EVALUATION OF 3M™ SCOTCHLITE™ LINEAR DELINEATION SYSTEM

Final Report

SPR 306-291

EVALUATION OF 3M™ SCOTCHLITE™ LINEAR DELINEATION SYSTEM

FINAL Report

SPR 306-291

by

Kevin Haas, P.E.

for

Oregon Department of Transportation
Research Unit
200 Hawthorne SE, Suite B-240
Salem OR 97301-5192

and

Federal Highway Administration
Washington, D.C.

September 2004

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
OR-EF-05-03		

4. Title and Subtitle	5. Report Date
Evaluation of 3M™ Scotchlite™ Linear Delineation System	September 2004
	6. Performing Organization Code
7. Author(s) Kevin Haas, P.E.	8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Unit 200 Hawthorne SE, Suite B-240 Salem, Oregon 97301-5192	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Unit and Federal Highway Administration 200 Hawthorne SE, Suite B-240 Washington, D.C. Salem, Oregon 97301-5192	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Major construction projects present many hazards for drivers to negotiate. Detours, lane shifts and confusing curves present unique challenges to all drivers. At night, the difficulties in negotiating these obstacles are amplified due to reduced visibility. Over the past several years, the Oregon Department of Transportation has been particularly interested in evaluating concrete barrier marking products the improve the delineation of lane shifts, sharp turns, and detours within highway work zones. This project evaluated the installation, maintenance and effectiveness of the 3M™ Scotchlite™ Linear Delineation System (LDS) mounted on concrete barriers within three different highway work zones.

The installation of the LDS panels proved to be more challenging then envisioned, primarily because installation is a time intensive process. Users need to be aware of the productivity rates for installation. A maintenance concern with the panels is to keep them relatively clean from dirt and road grime to maintain an optimal level of retroreflectivity.

The LDS panels provide a good alternative to traditional concrete barrier delineation methods (such as reflective barrier markers). At the end of construction, panels can be removed from the barrier and reused on future projects. The success of the panels has led ODOT to consider further implementation on future construction projects, as well as permanent installation in areas where crash histories warrant additional safety measures.

17. Key Words	18. Distribution Statement
CONCRETE BARRIER DELINEATION, WORK ZONE SAFETY, 3M, OREGON	Copies available from NTIS, and online at http://www.odot.state.or.us/tddresearch

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	32	

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

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
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
		VOLUME		
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 m^3.				
		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	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
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
		MASS		
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	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The author would like to thank the following for their assistance in this project and with the preparation of this report:

McGregor Lynde, ODOT Research
Norris Shippen, ODOT Research
Mike Dunning, ODOT Qualified Products
Joel Fry, ODOT Office of Maintenance
Jeff Graham, FHWA-Oregon Division
Scott McCanna, ODOT Roadway Engineering
Joe Thomas, ODOT Region 3
Julia Wellner, ODOT Traffic Management
Dave Davies, ODOT Region 2
Jeff Gower, ODOT Construction
Barnie Jones, ODOT Research
Cathy Ardanaz, 3M™

DISCLAIMER

EVALUATION OF 3M™ SCOTCHLITE™ LINEAR DELINEATION SYSTEM

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

Major construction projects present many hazards for drivers to negotiate. Detours, lane shifts, and confusing curves present unique challenges to all drivers. At night, the difficulties in negotiating these obstacles are amplified due to reduced visibility. Over the past several years, the Oregon Department of Transportation (ODOT) has been particularly interested in evaluating concrete barrier marking products that improve the delineation of lane shifts, sharp turns, and detours within highway work zones. These products have the potential to increase safety and reduce crashes in work zones. This project evaluated the installation, maintenance and effectiveness of the 3M™ Scotchlite™ Linear Delineation System (LDS) mounted on concrete barriers to enhance the alignment of a lane shift within three different highway work zones.

1.2 BACKGROUND

Safe and efficient traffic movements through work zones are a key concern for every construction project, particularly when space limitations require lane shifts or detours. As seen in Figure 1.1, concrete barriers are often used to guide traffic through the construction area, and warning signs are used to alert drivers of the changing traffic patterns.

Figure 1.1: Typical concrete barrier used for a lane shift in an Oregon work zone

At night or during inclement weather conditions, drivers experience reduced visibility and therefore have more difficulty anticipating and responding to the changes indicated by signs and barriers. The LDS is intended to reduce crashes on highway curves or through a construction work zone by providing motorists with continuous, positive guidance along the roadway.

This study is a follow-up to an ODOT Research Unit project that was completed in 2000, focusing on an evaluation of the 3M™ Lighted Guidance Tube (LGT) that was used on the Eddyville—Cline Hill construction project along the Corvallis—Newport Highway (US 20). The report published in August 2000 was highlighted by generally positive feedback from motorists traveling through the section of the construction project where the LGT was installed. However, 3M™ no longer markets the LGT product and the report recommended that ODOT should consider evaluating other concrete barrier delineation products. One product recommended in the report was the 3M™ Scotchlite™ Linear Delineation System. (*Griffith 2000*)

1.3 DESCRIPTION OF LDS

The LDS uses 3M™ Scotchlite™ Diamond Grade™ Reflective Sheeting laminated onto a thin gauge aluminum substrate. The panels are edge hemmed to protect the sheeting from delamination while in use and during cleaning. As shown in Figure 1.2, the panels used for this project were white and orange.

The unique "crimped wave" shape makes the LDS panels highly visible, even in areas with high entrance angles. The 34 inch long panels are available in 4 or 6 inch widths and can be applied to both concrete barriers and guardrail. (*3M 2003*)

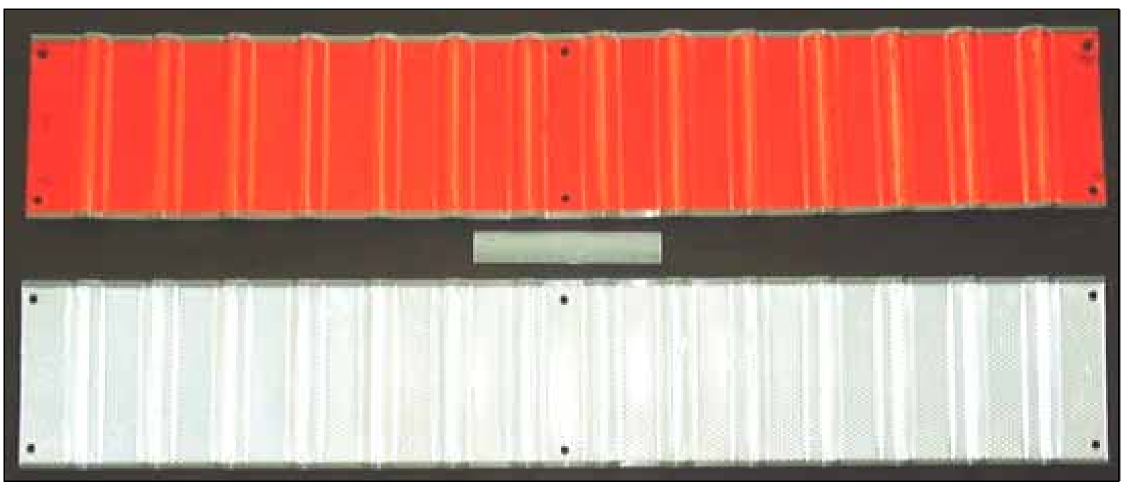

Figure 1.2: Close-up of the 6-inch 3M™ LDS panels

3M™ contracted out the manufacturing of the LDS panels to Irwin-Hodson, of Portland, Oregon. The Irwin-Hodson Company is one of Oregon's longest established industrial manufacturers, having been in business since 1894. In addition to manufacturing the LDS panels for 3M™, Irwin-Hodson has a long standing relationship with ODOT in the design and manufacturing of various license plates for ODOT's Driver and Motor Vehicle Services Division. Figure 1.3 shows part of the LDS manufacturing process.

Figure 1.3: 3M™ LDS panels being manufactured at Irwin-Hodson

1.3.1 Recommended Installation

For concrete barriers, the LDS panels are installed near the top of the barrier to avoid dirt, snow, sand or road grime. A chalk line is snapped on the barrier to ensure a level installation. The panels are laid out and the barrier is marked where they will be attached using the six pre-punched holes in each panel as a template. Once the barriers have been marked for location, a rotary hammer drill with a concrete drill bit is used to drill holes in the barrier. 3M™ recommends using an adhesive caulking system to attach the panels to the barrier prior to drilling, however this makes removal of the panels difficult at the end of a temporary project, such as in a work zone. After drilling the holes, stainless steel anchors, ¼ inch x 1 inch (6.3 mm x 25.4 mm), with a 5/16 inch (7.9 mm) nylon washer are used to secure the panels to the barrier, as seen in Figure 1.4.

Figure 1.4: Drill and anchor bolts used to attach 3M™ LDS panels to the concrete barrier

1.4 RESEARCH OBJECTIVES

The objective of this project was to evaluate the effectiveness of the 3M™ Scotchlite™ LDS in reducing the potential for work zone crashes. There were five tasks in the evaluation:

1. Literature review
2. Baseline data collection, including:
   - Analysis of the work zone site, noting traffic volumes, sight distances, weather patterns;
   - Compilation of crash data; and
   - Collection of spot speed data using a portable traffic data recorder in the work zone.
3. Installation - This task involved documenting the installation process including level of effort required (number of people, specialized equipment, etc.), ease of installation and difficulties encountered during the installation of the panels.
4. In-service monitoring and data collection. The performance monitoring included:
   - Compilation of crash data;
   - Collection of retroreflectivity data of the 3M™ LDS panels;
   - Collection of spot speed data using a portable traffic data recorder throughout various stages of construction.
5. Summary and recommendations.

2.0 LITERATURE REVIEW

There have been a limited number of studies done on concrete barrier delineation in the United States. Rather than recounting the literature review from Oregon's previous report published in August 2000 that focused on the 3M™ Lighted Guidance Tube, this section will focus on new information available since the publication of that report.

As previously mentioned, Griffith and Brooks *(2000)* reported on Oregon's experience with the 3M™ Lighted Guidance Tube (LGT) on a construction project along the Corvallis—Newport Highway (US 20). The study evaluated the LGT for its effects on vehicle speeds, crash rates, and driver perceptions. Although no correlation could be drawn between vehicle speeds and use of the LGT, drivers were generally positive when surveyed about the LGT. Drivers responded that the additional delineation provided by the LGT led to a greater level of comfort in traveling through the work zone. In addition, no crashes occurred in the work zone during the five months the LGT was in use.

A search of the Transportation Research Information Service (TRIS) from the National Transportation Library revealed only one other study relevant to this research effort that has been published since August 2000. In a presentation to the Institute of Transportation Engineers (ITE) Annual Meeting and Exhibit in Philadelphia, Pennsylvania, French *(2002)* looked at the safety aspects of concrete median barrier delineation. The study gathered background information on delineation in order to evaluate the effectiveness of concrete median barrier delineation in poor visibility conditions. Rather than field trials, the study focused on a survey of standards and specifications for concrete median barrier delineation from other states.

3.0 BACKGROUND INFORMATION OF TEST SITES

The LDS panels were installed and monitored on three different ODOT construction projects.

3.1 COAST FORK WILLAMETTE RIVER BRIDGE—BRIDGE #07745

The first site to have the LDS panels installed was the Coast Fork Willamette River Bridge project. The bridge is located on I-5 at MP 179.99 near Cottage Grove, see Figure 3.1. The average daily traffic (ADT) over this bridge is approximately 18,000 vehicles per day in the southbound direction. Construction on this project started in June 2002 and is scheduled for completion in December 2004. To accommodate the construction of a new bridge, the southbound lanes of I-5 were shifted to the east onto a temporary structure.

Figure 3.1: Location of Coast Fork Willamette River Bridge project

At the detour, I-5 southbound consists of two lanes with no shoulders. Both lanes are protected by concrete barriers running almost the entire length of the detour as seen in Figure 3.2. The detour is approximately 1500 feet (450 m) in length and the posted speed through the work zone is 55 mph (88 km/h).

Figure 3.2: Approaching lane shift at the Coast Fork Willamette River Bridge

3.2 MEDFORD VIADUCT—BRIDGE #08332

The largest test site for the evaluation of the LDS panels was the Medford Viaduct project. The viaduct is located on I-5 between MP 28.66 and MP 28.94 in the City of Medford, see Figure 3.3. The ADT on the viaduct is approximately 48,200 vehicles per day in both directions. Construction on this project started in January 2003 and was completed in June 2003. To accommodate the resurfacing and seismic retrofit of the viaduct, traffic was reduced from two lanes in each direction to a single lane in each direction. By reducing travel to a single lane in each direction, the construction schedule was condensed from 18 months to 6 months.

Figure 3.3: Location of the Medford Viaduct project

Construction at the site was divided into four stages. The first stage reduced traffic to single lanes on either side of the viaduct, while construction took place in the center of the structure. During this stage, both the northbound and southbound lanes were 16.7 feet (5.1 m) wide, with concrete barriers running the entire length of the viaduct on the inside of the travel lanes, see Figure 3.4. As can be seen in Figure 3.5, traffic was moved during Stages 2-4 from the outside to the inside of the structure where lane widths varied from 17 to 20.7 feet (5.2 to 6.2 m). The viaduct is approximately 3300 feet (1000 m) in length and the posted speed through the work zone was 45 mph (72 km/h).

Figure 3.4: Approaching lane shift at Medford Viaduct

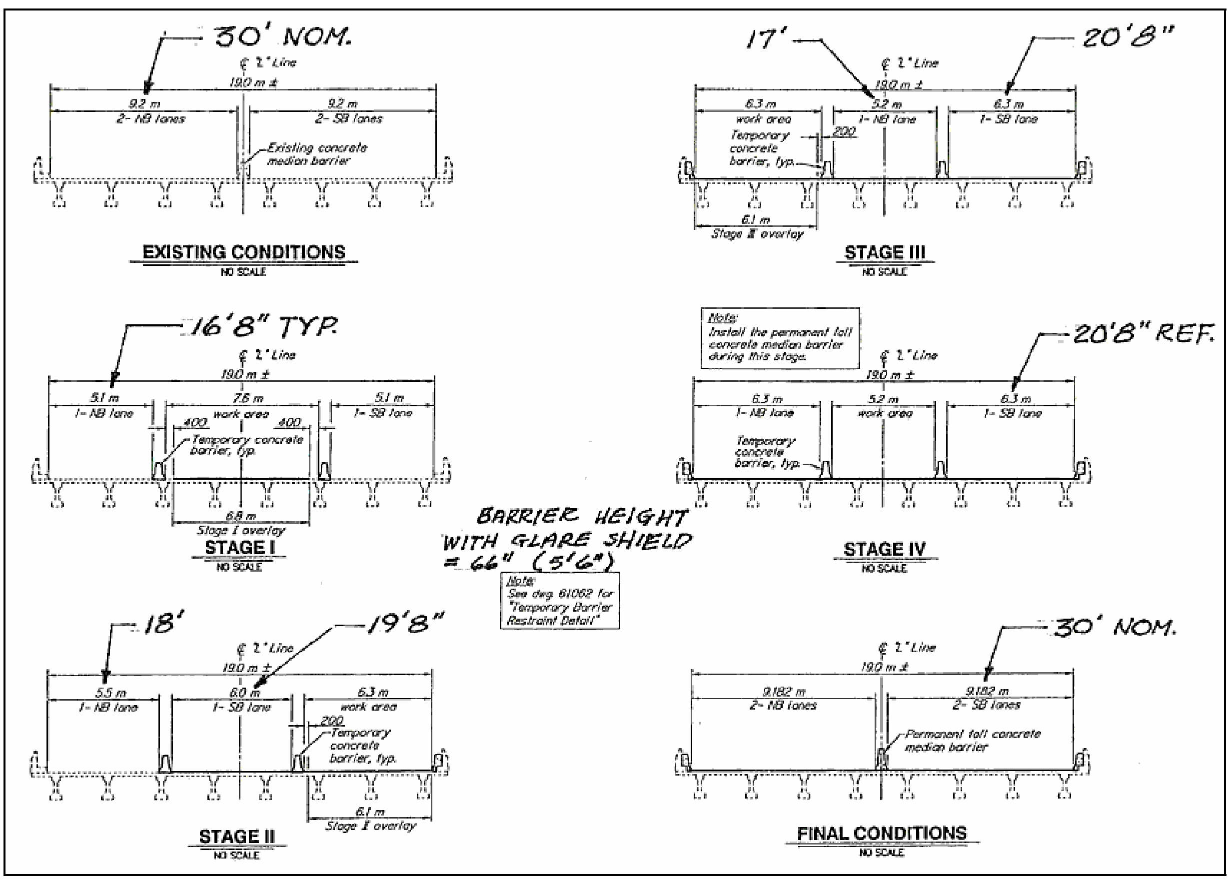

Figure 3.5: Staging details for Medford Viaduct project

3.3 BOB CREEK—BRIDGE #01177

The third site to have the LDS panels installed was the Bob Creek Bridge project. The bridge is located on the Oregon Coast Highway (US Route 101) at MP 169.94 south of Yachats, see Figure 3.6. The ADT over the bridge is approximately 2,000 vehicles per day in both directions. Construction started in May 2003 and was completed in July 2004.

Figure 3.6: Location of Bob Creek Bridge project

To accommodate the construction of a new bridge over Bob Creek, the alignment of the highway was shifted to the east onto a temporary structure. At 14 feet (4.3 m) wide, the temporary structure consisted of a single lane with no shoulders. The shared northbound and southbound lane was protected on both sides by a concrete barrier running almost the entire length of the detour as seen in Figure 3.7. The detour was approximately 600 feet (180 m) long, and traffic was controlled by a temporary signal with alternating phasing between northbound and southbound traffic. The posted speed approaching the work zone was 35 mph (56.3 km/h) and 25 mph (40.2 km/h) across the detour bridge.

Figure 3.7: Approaching lane shift onto the temporary structure at the Bob Creek Bridge

4.0 INSTALLATION OF LDS

The LDS panels are typically installed by a crew of 2-4 people. According to the 3M™ Product Bulletin for the LDS panels, "productivity rates for installation on concrete barriers range from 30 panels per hour for a 2-person crew, to 60 panels per hour for a 4-person crew" (*3M 2003*). Installation of the panels on the three ODOT construction projects closely matched the productivity rate given by 3M™.

All of the LDS panels were installed near the top of the barrier as per 3M™ recommendations to avoid dirt, snow, sand or road grime. Installation of the panels is a 4-step process. First, a chalk line is snapped on the barrier to ensure level installation as seen in Figure 4.1.

Figure 4.1: Snapping a chalk line on the concrete barrier at the Medford Viaduct project

Second, the LDS panels are laid out and the barrier is marked where holes will be drilled to accommodate the anchor bolts that attach the panels to the barrier, as seen in Figure 4.2. Crews found that laying out the panels in advance and using each panel for a template was preferable to using a single panel for this function. This is due to the fact that the layout of the pre-punched holes differs slightly on each panel due to the manufacturing process.

Figure 4.2: Marking holes for drilling

Once the barriers have been marked, the third step is to drill the holes in preparation for attaching the panels to the barrier, as seen in Figure 4.3. 3M™ recommends using a rotary hammer drill with a concrete drill bit to drill the holes in the barrier. 3M™ also recommends using an adhesive caulking system to attach the panels to the barrier prior to drilling. ODOT did not use the adhesive because it makes removal of the panels difficult at the end of a temporary project.

Figure 4.3: Drilling holes into the concrete barrier

The final step is to install the panels using $^{1}/_{4}$ inch x 1 inch (6.3 x 25.4 mm) stainless steel anchors, with a $^{5}/_{16}$ inch (7.9 mm) nylon washer, as seen in Figure 4.4. Although each panel contains six pre-punched holes for attaching the panel to the barrier, contractors used as few as two anchors at some locations to expedite the installation process. Panels that were attached using as few as 2-3 anchors were susceptible to separation from the barrier if one of the anchor bolts failed (see Section 5.2 for more information). From the field experience, 4-5 anchors per panel provided an optimum balance between secure attachment and speed of installation.

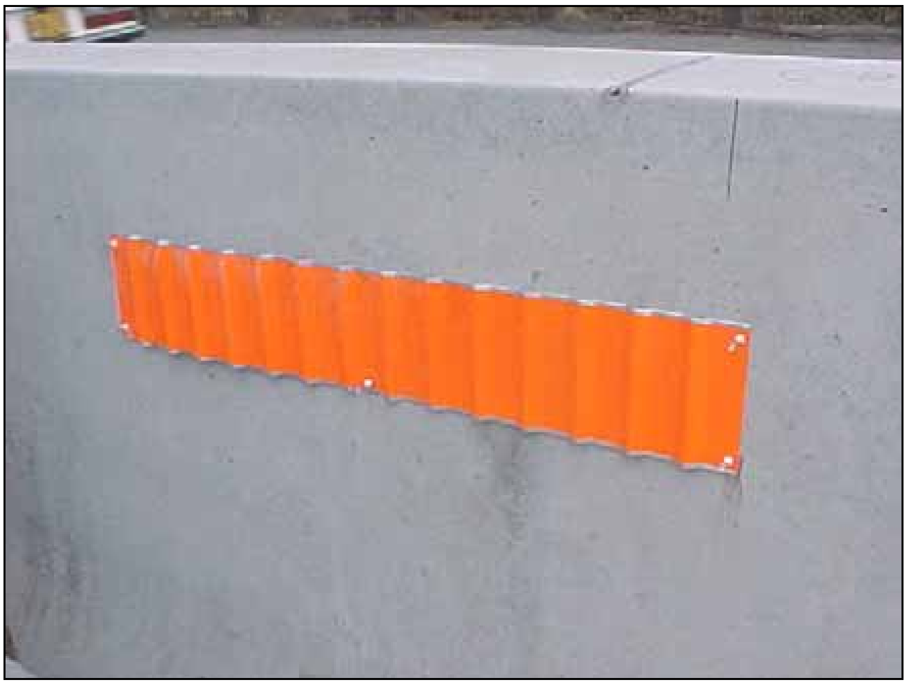

Figure 4.4: Stainless steel anchors, with nylon washers, were used to attach the panels

5.0 IN-SERVICE MONITORING AND DATA COLLECTION

5.1 SPOT SPEED STUDIES

Prior to the installation of the LDS panels, spot speed studies were conducted at both the Coast Fork Willamette River Bridge and the Medford Viaduct sites in the southbound travel lane, as seen in Figure 5.1. Data was collected using a Jamar Technologies TDC-8 Traffic Data Collector. The TDC-8 includes a spot speed module that allows spot speed studies to be conducted over fixed distances of up to 250 feet (76 m). A typical observation period included measuring the speeds of 100 total cars and semi-trucks to ensure a good statistical sample.

Figure 5.1: Spot speed study being conducted on I-5 at the Coast Fork Willamette River Bridge

Baseline speed data was collected for the Coast Fork Willamette River Bridge project in November 2002 and for the Medford Viaduct project in January 2003. Post-installation speed data was also collected at both sites in March 2003. Speed data was not collected for the Bob Creek project since a temporary signal controlled traffic flow through the work zone.

At the Coast Fork Willamette River Bridge site, vehicles traveling at excessive speeds through the work zone posed a significant problem in the months prior to the installation of the LDS panels. Table 5.1 illustrates that 45-62% of the vehicles traveling through the work zone, during a spot speed study in November 2002, were traveling at or above the posted speed. A follow-up spot speed study, conducted in March 2003 after the LDS panels were installed, showed that speeds had been significantly reduced through the work zone.

Table 5.1: Coast Fork Willamette River Bridge spot speed summary

Date	Time	Location	Average Speed		Median Speed		85th Percentile Speed		Percent vehicles traveling over 55 mph (88.5 km/h)
			mph	km/h	mph	km/h	mph	km/h	
11/26/2002 without LDS	1:35 PM	Entering lane shift	55	88.5	55	88.5	60	96.6	45
11/26/2002 without LDS	1:55 PM	Exiting lane shift	57	91.7	56	90.1	62	99.8	62
3/11/2003 with LDS	3:36 PM	Entering lane shift	37	59.5	37	59.5	42	67.6	0
3/11/2003 with LDS	3:52 PM	Exiting lane shift	44	70.8	44	70.8	48	77.2	0

Similarly, the Medford Viaduct site saw speed reductions after the LDS panels were installed. Table 5.2 illustrates that 100% of the vehicles were traveling over the posted speed, prior to the installation of the LDS panels. A follow-up spot speed study, conducted in March 2003, showed that only 8-25% of the vehicles were exceeding the posted speed and that the average speed had been reduced to 37-44 mph (59.5-70.8 km/h).

Table 5.2: Medford Viaduct spot speed summary

Date	Time	Location	Average Speed		Median Speed		85th Percentile Speed		Percent vehicles traveling over 45 mph (72.4 km/h)
			mph	km/h	mph	km/h	mph	km/h	
1/21/2003 without LDS	3:52 PM	Entering lane shift	60	96.6	59	95	66	106.2	100
1/21/2003 without LDS	4:15 PM	Exiting lane shift	61	98.1	60	96.6	68	109.4	100
3/11/2003 with LDS	6:41 PM	Entering lane shift	38	61.2	38	61.2	43	69.2	0
3/11/2003 with LDS	7:01 PM	Exiting lane shift	44	70.8	44	70.8	47	75.6	0

5.2 MAINTENANCE

One of the keys to successful implementation of the LDS panels is proper installation and maintenance. The tendency for temporary installations, such as work zones, is to use minimal time and effort in attaching the panels to the concrete barrier. This can lead to problems in the weeks and months that follow initial installation as panels are prone to detaching from the face of the concrete barrier due to debris and wind stirred up by passing vehicles. At the Coast Fork Willamette River Bridge project, some of the panels were installed with as few as two anchors. Figure 5.2 shows what happened when the panels began to detach from the face of the concrete barrier several weeks after initial installation.

Figure 5.2: Panel detachment from the barrier at the Coast Fork Willamette River Bridge project

Another maintenance concern is keeping the panels relatively clean from dirt and road grime to maintain an optimal level of retroreflectivity. Retroreflectivity of the LDS panels was monitored at both the Coast Fork Willamette River Bridge and the Medford Viaduct sites. Data was collected using a RetroSign™ retroreflectometer manufactured by Delta Light and Optics of Denmark. The retroreflectometer directly measures the coefficient of retroreflection (R_A).

Retroreflectivity data was collected on a random sampling of both orange and white LDS panels at both sites. Figure 5.3 illustrates how the coefficient of retroreflection (R_A) decreases over time when the LDS panels are not routinely cleaned. At the Medford Viaduct project, routinely cleaning the LDS panels, which had been in service for several months, with a pressure washer restored R_A values to roughly half of their original values.

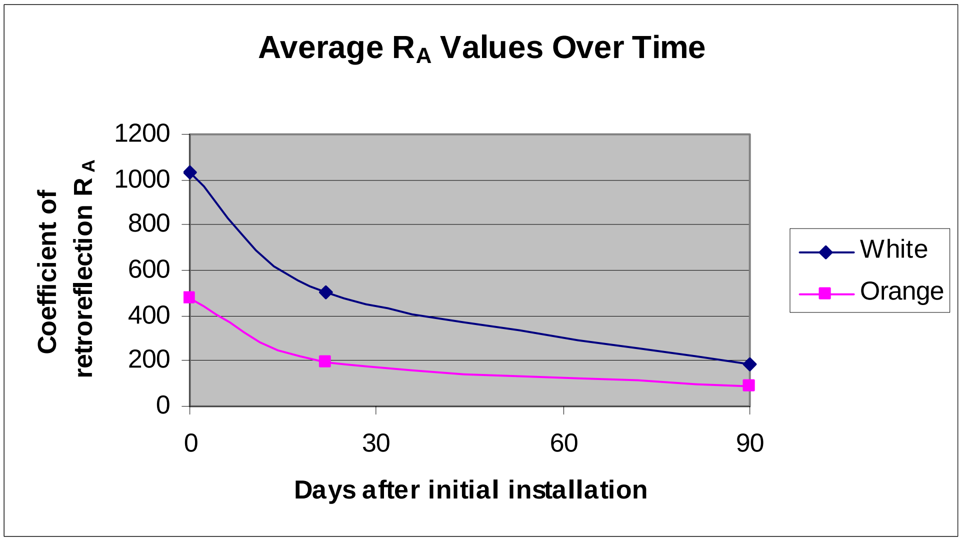

Figure 5.3: Average Coefficient of Retroreflection (R_A)

6.0 SUMMARY AND CONCLUSIONS

In the twelve months that the LDS panels were monitored, they proved to be effective in guiding motorists through difficult detours and lane shifts on the Coast Fork Willamette River Bridge, Medford Viaduct, and Bob Creek Bridge projects. During their time in-service, the LDS panels were evaluated for their effects on vehicle speeds, crashes, and driver perceptions. Figures 6.1 and 6.2 show how the LDS panels performed during the day and at night while installed at the Bob Creek Bridge project.

Figure 6.1: Day and night comparison of Bob Creek Bridge site looking southbound

Figure 6.2: Day and night comparison of Bob Creek Bridge site looking northbound

The effect on vehicle speeds was not tested for statistical significance. However, random observations at both the Coast Fork Willamette River Bridge and the Medford Viaduct sites showed reductions in average speeds by a magnitude of 10-20 mph (16-32 km/h). Although observed speeds were reduced at these sites after the LDS panels were installed, any reduction in speed appeared to be more related to levels of congestion rather than the presence of the LDS panels. When congestion through the work zone was not an issue, most drivers appeared to drive at or below the posted speed in both daytime and nighttime conditions. The fact that only a small percentage of drivers exceeded the posted speed could possibly be attributed to the presence of the LDS panels heightening the alertness of drivers' traveling through the work zone.

During the 12 month observation period, some minor property damage and injury crashes occurred in the work zones at the Coast Fork Willamette River Bridge and Bob Creek Bridge projects. None of these crashes appeared to be related to the presence of LDS panels. Several sideswipe crashes that occurred at Coast Fork Willamette River Bridge are likely attributable to excessive speed or inattentive drivers. At the Bob Creek Bridge project, there was a rear-end crash caused by an inattentive driver approaching the work zone. In contrast, there were several crashes at the Coast Fork Willamette River Bridge project prior to the installation of the LDS panels, including a fatality. Most observers agreed that the LDS panels provided better concrete barrier delineation than traditional barrier markers and drivers seemed more attentive when traveling through the work zone. Although not proven with statistically significant crash data, continued use of LDS panels for concrete barrier delineation could lead to lower crash rates in work zones using concrete barriers for lane shifts and detours.

The installation of the LDS panels proved to be more challenging then envisioned, primarily because installation is a time intensive process. Users need to be aware that productivity rates for installation range from 30 panels per hour for a two person crew to 60 panels per hour for a four person crew. Panels are individually attached to the barrier with anchor bolts after leveling with a chalk line and drilling holes into the barrier. A suggestion, which was repeated by more than one ODOT construction inspector, was to attach the panels to the concrete barriers prior to placement in the work zone. If this method is chosen, construction personnel need to take extra precautions to ensure that the LDS panels are not damaged as the barriers are being moved with heavy construction equipment.

In summary, the LDS panels provide a good alternative to traditional concrete barrier delineation methods (such as reflective barrier markers). At the end of construction, panels can be removed from the barrier and reused on future ODOT projects. Installation requirements, although time consuming, are minimal. The success of the three projects mentioned in this report have led ODOT to consider further implementation of LDS panels on future construction projects, as well as permanent installations in areas where crash histories warrant additional safety measures.

7.0 REFERENCES

3M Corporation. 3M™ Scotchlite™ Linear Delineation System Series 344/346 [online]. Accessed September 2003. URL: http://www.3m.com

Griffith, Andrew and Eric Brooks. *Lighted Guidance Tube Evaluation.* Oregon Department of Transportation, OR-EF-01-02, 2000

French, LJ and K. French. *Evaluation of Concrete Barrier Delineation Under Poor Visibility Conditions.* Institute of Transportation Engineers, 2002 Annual Meeting and Exhibit, 2002