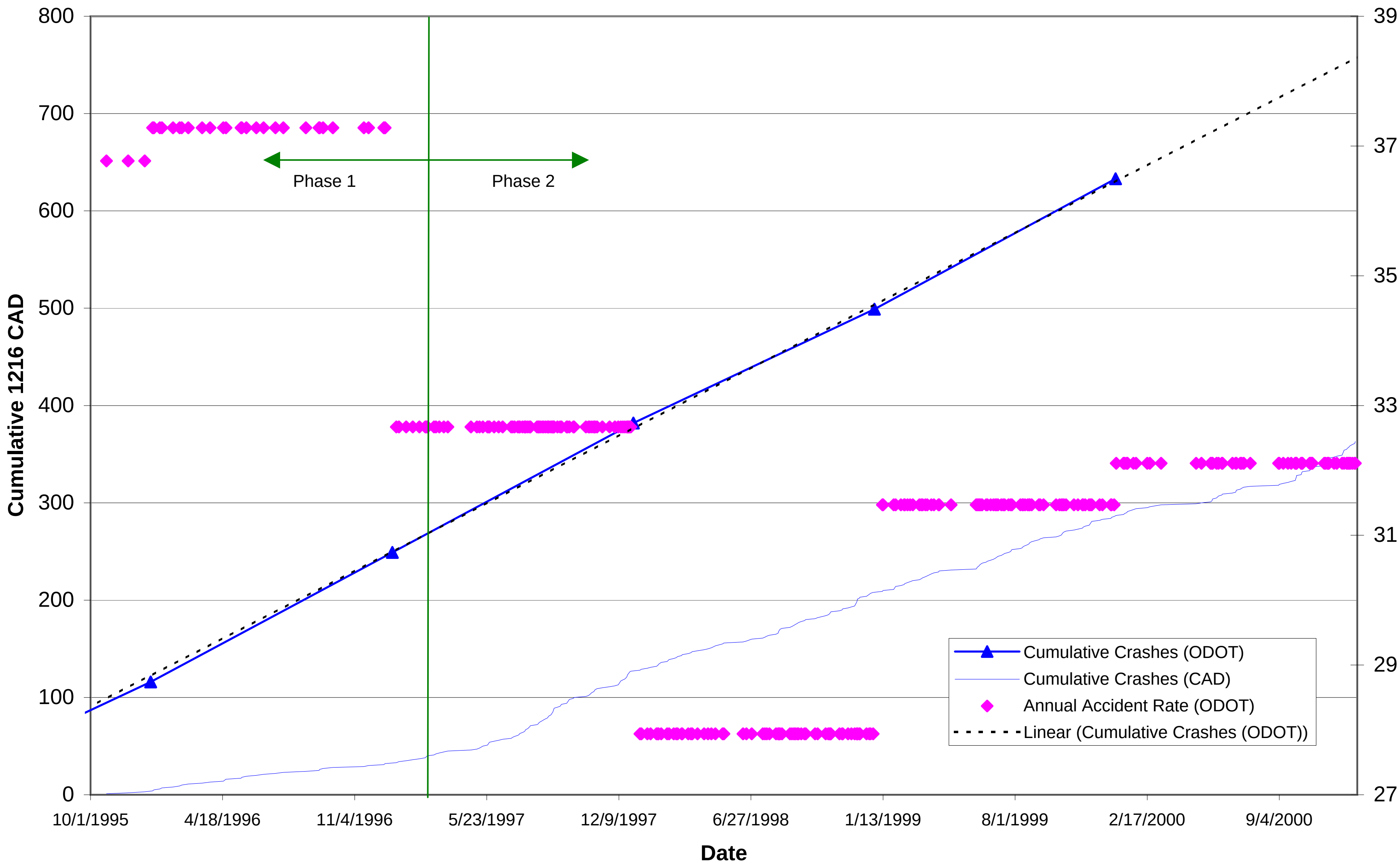


FIGURE 40 : Highway 18 Filtered Cumulative Accident (1216) Rate

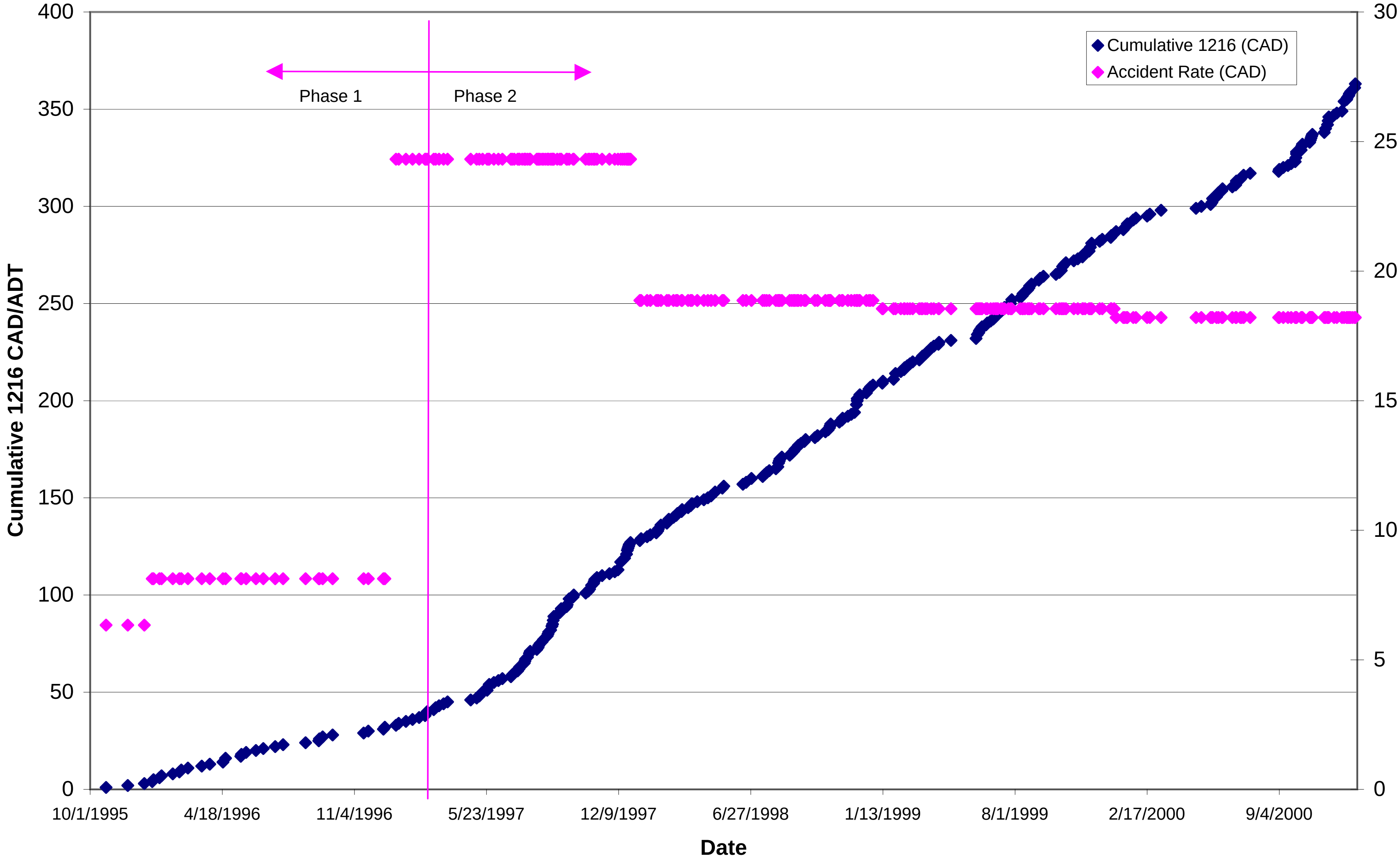


FIGURE 41: Highway 18 Filtered Durations

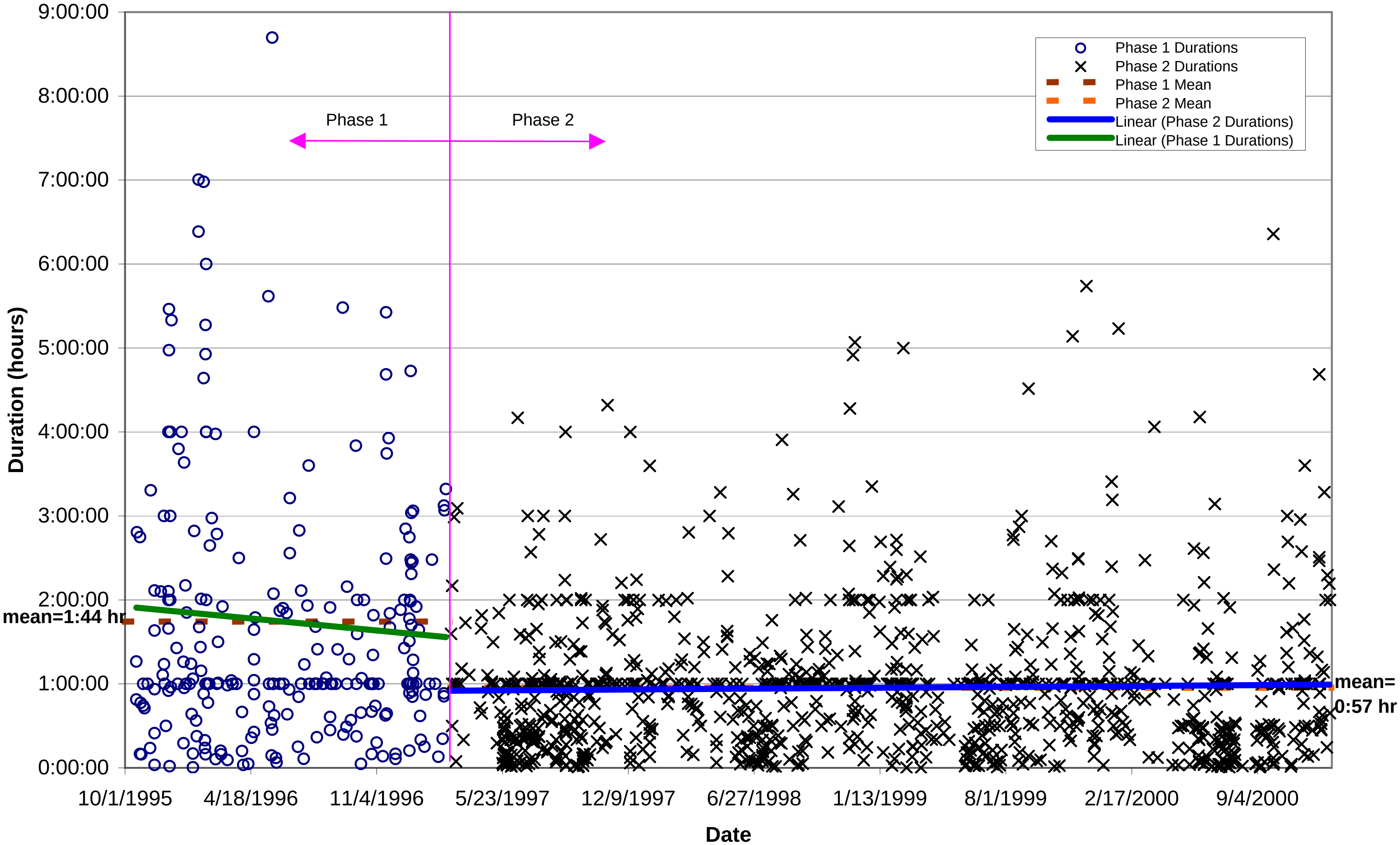


FIGURE 42: Highway 18 Cumulative Filtered Durations

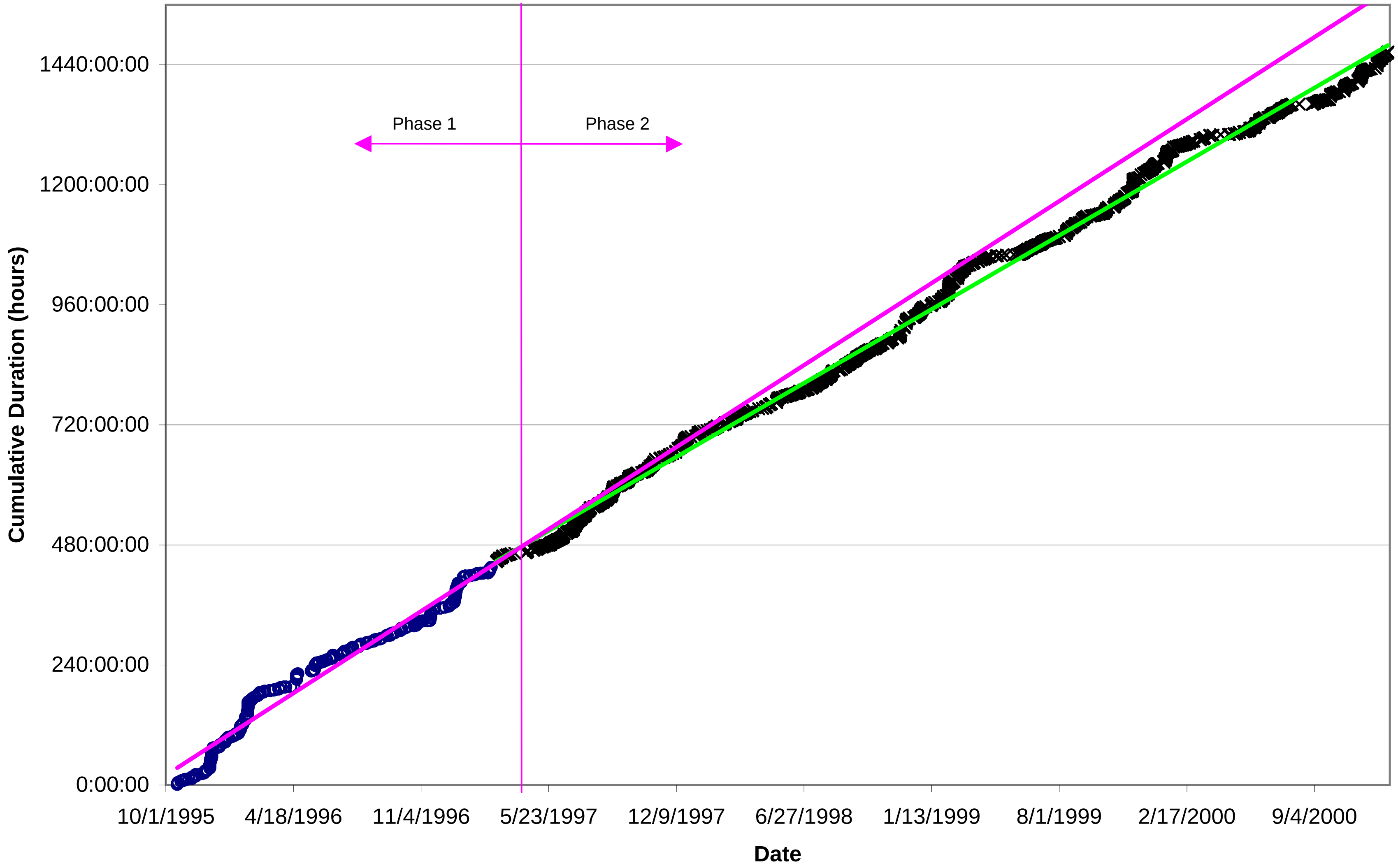


FIGURE 43: Interstate 5 Filtered Cumulative Accident (1216) Frequency

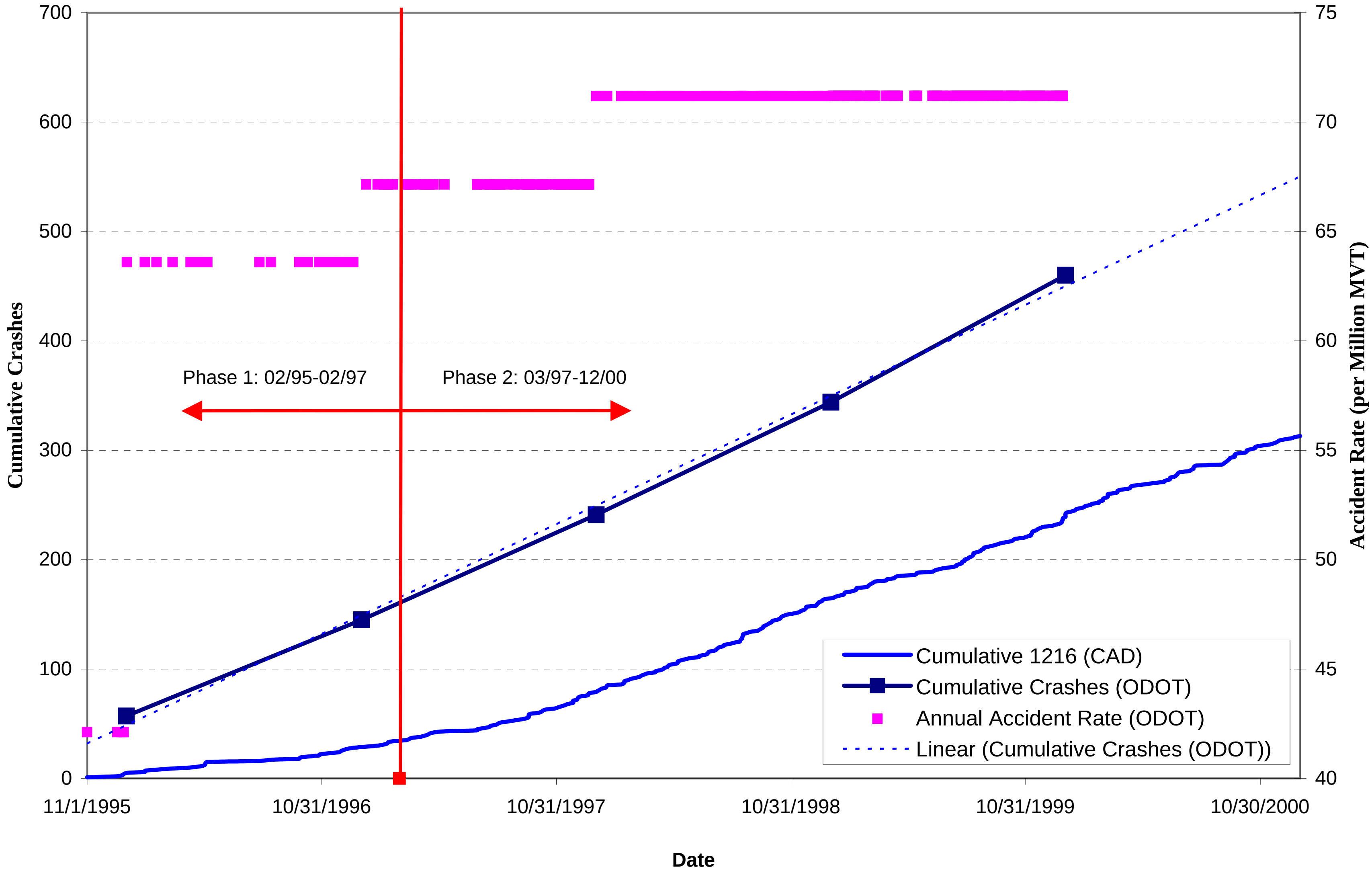


FIGURE 44: Interstate 5 Filtered Cummulative Accident (1216) Rate

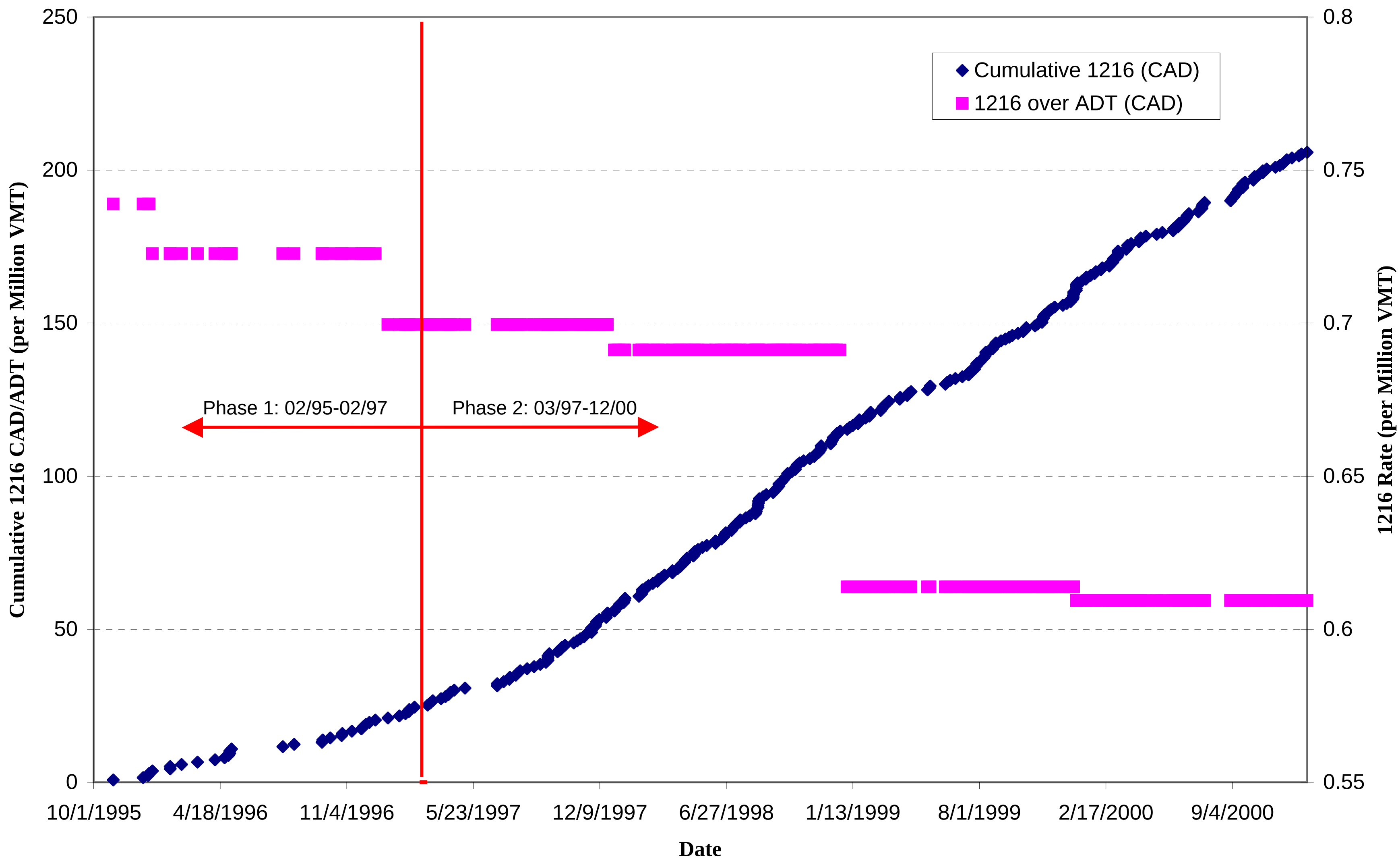


FIGURE 45: Interstate 5 Filtered Durations

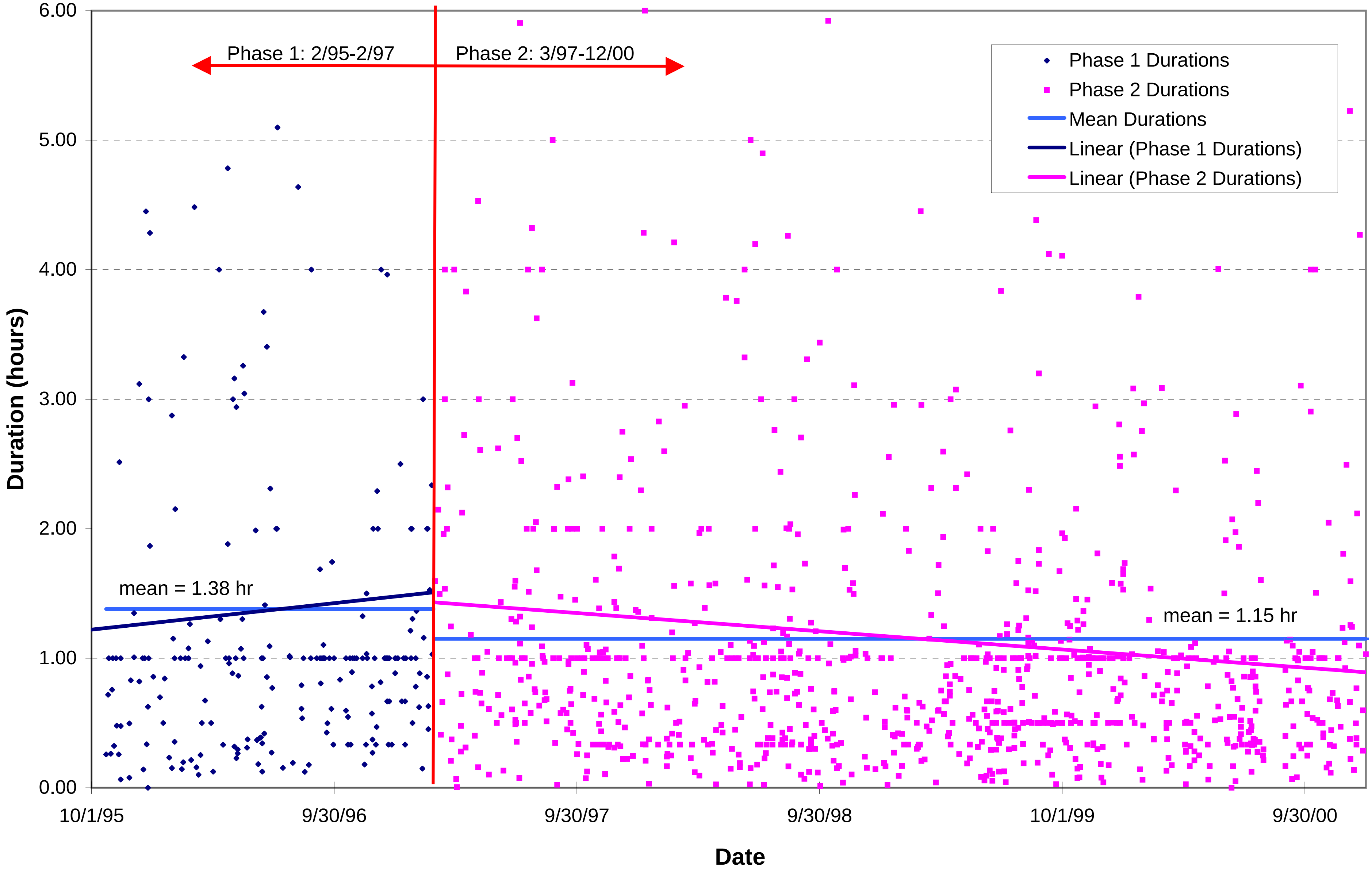


FIGURE 46: Delay-Duration Tool Analysis