

**THREE-CABLE
MEDIAN BARRIER
FINAL REPORT**

#OR-RD-99-03

by

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16. Abstract Oregon public interest peaked regarding crossover highway safety following three fatalities from a crossover accident in August of 1996. The Oregon Department of Transportation (ODOT) conducted a review of possible barrier solutions for the interstate highway median near Salem, Oregon. The weak-post three-cable median barrier system was selected. Unfortunately, there is not much information concerning the maintenance and repair costs of the cable barrier system. This study evaluates the effectiveness of the three-cable barrier in preventing crossover accidents on Interstate 5 (I-5), Oregon Highway Number 1, and evaluates the maintenance and repair costs in order to make recommendations for future installations. Based on the results of the study, the cable median barrier system proved to be cost-effective when compared to the concrete median barrier system and the system performed well, decreasing crossover accidents in the area. The cable median barrier system works well in medians with a minimum of 7 m width, where it is used to prevent the infrequent potentially catastrophic cross-median accidents.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<u>LENGTH</u>				
in	Inches	25.4	Millimeters	Mm
ft	Feet	0.305	Meters	M
yd	Yards	0.914	Meters	M
mi	Miles	1.61	Kilometers	Km
<u>AREA</u>				
in ²	square inches	645.2	Millimeters squared	mm ²
ft ²	square feet	0.093	meters squared	m ²
yd ²	square yards	0.836	meters squared	m ²
ac	Acres	0.405	Hectares	Ha
mi ²	square miles	2.59	kilometers squared	km ²
<u>VOLUME</u>				
fl oz	fluid ounces	29.57	Milliliters	ML
gal	Gallons	3.785	Liters	L
ft ³	cubic feet	0.028	meters cubed	m ³
yd ³	cubic yards	0.765	meters cubed	m ³

NOTE: Volumes greater than 1000 L shall be shown in m³.

MASS

oz	Ounces	28.35	Grams	G
lb	Pounds	0.454	Kilograms	Kg
T	short tons (2000 lb)	0.907	Megagrams	Mg

TEMPERATURE (exact)

°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C
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APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<u>LENGTH</u>				
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
M	meters	1.09	yards	yd
Km	kilometers	0.621	miles	mi
<u>AREA</u>				
Mm ²	millimeters squared	0.0016	square inches	in ²
M ²	meters squared	10.764	square feet	ft ²
Ha	hectares	2.47	acres	ac
Km ²	kilometers squared	0.386	square miles	mi ²
<u>VOLUME</u>				
ML	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
M ³	meters cubed	35.315	cubic feet	ft ³
M ³	meters cubed	1.308	cubic yards	yd ³
<u>MASS</u>				
G	grams	0.035	ounces	oz
Kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T

TEMPERATURE (exact)

°C	Celsius temperature	1.8 + 32	Fahrenheit	°F
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* SI is the symbol for the International System of Measurement

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THREE-CABLE MEDIAN BARRIER FINAL REPORT

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1.0 INTRODUCTION

Oregon public interest peaked regarding crossover highway safety between Salem and Portland on Interstate 5 (I-5), Oregon Highway Number 1, following three fatalities from a crossover accident in August of 1996. The two sections targeted for crossover reduction were from milepoint (MP) 265.25 to MP 268.81 and MP 273.21 to MP 278.67, for a total of 14.5 km. The Oregon Department of Transportation (ODOT) conducted a review of possible barrier solutions for the two sections and identified cable guardrail as an option.

The American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide advocates the use of cable guardrail “on irregular terrain and on wider medians where the need is only to prevent infrequent potentially catastrophic cross-median accidents” (AASHTO, 1996). The three-cable median barrier system (Figure 1.1) was selected for the targeted sections, which met the design standards of the barrier system, preserving the existing glare-guard median roses.



Figure 1.1: Three-cable median barrier system with spring turnbuckle

Although the two targeted sections had relatively low historical accident rates, the accidents that did occur were devastating. From 1987 through 1996, there were six fatalities and 14 injuries from median accidents. The intent of the cable barrier system median application is to reduce the incidence of serious injuries and fatalities.

In December of 1996, ODOT installed the two cable barrier test sections in the median of I-5. Unfortunately, there is not much information concerning the maintenance and repair costs of the cable barrier system. This study evaluates the effectiveness of the three-cable barrier system in preventing crossover accidents on I-5, and evaluates the maintenance and repair costs in order to make recommendations for future installations.

2.0 DESIGN & CONSTRUCTION

2.1 OREGON MEDIAN BARRIER OPTIONS

Three different types of median barrier systems can be used in the state of Oregon: concrete barriers (both the single slope and 'F' shaped types), W-beam barriers with rubrail, and cable barriers. Each type has particular design standards that dictate the use and placement. The median barrier systems are designed for a majority of the vehicle fleet, which primarily consists of passenger, pick-up and sport-utility vehicles.

2.2 THE WEAK-POST THREE-CABLE GUARDRAIL AND MEDIAN BARRIER

2.2.1 Usage

Weak-post cable guardrails have been used in many northern states for over 40 years since they allow plowed snow to pass through the cable system instead of building up in front. Weak-post cable guardrails and median barriers are intended to be used in locations where there is enough room for lateral deflection (Ray, 1997). Cable guardrails may have a deflection of up to 3.5 m. Therefore, the width of the median needs to be at least 7 m for a cable barrier system centered in the median. Cable guardrail and median barrier systems should not be used on sharp curves or where curbs exist.

2.2.2 Characteristics

The three-cable guardrail is a flexible barrier system that can be used as a roadside or median barrier. The weak-post guardrail system gradually redirects an impacting vehicle by elastically stretching the cables, minimizing forces on the vehicle occupants. During an impact, the kinetic energy of the vehicle is dissipated by breaking and bending the posts and stretching the cables (Ray, 1997).

The cable system is less expensive than other median barrier options, but it must be repaired after an impact to remain effective. Therefore, the use of the cable system in areas where it is likely to be hit frequently is not recommended (AASHTO, 1996). For repair considerations, if a post is impacted, a relatively long section will need repair.

Three-cable shoulder barriers passed the National Cooperative Highway Research Program (NCHRP) 350 crash test requirements, which included testing with a full-size pick-up truck.

2.2.3 System Installation Costs

The installation costs for concrete and cable systems are listed in Table 2.1. The actual installation costs for the cable system are 70% less than the concrete system. In addition, the concrete alternative required extensive grading for the foundation which would have eliminated the glare-guard median roses.

Table 2.1: Installation Costs

Median Barrier Type	Installation Cost (\$/km)
Cable (bid)	\$39,370
Cable (actual)	27,366
Concrete, including base (bid)	93,504

2.2.4 Design Details

The cable barrier system used consists of three steel 19 mm diameter cables with steel supporting posts a maximum of 5 m apart. For the post spacing requirements see Table 2.2.

Table 2.2: Post Spacing Requirements

Curve Radius (m)	Post Spacing (m)
210 m or more	5.0 m
209 to 66	3.5
65 to 33	1.8
Less than 33	Use not recommended

The bottom cable height is 540 mm; the top cable height is 840 mm (Figure 2.1). The foundation detail is in Figure 2.2. Anchor post brackets and breakaway anchor angles secure the ends of the cable run (Figure 2.3). The cable tension is controlled by the spring turnbuckles located near the ends of the cable run. The maximum distance between anchors is 600 m. Figures 2.4 to 2.6 are photographs of the installed anchor post system.

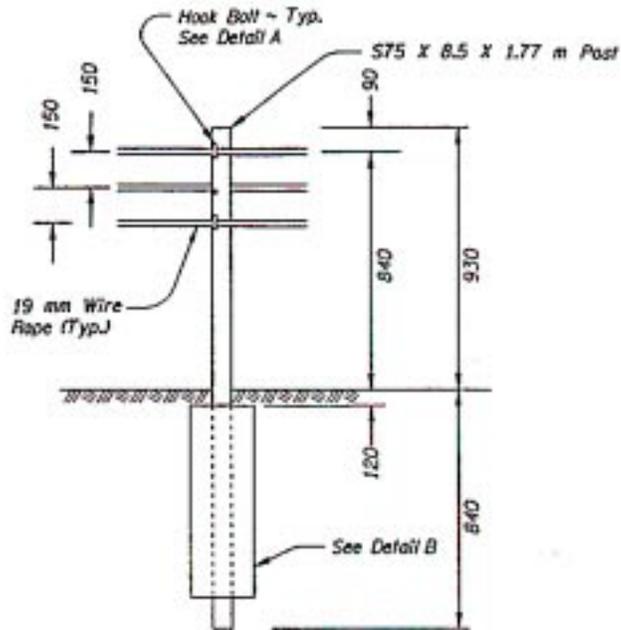


Figure 2.1: Post & cable assembly

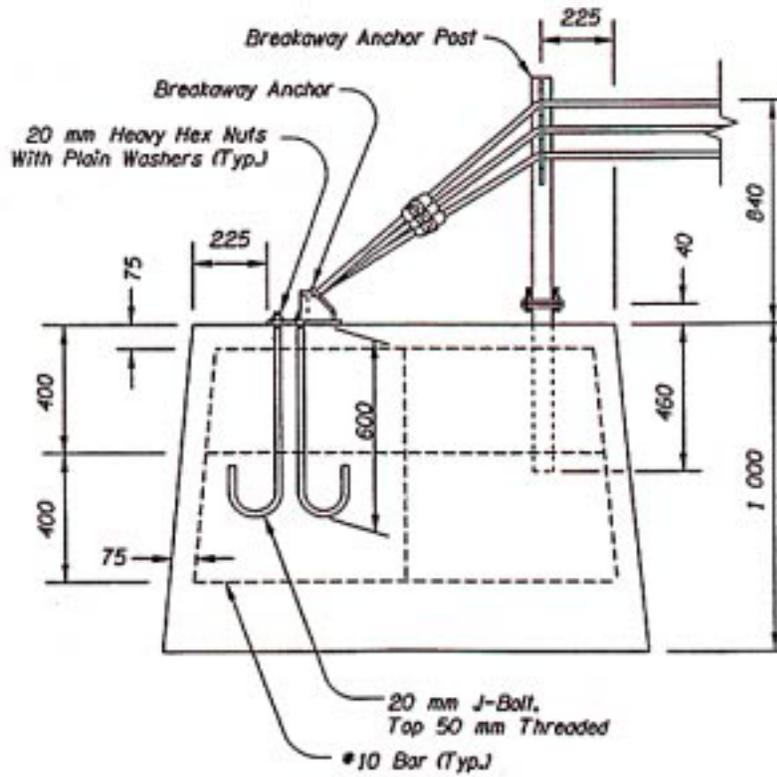


Figure 2.2: Footing elevation

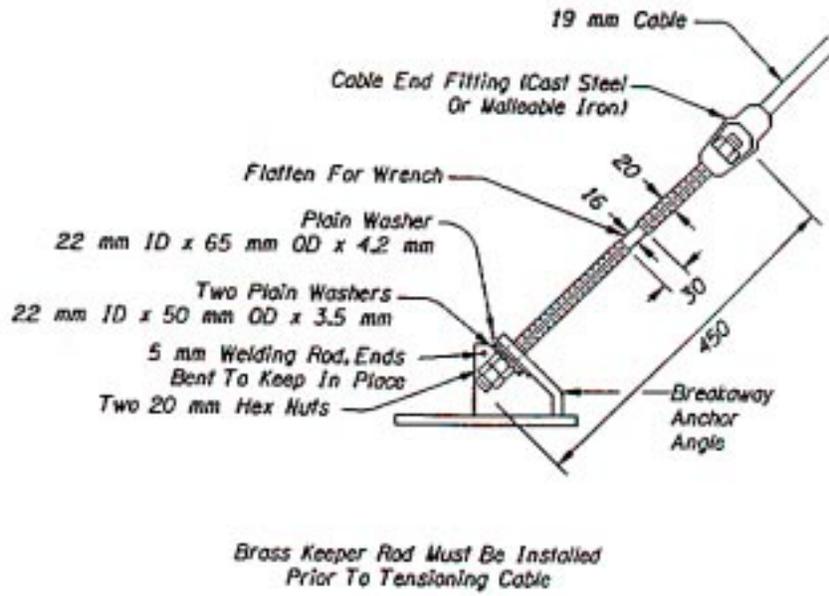


Figure 2.3: Cable end assembly to breakaway anchor angle



Figure 2.4: Anchor post bracket with 3mm tabs



Figure 2.5: Anchor post slip base and concrete footing



Figure 2.6: Breakaway anchor angle

2.2.5 Advantages and Disadvantages of the Cable Guardrail

From NCHRP Synthesis 244, *Guardrail and Median Barrier Crashworthiness* (Ray, 1997):

2.2.5.1 Advantages

- Cost of installation is inexpensive compared with other barrier systems;
- Forces on the occupants of the vehicles during a crash are low compared with other types of barriers;
- Cable barriers have good crash test performance (up to a 2000 kg pick-up);
- System is aesthetically appealing; and
- Sight distance problems are minimized.

2.2.5.2 Disadvantages

- Barrier damage is increased in a typical accident, when compared to other systems;
- Damaged installations need to be repaired or replaced quickly since the damaged run may be ineffective until repaired;
- A minimum clear space is required behind the barrier for cable deflection; and
- Periodic retensioning of the cables is required.

2.3 SITE CONDITIONS

The test sections are located between Salem and Aurora on I-5. The average median width is 15.2 m. The posted speed limit is 65 mph. The average daily traffic (ADT) for 1997 varies from 71,900 to 74,700 vehicles per day (VPD). The vehicle classification breakdown, based on a permanent automatic traffic recorder (ATR) station near Wilsonville, is in Table 2.3. 83% of the vehicle fleet is passenger cars and two-axle, four-tire vehicles, such as the popular sport-utility vehicles. The three-cable barrier system is designed to stop this majority of the vehicle fleet. The cable barrier system is not designed to stop the remainder of the vehicle fleet, comprised mostly of multiple axle trailer trucks. None of the available standard barrier systems are designed to stop these larger vehicles, as it is not cost effective.

Table 2.3: Vehicle Classification Breakdown (ATR 03-011)

Vehicle Classification	Percent of ADT
Passenger cars	48.85
Other 2 axle 4 tire vehicles	34.16
Single Unit 2 axle 6 tire	2.86
Single Unit 3 axle	0.71
Single Unit 4 axle or more	0.01
Single Trailer Truck 4 axle or less	0.94
Single Trailer Truck 5 axle	8.57
Single Trailer Truck 6 axle or more	1.64
Double-Trailer Truck 5 axle or less	0.23
Double-Trailer Truck 6 axle	0.33
Double-Trailer Truck 7 axle or more	1.21
Triple Trailer Trucks	0.18
Buses	0.21
Motorcycles and Scooters	0.10

3.0 CABLE MEDIAN BARRIER IMPACTS

3.1 HISTORICAL ACCIDENT SUMMARIES

From 1987 through 1996, there were six fatalities, seven injury accidents, and ten total accidents in the subject section of I-5 involving median section crossovers. This correlates to an average of 0.6 fatalities per year, 0.7 injury accidents per year and 1.0 accidents per year over the ten-year period. There were 14 individual injuries in the seven injury accidents, which were classified as five major injuries, seven moderate injuries and two minor injuries. The data was gathered from the ODOT accident data summaries by year database.

3.2 IMPACTS

The cable median barrier has been hit 53 times from December 1996 through March 1998, or about once every nine days, based on the repair records. The frequency and location of the impacts are shown in Figure 3.1. No cable barrier was installed between MP 268.81 and 273.21. The accident rate for the cable barrier, 40 per year, is much higher than the historical accident rate of 1.0 per year. The most likely explanation for the increase in accidents is vehicles that drove into the median prior to the barrier installation, and reentered the roadway without incident, are now impacting the cable system. So, the total number of vehicles entering the median was not captured in previous accident history.

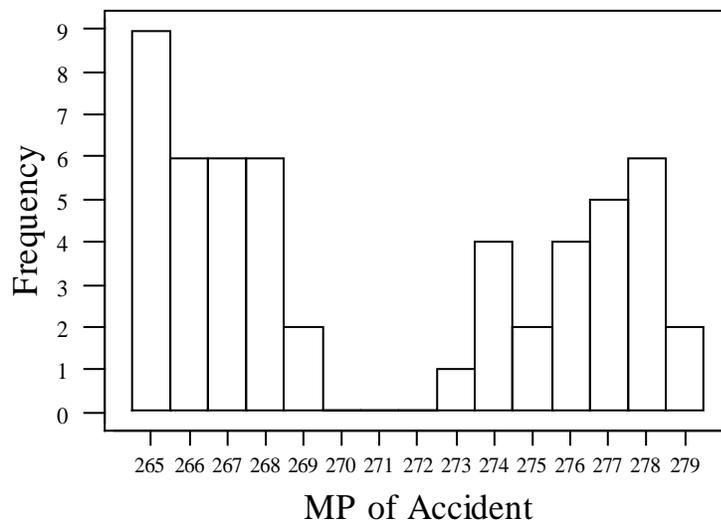


Figure 3.1: Impacts on the cable median barrier by MP

3.2.1 Analysis of Nine Barrier Impacts at MP 265

MP 265 had the highest frequency of impacts. There are accident reports for seven of the nine impacts (Appendix A). Four of the impacts are in the southbound direction and three are in the northbound direction.

Two of the southbound impacts listed hydroplaning in the accident records, with an average precipitation of 32.6 mm. The two other southbound impacts had negligible precipitation with an average of 1.5 mm. The southbound location is in a transition zone from a shed cross-section to a horizontal curve to the left. The alignment transition has a flat area that may drain water slower than normal. The potential accumulation of water is a likely explanation for both the hydroplaning and the higher frequency of impacts at MP 265 when compared to the rest of the system.

The three northbound impacts seem to be caused by driver error, as described in the accident reports. The three impacts had negligible precipitation with an average of 0.5 mm.

All weather data is based on the preliminary local climatological data for the Salem, Oregon site, which is available on the Internet at <http://nimbo.wrh.noaa.gov/portland/clisle.html>.

3.2.2 Potential Crossovers

There were 21 potential crossovers stopped by the cable median barrier, which is 40% of the total number of impacts. Although subjective, this estimate is based on analysis of the accident report descriptions and the number of line and anchor posts damaged. Increased damage to the system should correlate to increased momentum, which would carry the vehicle into opposing traffic lanes.

3.2.3 Fatalities and Injuries

There has not been a fatality associated with the cable barrier since it was installed. There were five injury accidents from December 1996 through March 1998, which correlates to 3.8 injury accidents per year. The injuries from the five injury accidents were minor. There have not been any major or moderate injuries.

To date, the cable barrier system has reduced the fatalities caused by crossover collisions. However, the incidence of nuisance and property damage accidents has increased in the subject sections. Vehicles that entered the median prior to barrier installation, could reenter the roadway, if they had not crossed over. Now, with a cable barrier in-place, these vehicles are impacting the cable system.

3.2.4 Cable Barrier Underride Events

Of the 53 impacts to the cable barrier, only two vehicles underrode the cables, but neither crossed over into the opposing traffic lanes.

The first vehicle, a Chrysler four-door, underrode the cable system on February 8, 1997, near MP 266. The temperature ranged from 0-7°C, with an average of 3°C. No precipitation was reported, with only 7.6 mm total rain for the previous week. The ground should have been firm, so soft ground can be ruled out as a contributing factor to the underride event. The damage to the vehicle was not specified in the accident report (Appendix A).

The other vehicle, a 1991 Subaru four-door, underrode the barrier on June 29, 1997, near MP 274. The temperature ranged from 9-23°C, with an average of 17°C. There was 0.3 mm of rain, with only 6.6 mm total for the previous week. Again, soft ground can be ruled out as a contributing factor. The cables tore the hood off and crushed the windshield of the Subaru.

Injuries were not reported for either accident.

3.2.5 Cable Barrier Crossover Events

Two vehicles crossed through the cable barrier system into the opposing lanes of traffic.

On July 24, 1997, the first vehicle lost control for an unknown reason, crossed over at the emergency turnaround at MP 267, and struck a vehicle traveling in the opposite direction (Appendix A). This operator either traveled through the median at the exact location of the emergency turnaround or was making an illegal U-turn. Although the barrier was not impacted, this vehicle did crossover in the section of highway protected by the barrier.

On September 23, 1997, the only median crossover impacting the barrier occurred. A semi-truck went through the median barrier, dragged the cables across the opposing traffic lanes, hitting a GMC Yukon. The driver of the Yukon suffered minor injuries. The semi-truck driver suffered from a seizure before crossing through the median. As stated in Section 2.3, none of the barrier options are designed to stop these larger vehicles, as it is not cost effective.

Figures 3.2-3.4 document the path of the semi-truck crossover. Figures 3.5-3.10 document the results of the semi-truck crossing through the cable median barrier system, as well as, the energy dissipation characteristics of the system components.



Figure 3.2: Semi-truck crossover through cable median barrier



Figure 3.3: Semi-truck pulled barrier cables across northbound lanes



Figure 3.4: Semi-truck stopping location after crossover



Figure 3.5: Energy dissipation-cable release from breakaway anchor angle and anchor post bracket (north end)



Figure 3.6: Energy dissipation-cable release from breakaway anchor angle and anchor post bracket (south end)



Figure 3.7: Energy dissipation-cable release from round bend hook bolts



Figure 3.8: Energy dissipation-cable release from breakaway anchor angle and anchor post slip base failure



Figure 3.9: Energy dissipation-weak-post bending



Figure 3.10: Energy dissipation-spring cable turnbuckle deformation

As shown in Figures 3.2-3.10, significant barrier damage may occur with any single hit. So far, there has not been a cross-median accident in a location where the barrier needs repair work. Even so, consideration should be given to the risk of cross-median accidents where the barrier is damaged.

3.3 ACCIDENT RECORDS

The 53 impacts are detailed in Table 3.1. The following assumptions were made in developing Table 3.1.

- The impacts were matched up with the repairs based on the date, the MP, the number of posts damaged and the accident descriptions (Appendix A). As these are not confirmed matches, some correlation may be incorrect.
- The MP's reported by Coral Construction for each repair location do not match the MP's reported by the Oregon State Police (OSP) for each accident location (Appendix A). The MP's listed in Table 3.1 are the Coral Construction repair locations.
- In searching for patterns and relationships in the data set, no apparent correlation exists between impacts and weather (precipitation), season, month, day of week, or time of day.
- Appendix A contains information from the OSP daily logs and the ODOT dispatch records for each impact date.

Table 3.1: Impact Data

Impact #	MP	Impact Date	Repair Date	Days Down	Line Posts*	Anchor Posts*	Repair Cost	Injury Accident	Precipitation (mm)	Potential Crossover
1	265.3 S	12/9/96	12/26/96	17	6	0	\$1,375.00	No	0.5	Yes
2	265.3 S	1/31/97	2/10/97	10	6	0	\$1,275.00	No	24.1	Yes
3	266.0 S	2/8/97	2/10/97	2	2	0	\$350.00	NA	0.0	
4	268.0 S	1/6/97	2/10/97	35	2	0	\$350.00	No	NA	Yes
5	278.6 N	1/31/97	2/10/97	10	1	0	\$150.00	No	24.1	
6	268.4 ?	3/11/97	3/17/97	6	5	0	\$1,100.00	NA	12.2	Yes
7	275.1 N	3/9/97	3/17/97	8	7	0	\$1,400.00	NA	8.1	Yes
8	265.3 S	3/31/97	4/3/97	3	5	0	\$1,150.00	No	2.5	Yes
9	278.8	-	4/3/97	-	2	0	\$375.00	-	-	
10	278.0	-	5/20/97	-	4	0	\$925.00	-	-	Yes
11	276.5 N	4/28/97	5/20/97	22	2	0	\$375.00	No	2.5	
12	267.0 S	4/30/97	5/20/97	20	2	0	\$375.00	Yes, Minor	3.8	
13	266.6 S	6/15/97	8/8/97	54	4	0	\$675.00	No	0.0	Yes
14	266.8 N	6/6/97	8/8/97	63	1	0	\$175.00	No	0.0	
15	268.2 N	5/21/97	8/8/97	79	3	0	\$500.00	No	0.0	Yes
16	268.3 N	7/18/97	8/8/97	21	2	0	\$350.00	Yes, Minor	0.0	Yes
17	276.5 S	7/17/97	8/8/97	22	6	0	\$1,225.00	No	0.0	Yes
18	265.1	-	9/8/97	-	3	0	\$500.00	-	-	
19	266.1 S	9/6/97	9/8/97	2	3	0	\$500.00	NA	0.0	
20	274.1	-	9/8/97	-	1	0	\$175.00	-	-	
21	278.4 N	8/26/97	9/8/97	13	1	0	\$175.00	Yes, Minor	5.8	
22	273.8	-	9/8/97	-	5	0	\$1,050.00	-	-	Yes
23	265.3	-	9/8/97	-	1	2	\$800.00	-	-	
24	274.1 S	6/29/97	9/8/97	71	1	1	\$625.00	No	0.3	Yes
25	278.3 S	9/23/97	11/7/97	45	26	3	\$6,586.00	Yes, Minor	0.0	@
26	276.0	-	11/7/97	-	1	0	\$175.00	-	-	
27	273.5	-	11/7/97	-	1	0	\$175.00	-	-	
28	268.2	-	11/7/97	-	1	0	\$175.00	-	-	
29	267.1	-	11/7/97	-	1	0	\$175.00	-	-	
30	266.2 S	10/14/97	11/7/97	24	9	1	\$1,950.00	No	0.3	Yes
31	277.5	-	11/7/97	-	1	0	\$175.00	-	-	
32	277.5	-	11/7/97	-	1	0	\$175.00	-	-	
33	277.2 S	9/24/97	11/7/97	44	1	0	\$175.00	Yes, Minor	0.0	
34	265.9	-	11/8/97	-	0	1	\$450.00	-	-	
35	265.4 N	9/7/97	11/8/97	62	6	0	\$1,375.00	No	0.0	Yes
36	276.7	-	1/19/98	-	1	0	\$175.00	-	-	
37	278.3	-	1/19/98	-	1	0	\$175.00	-	-	
38	278.1	-	1/19/98	-	3	0	\$475.00	-	-	
39	276.0	-	1/19/98	-	2	0	\$325.00	-	-	
40	276.3	-	1/19/98	-	4	0	\$650.00	-	-	Yes
41	276.1	-	1/19/98	-	3	1	\$950.00	-	-	
42	266.9 S	12/24/97	1/19/98	26	2	0	\$325.00	No	NA	
43	265.4 N	12/8/97	1/19/98	42	3	0	\$475.00	No	0.5	
44	268.5	-	1/19/98	-	2	0	\$325.00	-	-	
45	265.3 S	12/16/97	1/20/98	35	9	1	\$1,550.00	NA	41.1	Yes
46	273.4	-	1/20/98	-	1	0	\$175.00	-	-	
47	266.8	-	1/20/98	-	1	0	\$175.00	-	-	
48	266.2	-	1/20/98	-	0	1	\$475.00	-	-	
49	265.6	-	3/16/98	-	6	0	\$1,225.00	-	-	Yes
50	267.5	-	3/16/98	-	4	0	\$875.00	-	-	Yes
51	268.5	-	3/16/98	-	1	0	\$175.00	-	-	
52	274.5	-	3/16/98	-	5	0	\$1,050.00	-	-	Yes
53	265.2 N	2/15/98	3/17/98	30	6	1	\$1,825.00	NA	1.0	Yes
Totals:					177	12	\$38,936.00	5 (Minor)		21

Key: MP: Milepoint; N: Northbound; S: Southbound; NA: Not available

Days Down numbers are discussed in Section 4.5

-: No accident report, driver left scene of impact

*: Number damaged; @: Semi-truck crossover

4.0 MAINTENANCE AND REPAIR

4.1 CABLE MEDIAN BARRIER MAINTENANCE AND REPAIR COSTS

Coral Construction accomplished all cable barrier repairs listed in Table 3.1, under an ODOT contract. The total cost for cable barrier maintenance and repair was \$38,936 for the period from December 1996 through March 1998. Consequently, the average annual maintenance and repair cost is \$29,202, or \$2,014/km/year. When possible, ODOT recovers costs for repairing the system from the parties responsible for the damage.

So far, no maintenance has been required for the system. The expected periodic retensioning of the cables seems to be accomplished as part of the repairs, since the cable system is retaining tension.

The Oregon Department of Motor Vehicles has vehicle property damage cost records, but the information is not available for cost analysis, as it is confidential.

4.2 COST ANALYSIS

A cost analysis was accomplished to determine the annual costs of the cable system compared to those of the concrete system. The period studied is 16 months and the subject section is 14.5 km. The analysis included installation costs, and maintenance and repair costs collected to date, as shown in Table 4.1.

Table 4.1: System Costs

Median Barrier Type	Installation Cost (\$/km)	Annual Maintenance & Repair Cost (\$/km/year)
Cable (actual)	\$27,366	\$2,014
Concrete, including base (bid)	93,504	35

The concrete median barrier annual maintenance and repair costs are estimated by assuming three sections required replacement over the 16-month period. The assumption is based on replacing three sections for the semi-truck impact, which occurred on September 23, 1997. The cost for one section of new concrete barrier in-place is approximately \$225.

The annual cost per km per year was calculated using the following equation:

$$[\text{Installation Cost (\$/km)} * (\text{A/P, } i=4\%, n \text{ years})] + [\text{Maintenance \& Repair Cost (\$/km/year)}] \quad (4-1)$$

A: Annual Amount
P: Present Worth
A/P: Discount factor to convert P to A
i: interest rate.

To determine how many years of service life are required before a concrete system is more cost effective than a cable system, Equation 4-1 was used as follows:

$$[\$27,366 * (A/P, 4\%, n)] + [\$2,014] = [\$93,504 * (A/P, 4\%, n)] + [\$35] \quad (4-2)$$

Inputting the discount factors iteratively into Equation 4-2 for different years, n, results in a discrepancy between the cable and concrete systems ranging from \$66,804/km/year (one year) to \$1844/km/year (30 years). The annual costs associated with the cable median barrier system will never equate to the costs of the concrete median barrier system for the subject location, period of study, and inflation rate. The discrepancy between the installation costs for the concrete and cable systems is too great for the maintenance and repair costs to overcome. The annual maintenance and repair cost for the cable barrier system would have to exceed \$3,857 for the annual costs of the two systems to equate at 30 years service life.

The life cycle information for each system has not been included in these calculations. The assumption is annual maintenance and repair costs account for long-term system upkeep.

4.3 CABLE BARRIER STUDIES FROM OTHER STATES

The repair costs from three other states are compared to the Oregon repair costs in Table 4.2.

Table 4.2: Accident Cost Comparisons with Other States

	Oregon	North Carolina	Iowa	New York
Study Year	1998	1995	1978	1969
Km Cable Median Barrier	14.5	13.7	NA	NA
Police & State-Reported Accidents/Year	20	NA	16	125
Repairs/Year	40	71	29	NA
# Fatalities/Year	0	0	0.5	1.3
# Injury Accidents/Year	3.8	21.1	2.5	6.0
Repair Cost/Accident (Study Year)	\$735	NA	\$212	\$90
Repair Cost/Accident (1998 \$)	\$735	NA	\$465	\$281
Repair Cost/Post (Study Year)	\$206	\$65	\$35	NA
Repair Cost/Post (1998 \$)	\$206	\$70	\$78	NA
Average Property Damage Loss (Study Year)	NA	NA	\$1874	NA
Average Property Damage Loss (1998 \$)	NA	NA	\$4106	NA

NA: Not available

4.3.1 North Carolina

The North Carolina Department of Transportation is currently performing a study to find the maintenance and repair costs for the 13.7 km cable barrier installed on Interstate 40. From January 1994 through September 1995, there were 125 accidents involving the cable barrier. There were no fatality accidents, but there were 37 injury accidents. The estimated repair costs were \$60 to \$65 per post for the subject section, which is 66% less than the repair costs per post in Oregon (Table 4.2), (Mustafa, 1997).

4.3.2 Iowa

Iowa studied cable barrier effectiveness in the late 1970's. There were 31 police-reported accidents for 1977 and 1978, consisting of one fatality and five injury accidents. Since there were 58 repairs to the cable barrier, it follows that 27 accidents occurred that were not reported to the police. The repair cost was \$212 per accident, which is 37% less than the average repair cost per accident for Oregon. On average, six posts were damaged per accident. The average property damage loss was \$1874 per accident, \$760 less than the average accident for all barrier types (Table 4.2). The study concluded cable barrier impacts were less costly and less severe than impacts with other barriers, and the cable system was performing adequately, (Ray, 1997).

4.3.3 New York

The 1977 study of cable barriers in use on New York State roads found for a three-year period, 1967-1969, there were 375 police-reported cable barrier related accidents. In 27% of the accidents, the cable system was penetrated. There were four fatalities, two involving penetrated barriers, and 18 injury accidents. The average repair cost of the cable barrier was \$90 per accident, which was 55% less than the average repair cost of \$201 per accident for strong-post W-beam guardrails. The average repair cost per accident in New York is 62% less than the average repair cost per accident for Oregon. New York's study concluded the weak-post cable barrier resulted in less severe crashes than strong post W-beam guardrail systems, (Ray, 1997).

4.4 CABLE MEDIAN BARRIER REPAIRS

Coral Construction was responsible for all repairs completed from December 1996 through March 1998. Coral Construction used a three or four-person crew, depending on the nature of the repairs. Because of the wide shoulders along the median of the interstate, no lane closures were required for repairing the cable barrier.

Equipment used for normal repair of the cable barrier:

- One truck-mounted hydraulic crane,
- One portable hydraulic hammer,
- One four-wheel drive truck with winch (tension cables),
- One truck mounted impact attenuator,
- Traffic-cones and proper road work signs, and
- Hand wrenches to tighten the J-bolts that attach the cables to the line posts

4.4.1 One Repair Event

To replace the posts, Coral Construction pulled the damaged posts out of the ground using a truck-mounted hydraulic crane (Figure 4.1). The two-person (one laborer and one operator) operation pulled 19 posts out in 22 minutes. The crane pulled the posts out of the ground from the shoulder of the road. Driving in the median is undesirable during the rainy season due to the soft soil and high water table in the median.



Figure 4.1: Removing damaged steel posts

Coral Construction used a hydraulic hammer to drive the new posts into the ground (Figure 4.2). The same two people that pulled out the old posts installed new posts. The crane carried the hydraulic hammer from one post to the next. It took about 45 minutes to install the 19 posts. The time to drive a post varied depending on the ground condition. A mark was made on the post to aid in placing the post at the correct depth. The new posts were offset slightly from the original position of the bent post.



Figure 4.2: Installing new steel posts

Three people took 20 minutes to attach the cable to the 19 posts. A core was cut in the concrete anchor for the new stub taking 1 hour, 25 minutes (Figure 4.3). This repair was an unusual repair. The bolts for the anchor post are supposed to break rather than the stub; however, this anchor post has been broken several times due to direct impacts and high system tension.



Figure 4.3: Coring a new hole for a replacement anchor post

Coral Construction used a four-wheel drive truck with an electric winch to stretch the cables. One person operated the electric winch and two people attached the cable on the anchor posts and adjusted the tension of the cable. Stretching the three cables took about five minutes, (Figure 4.4).



Figure 4.4: Stretching the reattached cables

The total time required to accomplish the repair of the 19 posts was two hours and 57 minutes. The time required for the repair of the 19 posts only, without the core cut, was one hour and 32 minutes.

4.5 DOWN TIME DUE TO DAMAGED BARRIER AWAITING REPAIR

The average down time before damaged barrier is repaired is 30 days, based on data collected and noted in Table 3.1. The least amount of down time before damaged barrier was repaired was two days. The most amount of down time before damaged barrier was repaired was 79 days.

ODOT is notified of damage to the cable system by various sources to include ODOT personnel, the travelling public, police and Coral Construction employees.

Once ODOT is notified, the contractor is informed of the impact. The contract did not specify length of time requirements to repair the barrier. The contractor did not maintain an inventory of line and anchor posts, so the contractor ordered posts for each of the repairs on an as needed basis. It was more efficient to fix groups of repairs to minimize the delay for material shipments. In addition, the contractor was very busy with other construction projects, so the repairs were also delayed due to scheduling conflicts. The new contract for cable barrier maintenance and repair contains a clause that all repairs must be accomplished within two weeks of notification. So, the long down times experienced to date should not repeat in the future.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The cable median barrier system was effective in preventing crossover accidents at the subject location, from December 1996 through March 1998. Of the 53 barrier impacts, 21 potential crossovers were restrained from entering the opposing traffic lanes. Only three vehicles went through the cable barrier system. The two that underrode the cables did not crossover into the opposing traffic lanes. The third vehicle, a semi-truck, went through the cable barrier, crossing over into the opposing traffic lanes. None of the median barriers used in Oregon are designed to stop these larger vehicles, as it is not cost effective.

The fatality rate dropped from 0.6 per year for 1987 through 1996, to zero per year for the study period. In contrast, the injury accident rate increased from 0.7 per year for 1987 through 1996, to 3.8 per year for the study period. The most likely explanation for the increase in accidents is vehicles that drove into the median prior to the barrier installation, and reentered the roadway without incident, are now impacting the cable system.

ODOT's experience with the cable barrier is consistent with the studies other states have done. The main difference is the repair costs are considerably higher in Oregon. Other states have experienced a discrepancy between the number of police-reported accidents and the number of repairs. In general, vehicles hitting the barrier system leave the scene, so police-reported accidents are available for only 51% of barrier impacts in this study (Appendix A).

The annual costs of the cable median barrier system will always be less than the annual costs of the concrete median barrier system for the subject location, period of study, and selected inflation rate.

Since the cable median barrier is effective to date, ODOT installed 20.2 km of cable barrier in the gaps between Wilsonville and Keizer in the spring of 1998.

5.2 RECOMMENDATIONS

The cable median barrier system should be considered in all locations that meet or exceed the requirements for the system as it is cost effective and exhibits good performance. The cable system is intended for use in locations where there is enough room for lateral deflections of up to 3.5 m. The width of the median needs to be at least 7 m for a cable system centered in the median. Cable systems should not be used on sharp curves or where curbs exist or in areas where it is likely to be hit frequently.

Once the system is installed, repair locations should be tracked as per Figure 3.1 in order to identify possible roadway design problems.

6.0 REFERENCES

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M.E. Boushele. *The Use of 3-Strand Cable Barrier in Oregon*. Federal Highway Administration (FHWA). 1998.

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APPENDIX A

ACCIDENT RECORDS

Definitions:

OSP: Oregon State Police
I-5: Interstate 5 (Oregon Highway Number 1)
S: Southbound
N: Northbound
MP: Milepoint
V#1: Vehicle #1
V#2: Vehicle #2
V#3: Vehicle #3
MCJ: Marion County Jail
OP#1: Operator of Vehicle #1
OP#2: Operator of Vehicle #2
PASS#1: Passenger of Vehicle #1
'A' Lane: Left lane
'B' Lane: Middle lane
'C' Lane: Right lane

Time/Date: 2300; 12/9/96

Source: OSP Log

Location: I-5 S, Waconda Road

Vehicle: V#1: 1994 Toyota Camry 4dr (black) - Washington plates

Description

V#1 was S in 'A' lane at "65" MPH when it hit standing water and careened into the median, taking out about 100 feet of cable and metal (new guardrail). All occupants seat-belted - No injuries. Subjects were en route to California from Washington. V#1 had extensive damage, not driveable. Subjects and belongings transported to motel in Salem. Other traffic did not appear to have trouble with the water on the roadway.

ODOT Dispatch Notes: V#1 operator says they hit a great deal of water. OSP advised of ½ inch of standing water in 'A' lane.

Time/Date: 1600; 1/6/97

Source: OSP Log

Location: I-5 S MP 267 @ Emergency cross-over

Vehicle: V#1: 1990 Honda Civic 2dr (white) - Oregon plates

Description

Single vehicle non-injury accident occurred when V#1 was forced off the road into the median. V#1 struck the cable median barrier anchor at the emergency crossover. Cable restraint prevented vehicle from crossing into the N lanes.

Time/Date: 0020; 1/31/97

Source: OSP Log

Location: I-5 S MP 265

Vehicle: V#1: 1989 Honda Civic - Oregon plates

Description

Single vehicle, non-injury into median arresting cables. Four sections of cable were damaged. V#1 hydroplaned into median.

Date: 1/31/97

Source: ODOT Dispatch Notes

Location: I-5 N MP 278

Vehicle: V#1: Honda, no plates

Description

Non-injury, single vehicle into cable which has been damaged.

Time/Date: 2134; 2/8/97

Source: OSP Log

Location: I-5 S MP 264

Vehicle: V#1: Red Chrysler 4dr

Description

V#1 went under the cable barrier and came to a stop in the median. That is when PASS#1 took over driving when OP#1 fled. V#1 was towed. Defendant was transported to MCJ and cited for DUII and DWR-Felony. A hold was put on PASS#1 by parole officer.

Time/Date: 0947; 3/9/97

Source: OSP Log

Location: I-5 N MP 274

Vehicle: V#1: 1988 Ford sedan 4dr (black); moderate body damage

Description

V#1 found in grassy median resting against 3-cable restraint system. V#1 was apparently N lane 'A', when it left roadway, spun in median taking out about 100 feet of the triple cable system. V#1 towed as a hazard in the median.

Date: 3/11/97

Source: ODOT Dispatch Notes

Location: I-5 MP 268.58

Vehicle: Unknown

Description

Five posts damaged of median cable guardrail.

Time/Date: 1835; 3/31/97

Source: OSP Log

Location: I-5 S MP 266

Vehicle: V#1: 1985 Nissan 4dr; moderate/heavy damage

Description

V#1 S, left travel portion into median, striking center divider cables. Approximately 50 feet of cable damage. Info provided to ODOT. No report/citation. Non-injury.

Date: 4/28/97

Source: ODOT Dispatch Notes

Location: I-5 N MP 276

Vehicle: V#1: 1995 Toyota Corolla (Gold)

Description

V#1 two miles north of Woodburn in median. Non-injury. Two posts damaged.

Time/Date: 2145; 4/30/97

Source: OSP Log

Location: I-5 S MP 267

Vehicle: V#1: 1983 Datsun 2dr (blue); towed

V#2: 1986 Ford Taurus 4dr (silver); towed

V#3: Unknown, fled

Description

V#1 was S in 'B' lane, just ahead of V#2, which was S in the 'A' lane. V#3 came up in the 'A' lane at a high rate of speed, changed to the 'B' lane to pass V#2, and clipped the rear end of V#1 as it changed back into the 'A' lane. The impact with V#1 caused V#3 to strike V#2. V#2 spun into the median, while V#1 spun to the right shoulder. V#3 left the scene prior to arrival of Emergency Personnel. OP#1 complained of minor neck pain but refused transport. OP#2 was arrested for DUII and transported to MCJ where cited and released.

Time/Date: 1200; 5/21/97

Source: OSP Log

Location: I-5 N MP 268.3

Vehicle: V#1: 1981 Audi 4dr (black); left side damage, driveable after removed from median

V#2: 1988 Ford Ranger 4x4 PU (Dark blue); not damaged

Description

V#1 was in the 'A' lane passing V#2. As V#1 was alongside V#2, V#2 started changing lanes from 'B' to 'A'. V#1 swerved to left to avoid V#2. V#1 then veered back to the right to avoid the median bushes, traveled into the 'B' lane in front of V#2, then swerved back to the left to avoid traffic. Ultimately V#1 went into the median at an angle and was stopped by the center median cables restraint system. Damage to approximately 60 feet of cable. ODOT notified of damage. It probably prevented a head-on collision. Due to conflicting statements by subjects involved and no independent non-partisan witnesses, no action was taken. No injuries.



Time/Date: 0230; 6/6/97

Source: OSP Log

Location: I-5 N MP 266

Vehicle: V#1: 1984 Toyota Corolla 4dr

Description

V#1 left roadway on east side, overcorrected coming to rest in median. Damage to cable barriers. Non-injury.

Time/Date: 0740; 6/15/97

Source: OSP Log

Location: I-5 S MP 266.9

Vehicle: V#1: 1996 Subaru Legacy 4wd (green)

Description

OP#1 was traveling S I-5 near MP 267 when she fell asleep. V#1 drifted onto the shoulder then struck a metal marker, which woke her up. OP#1 then swerved back to the left causing the vehicle to cross all three lanes S and then into the center median. V#1 struck the cable and flipped over onto its top. Neither OP#1 nor PASS#1 was injured. V#1 was towed. ODOT notified that the cable support was damaged and will need repair.

Time/Date: 1300; 6/29/97

Source: OSP Log

Location: I-5 S MP 274

Vehicle: V#1: 1991 Subaru 4dr (Maroon)

V#2: 1994 Ford Van (Maroon)

Description

V#1 was S lane 'B'. V#2 was S lane 'C'. OP #1 looked down for a second and when OP#1 looked up V#1 swerved a little, OP#1 overcorrected back, tapped V#2 causing minor damage to V#2. V#1 left roadway, struck 3-cable restraint system, passed through cables and stopped. Cables tore hood off V#1 and crushed windshield. V#1 stopped in median. Non-injury.



Time/Date: 2020; 7/17/97

Source: OSP Log

Location: I-5 S MP 275

Vehicle: V#1: 1986 Ford Mustang LX (White)

Description

OP#1 was traveling in 'A' lane at approximately 70-75 mph when OP#1 hit a piece of a semi tire in the roadway. OP#1 lost control of V#1 and went into the median where V#1 hit the divider and spun around. OP#1 was not injured but was cited for driving uninsured and driving while suspended. Center median damaged. ODOT notified that barrier cable needs repair. V#1 towed.

Time/Date: 1330; 7/18/97

Source: OSP Log

Location: I-5 N MP 268

Vehicle: V#1: 1986 Chevy Van (White)

Description

V#1 was I-5 N at MP 268. Witnesses said V#1 was following too close. A vehicle in front braked. OP#1 slammed on the brakes and lost control. OP#1 hit the median 3-cable system and flipped. OP#1 received minor injuries and was treated and released from hospital. OP#1 was issued a citation for careless driving.



Time/Date: 0400; 7/24/97

Source: OSP Log

Location: I-5 S MP 267

Vehicle: V#1: 1997 Ford Van
V#2: 1982 Mazda 2dr

Description

V#2 N I-5, crossed median after OP#2 reported loss of control for an unknown reason. V#2 crossed median, striking S V#1. Non-injury. V#1 driven from scene, V#2 towed. OP#2 cited for Driving Uninsured.

Note: Cable barrier not impacted. Crossover at emergency turnaround.

Time/Date: 0348; 8/26/97

Source: OSP Log

Location: I-5 N MP 278

Vehicle: V#1: 1979 Ford Bronco (Brown)
V#2: 1995 Nissan Maxima 4dr (white)

Description

V#1 was in 'A' lane travelling ~65 MPH. V#2 in 'C' lane at ~90 MPH began to change lanes across 'B' lane into 'A' lane. Rear end impact occurred with V#1. V#1 came to rest ~500 feet north of impact. V#2 came to rest against median cables. OP#2 cited for reckless driving. OP#1 transferred to hospital for neck soreness.

Time/Date: 0205; 9/6/97

Source: OSP Log

Location: I-5 S MP 266

Vehicle: V#1: 1991 Ford van (gray)

Description

OP#1 rolled V#1 on its side, taking out a stretch of cable in the median. DUII.

Time/Date: 1640; 9/7/97

Source: OSP Log

Location: I-5 N MP 266

Vehicle: V#1: 1990 Mazda 4dr (Blue)
V#2: 1989 Ford 2dr (Red)

Description

V#1 and V#2 had been traveling together at speeds between 80-85 mph through Salem and north. OP#1 would not let V#2 pass. Multiple lane changes, following too close, etc. Moderate to heavy traffic. V#1 pulled about 1/8 mi. ahead of V#2 still speeding and passing cars, when another vehicle made a lane change in front of it. OP#1 veered onto median shoulder and lost control, spinning through median. About 75' of cable was damaged. V#2 not involved in wreck. Both OP#1 and OP#2 admitted to bad driving and were cited and released at the scene for reckless driving. Medical treatment refused at scene.

Time/Date: 1220; 9/23/97

Source: OSP Log

Location: I-5 S MP 278

Vehicle: V#1: 1986 Peterbuilt conventional (Blue)

V#2: 1996 GMC Yukon 4dr (green)

Description

Preliminary investigation indicates that OP#1 suffered a seizure. V#1 was S on I-5, crossed the median, broke through the cable barrier, struck V#2 and continued across the N lanes where it came to rest in a field. OP#2 received minor injuries/treated and released at hospital. V#2 totaled and towed. V#1 sustained major front-end damage.



Time/Date: 1130; 9/24/97

Source: OSP Log

Location: I-5 S MP 277

Vehicle: V#1: 1978 Chevrolet Van (White)

Description

V#1 S in lane 'A' when tire blew, causing OP#1 to lose control. V#1 hit the cable median divider and rolled over. V#1 towed. Both OP#1 and PASS#1 were taken to hospital and released with minor injury.

Time/Date: 1212; 10/14/97

Source: OSP Log

Location: I-5 S MP 266

Vehicle: V#1: 1988 Plymouth Horizon 4d (gray)

Description

V#1 lost control and crashed into the median cable barrier. OP#1 stated that a truck was changing lanes and forced V#1 off the road. There were many trucks around V#1 at the time but police did not witness this event. Non-injury.

Time/Date: 12:55; 12/8/97

Source: OSP Log

Location: I-5 N MP 266

Vehicle: V#1: 1991 Ford Mustang (red)

Description

V#1 was N in 'B' lane when V#1 veered to the right shoulder then out of control over to the median where the cables stopped it. Non-injury.

Time/Date: 1530; 12/16/97

Source: OSP Log

Location: I-5 S MP 265.6

Vehicle: V#1: 1995 Chevrolet Pickup (blue)

Description

V#1 was S overtaking a truck in the 'A' lane. The truck in the 'B' lane made a movement to the left and OP#1 applied the brakes and V#1 went out of control on the wet pavement. V#1 spun around and went off the road impacting with the median arresting cable. The cable was pulled loose from one upright support.

Time/Date: 1650; 12/24/97

Source: OSP Log

Location: I-5 S MP 266

Vehicle: V#1: 1992 Toyota Camry (red)

Description

OP#1 stated that V#1 just caught the edge of the road and spun and then went into the center wires. Non-injury.

Time/Date: 0317; 2/15/98

Source: OSP Log

Location: I-5 N MP 266.7

Vehicle: V#1: 1985 Ford Thunderbird 2dr (white)

Description

V#1 was actually traveling S, then it crossed the median taking out the center cable barriers coming to rest on the west side of the N median. V#1 sustained heavy rear-end damage, so it was towed.
