Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-04/4174-1		

4. Title and Subtitle	5. Report Date
IDENTIFICATION OF HAZARDS ASSOCIATED WITH MOBILE AND SHORT DURATION WORK ZONES	September 2003
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Brooke R. Ullman, Melisa D. Finley, and Nada D. Trout	Report 4174-1

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Project No. 0-4174

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080	Research: September 2002-August 2003 14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
Research Project Title: Traffic Control Devices and Strategies to Improve the Safety of Mobile and Short Duration Work Zones

16. Abstract Project

This report documents the research activities completed during the first year of a two-year research project concerning the safety of mobile and short duration work zone operations. The objective of the first year of the research project was to identify the potential hazards associated with mobile and short duration maintenance operations, as well as the probable underlying causational factors.

In order to determine the current practices employed by other states during mobile and short duration maintenance operations, researchers conducted a survey of state transportation agencies. Focus groups of Texas Department of Transportation employees were held to identify the hazards encountered during mobile and short duration maintenance operations, as well as to stimulate new ideas and creative concepts that could improve worker and motorist safety. Field observations of 11 mobile and 18 short duration maintenance operations were conducted to document the work zone setups used, as well as the motorist behavior surrounding these types of work activities.

The primary categories of hazards identified in this research were motorist behavior, motorist comprehension, worker exposure, and vehicle conflicts. In addition, researchers found that the definitions of mobile and short duration maintenance operations, as well as the classification of specific operations, were not consistent.

17. Key Words	18. Distribution Statement
Work Zones, Mobile Operations, Short Duration Operations, Traffic Control Devices	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	114	

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

IDENTIFICATION OF HAZARDS ASSOCIATED WITH MOBILE AND SHORT DURATION WORK ZONES

by

Brooke R. Ullman
Associate Transportation Researcher
Texas Transportation Institute

Melisa D. Finley, P.E.
Assistant Research Engineer
Texas Transportation Institute

and

Nada D. Trout
Assistant Research Scientist
Texas Transportation Institute

Report 4174-1
Project Number 0-4174
Research Project Title: Traffic Control Devices and Strategies to Improve the Safety of Mobile and Short Duration Work Zones

Sponsored by the
Texas Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

September 2003

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report is not intended to constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was Melisa D. Finley, P.E. (TX-90937).

ACKNOWLEDGMENTS

The authors would like to thank the Texas Department of Transportation (TxDOT) and Federal Highway Administration (FHWA), who sponsored the research, and the following individuals who provided guidance and expertise in various phases of the project: Paul Montgomery of TxDOT, who served as project director; Angie Ortegon and Paul Frerich of TxDOT, who served as the project coordinators; Wade Odell of TxDOT, who served as the Research and Technology Implementation (RTI) office liaison; and Greg Brinkmeyer and Craig Kleypas of TxDOT, who served on the project monitoring committee.

The authors would also like to thank the participants of the area engineer focus group, the participants of the TxDOT Maintenance Conference focus group, and the following TxDOT offices who participated in the maintenance crew focus groups and assisted with the field observations: Bryan Area Office, East El Paso Area Maintenance Office, Fort Bend Maintenance Office, Southeast Dallas Maintenance Office, and San Angelo District Office.

In addition, the authors would like to acknowledge the following individuals at the Texas Transportation Institute who provided valuable assistance during this project: Sandra Sanders, Andrew Holick, Dan Walker, and Todd Hausman.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

1. INTRODUCTION

Mobile and short duration operations present a traffic control challenge due to the impracticality of installing traffic control devices for these operations due to the fact that it takes longer to setup the traffic control devices than to perform the work activity. Maintenance work is often accomplished using mobile work zones where one or more vehicles move along the road intermittently or continuously at very slow speeds relative to the normal traffic stream. Short duration work zones occupy a location for only up to one hour. Research was needed to identify and evaluate new strategies and technologies that could be used to improve the safety of mobile and short duration work zone operations.

PROJECT OVERVIEW AND REPORT ORGANIZATION

This report documents the research activities completed by the Texas Transportation Institute (TTI) during the first year of a two-year research project for the Texas Department of Transportation (TxDOT). The objective of the first year of the research project was to identify the potential hazards associated with mobile and short duration maintenance operations, as well as the probable underlying causational factors. Described below are the activities that were completed, as well as the report organization.

- *Literature Review* – The research team reviewed the current guidelines, as well as previous research, concerning mobile and short duration work zone operations. Chapter 2 summarizes the guidelines and research reviewed.
- *State Survey* –To determine the current practices employed by other states during mobile and short duration maintenance operations, as well as the hazards associated with this type of traffic control, researchers conducted a survey of state transportation agencies. Chapter 3 documents the responses received from 17 states.
- *Focus Groups* – Seven focus groups were conducted to obtain the opinions of both field and supervisory personnel concerning the safety of mobile and short duration maintenance operations. In addition, the focus groups were used to stimulate new ideas and creative concepts that could improve worker and motorist safety. Chapter 4 contains the results of the focus groups.
- *Field Observations* – The research team also conducted field observations of 11 mobile and 18 short duration maintenance operations to document the work zone setups used, as well as the motorist behaviors surrounding these types of work activities. Chapter 5 summarizes the characteristics of each observed work zone, while Chapter 6 documents the results of the field observations.
- *Conclusions* – Based on the results of the first year activities, the research team identified potential strategies and technologies that may improve the safety of mobile and short duration maintenance operations. Chapter 7 contains these conclusions and recommendations for second year work activities.

2. LITERATURE REVIEW

Temporary traffic control planning provides for continuity of the movement of motor vehicles and other modes of transportation when the normal function of a roadway is suspended. Consideration for the safe and efficient movement of the road user, as well as the safety of the workers, is an integral element of every work zone. However, this is challenging since conditions are constantly changing, and no one set of traffic control devices can satisfy all conditions. In addition, as the need to rehabilitate and improve existing roadways increases, the exposure of both workers and motorists to work zones will continue to increase.

TYPES OF WORK ZONES

Many variables, such as type of work, location of the work, road type, road geometry, and traffic volumes, affect traffic control needs at each work zone. A major factor in determining the traffic control devices to be used is work duration. The five categories of work duration are (*1*, *2*, *3*):

- mobile – work that moves intermittently or continuously;
- short duration – work that occupies a location up to one hour;
- short-term stationary – daytime work that occupies a location from one to 12 hours;
- intermediate-term stationary – work that occupies a location more than one daylight period up to three days, or nighttime work lasting more than one hour; and
- long term-stationary – work that occupies a location more than three days.

The traffic control that is typically used with short-term stationary, intermediate-term stationary, and long-term stationary operations is relatively extensive since the work zone is semi-permanent and worker exposure to the traffic stream is fairly high. In contrast, the traffic control for mobile and short duration operations is generally portable and consists of relatively few devices due to the nature of the work area (i.e., short work time and/or moving work area).

GUIDELINES

The Millennium edition of the Manual on Uniform Traffic Control Devices (MUTCD) (*1*) and the 2003 Texas MUTCD (*2*) support the need for a simplified control procedure for mobile and short duration operations. In general, both manuals state that mobile and short duration operations might involve different types of traffic control devices or a reduction in the number of traffic control devices because it often takes longer to set up and remove the devices than to perform the actual work. More specifically, the manuals state that appropriately colored or marked vehicles with rotating/strobe lights may be used in place of signs and channelizing devices. Both manuals also note the importance of the mobility of the traffic control, so that it can be moved periodically as the work progresses. However, these manuals explicitly state that the safety of mobile and short duration operations should not be compromised by using fewer devices simply because the operation will frequently change locations.

TxDOT uses mobile and short duration operations for a variety of work activities including, but not limited to, pavement marking placement, pothole patching, crack sealing, sweeping, litter

cleanup, sign maintenance, and herbicide. The Texas MUTCD and TxDOT traffic control plans (*3*) address mobile operations on two-lane, two-way roadways, undivided multilane roadways, and divided multilane roadways. The following vehicles and traffic control devices may be used with mobile operations: lead vehicle, work vehicle, shadow vehicle, trail vehicle, yellow rotating beacons or strobe lights, Type B or C arrow panels, truck mounted attenuators (TMAs), flaggers, channelizing devices, flags, and signs. Based on the prevailing roadway conditions, traffic volume, and sight distance restrictions, the engineer determines if the lead vehicle and/or the trail vehicle are required. In addition, the Texas MUTCD provides guidance to the engineer concerning what traffic control devices and vehicles should be used in high-volume conditions.

The Texas MUTCD and TxDOT traffic control plans also address short duration operations on two-way roadways, undivided multilane roadways, and divided multilane roadways. The following vehicles and traffic control devices may be used with short duration operations: work vehicle, shadow vehicle, rotating lights or strobe lights, arrow panels, portable dynamic message signs (DMSs), TMAs, flaggers, channelizing devices, flags, and signs. TxDOT uses many of the same standard traffic control plans for short duration operations and longer duration work (e.g., work that occupies a location for more than one hour); thus, some of the traffic control plans include fairly complex setups. However, as discussed previously, since it often takes longer to set up and remove the traffic control devices than to perform the actual work, a reduction in the number of traffic control devices may be warranted for short duration operations. Thus, all of the devices listed above are not always used.

RELATED RESEARCH

From 1977 to 1981, TTI conducted multiple studies in Texas to develop improved guidelines, as well as more specific guidelines, for traffic control during urban freeway maintenance activities (*4*). As part of these studies, researchers observed five moving maintenance operations on urban freeways. Based on the observations, researchers identified safety problems and grouped them into design-related and operational-related categories. The freeway design elements that contributed to the safety problems were:

- entrance and exit ramps,
- major interchanges (freeway-to-freeway), and
- horizontal and vertical curvature.

At ramps near the work activity, researchers observed motorists crossing through the work convoy and making erratic maneuvers. To reduce motorist confusion and indecision, researchers recommended the use of temporary ramp control, advance signing, and/or better control of the work convoy length. At major interchanges when the work convoy was near the entrance or exit ramp connectors, researchers observed motorist confusion with identifying the proper lane they should be in for the desired routing. In this situation, it was recommended that maintenance workers use special interchange signing and temporary ramp closures. Researchers also noted that a major problem at horizontal and vertical curves was providing adequate sight distance to the work convoy. The use of advance signing and better control of the work convoy length was recommended to reduce this problem.

The operational elements that contributed to the safety problems were:

- improper use of arrow panels,
- lack of uniform procedures for freeway entry and exit,
- large spacing between convoy vehicles, and
- unnecessary lane blockage by the convoy.

Researchers observed the work convoy displaying incorrect information on arrow panels to approaching motorists (e.g., flashing left or right arrow when it should be displaying caution). Researchers recommended the placement of the arrow panel controls inside the vehicle, so the displays could be changed as needed. Movement of the work convoy onto and off of the freeway can have a major effect on the operation of the roadway; however, entry and exit procedures differed for each maintenance crew observed. Researchers recommended the development of uniform procedures for freeway entry and exit to help alleviate the problems observed. Researchers also observed large spacing between the work convoy vehicles and unnecessary lane blockage by the work convoy. Since large spacing between work vehicles encourages motorists to enter into the convoy, researchers recommended guidelines for work convoy spacing.

3. STATE SURVEY

The research team conducted a survey of state transportation agencies with regard to mobile and short duration maintenance operations. The purpose of this survey was to determine the current practices employed by states during mobile and short duration maintenance operations, as well as to identify hazards associated with traffic control in these situations. The survey was distributed to 49 state transportation agencies (all except Texas) using email. Responses were received from 17 states, representing a return rate of 35 percent. Of these responses, Maryland did not return the official survey but sent supporting materials as examples of their current practices for temporary traffic control.

DEFINING MOBILE AND SHORT DURATION MAINTENANCE OPERATIONS

The researchers' initial concern was to ensure that each of the responding states was working with the same definitions of mobile and short duration maintenance operations. The state transportation agencies established if their state's definitions of mobile and short duration operations were consistent with TxDOT's based on the following TxDOT definitions provided to them:

- mobile maintenance operations – work that moves intermittently or continuously, and
- short duration maintenance operations – work that occupies a location up to one hour.

The majority of the responding states indicated that the definitions used in their areas were consistent with those provided in the survey. However, there were some cases in which the definitions varied from those indicated or had minor alterations based on the identified cases. For mobile maintenance operations, the Oregon DOT definition contained no reference to intermittent stops. Thus, the Oregon DOT defines mobile maintenance operations as continuously moving operations only. It was also noted that in different states, snow and ice removal were either specifically included in a state's examples of mobile operations (Alaska and Nevada DOTs) or specifically excluded from the mobile maintenance definition (Illinois DOT).

The short duration maintenance operation definitions varied from allowing less than 15 minutes of work (Oregon DOT) to work that lasts up to 12 hours (Maryland DOT). For the Nevada DOT, their definition agrees with the one stated above; however, the survey indicates that the agency acknowledges that the work categorized in this area could take several hours. One interesting note made by several states is that the work encompassed by the definition of short duration maintenance can frequently take a shorter amount of time to complete than to set up and remove the appropriate traffic control devices. Interestingly, the short duration maintenance criteria established for the Florida DOT falls within TxDOT's mobile maintenance operations definition. In this case, the Florida DOT considers intermittent stops in the same terms as TxDOT classifies short duration work.

One particularly unusual case identified was the definitions utilized by the New York DOT. Three categories of work were included in the responses from the New York DOT: mobile, slow

moving, and short duration stationary operations. The three work categories were aligned with the TxDOT definitions using examples of work provided by the New York DOT:

- *Mobile* – Although the term mobile was used as a descriptor, the activities defined under this category (debris pickup, signal lamp change, traffic counter installation) were more closely related to the TxDOT definition of short duration operations. Researchers believe that this work is termed "mobile" within New York due to the fact that the operation does not occupy one site for a significant period of time.
- *Slow Moving* – The work activities defined within this category are those in which special equipment or workers on foot in the roadway are moving at a slow pace (pouring cracks, pavement overlay). In this evaluation, these operations align with the TxDOT definition of mobile maintenance operations.
- *Short Duration Stationary* – These activities are considered to be any work that would occupy an area for greater than a brief period (installing signs, guard rail repair, patching pavement). Again, this falls within the definition of the TxDOT short duration operations; however, the time allowed under the New York DOT activities can be up to one working day (i.e., eight hours).

Survey respondents were also asked to identify the conditions under which they used either mobile or short duration maintenance operations. Table 1 contains the most common responses to this question. Even though the answers greatly varied, many of the operations commonly identified were given both for mobile and short duration maintenance activities. This emphasizes the issue that the categorization of mobile and short duration operations is difficult.

Table 1. Maintenance Operations Identified as Mobile or Short Duration by Survey Respondents.

Mobile Maintenance Operations	Short Duration Maintenance Operations
Crack Sealing	Guardrail Work
Debris Removal	Lighting Maintenance
Herbicide	Paving Operations
Mowing/Brush Cutting	Pothole Patching
Pothole Patching	Sign Repair and Installation
Raised Pavement Marker Replacement	Signal Work
Sign Repair	
Snow and Ice Control	
Striping	
Sweeping	

CURRENT PRACTICES

Of the states that responded, all have defined procedures and plans for mobile and short duration maintenance operations. The most common response was that the standards and plans were compliant with those set by the MUTCD. In addition, all responding states indicated that they have standard traffic control plans for mobile maintenance operations, and all but one of the

responding states indicated that they have standard traffic control plans for short duration maintenance operations. The state that does not have specific standards for short duration operations (Connecticut) leaves it to the general supervisors of the maintenance crews to use their best judgment and simplify the standard traffic control plans used for longer duration work zones to fit the current situation. In the case of both mobile and short duration maintenance operations, the procedures outlined by the responding states are, for the most part, consistent with the current practices of TxDOT.

Beyond these basic guidelines, 12 of the responding states have also created maintenance or safety manuals that address the issue of common procedures for mobile and short duration maintenance operations and worker safety. Within these manuals, the states address a variety of issues with the common components being:

- general guidelines (taper lengths, buffer zones, traffic control devices, etc.),
- flagger instruction, and
- work zone diagrams or layouts.

The work area diagrams presented in the manuals are typically broken into sections based on the type of roadway and the effected area of the roadway (i.e. shoulder, lane, center lane) instead of by duration of work. However, most of the manuals address mobile operations as a separate issue. In the mobile operations sections, work is again typically separated based on the roadway type and the effected area of the roadway. One point of interest within this section is that several of the manuals provided diagrams for specific operations such as:

- striping,
- mowing and chemical treatment (herbicide), and
- pothole and edge patching.

There are a few points of interest that stood out within the manuals provided by the states. In the Illinois DOT diagrams, daily speed of the operation is a deciding factor in selecting traffic control for mobile operations. If the operation is moving less than 4 miles/day, the work zone setup requires a greater number of signs.

Included with the Maryland DOT guidelines for traffic control are device selection charts. The charts identify the required and optional devices based on roadway type, work location, roadway speed, and work duration.

The short duration and mobile operations diagrams from the Michigan DOT included information on speed reductions. In this case, speed reduction signs are located on the shadow vehicles. The Michigan DOT also provided a list of considerations regarding the use of optional shadow vehicles. The shadow vehicles are considered mandatory for any lane closure on roads with speeds greater than 55 mph; however, shadow vehicle use in other work situations is based on the following factors:

- time of day,
- seasonal traffic volume variations,
- length and duration of lane closure,
- roadway speed, and
- vehicle behaviors (i.e., stopping and turning).

In the Oregon DOT safety manual, the discussion provided under the scope of the manual highlights an important issue: safety considerations surrounding the trade-off between the amount of time it takes to set up and remove traffic control devices and the duration of the work. The following is a direct quote from this manual.

> "There are safety concerns for the crew in setting up and taking down traffic control zones. Since the work time is short, the time during which road users are affected is significantly increased when additional devices are installed and removed. Considering these factors, it is generally held that simplified control procedures are warranted for short duration activities. Such shortcomings may be offset by the use of other more dominant devices such as special lighting units on work vehicles" (5).

A quote, from the Washington DOT manual also addresses the set up and removal of traffic control devices: "Remember, short duration work is not a 'short-cut'; it's a traffic control method that reduces worker exposure to traffic hazards by using larger, more mobile equipment instead of many smaller devices" (6).

Finally, special note should be made of the Arkansas safety manual. Within this manual, although there are standard layout diagrams and recommendations, the focus centers on what the worker should be doing to ensure their own safety. This includes such items as how to handle asphalt safely and how best to place equipment for safety. This specific focus makes the manual much more worker and job-duty oriented versus operation oriented.

HAZARDS

Survey respondents generally felt that the hazards encountered during mobile and short duration operations were similar. The primary hazards identified were:

- high speed traffic,
- inattentive motorists not noticing the work area,
- shadow vehicles being rear-ended by traffic, and
- erratic vehicles entering the convoy or work area.

The states address some of these issues through the use of additional advance warning devices such as signs, shadow vehicles, or portable DMSs. It is believed by some respondents that if the traveling public can be alerted sooner to the upcoming conditions, they will react in a more appropriate manner to the situation, such as changing lanes further upstream of the work area or slowing down.

Operational considerations taken to reduce hazards include increasing the work zone length to allow greater reaction time, ensuring a correct work zone setup to provide motorists optimum warning, and using spotters to warn exposed workers when they are in immediate danger.

Additional ideas that have been used to address the hazards are law enforcement and drone radar to slow down traffic, and an annual public information program used in Wisconsin to increase driver awareness of work zones. The New York DOT has specifically identified six intrusion countermeasures to be used in their operations:

- increased police enforcement,
- reduced channelization spacing,
- enhanced flagger station,
- rumble strips,
- reduced speed limits,
- DMSs, and
- drone radar.

NEW TECHNOLOGIES

During this effort, researchers also identified new technologies or procedures utilized by the state DOTs as a means of reducing hazards to workers and the traveling public. Again, the responses received for mobile and short duration operations were very similar. The most common response given by states was that the use of portable DMSs has greatly helped their operations through the ability to provide drivers with real-time, accurate early warning information about the upcoming work area. In two states, Georgia and Washington, DMSs have been mounted on shadow vehicles. Also, many states mentioned using standard traffic control devices more frequently. Devices included in this group are truck-mounted attenuators, highway advisory radio, and arrow panels. The increased use of standard traffic control devices is considered to be especially effective in increasing motorist awareness and worker safety on high-speed roadways. Arkansas mentioned the addition of flashing lights to truck mounted warning signs as a means of capturing the attention of motorists. All states felt that the technologies they implemented increased the safety of their mobile and short duration maintenance operations.

SUMMARY

Researchers conducted a survey of state transportation agencies to determine the current practices employed by states during mobile and short duration maintenance operations, as well as to identify hazards associated with this type of traffic control. Below is a summary of the findings.

- The primary hazards identified relate to motorist behavior (e.g., speeding and inattention) and the interaction between traffic and the work vehicles (e.g., erratic vehicles entering or hitting the convoy).
- Countermeasures used as a means to reduce these hazards included the addition of traffic control devices, the use of law enforcement, and driver education.

- Several states expanded their basic guidelines to include specific recommendations regarding required and optional traffic control devices based on work location, work duration, roadway speed, and/or the speed of the operation.

4. FOCUS GROUPS

Researchers used the focus group method to identify the hazards encountered during mobile and short duration maintenance operations, as well as to stimulate new ideas and creative concepts that could improve worker and motorist safety. The focus groups targeted two different segments of TxDOT personnel. The first was field personnel (i.e., employees who perform maintenance activities on a day-to-day basis), and the second was supervisory personnel (i.e., area engineers and maintenance supervisors).

FIELD PERSONNEL FOCUS GROUPS

Participants

To obtain opinions on operations and potential hazards related to mobile and short duration maintenance operations from a field personnel perspective, TTI researchers held focus groups with maintenance personnel in the following five TxDOT districts: Bryan, El Paso, Houston, Dallas, and San Angelo. In each of the districts, researchers held a focus group at either an area office or maintenance office. Researchers invited all personnel within a maintenance office to attend the focus group and share their opinions on mobile and short duration maintenance operations. In total, 87 maintenance personnel participated in the discussions. Table 2 contains information regarding the location and participants for each focus group.

Table 2. Focus Group Locations and Participants.

District	Focus Group Location	Number of Participants	Average Years of Experience
Bryan	Bryan Area Office	15	15
El Paso	East El Paso Maintenance Office	17	16
Houston	Fort Bend Maintenance Office	24	10
Dallas	Southeast Dallas Maintenance Office	24	10
San Angelo	San Angelo District Maintenance Office	7	17

Protocol

The organization of the focus group protocol established a directed discussion where each type of operation was addressed separately. However, at different times during the focus group process, the research team altered the order of the questions to enhance the flow of the resulting discussion. An example of the protocol can be found in Appendix A.

To obtain background information on the participants and to encourage the participant to focus on maintenance operations, the moderator distributed a short survey prior to the focus group. In response to the primary question on the survey, participants identified the type of maintenance operation they felt was the most hazardous.

To begin the discussion, the moderator asked each participant to share with the group the number one hazard (or closest call) they had encountered while completing mobile or short duration maintenance operations. Once each participant had an opportunity to respond to this question, the moderator led the group through the rest of the protocol in an open discussion format.

Definitions of Mobile and Short Duration Operations

As a point of reference, each group identified for researchers the types of operations they considered to be classified as either mobile or short duration maintenance operations. Tables 3 and 4 detail the responses received from each of the focus groups.

Table 3. Maintenance Operations Considered to be Mobile by Field Personnel.

Maintenance Operation	Districts				
	Bryan	El Paso	Houston	Dallas	San Angelo [a]
Crack Sealing	X	X	X		
Edge Repair		X			
Herbicide	X	X	X	X	
Pothole Patching	X			X	
RPM [b] Installation	X		X		X
Sealcoat	X				
Sign Maintenance			X	X	
Snow Removal		X			
Spot Litter Pickup		X	X		
Striping		X	X		X
Sweeping	X	X	X		

[a] This crew was specifically responsible for pavement markings.
[b] RPM - Raised Pavement Marker

Similar to the state survey results, different focus groups classified the same operations as both mobile and short duration. This highlights the issue that selecting the proper traffic control setup for maintenance operations can be difficult for field personnel since the classification of mobile and short duration operations is not consistent. Thus, there may be a need to create a greater distinction between mobile and short duration operations, as well as providing guidance with respect to the application of standards to specific operations.

Another issue identified during this discussion was that workers do not always use the proper definition of short duration maintenance (i.e., work activity that occupies a location up to one hour). In the San Angelo and Houston Districts, participants classified several work activities that take two to eight hours to complete as short duration operations.

Table 4. Maintenance Operations Considered to be Short Duration by Field Personnel.

Maintenance Operation	Districts				
	Bryan	El Paso [a]	Houston	Dallas	San Angelo [b]
Bridge Repair		X			
Crack Seal		X			
Ditch Maintenance			X		
Edge Repair		X			
Guardrail Repair		X			
Hot Tape					X
Litter Pickup	X				
Milling Asphalt		X	X		
Pothole Patching	X	X	X	X	
Rumble Strips					X
Sign Maintenance	X	X	X	X	
Shoulder Work		X			
Spot Litter Pick-up	X			X	

[a] El Paso defined short duration as work that takes less than eight hours or one day to complete.

[b] This crew was specifically responsible for pavement markings.

Bryan District

In both the initial survey and the group discussion, the hazards identified by the Bryan District focus group were somewhat broad and did not indicate a particular hazardous event. Many of the participants stated that any work activity on the roadway is a hazard. However, the group mentioned some more specific situations including:

- operations on high-volume, high-speed roadways,
- working on hot mix asphalt projects at intersections,
- removing debris from the roadway, and
- flagging.

The number one hazard identified with regard to both mobile and short duration maintenance operations was inattentive motorists. Additional hazards that were identified in relation to mobile maintenance were speeding and vehicles entering the convoy or encroaching on the work area. With respect to vehicles entering the convoy, participants noted that as soon as a motorist passes the shadow vehicle, the motorist moves back into the closed lane between work vehicles.

As a means of improving the safety of mobile maintenance operations, the addition of a second vehicle with a TMA has been used as a means of providing motorists with additional advanced warning of a work activity. Another recommendation is to use a complete lane closure to increase the safety of workers when performing RPM installation or seal coat activities.

For short duration activities, the addition of light bars and blue lights to vehicles have been used to increase the visibility of the operations. Workers also believe that the use of florescent yellow-green (FYG) vests increase worker visibility and improve safety.

Additional suggestions regarding improving the safety of both mobile and short duration maintenance operations include the use of law enforcement to control speeding and detouring traffic to frontage roads so that work activities on high-volume, high-speed roadways can be completed without interacting with traffic.

El Paso District

Similar to the Bryan District focus group, several participants in the El Paso District stated that any work activity on the roadway is a hazard. However, the group mentioned the following more specific situations:

- operations on high-volume, high-speed roadways,
- rotomilling,
- sweeping in depressed roadway sections, and
- shoulder work on two lane roadways.

With respect to mobile operations, the entire group agreed that the greatest hazards encountered are speeding and inattentive motorists. With regard to sweeping, participants feel that motorists cannot see the amber lights and arrow panels when the sweeper travels around corners.

It should be noted that the El Paso District focus group defined short duration maintenance operations as work that takes less than eight hours (or one workday) to complete. Thus, not all of the suggestions and concerns addressed during the discussion were relevant to this research. One hazard identified with respect to short duration operations was motorist comprehension of text signs in border areas due to the large population of non-English speaking motorists. The group feels that symbols on signs are a more effective means of expressing the necessary information to motorists. The group states that it is common practice for them to place additional signs and extend the work zone for short duration maintenance operations as a means to enhance the work area visibility and, therefore, safety.

Another hazard mentioned involves commercial vehicles that travel close together (i.e., one right behind another). Workers have observed that when the first commercial vehicle makes a last minute lane change out of the blocked lane, the second commercial vehicle driver does not have time to react. Participants specifically mentioned two incidents where the rear vehicle of a striping operation was hit in this type of situation. When flagging, the participants indicate that they feel it is necessary to move around to capture the attention of multiple commercial vehicles in convoy even though the flagger-training course teaches field personnel to stand in one location. They suggested that the flagger guidelines be revised to address this issue. In addition, the participants expressed a need to educate the public on how to react to and interpret the actions of a flagger.

Suggestions provided by the group to address these hazards include the use of:

- arrow panels on the back of sweepers,
- additional lights (specifically red or blue) on work vehicles,
- radio station announcements to alert the public about maintenance work areas,
- portable traffic signals to capture the attention of motorists, and
- advance stop signs to stop traffic prior to arriving at the work area.

The group feels that there is no significant difference in the hazards faced in mobile versus short duration operations. Hazards identified by the group concerning both mobile and short duration operations are the setup/removal of traffic control devices, the low visibility of vests from a side perspective, and motorists who stop in the open lane of traffic to ask workers questions. Overall, the major hazards concerning mobile and short duration operations that the entire group agreed upon included:

- speeding,
- motorists ignoring or not understanding traffic control devices,
- vehicles entering the convoy,
- road rage, and
- inattentive motorists.

Final suggestions regarding the improvement of motorist and worker safety include the use of law enforcement, steeper fines, and education to affect motorist behavior.

Houston District

In identifying their most hazardous situation, the Houston District focus group responses were somewhat general; however, the majority focused on traffic control procedures and setup. Others stated lane closures, motorist inattention, and flagging as the number one hazard.

During all areas of discussion, the primary concerns expressed by the participants were inattentive motorists ignoring the traffic control and/or flagger and vehicles entering the work area. This was specifically a concern during mobile maintenance operations, as the traveling public will go around the shadow vehicle and then enter the work convoy. Other concerns mentioned by the group include:

- high traffic volumes and speeds,
- vehicles stopping in an active lane, and
- wide-load vehicles maneuvering in work areas.

The group suggested the following items to capture the attention of motorists:

- the use of better or additional lighting on work vehicles, such as solid light bars, blue lights, or light emitting diode (LED) lights;
- the use of flags instead of stop/go paddles;
- the use of flashing DMSs;
- the use of cones during shoulder work to increase visibility of the work area;
- the use of police to enforce traffic laws, specifically the double fine law; and
- the use of public service announcements (PSAs) and driver training to educate the public on the importance of work zones.

Worker complacency is a concern in relation to short duration maintenance operations. It is the opinion of the group that workers are in a hurry during these types of operations and thus do not focus on the traffic control. One solution stated to address this concern includes the crew leader establishing a work plan prior to beginning the traffic control setup. This allows the crew leader to ensure that everyone understands what is to be accomplished. The group also notes that communication among the crew is vital because if workers are confused about the operation, it is likely that motorists will be confused.

The group feels that the primary difference between mobile and short duration operations is the dynamic nature of the hazards associated with mobile operations. For example, as a mobile operation progresses along the roadway the work activity can move from a section with no turning movements into an area with a side street. Because of this variability, workers feel they need to be more attentive during mobile operations. Another comment suggested that the hazards are more dependent upon the work location (i.e., in a lane or on a shoulder) than the type of work activity.

Dallas District

The responses from the Dallas focus group regarding the most hazardous operation varied greatly. Some of the main points include:

- lane closure operations,
- setup and removal of traffic control devices,
- sign repair,
- mobile pothole repair,
- any type of work on a roadway, and
- any type of maintenance operation.

The primary hazard addressed by the group is motorist inattention to work zones. Participants specifically mentioned the following driver behaviors:

- "hugging" the line near the work area,
- speeding,
- cutting through a convoy or work area, and
- last minute lane changes.

The group also feels that some of the worst hazards are created when setting up and removing traffic control devices. The participants indicate that the use of a shadow vehicle increases the safety of the workers in this situation.

Another issue discussed is the ineffectiveness of the stop/slow paddle. The group's perception is that motorists obey the stop side of the paddle but tend to increase their speed when the slow side is displayed. In addition, the group prefers to use a flag instead of the stop/slow paddle. The participants agree that the use of law enforcement is the most effective method to slow down motorists.

In a discussion related specifically to short duration maintenance operations, the group stated that when installing signs, there is often very little space to move off the roadway; thus, traffic is very close to the work activity. Additionally, when the crew is working at a gore area, there is an increased hazard because drivers are indecisive about their direction of travel. As a solution, workers are setting up cones to alert traffic even though this increases the workers' exposure to the traffic stream. One member of the group states that workers can use signs on either side of the road, different types of cones, or strobe lights on the work vehicles to capture the motorist attention.

When asked to identify the differences between the hazards that occur with mobile and short duration maintenance operations, participants indicate that during short duration operations workers experience more exposure to traffic since they are out of a vehicle.

Suggestions on how to improve the safety of mobile and short duration maintenance operations include the following:

- the use of more enforcement,
- expanding the double fine law to include maintenance areas,
- the use of red and blue lights,
- the use of different color signs for maintenance activities,
- the use of additional signs,
- improving the reflective safety apparel,
- using a spotter, and
- closing lanes adjacent to the work area.

San Angelo District

It should be noted that the maintenance personnel who participated in the San Angelo District focus group specialized in pavement marking operations. This differed from the other focus groups where the participants were responsible for multiple types of maintenance operations.

The responses of the group regarding the most hazardous operations focused on the placement of RPMs. The following are the key concerns mentioned by the group:

- motorists do not understand how to react to the convoy,
- misinterpretation of arrow panels (especially in four-corner caution mode),
- speeding, and
- lack of visibility to motorists.

The group identified inappropriate motorist behaviors as the most frequently encountered hazards during mobile operations. Specifically, they mentioned high-speed traffic and road rage due to the slow speed of mobile operations. Also mentioned was the relationship between traffic volume and the number of motorists entering the work convoy. More specifically, as the traffic volume increases, more vehicles tend to enter the convoy.

Suggestions for improving the safety of mobile operations include educating the public on the meaning of the four-corner caution mode (possibly through a newspaper article) or, as an alternative, using the word "CAUTION" on a DMS. However, the group noted that the addition of more devices to mobile maintenance operations could be detrimental to motorist comprehension, since motorists only have a short amount of time to process all of the information provided when traveling at high speeds.

Unique to the mobile operations in the San Angelo District is the use of a speed display board. TxDOT purchased the speed display board two years ago to improve the safety of mobile operations. The board is mounted on the rear of the trail vehicle and displays the speed of approaching vehicles. The participants' opinion is that the speed displays capture the attention of the traveling public, especially commercial vehicle drivers. However, the group also noted that the reaction varies depending on the age of the driver, with older drivers having to get closer to the convoy before being able to read the display.

SUPERVISORY PERSONNEL FOCUS GROUPS

Focus groups were held with supervisory personnel to obtain insight into the concerns being addressed at an administrative level. The focus groups were held in two locations during conferences sponsored by TxDOT and involved participants from across the state. In both cases, researchers strived to attract a diverse group of TxDOT personnel in relation to experience and work environment.

Protocol

Researchers organized the protocol for the supervisory focus groups based on categories of work (i.e., mobile vs. short duration). The moderator led the group through the discussion. To begin, the moderator had everyone share their greatest concern relating to maintenance operations. The session then continued in an open discussion format led by the moderator to ensure that all topics were discussed. Appendix B contains an example of the protocol.

Prior to the start of the discussion, the moderator asked participants to complete a survey that collected basic background information on the participants and started the participants focusing on mobile and short duration maintenance operations. Researchers changed the survey questions following the first focus group. Initially, participants were asked to only define mobile and short duration operations. At the second focus group, participants also identified the type of operations they felt were the most hazardous.

TxDOT Area Engineer Focus Group

Participants

The eight participants at this focus group were TxDOT area engineers attending the 76th TxDOT Annual Transportation Short Course. Table 5 provides background information on the group participants. Three of the area engineers were from rural areas, two were from urban areas, and the remaining three were from areas that consist of both urban and rural conditions. All of the participants have worked for TxDOT in some capacity for at least 14 years.

Table 5. TxDOT Area Engineer Focus Group Background Information.

District	Area		Years Employed by TxDOT	Years of Experience in Maintenance Operations	Percent of Maintenance Work Completed	
	Urban	Rural			By TxDOT (%)	By Contract (%)
Houston	X	X	15+	4+	20	80
Austin		X	15	7	25	75
Houston	X	X	19+	4	50	50
El Paso	X	X	15	12	50	50
Bryan	X		17	10	60	40
Dallas	X		16	15	50	50
San Antonio		X	23	20	60	40
San Antonio		X	14	5	60	40

Results

Table 6 is a summary of the responses provided by the participants when asked to define mobile and short duration operations. Interestingly, three of the eight participants define mobile operations as work that does not stop on the roadway or is continuously moving along the

roadway. However, the Texas MUTCD (2) defines mobile operations as work that moves intermittently or continuously. In addition, half of the participants consider work that takes one day to one week to be short duration operations, even though the Texas MUTCD defines short duration operations as work that occupies a location up to one hour. These findings illustrate the lack of consistency between the definitions used by area engineers for each type of operation.

This trend is also evident in the type of operations considered to be mobile or short duration. The participants consider the following operations to be mobile: sweeping, striping, pavement markings, herbicide, crack seal, spot litter pickup, and pothole patching. However, some participants also consider pothole patching to be short duration. As discussed previously in the chapter, the inconsistency among the definitions and classification of mobile and short duration operations makes it difficult for personnel to determine which traffic control setup should be used.

Table 6. TxDOT Area Engineer Focus Group
Definitions of Mobile and Short Duration Operations.

Mobile Operations	Short Duration Operations
Litter pick up, frequent stops, on side of the road – daily operations	No more than a daily operation, typically a few hours (e.g., pothole repair and instant patch material)
Impractical to do a standard lane closure	Practical to implement a lane or shoulder closure
Takes one hour or less at one location	Takes less than eight hours at one location
Not stationary and usually in a convoy configuration	Taking place in a defined area designated by appropriate signage
Constantly moving at approximately 3 mph (e.g., striping, buttons, and crack sealing)	One hour or less
Roadway repair made in a lane closure where work is done without equipment stopping on roadway	Work completed within one day or one week, depends on whose definition of short duration used
Striping, button placement	Pothole, debris removable
Work continuously moving along roadway (e.g., striping and sweeping)	Work requiring signs and barricades set up for one to two day periods (e.g., stabilization and pothole repair)

Based on the focus group discussion, the following concerns regarding mobile and short duration operations were identified:

- motorist understanding of work zone traffic control devices,
- motorist inattention,
- effectiveness of current traffic control devices,
- proper setup of short term traffic control devices,
- safety of workers and their length of exposure to traffic, and
- lack of training for new employees.

All participants agree that motorist understanding of work zone traffic control devices is an issue. Two of the participants suggested that more training regarding traffic control devices be added to driver education courses. The group considers the following traffic control devices to be misunderstood by motorists:

- signs with flags,
- stripes on barricades and vertical panels,
- various construction signs,
- stop/slow paddle, and
- typical pavement markings.

In addition, participants are concerned with motorist inattention and the effectiveness of the traffic control devices currently used. The entire group believes that more law enforcement is the most effective way to increase motorist attention and compliance with work zone operations. However, they identified several problems with hiring off-duty officers on maintenance activities, such as providing insurance coverage and the cost. Suggestions to improve the effectiveness of traffic control devices include:

- research on more effective sign colors (e.g., fluorescent orange);
- the use of flags, not stop/slow paddles;
- the use of high-intensity flashing lights;
- the use of flags on signs; and
- the use of circular object markers with high-intensity sheeting.

Participants are also concerned with proper setup of traffic control devices, especially when the setup takes longer than the repairs. All of the participants agree that a major issue is the balance between productivity and safety. It was noted that workers are reluctant to utilize extensive traffic control for work that only takes a few minutes to complete. In addition, the set up and removal of traffic control devices increases the workers' exposure to traffic. The conflict between work duration and the time it takes to implement traffic control often results in the use of inadequate procedures.

Another related issue raised by participants is the location of the traffic control devices with respect to the work activity. The group felt that when traffic control is set up too far in advance of the work activity, motorists ignore the traffic control devices and are surprised by the operation. With respect to proper setup of traffic control devices, the following strategies were suggested:

- implement restricted guidelines on the use of mobile operations,
- conduct safety meetings every morning,
- ensure that the traffic control required for both mobile and short duration operations is relative to the duration of the work, and
- ensure that traffic control devices are moved with the work activity.

A lack of adequate training for new employees was another issue raised by participants. Participants state that this lack of training occurs because of the high turnover rate of employees. In addition, the increase in the number of new employees leads to crews that are not as experienced and may not realize the importance of temporary traffic control.

The entire group agrees that worker complacency is a problem. One suggested solution is to implement a method for rewarding workers based on safety. Another participant states that part of the problem is the restriction on the number of maintenance employees that can be hired and suggests that TxDOT hire more employees who can be shared throughout a district or increase the amount of contract work.

At the conclusion of the focus group, the moderator asked participants to identify the top three hazards associated with mobile and short duration operations. After a brief discussion, the following three hazards were identified in ranked order:

1. motorist behavior (e.g., inattention and speeding),
2. impaired drivers (e.g., alcohol, cell phones, etc.), and
3. improper procedures (e.g., lack of signing or lighting on vehicles).

With respect to the concerns and hazards identified, participants suggested the following to improve the safety of motorists and workers in mobile and short duration operations:

- use of law enforcement;
- increase the use of specific light configurations on work vehicles (i.e., light bars, blue lights, and wigwam lights);
- add a shadow vehicle to mobile operations when the geometry of the road is complex (i.e., horizontal and vertical curves);
- increase the use of traffic control devices that are attached to work vehicles;
- increase the use of the static "lane blocked" sign;
- use DMSs more effectively;
- develop equipment that could be used to move debris off the roadway onto the shoulder; and
- use more positive barriers between workers and motorists (something that is easy and quick to move and setup).

Maintenance Conference Focus Group

Participants

The 19 participants were TxDOT employees recruited from those attending the TxDOT Statewide Maintenance Conference. Table 7 contains a summary of background information collected from the participants. The participants represent diverse locations with 26 percent from urban areas and 74 percent from rural areas. All participants have worked for TxDOT for at least eight years.

Table 7. Maintenance Conference Focus Group Background Information.

District	Area		Years Employed by TxDOT	Years of Experience in Maintenance Operations
	Urban	Rural		
San Antonio		X	36	23
San Antonio	X		13	3
Fort Worth	X		35	35
Fort Worth	X		18	5
Atlanta		X	25.5	21.5
San Angelo		X	23	19
Houston	X		21	16
Bryan		X	8	3
Wichita Falls		X	22	9
Lufkin		X	15	12
Tyler		X	20	20
Odessa		X	20	20
Childress		X	25	25
Abilene		X	19	19
Childress		X	6.5	7
Pharr		X	17+	3
Laredo		X	15.5	6
Wichita Falls		X	16	16
San Antonio	X		9	15

Results

Initially, participants provided their definitions of mobile and short duration operations. Table 8 is a summary of the responses. As with the area engineer focus group, the definitions provided for both mobile and short duration operations were diverse and not always consistent with the Texas MUTCD definitions. Many participants defined mobile operations as work that is only continuously moving along the roadway. In relation to short duration operations, the group provided a wide range of time periods (from 15 minutes to two weeks); however, the majority of the participants classified short duration operations as work that takes one day or less to complete.

Participants all agree that the following types of operations are mobile: striping, herbicide, RPM installation, small pothole patching, and deicing. However, with respect to roadside cleanup, participants note that the operation can be mobile when it is spot litter pickup, but many times it is a short duration operation.

Table 8. Maintenance Conference Focus Group
Definitions of Mobile and Short Duration Maintenance Operations.

Mobile Operations	Short Duration Operations
Operations that are continuously moving down the roadway (e.g., striping, installing RPMs, and herbicide)	Operations that take one day or less (e.g., spot sealing, crack sealing, stabilizing, and level-up)
Moving operation (e.g., striping, RPM placement, and sweeping)	Work done during the day (e.g., level-up, patching, and striping at intersections)
Slow moving operation, 5-10 mph	Three to five minutes (e.g., patching potholes)
An operation not requiring a fixed traffic control set up	One day to two weeks, mostly one day
Continuously moving or stopping intermittently	Work occupying a location for up to one hour
Operation that moves along the roadway involving occasional brief stops	Operation that involves work activity at one location for up to eight hours
Moving operation with stops shorter than one minute	Less than two hours
Operations that move intermittently or continuously during the course of the day (e.g., striping and RPMs)	Operations at one location that do not last very long, perhaps up to three to eight hours (e.g., blade patches and pothole repairs)
Activities that are moving or occupy a location no more than 15 minutes	Activities that occupy a location up to one hour
Continuously moving, no stopping	Stopping up to one hour
Maintenance operation stopping or pausing in or near the roadway for less than 15 minutes to make a repair or identify a needed repair and then moving on	Maintenance operations that take longer than 15 minutes but less than one hour to either make or identify a repair
Fast moving, continuous flow, stop and go	One to two hour work areas, work that can be accomplished in one day
Operations that move along (e.g., striping, sweeping, and herbicide)	30 minutes or less operation
Operations that takes less than 15 minutes and require momentary exposure to direct traffic, operations that do not stop or only stop for short periods of time	Daily activities in maintenance to repair and maintain transportation systems requiring work to be performed during a normal work day possibly in multiple locations
Work operations that provide continuous movement of work or convoy	Mobile or stationary work that lasts up to one hour
Operations that require continuous movement of work vehicles but allows short intermittent stops	Operations that occupy the roadway surface for less than four to six hours
An operation that moves or is continuous within a designated location	A designated work area in which a task can be accomplished in a four hour period
Movement down the road in a somewhat stop and go process (e.g., centerline stripe)	Temporary setup that is not moving more often than every 30 minutes
Continuous mobile operations with a max stop of 15 minutes	Operations lasting more than 15 minutes but less than 45 minutes

The group also agrees upon the following short duration operations: pothole patching, sign installation, short-line pavement markings, and signal repair. However, the idea of crack sealing as a short duration operation generated a great deal of discussion. Many participants feel that crack sealing should be classified as mobile maintenance since the operation progressively moves down the roadway (i.e., starts at point A and proceeds down the road to point B). However, due to the large amount of worker exposure, the fact that workers are on foot in the roadway, and the slowness of the operation, many participants feel that the operation does not qualify as mobile. One distinction that became evident through this discussion is that on multilane facilities crack sealing can be considered a mobile operation because traffic can move out of the blocked lane.

However, when crack sealing is performed on a two-way, two-lane facility, the general opinion is that it must be considered short duration and treated accordingly. For example, one district uses flaggers or a pilot car as a means of traffic control during crack sealing operations on two-way, two-lane facilities; thus, the setup resembles a short duration operation more than a mobile operation.

Another specific case discussed was one district that performs mobile milling operations using cones. In addition to the traditional mobile setup, the crew places and removes cones along side of the work convoy as it progresses down the roadway. The additional traffic control is used to keep motorists from entering the convoy.

Participants also identified the type of maintenance operations they feel are the most hazardous. The majority of the participants indicated that mobile operations are the most hazardous due to the slow speed of the operations and the speed differential this creates with the normal traffic stream. They also note that in mobile operations, there is less opportunity to utilize advanced warning traffic control devices to alert motorists. In contrast, some participants feel that short duration operations are the most hazardous due to greater worker exposure. In addition, several participants commented that the hazard is not based on the type of work but on the roadway conditions (i.e., volume and speed) and location of work.

The focus group discussion identified the following concerns regarding mobile and short duration operations:

- the need for improved guidelines/standards,
- motorist understanding of work zone traffic control devices,
- motorist inattention, and
- safety of workers and their length of exposure to traffic.

As discussed previously, the types of work considered to be mobile or short duration operations varied among the focus group participants. With this in mind, participants indicated a need to create a greater distinction between mobile and short duration operations, as well as to provide guidance with respect to which standards should be used for specific operations. The group also suggested that there should be guidelines concerning the use of optional devices based on traffic volume and/or roadway speed. Participants further note that there needs to be consistency among the guidelines/standards used for contractors and those used for the in-house maintenance.

With respect to traffic control devices, participants feel that motorists do not understand the four-corner caution mode used on arrow panels. In addition, participants commented that the language barrier causes problems near the border, since some motorists cannot read signs in English. One issue specific to mobile work concerns the use of the "Lane Blocked" sign. Participants feel that the traveling public does not understand this sign, and thus do not exit the closed lane upstream of the work activity as desired.

Concerns regarding worker safety include the visibility of workers and worker complacency (especially on low volume roadways). In addition, participants commented that the setup of short duration operations often takes longer than the work and increases workers' exposure to traffic. More specifically, the setup of short duration or flagging operations for crack sealing leads to more worker exposure than the mobile setup with protection vehicles behind the workers.

With respect to the concerns and hazards identified, participants suggested the following to improve the safety of motorists and workers:

- use of law enforcement and radar drones (in particular, having officers on the TxDOT payroll);
- increase the fines for speeding in a work zone;
- use of speed trailers with cameras;
- motorist education regarding work zones;
- use of DMSs to display the estimated delay;
- use of better safety apparel to create more contrast with the background; and
- use of a flag instead of the stop/slow paddle.

SUMMARY

Researchers conducted seven focus groups to identify the hazards encountered by TxDOT field personnel during mobile and short duration maintenance operations. In addition, the focus groups were used to stimulate new ideas and creative concepts that could improve worker and motorist safety.

Throughout all of the focus groups, it was evident that the definitions of mobile and short duration operations, as well as the classification of specific operations as mobile or short duration, were not consistent among TxDOT personnel. These variations make it difficult for field personnel to select the proper traffic control for maintenance operations. Participants indicated a need to create a greater distinction between mobile and short duration operations, as well as to provide guidance with respect to the application of standards to specific operations. In addition, participants indicated a desire to have guidelines concerning the use of optional devices based on traffic volume and/or roadway speed.

The primary hazards identified related to motorist comprehension, motorist behavior, and worker safety. With respect to motorist comprehension, participants considered the four-corner caution display, stop/slow paddle, and "Lane Blocked" sign to be misunderstood by motorists. Education and the use of alternative signing, DMSs, or flags were suggested as possible solutions.

The motorist behaviors identified included motorist inattention, speeding, entering the convoy or encroaching on the work area, and last minute lane changing. Participants also noted that motorists do not know how to react to a work convoy. Countermeasures suggested to address these hazards were the use of law enforcement, the use of speed display boards, expanding the double fine law, and education. Measures recommended to specifically catch the attention of motorists included: the use of additional lights, flags instead of the stop/slow paddle, different sign colors, and DMSs.

Worker safety issues included worker exposure, worker complacency, and the visibility of workers and vehicles. The groups identified the use of additional vehicles with TMAs, complete lane or roadway closures, training, additional lights on vehicles (i.e., blue lights, red lights, and light bars), additional traffic control devices (e.g., signs and cones), and flags instead of the stop/slow paddle as possible solutions.

5. FIELD OBSERVATION SITES

The research team conducted field observations of mobile and short duration maintenance operations to document the work zone setups, as well as the motorist behaviors that create hazardous conditions for both motorists and workers. With input from TxDOT panel members, the researchers choose to conduct the field observations in five TxDOT districts. These study sites represented a diverse group of work locations and included both rural and urban conditions. In total, the research team observed 11 mobile and 18 short duration maintenance operations in the following districts:

- Bryan/College Station,
- El Paso,
- Houston,
- Dallas, and
- San Angelo.

Depending on the location and type of work zone operation observed, researchers collected various types of data. The following bullets represent the types of data that researchers collected at some or all of the observation sites:

- type of operation,
- environment (e.g., urban vs. rural, weather),
- equipment used (e.g., number of work vehicles, traffic control devices, number of workers),
- characteristics of the operation (e.g., duration, progression, practices used, vehicle spacing, convoy length, speed),
- roadway characteristics (e.g., geometry, sight distance, speed limit),
- traffic speed, and
- erratic maneuvers around operation (e.g., hard braking, vehicle conflicts, near misses, last minute lane changing).

Researchers based the classification of urban and rural for this project on the definitions provided in the 2001 Green Book (*7*). Urban areas are considered to be locations with a population of 5000 or more, while rural areas are those with a population less than 5000. In addition, the traffic volume at each site was obtained from the 2001 TxDOT average annual daily traffic (AADT) information.

MOBILE MAINTENANCE OPERATIONS

The research team observed 11 mobile maintenance operations. The operations were categorized as: RPM replacement, edge repair, striping, crack seal, litter pickup, herbicide, or sweeping. Illustrations of each operation are located in Appendix C. Table 9 contains the types of work operations, the number of sites observed, and the work location characteristics.

It should be noted that two litter pickup operations were observed – one was classified as mobile and the other as short duration. The litter pickup in the Houston District was considered a mobile operation since the work vehicle and workers were moving along a 9-mile portion of a roadway. In contrast, for the litter pickup operation in El Paso, the work vehicles and workers were primarily stationary and thus considered to be a short duration operation.

Table 9. Study Location Characteristics for Mobile Maintenance Operations.

Type of Operation	District	Roadway [a]	Roadway Cross-section	Shoulders	AADT (vpd)	Speed (mph)
RPM Replacement	San Angelo	FM 2111	2-lane		180 [b]	70
		FM 158	2-lane	✓	1650 [b]	35-70
Edge Repair	El Paso	FM 76	2-lane		1550	55
Striping	Bryan	SH 6	4-lane divided	✓	40,260 [b]	70
Crack Seal	Bryan	BUS 6	6-lane divided		46,670 [b]	40
Litter Pickup	Houston	FM 521	2-lane	✓	9040 [b]	45-60
Herbicide	El Paso	I-10	4-lane divided	✓	17,000	70
Sweeping	Dallas	US 175	4-lane divided	✓	45,800 [b]	60/40
	El Paso	FM 258	2-lane	✓	9200	40
		FM 258	2-lane	✓	15,800	45
		LP 375	4-lane divided	✓	7390 [b]	65

[a] FM – Farm-to-Market; SH – State Highway; BUS – Business; I – Interstate; US – United States Highway; LP – Loop
[b] Rounded average of the AADT over the length of the work area

The following sections contain a summary of each mobile maintenance operation observed. Researchers conducted all observations during off-peak time periods. At the eight TxDOT operations observed, the workers wore hard hats and orange or FYG vests. There were also three private contractor operations observed: the striping operation in the Bryan District, the litter pickup operation in the Houston District, and the sweeping operation in the Dallas District. At the litter pickup and sweeping operations, the workers wore hard hats and either orange or FYG vests. However, at the striping operation, the crew wore FYG vests, but not all of the workers wore hard hats.

Raised Pavement Marker Replacement

The two RPM replacement sites were in the San Angelo District. Both locations were on rural two-lane Farm-to Marker (FM) roadways (one with a shoulder and one without) with a posted speed limited of 70 mph. The AADT volumes were 1650 and 180 vehicles per day (vpd), respectively.

The work convoy at both sites consisted of four vehicles: a pickup truck (lead vehicle), a pickup with a trailer (work vehicle), a shadow vehicle, and a trail vehicle. All vehicles used multiple warning lights (including amber and blue), and all used a Type B flashing arrow panel facing approaching motorists; three of the work vehicles also used arrow panels facing the opposing

traffic. The flashing arrow displayed right arrows at the study site that had shoulders, and the four-corner caution at the site with no shoulders. In addition, the lead vehicle used a light bar and the work vehicle had a "SLOW" sign mounted on the trailer. The shadow and trail vehicles both had TMAs with conspicuity markings (i.e., red and white markings). The trail vehicle, as shown in Figure 1, used a speed display board placed below the arrow panel. Due to the use of the speed display board, there was no "Work Convoy" sign used in this operation.

Figure 1. Trail Vehicle Used in RPM Operation.

There were six crew members at each site. Five rode in vehicles while the other placed RPMs. However, at times it was necessary for the driver of the trail vehicle to get out of the vehicle and direct traffic around the work convoy. The crew rotates work assignments on the equipment every 30 minutes to restock necessary materials and to allow all crew members the opportunity to experience each work position on the crew.

The work convoy traveled in an open traffic lane. On the FM road with no shoulders, the trail vehicle was approximately 1200 ft upstream of the shadow vehicle. Due to the more frequent occurrence of horizontal and vertical curvature on the FM road with shoulders, the trail vehicle was approximately 1700 ft upstream of the shadow vehicle. At both sites, the spacing between the lead vehicle and the work vehicle was approximately 60 ft, and the spacing between the work vehicle and shadow vehicle was approximately 25 ft.

Edge Repair

Researchers observed an edge repair operation in the El Paso District. The work activity was conducted on a rural two-lane FM road with an AADT of 1550 vpd and a posted speed limit of 55 mph. However, due to the work activity being near an intersection, the observed speeds indicated that motorists traveled at approximately 30 mph.

The work convoy consisted of one pickup and two dump trucks. Figure 2 shows examples of the dump trucks. The first dump truck, which held the asphalt, utilized the following lights: the vehicle hazard lights, amber strobe lights, and red hazard lights on the truck bed. In addition, two cones were placed adjacent to this dump truck (one in front and one behind the vehicle). The pickup truck, when off to the side of the work area, used no warning lights. However, it used

amber warning lights when the truck was repositioned next to the dump trucks. The second dump truck used three amber warning lights and red hazard lights on the truck bed. Similar to the first dump truck, this truck had one cone placed in back of the vehicle. However, unlike the first truck, it did not use the vehicle hazard lights. "Shoulder Work" signs with flags and a cone were placed on the shoulder in advance of the work activity in both directions.

Figure 2. Example of Dump Trucks Used in Edge Repair.

The work crew consisted of five workers. Two crew members worked adjacent to the roadway behind the first dump truck, two crew members worked mainly from the work vehicles, and one crew member was a flagger. The flagger was positioned between the advance "Shoulder Work" sign and the work area. However, due to the low traffic volumes and speeds, traffic was generally self-regulating.

The work convoy traveled on the unimproved shoulder with minor encroachment on the active travel lanes. The work zone was approximately 18,000 ft long; however, the work convoy only moved 300 ft during the research team's observations (one hour). The distance between the two dump trucks (located adjacent to the roadway) was approximately 25 ft. The terrain was flat, so adequate sight distance was provided in both directions.

Striping

Researchers observed a striping operation in the Bryan District. A private contractor conducted this work activity on a four-lane divided state highway in an urban area. The AADT was 40,260 vpd, and the posted speed limit was 70 mph.

Figure 3 illustrates the three convoy vehicles (one striping truck and two shadow vehicles) used to stripe the entrance/exit ramps and the outside edge line of the main lanes. One shadow vehicle remained behind the striping truck on the entrance/exit ramps, while the other stayed in the outside main lane. All three vehicles used vehicle hazard lights, amber warning lights, and flashing arrow panels. The striping truck and shadow vehicle on the ramp used the four-corner

caution mode, while the shadow vehicle on the main lanes displayed a left directional arrow. In addition, both shadow vehicles had TMAs with conspicuity markings and "Work Convoy" signs placed on back of the trucks in front of the arrow panels. However, the TMA on the shadow vehicle located on the ramps partially blocked the "Work Convoy" sign.

Figure 3. Striping Operation in Bryan District.

Due to the fact that the striping operation was part of a larger overlay project, advance signing was present in the 13 mile work zone, with "Road Work Ahead" signs posted at all entrance ramps and "End Roadwork" signs at all exit ramps. In addition, cones were located at various places where the outside edge line had not yet been striped.

The majority of the work crew rode inside the work vehicles, with the exception of one crew member who worked in back of the striping vehicle operating the paint machine. On occasion, it was necessary for the driver of the shadow vehicle located on the ramps to get out of the vehicle and stop traffic entering the highway. Researchers noted that not all of the crew members wore hard hats when they were working outside of the vehicles. Based on the observations, the two shadow vehicles were positioned upstream of the striping truck, such that the vehicle spacing was approximately 600 ft.

Crack Seal

Researchers observed a crack seal operation in the Bryan District on a six-lane divided urban arterial. The AADT was 40,670 vpd, and the posted speed limit was 40 mph.

The three work vehicles used at this site were: a shadow vehicle, a crack seal truck with a trailer, and a truck with an air compressor trailer (lead vehicle). The crack seal truck and lead vehicle used amber strobe lights, while the shadow and crack seal truck both used vehicle hazard lights. The shadow vehicle, which was a private contractor vehicle, used a TMA with conspicuity

markings, a Type C arrow panel, and a flexible "Work Convoy" sign. However, as shown in Figure 4, the "Work Convoy" sign partially blocked the view of the arrow panel. In addition, at times the wind would knock down the flexible sign. The crack seal truck used a Type B arrow panel and had two flags (one on each side) on the trailer.

Figure 4. Crack Seal Operation in Bryan District.

There were eight crew members; all wore hard hats and FYG or orange vests. One crew member walked between the lead vehicle and the crack seal truck, three drove vehicles, and the remaining three crew members and the flagger worked between the crack seal truck and the shadow vehicle.

The work zone was approximately 4800 ft long. The average sight distance to the operation was 2300 ft, and the vehicle spacing between both sets of vehicles was approximately 50 ft. The convoy traveled at a speed less than 5 mph.

The research team observed the striping operation working in all three lanes (inside, center, and outside). The TxDOT workers (in the crack seal truck) utilized the appropriate arrow panel displays; however, at times the contractor (in shadow vehicle) used improper displays (e.g., sequential arrows). In addition, the contractor was continually changing the arrow panel display (i.e., frequently changing between chevrons, directional arrows, and sequential arrows).

Litter Pickup

The litter pickup operation was observed in the Houston District. A private contractor conducted the work activity on a two-lane FM road in a rural area. The speed limit varied from 45 mph to 60 mph as the work crew traveled down the roadway. The AADT was 9040 vpd.

The contractor used one trash van with a trailer for the litter pickup activity. The van used amber warning lights, vehicle hazard lights, and a "Litter Crew Ahead" sign placed on the back of the trailer. The van traveled on the shoulder while eight crew members, who all wore hard hats and orange vests, walked in the right of way collecting litter. The crew members worked in groups of two on both sides of the roadway for approximately 9 miles. Figure 5 shows one of the crew members from the litter pickup operation.

Five advance “Litter Pickup” signs were used: four in the northbound direction and one in the southbound direction. A “Litter Pickup Ahead” sign was also used at the beginning of the work area in the southbound direction (in conjunction with a “Litter Pickup” sign). The average sight distance to the advance warning signs was approximately 2250 ft, while the average sight distance to the workers was approximately 375 ft.

Figure 5. Litter Pickup Crew Member in the Houston District.

Herbicide

Researchers observed a herbicide operation in the El Paso District on a four-lane divided freeway in a rural area. The speed limit was posted as 70 mph, and the AADT was 17,000 vpd.

The work vehicle shown in Figure 6 was a spray truck that used three amber warning lights, conspicuity markings on the bumper, and a Type B arrow panel that displayed the caution bar. The vehicle traveled approximately 40 mph on the inside median adjacent to the inside shoulder. The average sight distance to the work vehicle was approximately 2600 ft.

Figure 6. Herbicide Truck Used in the El Paso District.

Sweeping

Researchers observed one sweeping operation in the Dallas District and three in the El Paso District.

Dallas District

The sweeping operation in the Dallas District was on a four-lane divided U.S. highway with a frontage road. The AADT was 45,800 vpd, and the site was in an urban area. The posted speed limit was 60 mph on the main lanes and 40 mph on the frontage roads. A private contractor conducted the work.

There were four sweepers and two shadow vehicles used at this site. All four sweepers used Type B arrow panels. The two shadow vehicles used a Type C arrow panel, amber beacons and strobe lights, a TMA with conspicuity markings, and a "Work Convoy" sign. In addition, additional construction signs and traffic control devices for another work zone were evident along the sweeping route.

The contractor conducted the sweeping operation on both sides of the main lanes, the exit and entrance ramps, and on the frontage roads. During the operation, the two shadow vehicles rotated between the four sweeper locations. As shown in Figure 7, the shadow vehicles were not always located behind the sweepers; on occasion they would be located on the frontage road shoulder where they would be used as a dump truck for the dirt accumulated by the sweepers. The sweepers also frequently changed locations (e.g., move from inside shoulder to outside shoulder). However, at times the workers would not change the arrow panel display; thus, the arrow panel would be displaying incorrect information to approaching motorists (e.g., flashing a left arrow when it should be a right arrow).

Figure 7. Sweeping Operation in Dallas District.

El Paso District

There were three sweeping operations observed in the El Paso District. Two were on two-lane urban arterials (FM roads), and one was on a four-lane divided rural arterial. The AADT ranged from 7390 to 15,800 vpd, while the posted speed limit ranged from 40 to 65 mph.

The same two vehicles were used at all three observed sites: a shadow vehicle and a sweeper. The shadow vehicle used a Type C arrow panel, blue and amber warning lights, vehicle hazard lights, a "Work Convoy" sign, and a TMA with conspicuity markings. The sweeper used an orange triangle on the back of the vehicle, vehicle hazard lights, and an amber warning light. The shadow vehicle displayed the caution bar, as shown in Figure 8, at the first two sites and the left arrow display at the third site. The sweeper traveled on the shoulder at all locations, while the shadow vehicle traveled on both the shoulder and in an open traffic lane. There were two crew members who generally stayed in the work vehicles; however, when outside of the vehicles, the proper FYG vest and hard hat were worn.

Figure 8. Sweeping Operation in the El Paso District.

On the two-lane urban arterials, the sight distance to the shadow vehicle was approximately 2600 ft and the spacing between work vehicles was approximately 70 ft. However, at times, the dust created by the sweeper made it difficult for the oncoming traffic to see the work vehicles. On the four-lane divided roadway, the sight distance was approximately 6500 ft and the vehicle spacing approximately 190 ft. In addition, at this site the work vehicles traveled approximately 20 mph.

SHORT DURATION MAINTENANCE OPERATIONS

The research team observed 18 short duration maintenance operations. The operations were categorized as follows: bridge height measurements, litter pickup, sign maintenance, and delineator maintenance. Illustrations of each operation are located in Appendix D. Table 10 summarizes the general characteristics of the short duration operations, while the following sections provide a summary of each observed short duration operation. Researchers conducted

all of the observations during off-peak time periods, and at all of the sites workers wore hard hats and FYG vests.

Table 10. Study Location Characteristics for Short Duration Maintenance Operations.

Type of Operation	District	Roadway [a]	Roadway Cross-section	AADT (vpd)	Speed (mph)	Duration (minutes)
Bridge Height Measurements	Bryan	FM 60	4-lane divided	18,900	40	11
		FM 2818	4-lane undivided	24,000	60	4
		Airport Blvd.	4-lane divided	-	30	4
		SH 47	4-lane divided	5000	70	11
Litter Pickup	El Paso	LP 375	4-lane divided	43,650	55	47
Sign Maintenance	El Paso	FM 659	4-lane undivided	9200	45	16
		FM 76	6-lane divided	15,100	35	26
		FM 258	2-lane	13,600	45	21
		I-10	4-lane divided	33,790	70	35
	Houston	SH 99	4-lane divided	12,400	60	23
		FM 723	2-lane	5100	60	9
	Dallas	US 175	4-lane divided	48,410	60	40
		I-30	8-lane divided	168,960	60	23
Delineator Maintenance	Houston	US 59	4-lane divided	27,340 [b]	65/45	75
	Dallas	I-30	8-lane divided [c]	127,920 [b]	55	43
		I-30	8-lane divided	186,900	55	12
		US 175	4-lane divided	51,460 [b]	60	23
		US 175	6-lane divided	51,460 [b]	60	40

- No data

[a] FM – Farm-to-Market; SH – State Highway; LP – Loop; I – Interstate; US – United States

[b] Rounded average of the AADT over the length of the work area

[c] Turned into a four-lane roadway as the work progressed

Bridge Height Measurements

Researchers observed the four bridge height measurement operations in the Bryan District. The study sites included one site on a rural four-lane undivided FM road and three sites on four-lane divided roadways (urban FM road, rural local street, and rural state highway). The AADT ranged from 5000 to 24, 000 vpd. The posted speed limit ranged from 30 to 70 mph. The average time to complete each operation was approximately eight minutes.

As shown in Figure 9, the work vehicle was a bucket truck with two amber warning lights and two blue warning lights. The vehicle hazard lights were also used at three of the four sites. No other traffic control devices were used; however, due to the presence of another work zone in the area there was a "Road Work Ahead" sign located upstream of the work area in the eastbound direction.

The work vehicle was parked on the shoulder at two study sites, on the raised median (no shoulder) at one site, and in the outside travel lane (no shoulder or median) at the remaining site. At two of the four locations, workers parked the bucket truck under the overpass. At the other two sites, it was necessary to park the vehicle either upstream or downstream of the overpass due to the design of the roadway (e.g., curvature).

The two crew members worked outside of the vehicle in the open lanes of traffic. More specifically, the crew members had to cross all lanes of traffic to measure the bridge height at various locations.

Figure 9. Work Vehicle for Bridge Height Measurements.

Litter Pickup

Researchers observed the litter pickup operation in the El Paso District on a four-lane divided urban arterial. The posted speed limit was 55 mph, and the AADT was 43,650 vpd. The amount of time the researchers observed the work activity was 47 minutes.

The work vehicles consisted of one dump truck with a trailer and one van. The back of the trailer and the van had no signs or markings. The dump truck had conspicuity markings on the tailgate; however, they were difficult to see due to the equipment on the trailer (Figure 10). Even though the dump truck and trailer were equipped with amber warning lights, none of them were utilized. In addition, neither vehicle used the vehicle hazard lights. Workers parked the truck and van on the inside shoulder. There were eight crew members located in the median adjacent to the work vehicles. An advance "Road Work Ahead" sign and cone were placed upstream of the work activity on the inside shoulder. Sight distance to the sign and cone was approximately 950 ft.

Sign Maintenance

Researchers observed a total of eight sign maintenance operations. Seven were sign installations, and one was a sign base placement. As shown in Table 10, four study sites were in the El Paso District, two in the Houston District, and two in the Dallas District.

Figure 10. Dump Truck with Trailer for Litter Pickup.

El Paso District

Researchers observed sign maintenance operations on a variety of facilities in the El Paso District. The AADT range was 9200 to 33,790 vpd with the posted speed limits ranging from 35 to 70 mph as shown in Table 10. Three sites were categorized as urban and one as rural. The duration of the work activity ranged from 16 to 35 minutes, with an average of 25 minutes.

The four sign maintenance operations all used the same bucket truck shown in Figure 11. The truck had conspicuity markings on the bumper. In addition, two amber warning lights, as well as the vehicle hazard lights, were utilized at all four sites. At three of the four work sites, workers parked the truck in the right of way adjacent to the shoulder. At the remaining work site, the truck was parked on the shoulder. The two crew members worked adjacent to the work vehicle in the median at all of the work sites. Depending on the location of the truck, an appropriate number of cones (ranging from four to eight) were placed around the work vehicle. The workers also placed a "Road Work Ahead" sign and one cone in advance of each work area. Sight distance to the sign and cone varied from approximately 1000 ft to 5400 ft.

Houston District

Two sign installation sites were observed in the Houston District, one on a rural two-lane FM road and one on a rural four-lane divided state highway. Both sites had a posted speed of 60 mph, and the average work duration was 16 minutes. The AADT ranged from 5100 to 12,400 vpd.

Figure 12 shows the sign truck used at both sites. The truck used two amber warning lights located above the cab and the vehicle hazard lights. Workers placed four cones around the vehicle at each site; however, they used no advance signing. At one site, workers parked the truck in a u-turn lane, which limited the sight distance to the operation. At the other site, the truck was located in the right of way beyond the shoulder. There were two crew members at both work sites. The crew worked in the raised median at one site and beyond the outside shoulder adjacent to the work vehicle at the other.

Figure 11. Work Vehicle for Sign Maintenance Operations in the El Paso District.

Figure 12. Work Vehicle for Sign Maintenance Operations in the Houston District.

Dallas District

Researchers observed the final two sign installation sites in the Dallas District, one on a four-lane divided US highway and one on a eight-lane divided freeway. Both sites were considered to be in rural areas, and had a posted speed limit of 60 mph. The AADT ranged from 48,410 to 168,960 vpd, and the average work duration was 32 minutes.

Figure 13 shows the bucket truck used in these operations. The truck had two amber warning lights and conspicuity markings on both the back of the truck and the bucket. The vehicle hazard

lights were used at both locations; however, at one site, they were hard to see due to the sun glare. At both sites, the truck was parked on the shoulder in the gore area of a ramp. At one location, workers placed two cones around the truck, and at the other site 10 cones were used. No other traffic control devices were used by the sign crew; however, at one site, there were barrels along the inside shoulder of the main lanes for another work zone. The two crew members primarily worked in the median gore area near an exit ramp.

Figure 13. Work Vehicle for Sign Maintenance Operations in the Dallas District.

Delineator Maintenance

Researchers observed five delineator maintenance operations: one in the Houston District and four in the Dallas District. All five of the work sites were classified as urban areas.

Houston District

The delineator maintenance site in the Houston District was on a four-lane divided US highway near an exit ramp. The posted speed limit was 65 mph on the main lanes and 45 mph on the frontage road. The work crew considered this activity a short duration operation even though the time to complete the work activity was slightly longer than one hour (one hour and 15 minutes). The AADT for this location was 27,340 vpd.

The work vehicles consisted of a front end loader and a pickup truck. The front end loader used an orange warning triangle on back, one amber warning light, and the vehicle hazard lights. It was located on the frontage road in the right of way beyond the shoulder. The pickup had conspicuity markings on the tailgate and used one amber warning light and the vehicle hazard lights. Initially, workers parked the pickup in the gore area next to an exit ramp. Later, the pickup was moved to the frontage road behind the front end loader. A cone was placed behind the pickup when it was parked on the frontage road; however, no cone was used when parked on the main lanes.

There were three crew members worked in a large area (approximately 1000 ft in length) in the right of way between the outside shoulder of the main lanes and the inside shoulder of the frontage road. This work area was located immediately downstream of a vertical curve (i.e., overpass). Thus, the crew placed two advance "Road Work Ahead" signs, one on each side of the freeway, on the main lanes upstream of the overpass.

Dallas District

The remaining four delineator maintenance sites were in the Dallas District. The study sites included one four-lane divided US highway, one six-lane divided US highway, and two eight-lane divided freeways. It should be noted that one of the eight-lane freeways reduced to a four-lane freeway near an interchange. The speed limit ranged from 55 to 60 mph, and the AADT volume range was 51,460 to 186,900 vpd. The duration of the work activity ranged from 12 to 43 minutes, with an average of 30 minutes.

There were two crew members at all four sites. The bucket truck used at both freeway sites utilized two amber warning lights and the vehicle hazard lights. At one site, the workers first parked the truck on the inside shoulder of the main lanes and then moved the truck downstream to the grass median. At the first location, the crew worked upstream of the truck along the shoulder near the guardrail; however, at one time or another, both crew members crossed over the median to the shoulder of the opposite lanes of traffic. At the second location, both crew members worked on delineators across the median from the truck adjacent to opposing traffic. At the other freeway site, the workers parked the truck on the outside shoulder and worked adjacent to the vehicle.

At the two US highway sites, the bucket truck had conspicuity markings on the bucket and used two amber warning lights, and the vehicle hazard lights. The crew members at these two sites worked at several different locations along the roadway, including the outside main lane shoulder and both sides of exit and entrance ramps. Thus, the work vehicle was parked on either the outside shoulder of the main lanes or the inside shoulder of the frontage road.

At a majority of the locations, workers placed traffic cones (two to four) around the work vehicle. No other traffic control devices were used; however, at the US highway sites, advanced signing was present on the main lanes and the entrance/exit ramps for another work zone.

6. FIELD OBSERVATION RESULTS

Researchers categorized the hazards for each of the maintenance operations based on the type of maintenance work being completed. Overall, researchers observed four types of short duration maintenance operations and seven types of mobile maintenance operations. The identification of hazards was based on observed motorist reactions, roadway characteristics, and work activity.

For this study, researchers utilized the Texas MUTCD (*2*) definitions of mobile and short duration maintenance. The definition of mobile maintenance states that mobile operations are work that moves intermittently or continuously. Researchers interpreted intermittent to include brief stops for work activities or to switch worker positions, but that the activity could not include moving between locations at roadway speeds. The seven types of mobile maintenance operations observed were:

- RPM replacement,
- edge repair,
- striping,
- crack seal,
- litter pickup,
- herbicide, and
- sweeping.

TxDOT defines short duration maintenance operations as work that occupies a location up to one hour. For the purposes of this project, researchers categorized the following types of work activities as short duration maintenance operations:

- bridge height measurements,
- litter pickup,
- sign maintenance, and
- delineator maintenance.

It should be noted that researchers considered one of the litter pickup operations to be a mobile operation since the work vehicle and workers were moving along a 9-mile portion of a roadway. In contrast, in the other litter pickup operation the work vehicles and workers were primarily stationary and thus considered to be a short duration operation.

MOBILE OPERATIONS

The primary hazards observed during mobile maintenance operations were:

- apparent motorist misunderstanding of traffic control devices,
- vehicles entering the work convoy,
- speed differential between traffic and work convoy, and
- visibility of work vehicles.

The following sections identify specific issues that were observed with regard to particular work activities and roadway characteristics.

Work Activity Concerns

Slow-Moving Activities

For activities where mobile operations were working in a lane and moving at a significantly lower speed than the normal flow of traffic, a major concern and hazard was the inability of motorists to recognize the speed differential between the convoy and their vehicle. This led to many instances of extreme braking at the back of the convoy and last minute lane changes as motorists reacted to the presence of the convoy.

One unique situation involved the San Angelo District maintenance crew, which utilized a speed display board. This board was mounted on the rear of the trail vehicle and displayed the speed of approaching vehicles. It should be noted that this device does not communicate to motorists that the convoy is traveling at a slower rate of speed than the general flow of traffic. Additionally, this setup did not allow for the use of the "Work Convoy" sign. Although the maintenance crew perceived that the display slowed traffic, researchers still observed several vehicles making last minute erratic maneuvers to avoid collision with the convoy.

Multiple Vehicle Activities

Operations that require more than one work vehicle to be traveling in a lane encounter the hazard of motorists entering the work convoy. In many mobile maintenance situations, motorists reentered the convoy after passing the trail vehicle. This situation can be interpreted in two ways. First, in rural environments, the trail vehicle remains upstream of the rest of the convoy to ensure adequate site distance. In such a case, the operation is designed to provide traffic with information regarding upcoming conditions, as well as adequate space to reenter the convoy when necessary (e.g., two-lane roadways where the vehicle must enter an opposing traffic stream to pass the convoy). This interaction between the trail vehicle and the motorist hopefully encourages vehicles to travel at a slower rate of speed, as well as informs motorists that they are approaching additional work vehicles.

However, in urban environments, motorists entering the convoy can be a much greater hazard since the spacing between trail vehicles and work vehicles is decreased. Motorists entering the convoy in this type of environment typically entered perpendicular to the convoy from a side street. This maneuver exposes workers on foot to a direct stream of traffic (i.e., vehicles on a side street turning straight into a work area), and the motorist entering at the center of a convoy does not receive the information provided to traffic approaching the rear of the convoy (i.e., the "Work Convoy" sign and arrow panel displays). The most important factor in addressing the issue of vehicles entering a work convoy is to provide motorists with adequate information to recognize that there is a work area with multiple work vehicles and/or workers present.

Sweeping

In certain instances, sweeping creates a hazard for motorists when the visibility approaching the rear of the sweeper or shadow vehicle (depending on the operation) is greatly obstructed by a cloud of dust. At times, the work vehicles, as well as the approaching lanes of traffic, could not be seen due to reduced visibility. This created two specific concerns. First, motorists cannot see the slow-moving vehicles and, therefore, do not have the opportunity to acknowledge the conditions prior to approaching the work activity. Secondly, motorists are passing the work activity with limited visibility, making incidents with oncoming traffic a greater concern. Due to these issues, a queue often formed behind the work vehicles because motorists were unwilling to pass the convoy. This represented an additional hazard to workers and motorists by creating unexpected roadway conditions for approaching traffic.

Off Roadway Operations

Researchers found that work activities performed primarily adjacent to the roadway or on the shoulder have very little influence on traffic behavior. These types of operations included herbicide, edge repair, and litter pickup.

Roadway Characteristic Concerns

Two-Lane, Two-Way Facility

A major hazard observed on two-lane, two-way facilities was motorists' maneuvers to pass the convoy. There were two different situations observed for this type of facility: one without a paved shoulder and one with a paved shoulder. Based on observed reactions of the motorists at the first location (no paved shoulder), it would appear that the traffic control did not provide motorists with the necessary information to understand how to pass the convoy. The arrow panel display for this situation showed four-corner caution to approaching vehicles. Motorists' reactions to this setup included passing the convoy in the opposing traffic lane, remaining behind the convoy, and passing the convoy on an unimproved shoulder. The problem of passing the convoy was exasperated by the fact that the observed operation required the protection vehicles to straddle the centerline of the roadway to protect the worker placing the RPMs. When motorists remained behind the convoy for extended periods of time, worker exposure levels were elevated due to workers getting out of their vehicles to direct traffic around the convoy.

In the second observed situation, the work was being performed on a facility with paved shoulders adequate for passing. In this case the arrow panel at the rear of the convoy had a right arrow indication. However, the observed reactions of the motorists were much the same as on the roadway that did not have paved shoulders. Many motorists either hesitated behind the convoy before proceeding to the right or passed the convoy on the left regardless of the directional arrow. There were also still many instances where vehicles stopped behind the convoy for extended periods of time, making it necessary for workers to leave their vehicles to direct traffic around the convoy. It is the thought of researchers that this behavior is due to the fact that drivers are taught to pass vehicles on the left, and therefore, the guidance information

provided on the arrow panel went against natural driving tendencies. Thus, for this type of setup, motorists may need additional information to reiterate the appropriate passing maneuver.

Urban Multi-Lane Arterial

During the observed operations on urban arterials, there were a high number of turning movements through the convoy due to the greater number of driveways and cross streets present in the area. The addition/deletion of lanes also contributed to the conflict between the work vehicles and traffic. Signal operations further intensified the problem when the shadow vehicle was stopped by a red signal indication, consequently exposing workers to the flow of traffic. Spacing and flagging becomes very important in this type of setting. The higher volume of traffic makes it important that the work vehicles stay close to the workers to ensure worker safety and hinder turning movements through the work area. However, when this cannot be accomplished, the flagger must direct traffic around the exposed workers to ensure worker safety.

Freeway Ramps

During the observation of a striping operation on freeway ramps, researchers noted that the hazards in this situation were primarily due to motorists going around the shadow vehicles and entering the work area to use the entrance ramps. As presented in the literature review, freeway ramps have been identified before as a hazardous environment (*4*). Previous research recommended using temporary ramp control. This recommendation was followed in the observed operation. The traffic control setup included the use of two shadow vehicles: one blocking the ramps and the other blocking the outside main lane. Information was provided to motorists through the use of arrow panels on the rear of each shadow vehicle. The shadow vehicle on the ramp displayed four-corner caution, and the main lanes shadow vehicle displayed a left arrow. Based on the observed maneuvers of motorists going around the shadow vehicles and continuing to use ramps that were temporarily closed for work, it would appear that the information provided to motorists was not adequate for the given situation. However, it should be noted that the operation did not use a “Ramp Closed” sign.

SHORT DURATION OPERATIONS

The primary hazard observed by the research team at short duration maintenance operations was worker exposure.

Work Activity Concerns

Worker Exposure

Due to the extremely brief nature of short duration maintenance operations, one of the main hazards encountered was worker exposure due to the limited amount of traffic control devices that are used during this type of activity. The presence of a work vehicle was the only protection used in both the delineator maintenance and bridge measurements operations. However, there were many observations where workers did not park the vehicles near the work area. In some

cases, workers would walk away from the vehicle, either crossing a median or progressing upstream. Thus, motorists encountered the workers without any prior warning of a maintenance activity. Specifically related to the bridge measurement activities, the unprotected workers were taking measurements in an active lane of traffic while their vehicle was located on the shoulder or median. However, researchers noted that in all of the observed situations worker interaction with traffic was minimal due to low traffic volumes or the fact that workers were in a median.

Off Roadway Operations

As was previously mentioned for mobile operations, work activities performed primarily adjacent to the roadway or on the shoulder have very little influence on traffic behavior. These types of operations included sign maintenance and litter pickup.

7. CONCLUSIONS

The objective of the first year of this research project was to identify the potential hazards associated with mobile and short duration maintenance operations, as well as the probable underlying causational factors. To meet this objective, researchers utilized many different research techniques. These included: a survey of state DOT offices, focus groups, and field observations.

The two main hazards identified in the state survey were motorist behaviors (e.g., speeding and inattention) and the interaction between work vehicles and traffic. Researchers found that many states have expanded their basic guidelines to provide further direction on how to apply traffic control devices based on additional considerations (e.g., roadway speed or speed of operation).

The focus groups identified motorist comprehension of traffic control devices, motorist behavior, and worker safety as the primary hazards associated with mobile and short duration maintenance operations. The motorist behaviors identified included motorist inattention, speeding, entering the convoy or encroaching on the work area, and last minute lane changing. Participants also noted that motorists do not know how to react to a work convoy. Worker safety issues included worker exposure, worker complacency, and the visibility of workers and vehicles.

In the field observations, the primary hazards identified with regard to mobile maintenance operations were: apparent motorist misunderstanding of traffic control devices, vehicles entering the work convoy, speed differential between traffic and work convoy, and visibility of work vehicles. With regard to short duration maintenance operations, the field observations indicated that worker exposure was the primary hazard. It is concluded that many of these concerns could be addressed if motorists were provided more specific information regarding upcoming conditions and/or the appropriate action to take.

Information gathered through all three research methods highlighted the fact that the definitions of mobile and short duration operations, as well as the classification of specific operations as either mobile or short duration, were not consistent. Thus, it was concluded that there is a need for:

- a clearer distinction between mobile and short duration operations,
- guidance in applying standards to specific types of operations, and
- an enhancement of guidelines to provide direction related to roadway conditions (e.g., traffic volume, roadway speed, and speed of mobile operations).

SUGGESTIONS FOR SECOND YEAR WORK ACTIVITIES

Based on the findings of the first year research efforts, researchers suggest the following work activities for the second year of this project:

- Researchers will convene an advisory panel to address the need for enhancing the current maintenance guidelines.

- Human factors research will be conducted to address the informational needs of motorists in the following situations: speed differential, passing a mobile maintenance convoy, and motorist awareness of multiple work vehicles in a convoy.

8. REFERENCES

1. *Manual on Uniform Traffic Control Devices*, Millennium Edition with Revision No. 1 Changes. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 2001.

2. *Texas Manual on Uniform Traffic Control Devices*. Texas Department of Transportation, Austin, Texas, 2003.

3. *Standard Plans Texas Department of Transportation: Traffic Control Plans*. Texas Department of Transportation, Austin, Texas, 1998.

4. Dudek, C.L., S.H. Richards, and M.J.S. Faulkner. *Traffic Management During Urban Freeway Maintenance Operations*. Report 228-10F. Texas Transportation Institute, College Station, Texas, January 1982.

5. *Traffic Control on State Highways for Short Term Work Zones*. Oregon Department of Transportation, revised 1998.

6. *Work Zone Traffic Control Guidelines*. Washington State Department of Transportation, May 2000.

7. *A Policy on Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, 2001.

APPENDIX A:
EXAMPLE OF FIELD PERSONNEL FOCUS GROUP PROTOCOL

INTRODUCTION TO FOCUS GROUP

Hello, my name is _____, and this is _____. We are here today to conduct a group interview for a TxDOT research project. Our objective is to obtain your opinions on the operations and potential hazards related to mobile and short duration maintenance operations. If you have not turned in the **form** you were given as you arrived, please turn them in at this time.

You will notice that we are **recording** this session. The recording will be used as a backup to the notes we will be taking. In addition, it will allow us to concentrate on what you are saying in the group. I want to assure you that you will not be quoted by name. We would like you to remember that this focus group session is to obtain the **current practices in your area as well as your personal opinion**; your responses should not be based on monetary limitations or department policies. We need to know what you think and how you personally feel about the topics we're going to be discussing. Beyond your own initial responses and impressions, I want you to feel free to respond to whatever anyone else says. Remember, you do not have to agree.

Now, I'd like to go over a few items before we begin.

- The role of the moderator is to **lead the discussion** and ensure that everyone in the group has the opportunity to share his/her point of view about the topics being discussed. The session should last about one hour.
- **Only one person should talk at a time** because it becomes impossible to understand the tape when more than one person is talking. Also, if only one person is talking, it is much easier for the rest of us to focus on what that person is saying.
- Please **refrain from having side conversations** during the session, as it tends to be very distracting.
- Please **speak loud enough** so that the tape recorder can pick up your comments.
- Please **share your personal feelings** about the topic, **even if you have a negative comment**. Remember, this interview is being conducted to obtain **your opinions** on mobile and short duration maintenance operations.
- Please make your responses as **clear and precise** as possible.
- Now, I'd like to take just a few minutes and go around the room and have you introduce yourselves. Please state your name and **share with us the number one hazard (or closest call) you have encountered while completing mobile and short duration maintenance operations**.

FOCUS GROUP GUIDE

Question 1. What operations do you consider to be mobile maintenance operations?

Possible Response 1.

Moving activities

- Sweeping
- Striping

Intermittent stop activities

- Pavement marking or placement
- Pothole patching
- Crack sealing

Activities on the shoulder or off the roadway (similar to short duration)

- Road side cleanup
- Herbicide

Question 2. What operations do you consider to be short duration maintenance operations?

Possible Response 2.

- Sign replacement
- Road side cleanup
- Pothole patching
- Guardrail repairs
- Crack sealing

Now, for this project we are considering mobile maintenance operations to be stop and go operations, as well as continuously moving operations.

Question 3. With that in mind, what hazards have you encountered during mobile maintenance operations, and how were these hazards addressed or resolved?

Possible Response 3a.

- Maintenance crew becomes complacent to their surroundings
- Motorist behavior (speeding, erratic maneuvers, entering/crossing into convoy or caravan, ignoring or not understanding traffic control devices (TCDs), road rage, and driver distraction)
- Improper or inadequate procedures
- Roadway design
- Unique situations

Possible Response 3b.

- Continuous training on roadway hazards
- Use of law enforcement
- Use of new or innovative TCDs

- Review of traffic control plans (TCPs) (improve design of operations)
- Increase use of standard TCDs

Now, for this project we are considering short duration maintenance operations to be those operations that last less than one hour at one location.

Question 4. With that in mind, what hazards have you encountered during short duration maintenance operations, and how were these hazards addressed or resolved?

Possible Response 4a.

- Maintenance crew becomes complacent to their surroundings
- Motorist behavior (speeding, erratic maneuvers, entering/crossing into convoy or caravan, ignoring or not understanding TCDs, road rage, and driver distraction)
- Improper or inadequate procedures
- Roadway design
- Unique situations

Possible Response 4b.

- Continuous training on roadway hazards
- Use of law enforcement
- Use of new or innovative TCDs
- Review of TCPs (improve design of operations)
- Increase use of standard TCDs

Question 5. Do you see any significant difference in the hazards encountered during mobile vs. short duration operations?

Possible Response 5.

- Sight distance
- Speed differential
- Additional exposure of work crew to traffic
- TCPs

Question 6. Do you have any personal suggestions on how to improve the safety of both the motorists and work crew during mobile or short duration maintenance operations that is not based on departmental policy or monetary constraints?

That completes the group interview. Do you have any additional comments or suggestions regarding mobile or short duration maintenance operations?

Thank you for your time. We appreciate you participating in this interview.

FOCUS GROUP PARTICIPANT INFORMATION SHEET
MOBILE AND SHORT DURATION MAINTENANCE OPERATIONS

District: _____ Area Office: _____

Job Title: _____

How long have you been with the Texas Department of Transportation? _____

Approximately how many years of work experience do you have related to maintenance operations? _____

1) Which type of maintenance operation do you feel is the most hazardous? _____

_____

_____

_____

APPENDIX B:
EXAMPLE OF SUPERVISORY PERSONNEL FOCUS GROUP PROTOCOL

INTRODUCTION TO FOCUS GROUP

I'd like to welcome everyone and thank you for coming. Today we are conducting this focus group as part of TxDOT research project 0-4174: Traffic Control Devices and Strategies to Improve the Safety of Mobile and Short Duration Work Zones. During the first year of this project, our goals are to identify the potential hazards associated with mobile and short duration operations and to identify potential strategies and technologies that may improve the safety of these operations. During the second year of this project, we will evaluate the potential strategies and technologies and develop recommendations. Currently, we are in the first year of the project.

Today, our objective is to obtain your opinions on the operation and potential hazards related to mobile and short duration maintenance operations. Using the focus group method, we hope to stimulate new ideas and creative concepts that could be used to improve the safety of mobile and short duration operations.

My name is___. I am a sociologist and a researcher on the project. This is _____, who is also a researcher on the project. Everyone should have a **nametag** positioned so that I can see it. If you have not turned in the **form** you were given as you arrived, please turn it in at this time.

You will notice that we are **recording** this session. The recording will be used as a backup to the notes we will be taking. In addition, it will allow us to concentrate on what you are saying in the group. I want to assure you that you will not be quoted by name. We would like you to remember that this focus group session is being conducted to obtain the **current practices in your area as well as your personal opinion.** Your responses should not be based on monetary limitations or department policies. We need to know what you think and how you personally feel about the topics we're going to be discussing. Beyond your own initial responses and impressions, I want you to feel free to respond to whatever anyone else says. Remember, you do not have to agree.

Now, I'd like to go over a few items before we begin.

- The role of the moderator is to **lead the discussion** and ensure that everyone in the group has the opportunity to share his/her point of view about the topics being discussed. The session should last about one hour.
- **Only one person should talk at a time** because it becomes impossible to understand the tape when more than one person is talking. Also, if only one person is talking, it is much easier for the rest of us to focus on what that person is saying.
- Please **refrain from having side conversations** during the session, as it tends to be very distracting.
- Please **speak loud enough** so that the tape recorder can pick up your comments.
- Please **share your personal feelings** about the topic, **even if you have a negative comment**. Remember, this interview is being conducted to obtain **your opinions** on mobile and short duration maintenance operations.
- Please make your responses as **clear and precise** as possible.

Now, I'd like to take just a few minutes and go around the room and have you introduce yourselves. Please state your name, where you're from, and **share with us the number one concern you have regarding mobile and short duration maintenance operations**.

FOCUS GROUP GUIDE

Question 1. What operations do you consider to be mobile maintenance operations?

Possible Response 1.

Moving activities

- Sweeping
- Striping

Intermittent stop activities

- Pavement marking or placement
- Pothole patching
- Crack sealing

Activities on the shoulder or off the roadway (similar to short duration)

- Road side cleanup
- Herbicide

Question 2. What operations do you consider to be short duration maintenance operations?

Possible Response 2.

- Sign replacement
- Road side cleanup
- Pothole patching
- Guardrail repairs
- Crack sealing

Now, for this project we are considering mobile maintenance operations to be stop and go operations, as well as continuously moving operations.

Question 3. With that in mind, what type of traffic control do you use for mobile maintenance operations?

Possible Response 3.

- Shadow vehicles
- TMAs
- Cones
- Lighting (strobes, beacons, etc.)
- Signing
- Arrow panels
- Flags

Question 4. What hazards have you encountered during mobile maintenance operations, and how were these hazards addressed or resolved?

Possible Response 4a.

- Maintenance crew becomes complacent to their surroundings
- Motorist behavior (speeding, erratic maneuvers, entering/crossing into convoy or caravan, ignoring or not understanding TCDs, road rage, and driver distraction)
- Improper or inadequate procedures
- Roadway design
- Unique situations

Possible Response 4b.

- Continuous training on roadway hazards
- Use of law enforcement
- Use of new or innovative TCDs
- Review of TCPs (improve design of operations)
- Increase use of standard TCDs

Now, for this project we are considering short duration maintenance operations to be those operations that last less than one hour at one location.

Question 5. With that in mind, what type of traffic control do you use for short duration maintenance operations?

Possible Response 5.

- Shadow vehicles
- TMAs
- Cones
- Lighting (strobes, beacons, etc.)
- Signing
- Arrow panels
- Flags
- Flaggers
- FYG vests

Question 6. What hazards have you encountered during short duration maintenance operations, and how were these hazards addressed or resolved?

Possible Response 6a.

- Maintenance crew becomes complacent to their surroundings
- Motorist behavior (speeding, erratic maneuvers, entering/crossing into convoy or caravan, ignoring or not understanding TCDs, road rage, and driver distraction)
- Improper or inadequate procedures
- Roadway design
- Unique situations

Possible Response 6b.

- Continuous training on roadway hazards
- Use of law enforcement
- Use of new or innovative TCDs
- Review of TCPs (improve design of operations)
- Increase use of standard TCDs

Question 7. Do you see any significant difference in the hazards encountered during mobile vs. short duration operations?

Possible Response 7.

- Sight distance
- Speed differential
- Additional exposure of work crew to traffic
- TCPs

Question 8. Do you have any personal suggestions on how to improve the safety of both the motorists and work crew during mobile or short duration maintenance operations that is not based on departmental policy or monetary constraints?

That completes the focus group. Do you have any additional comments or suggestions regarding mobile or short duration maintenance operations?

Thank you for coming. We appreciate your participation in our focus group during your busy schedule here.

FOCUS GROUP PARTICIPANT INFORMATION SHEET
MOBILE AND SHORT DURATION MAINTENANCE OPERATIONS

Name: _____ District: _____

Address:_____

City:_____ State: _____ Zip Code:_____

1) How long have you been with the Texas Department of Transportation? _____

2) Approximately how many years of work experience do you have related to maintenance operations? _____

3) Approximately how many years have you worked in the field on actual maintenance operations? _____

4) Please give your definition of the following two terms:

Mobile Maintenance Operations: _____

_____

_____

Short Duration Maintenance Operations:_____

_____

_____

5) Which type of maintenance operation do you feel is the most hazardous and why?_____

_____

_____

APPENDIX C:
ILLUSTRATIONS OF OBSERVED MOBILE OPERATIONS

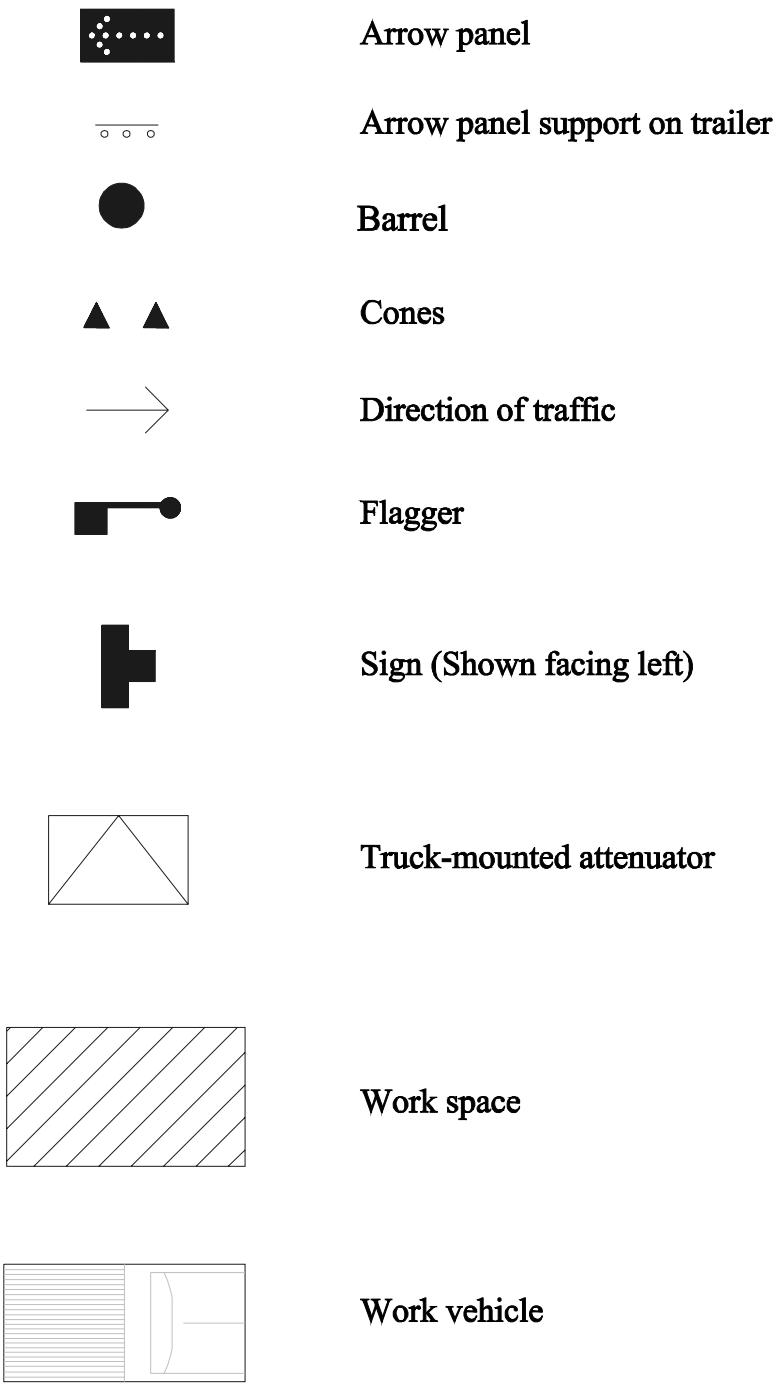

Figure C1. Legend.

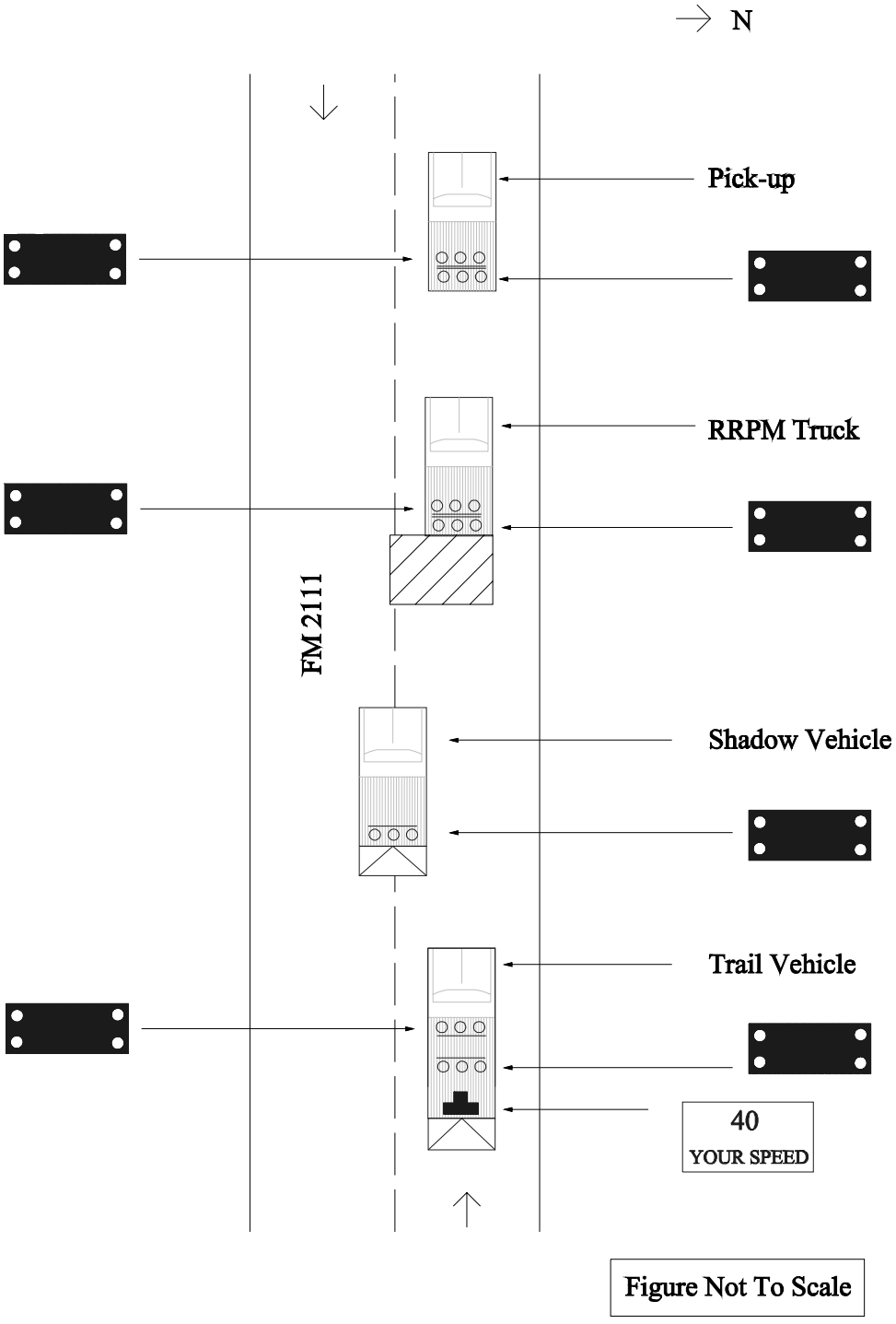

Figure C2. RPM Replacement on FM 2111.

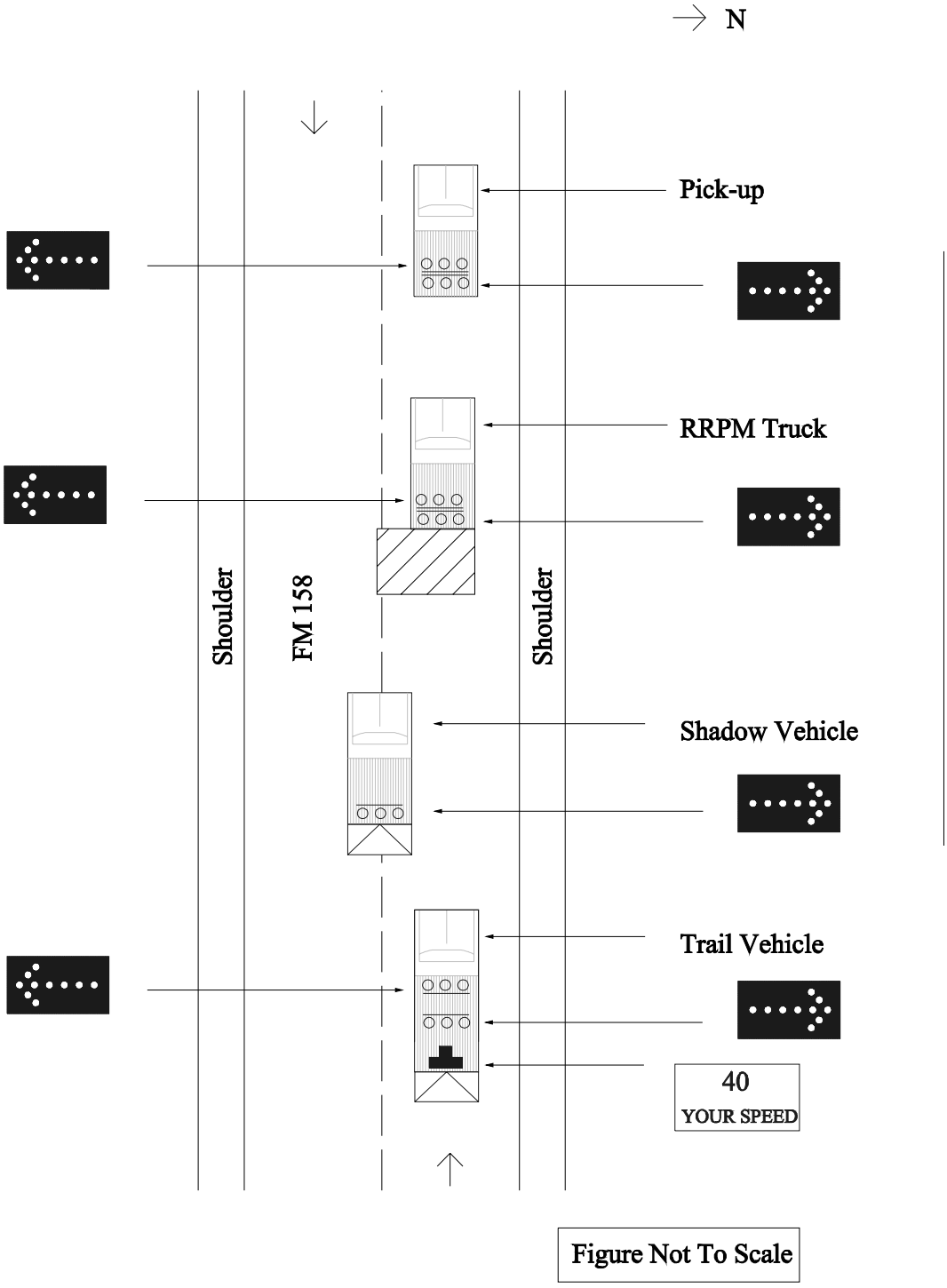

Figure C3. RPM Replacement on FM 158.

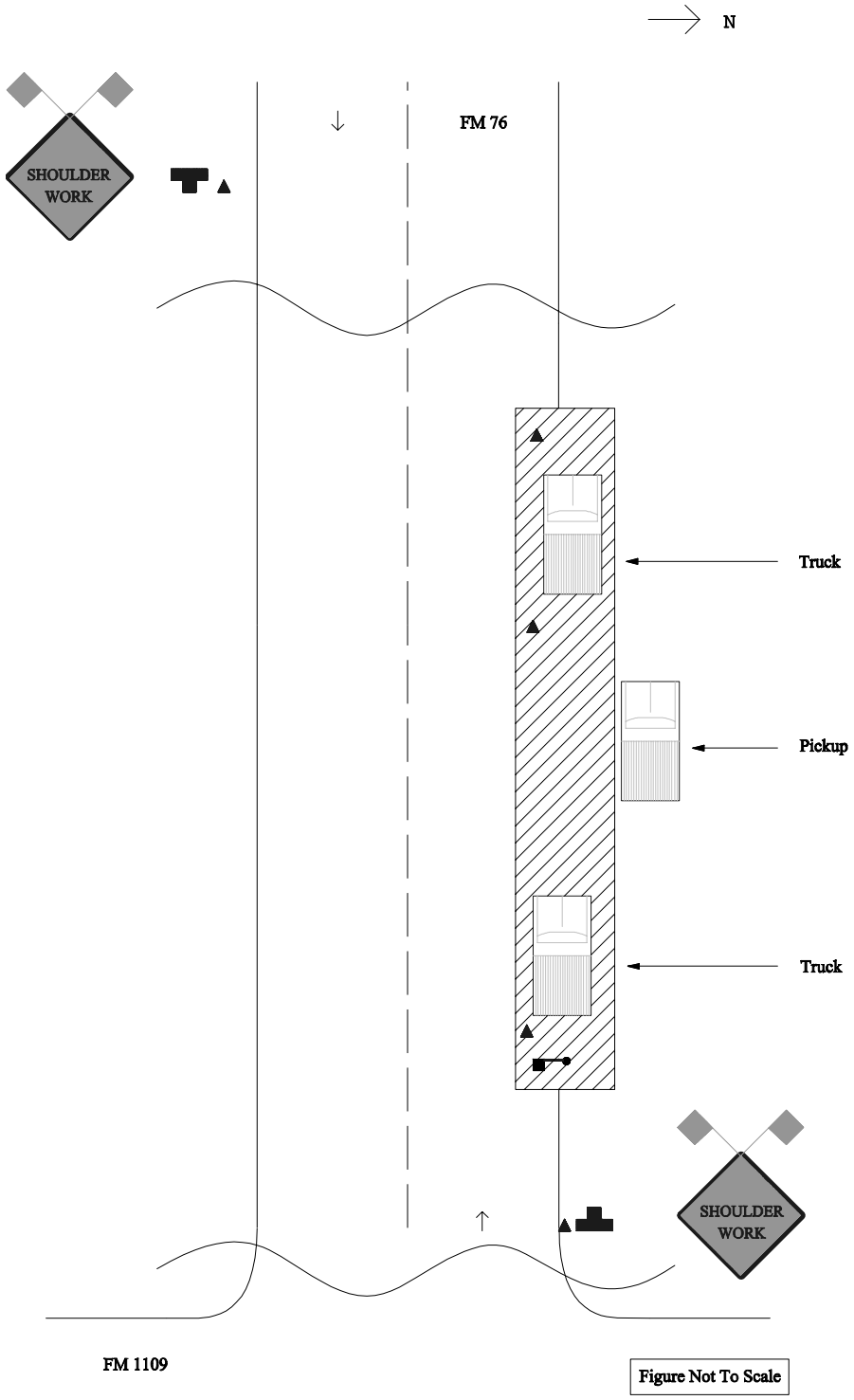

Figure C4. Edge Repair on FM 76.

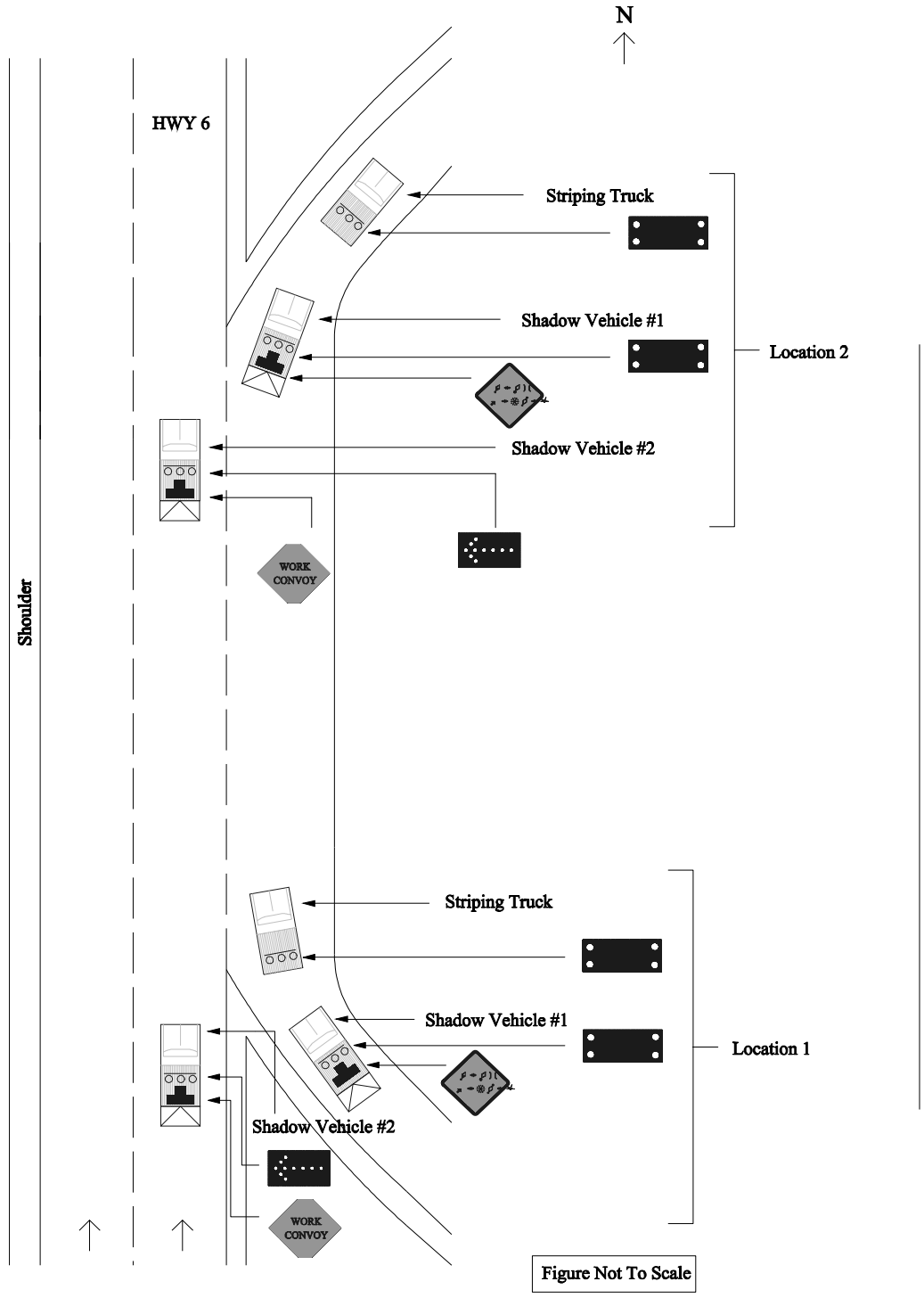

Figure C5. Striping on SH 6.

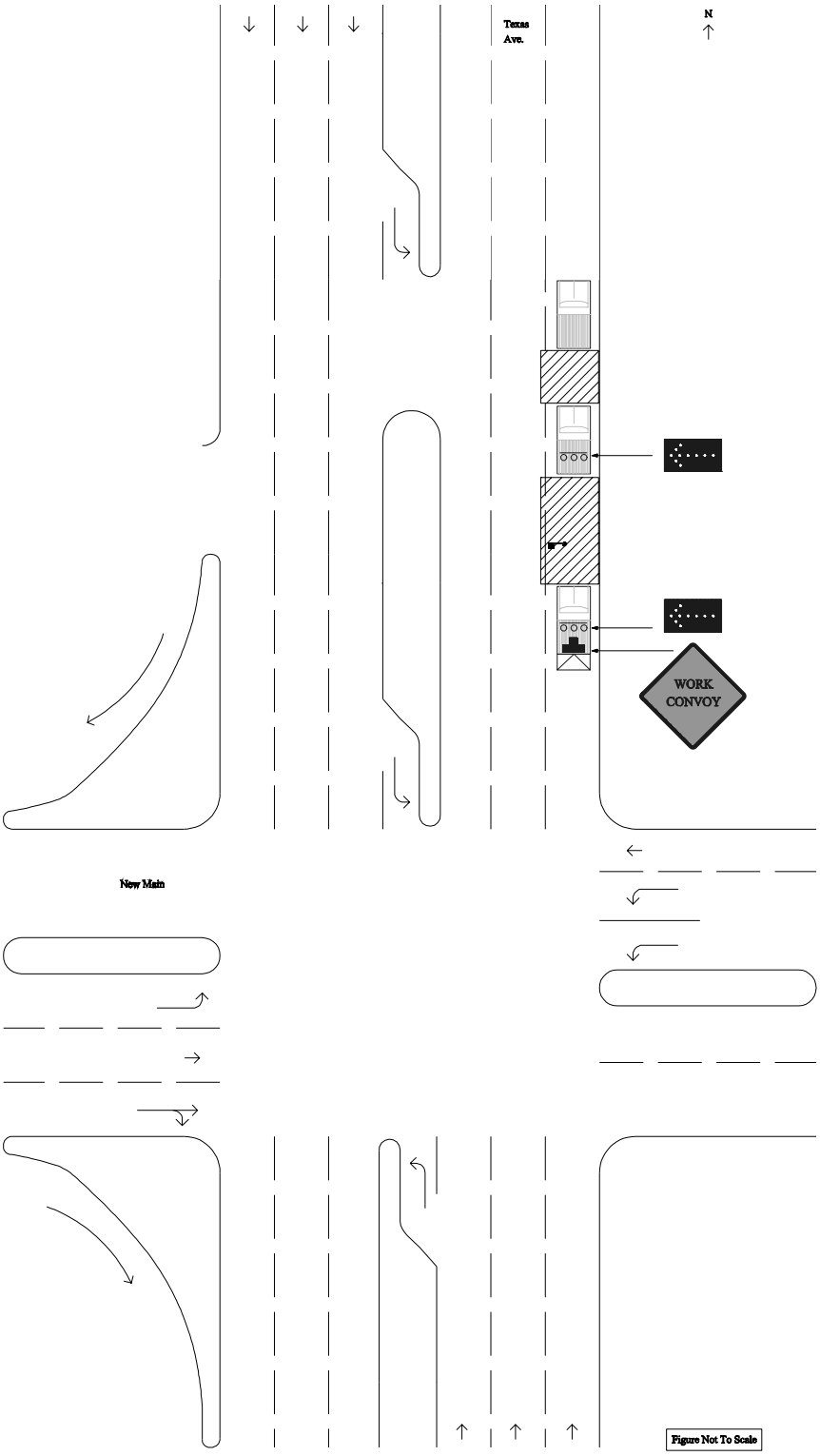

Figure C6. Crack Seal on Business 6 (Texas Avenue).

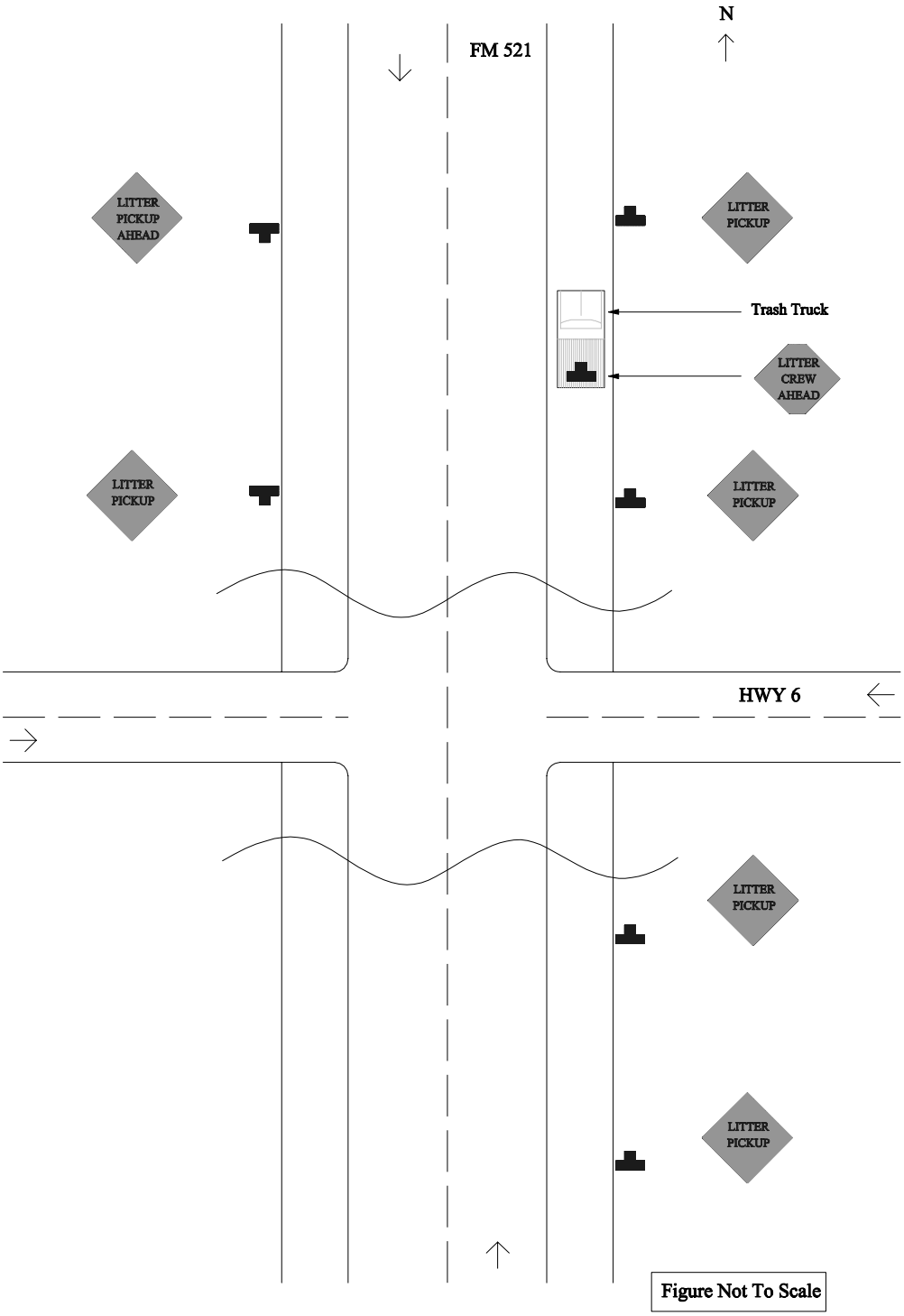

Figure C7. Litter Pickup on FM 521.

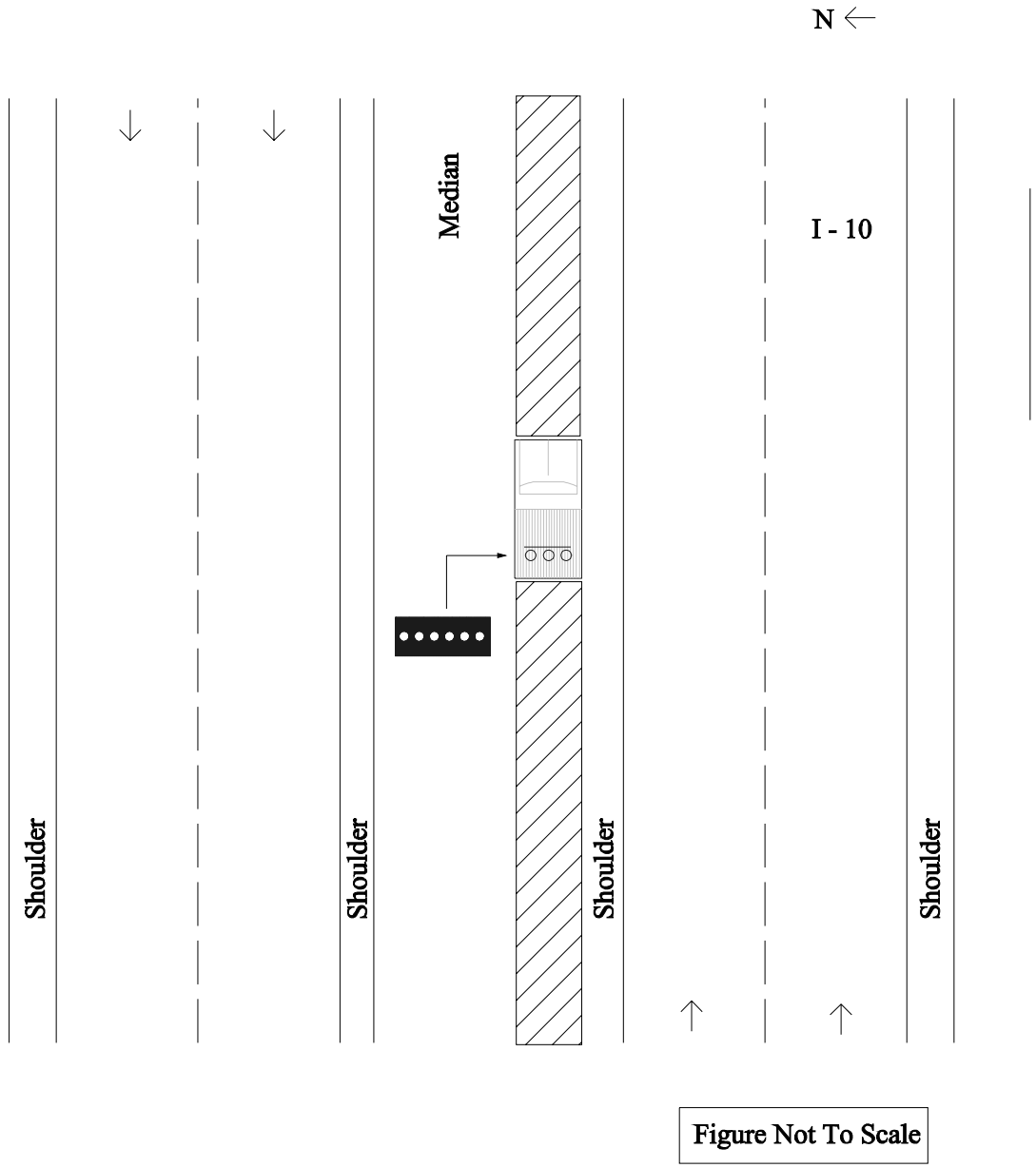

Figure C8. Herbicide on I-10.

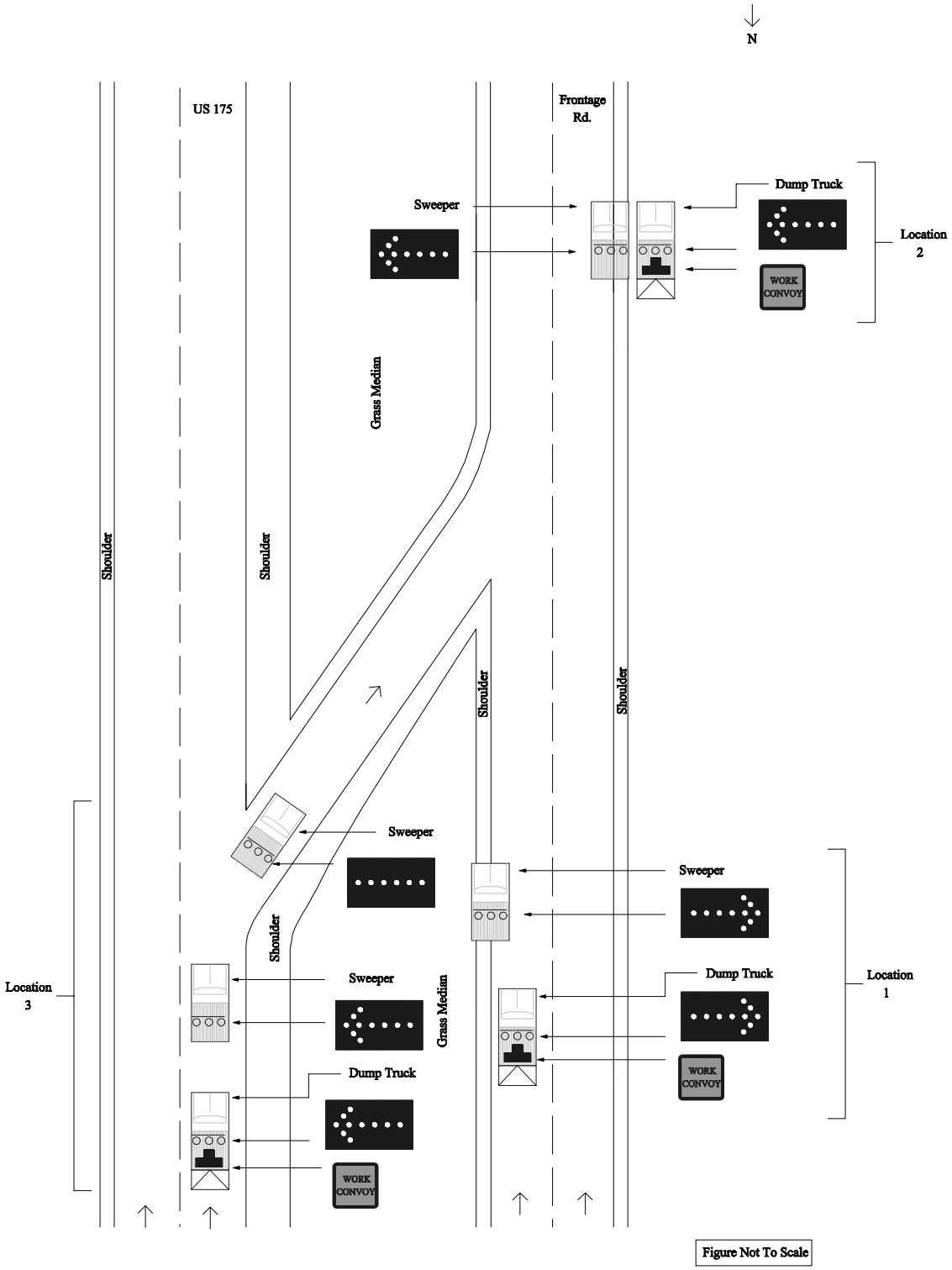

Figure C9. Sweeping on US 175.

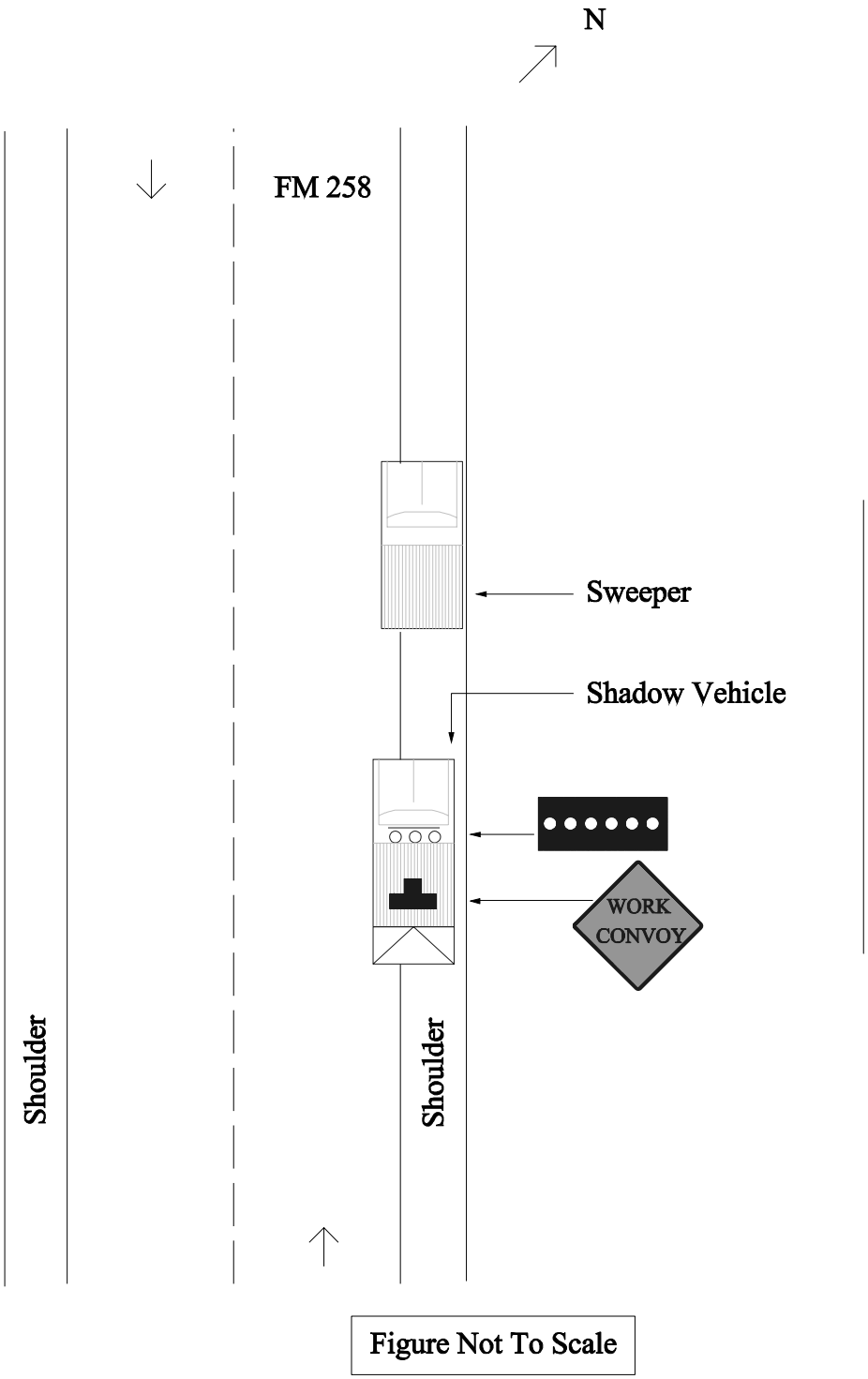

Figure C10. Sweeping on FM 258.

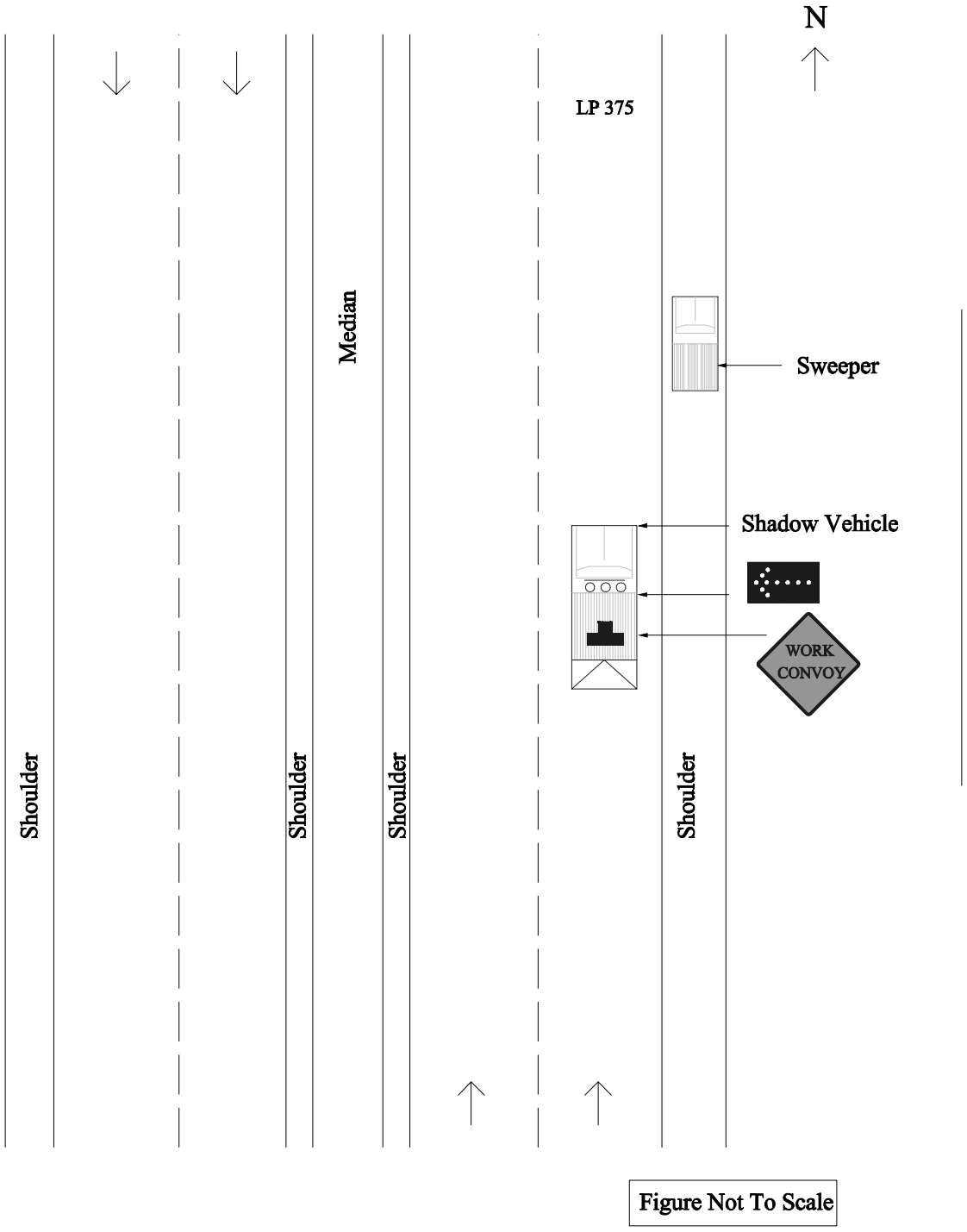

Figure C11. Sweeping on LP 375.

APPENDIX D:
ILLUSTRATIONS OF OBSERVED SHORT DURATION OPERATIONS

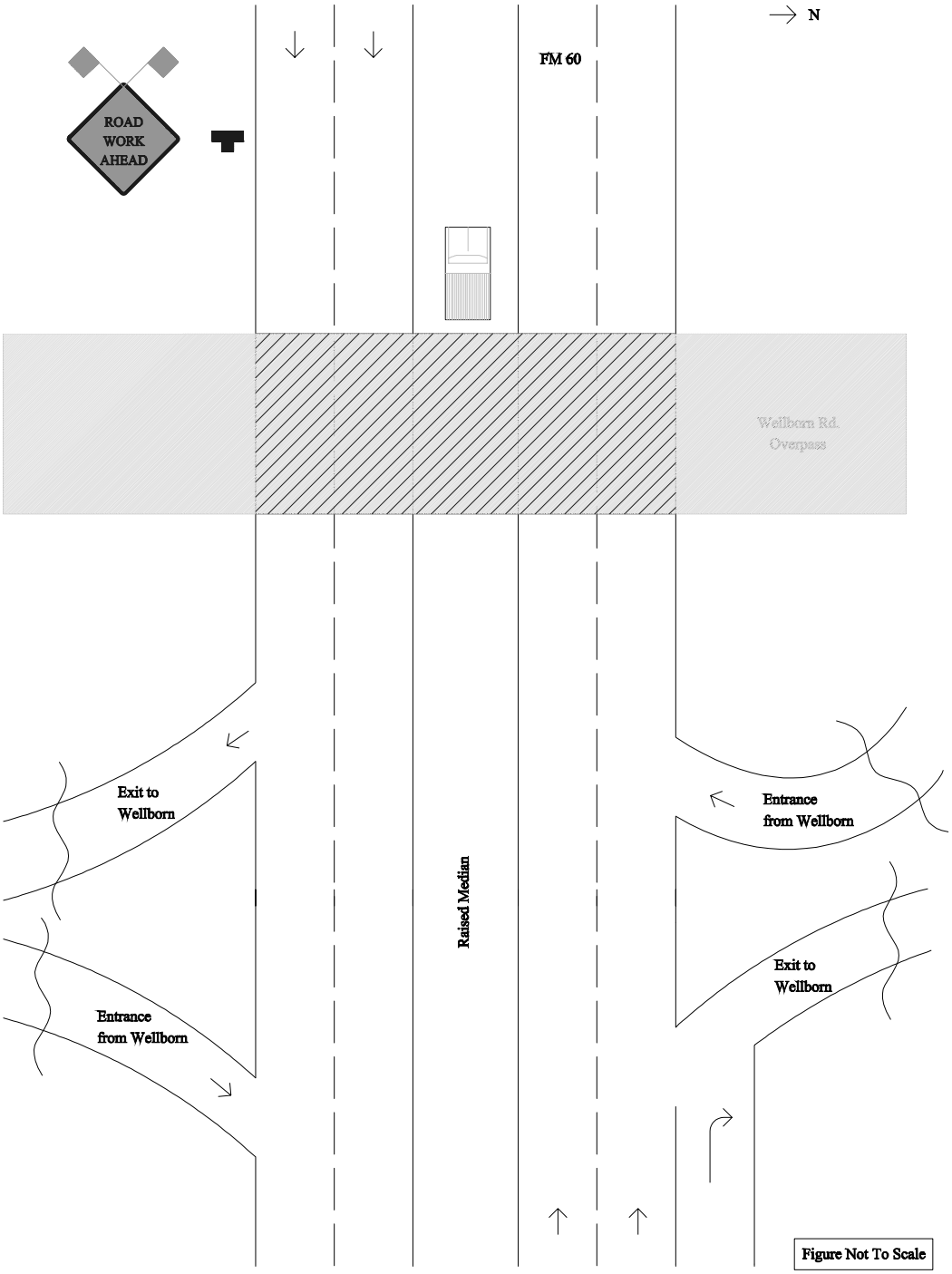

Figure D1. Bridge Measurements on FM 60.

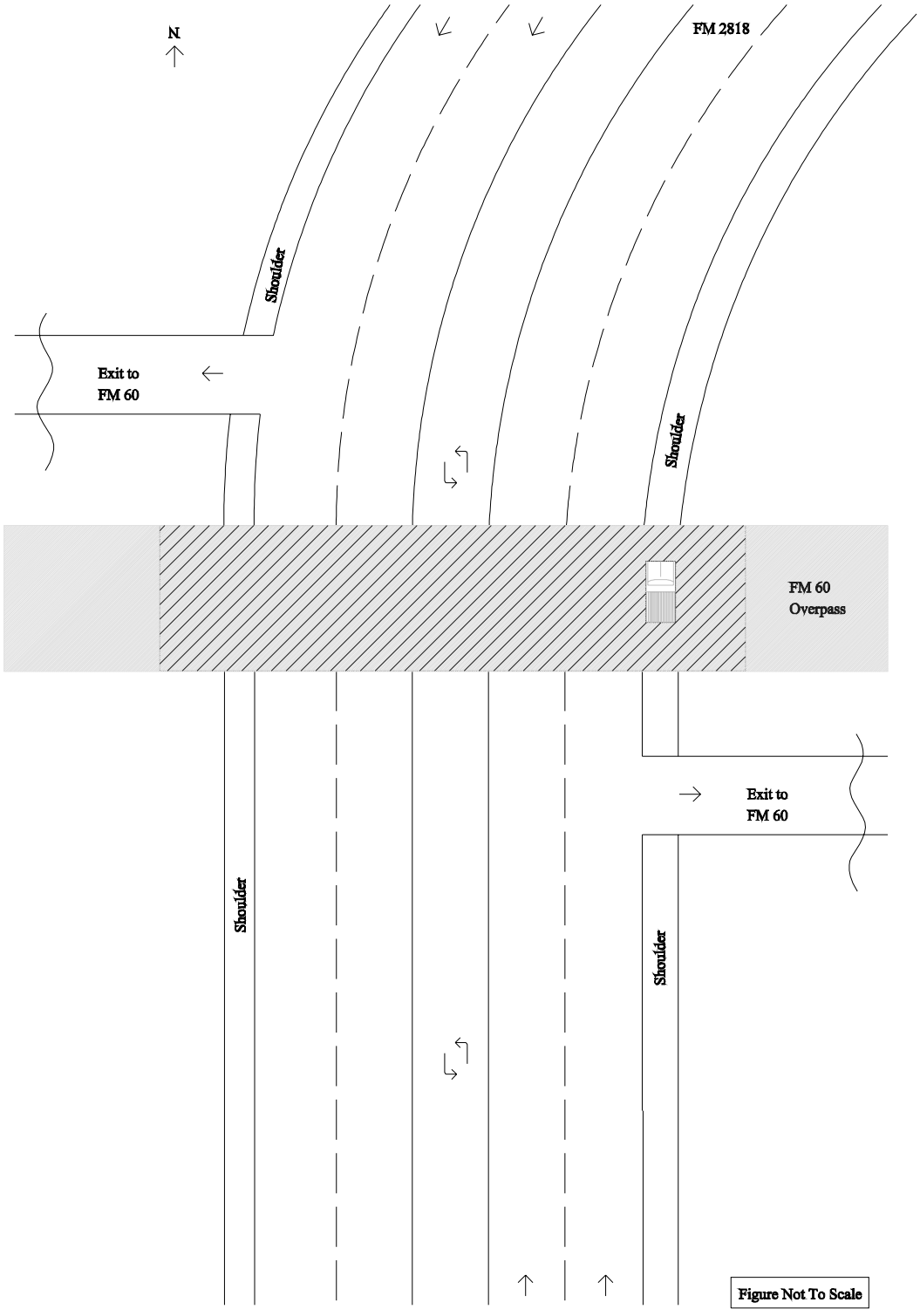

Figure D2. Bridge Measurements on FM 2818.

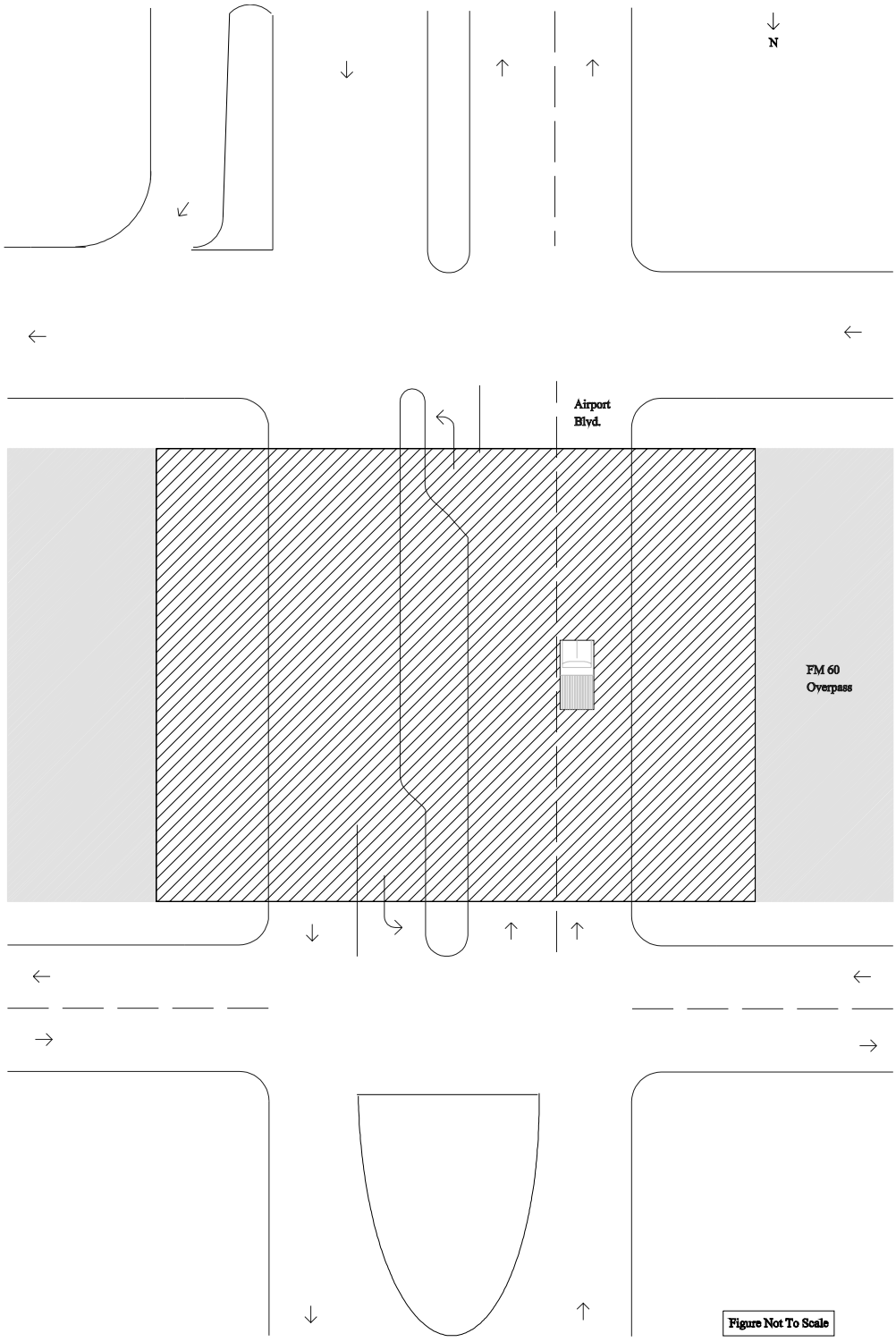

Figure D3. Bridge Measurements on Airport Boulevard.

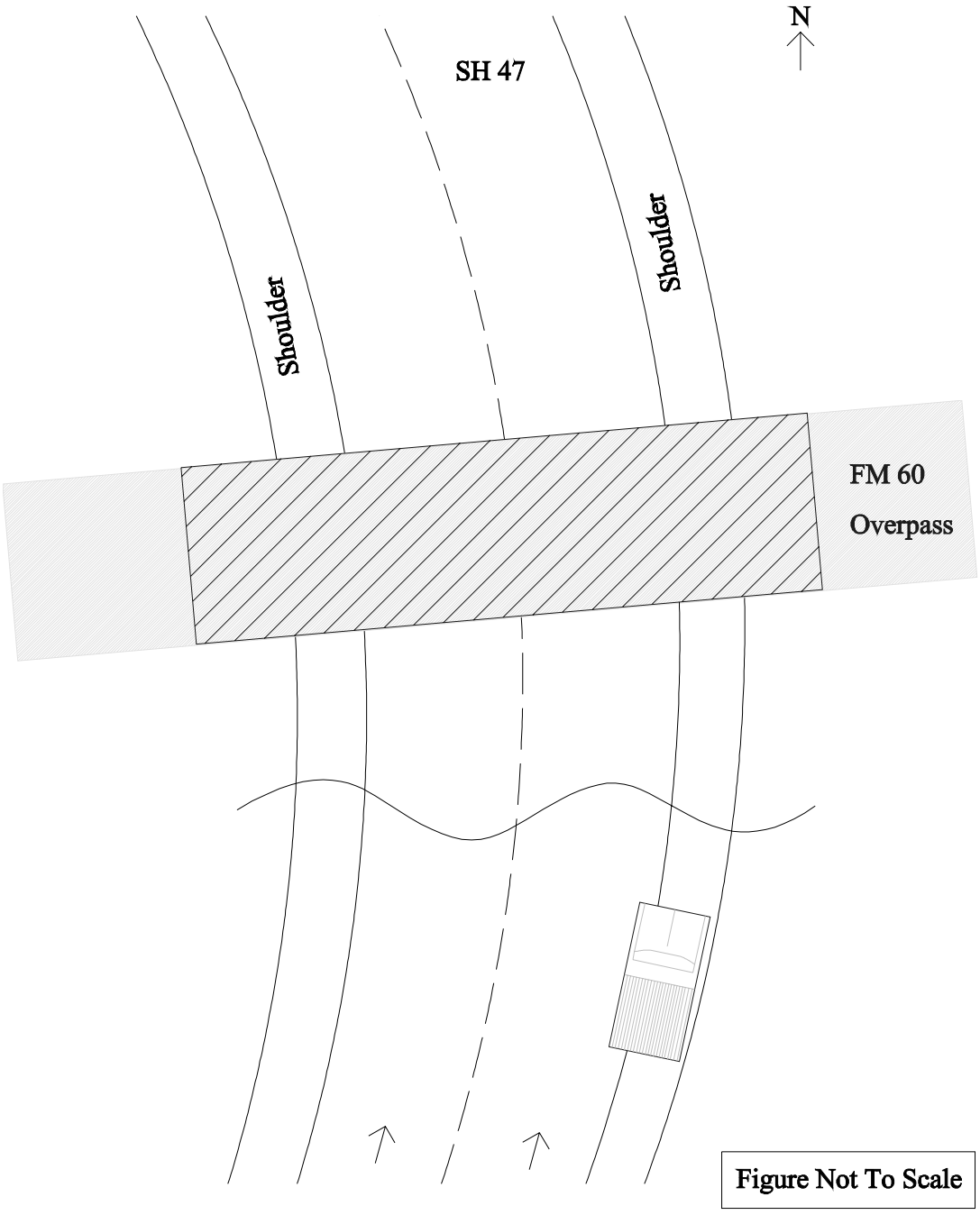

Figure D4. Bridge Measurements on SH 47.

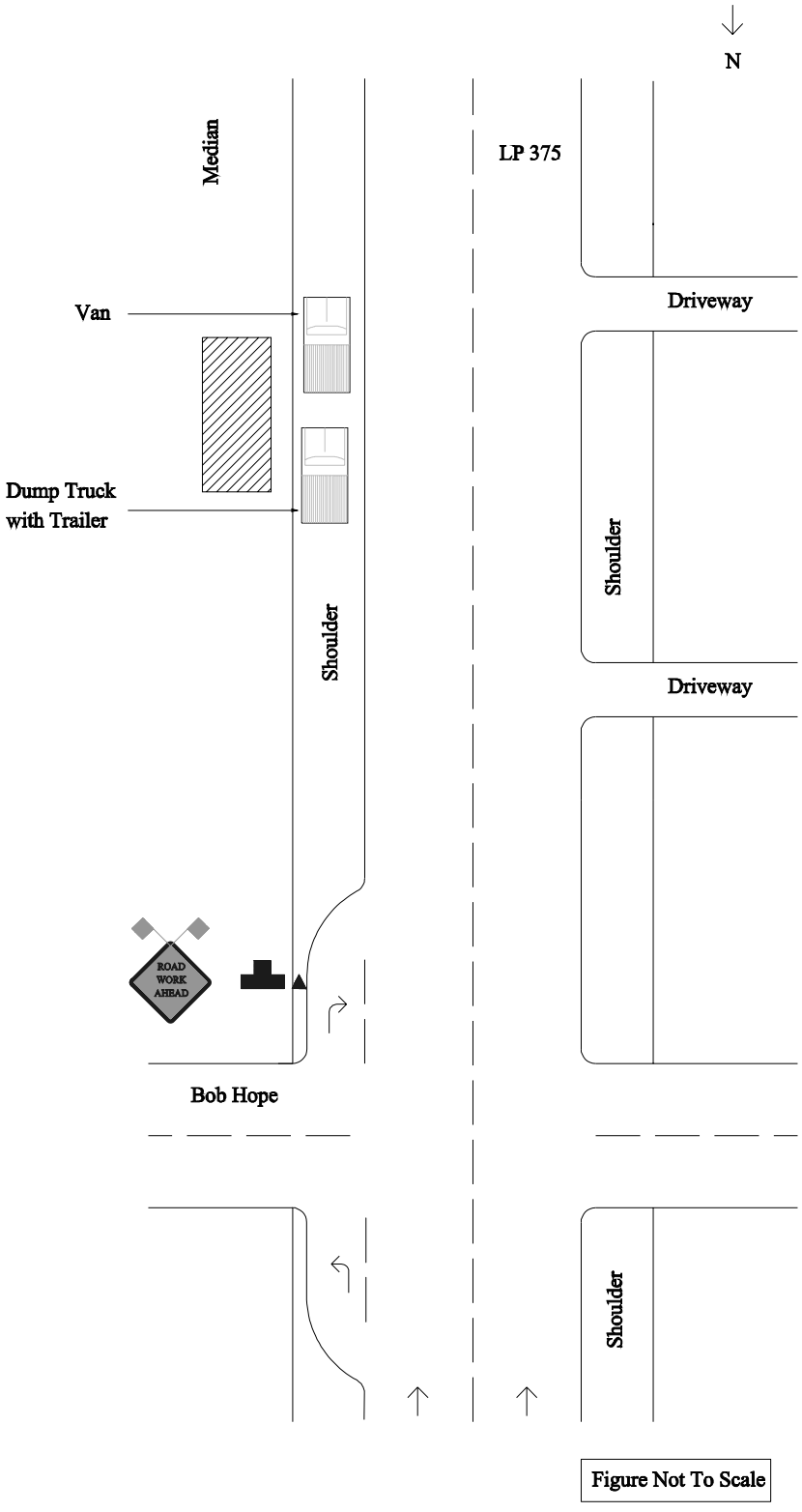

Figure D5. Litter Pickup on LP 375.

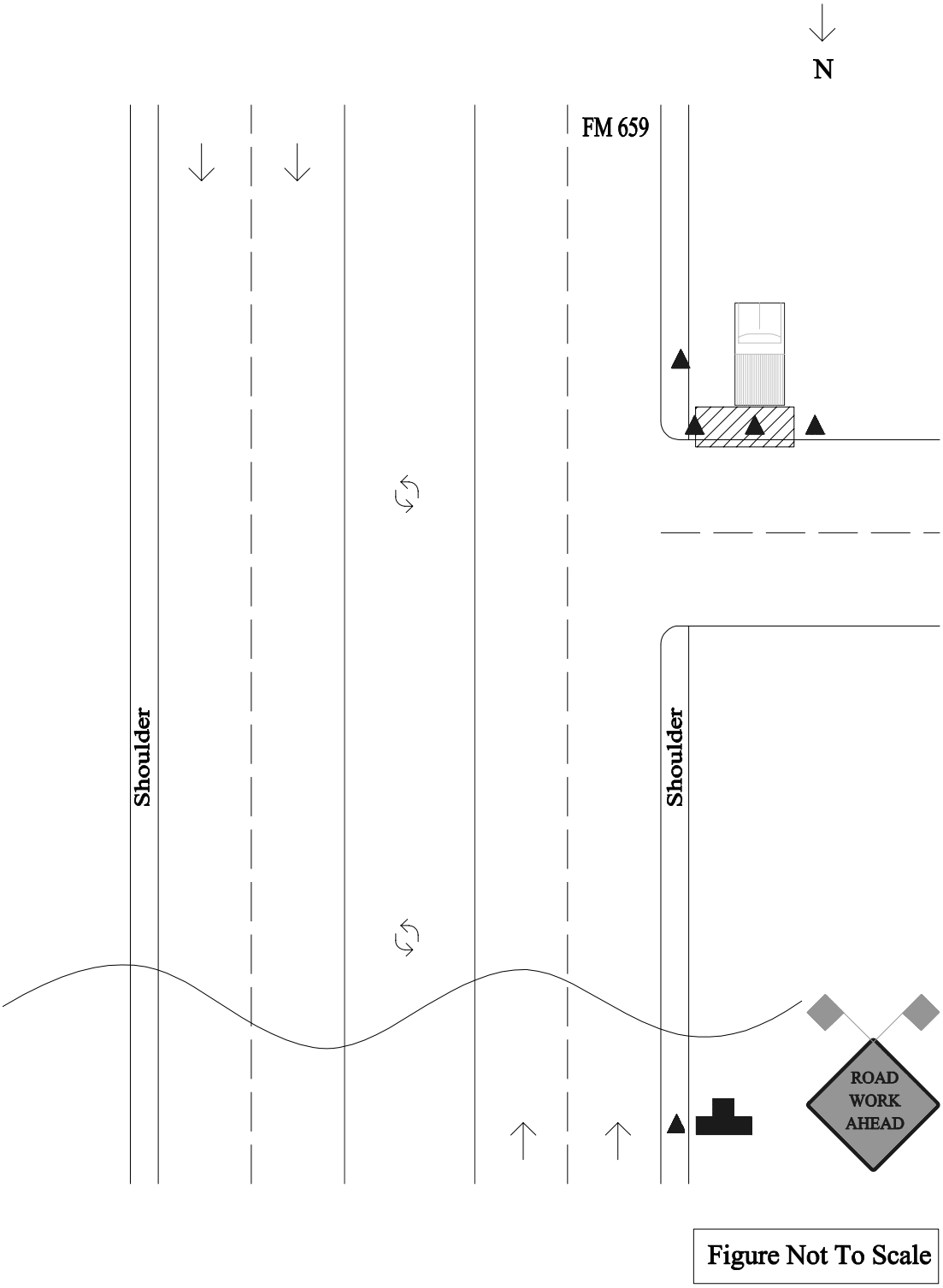

Figure D6. Sign Maintenance on FM 659.

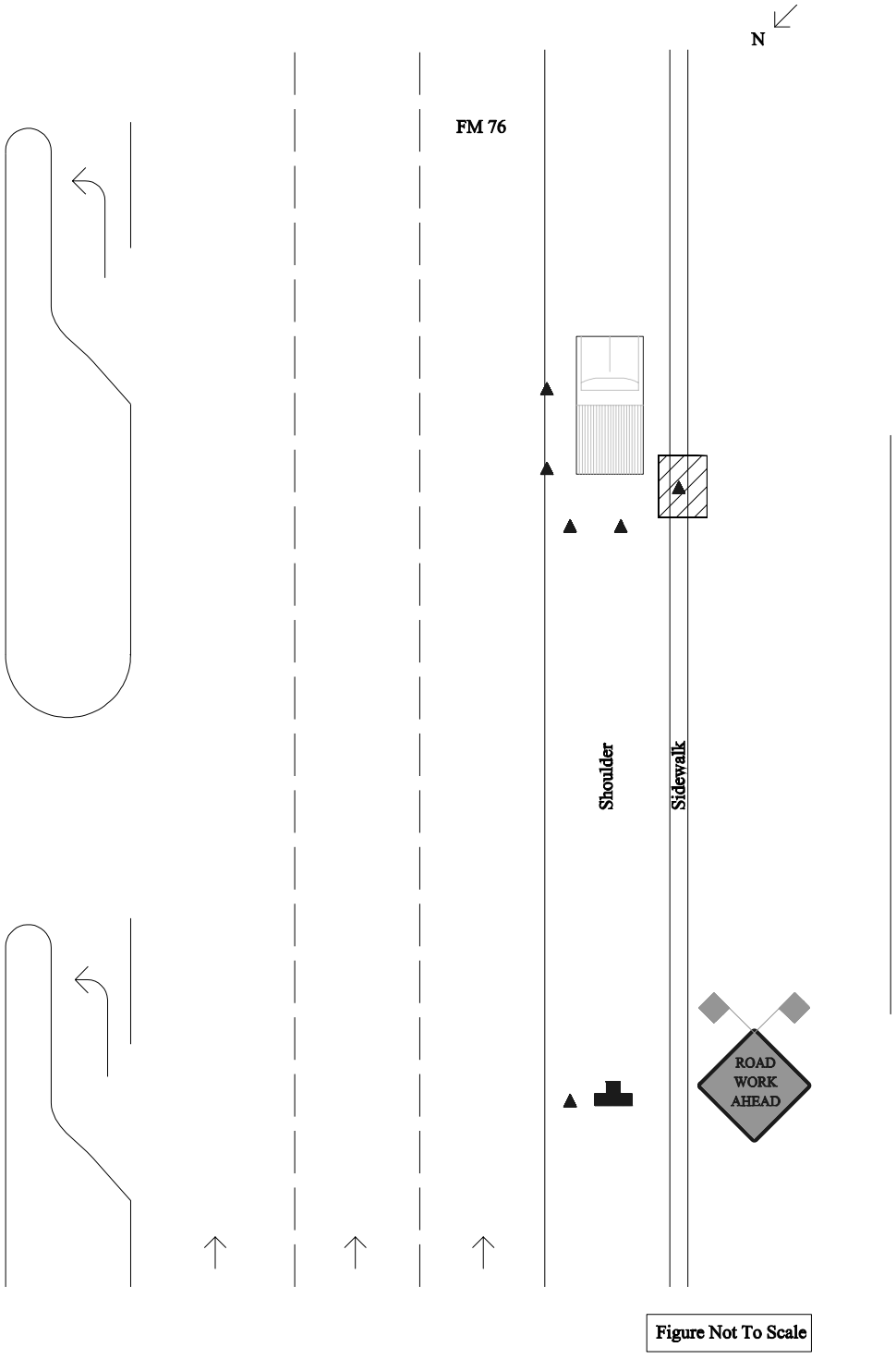

Figure D7. Sign Maintenance on FM 76.

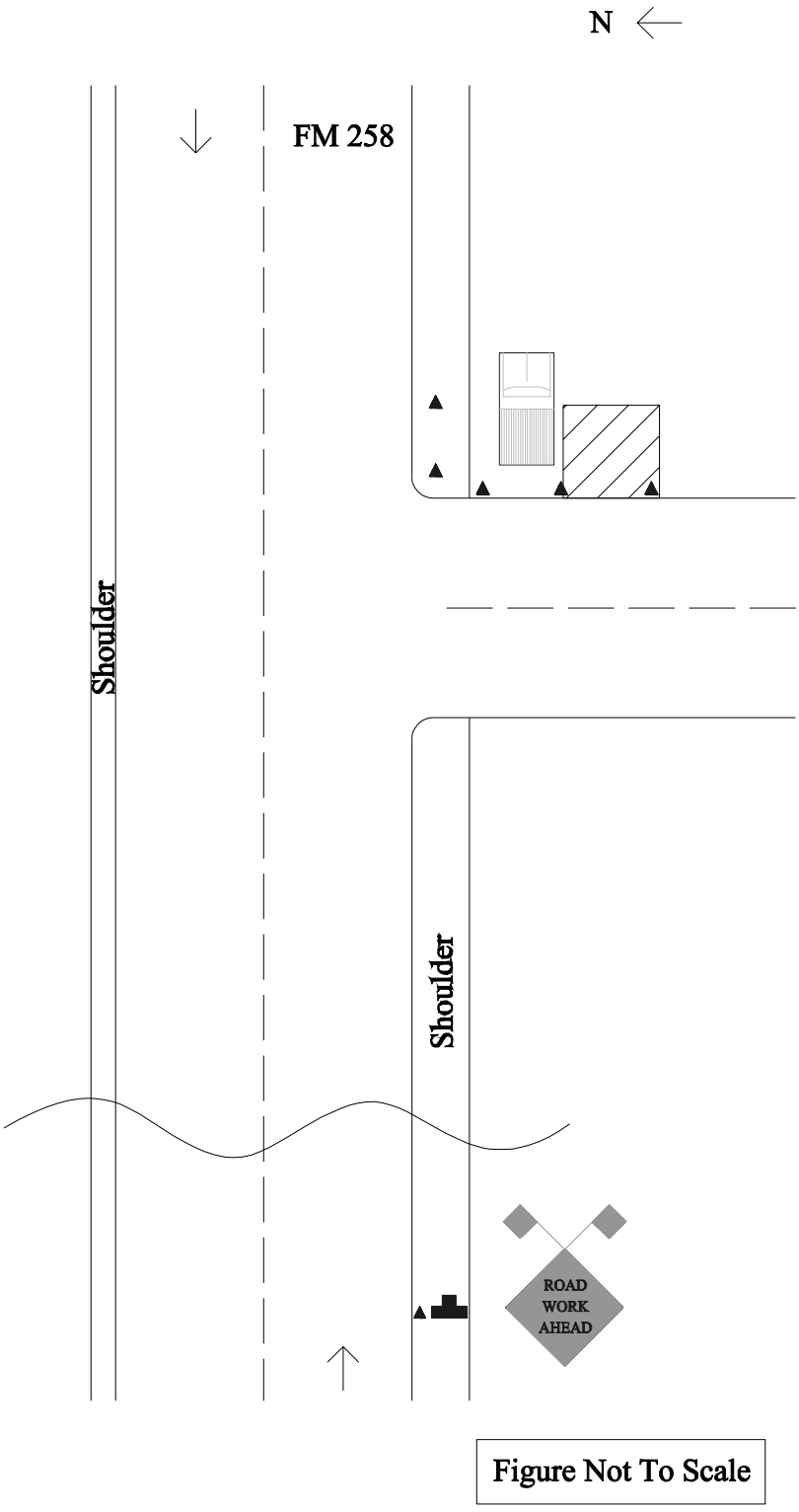

Figure D8. Sign Maintenance on FM 258.

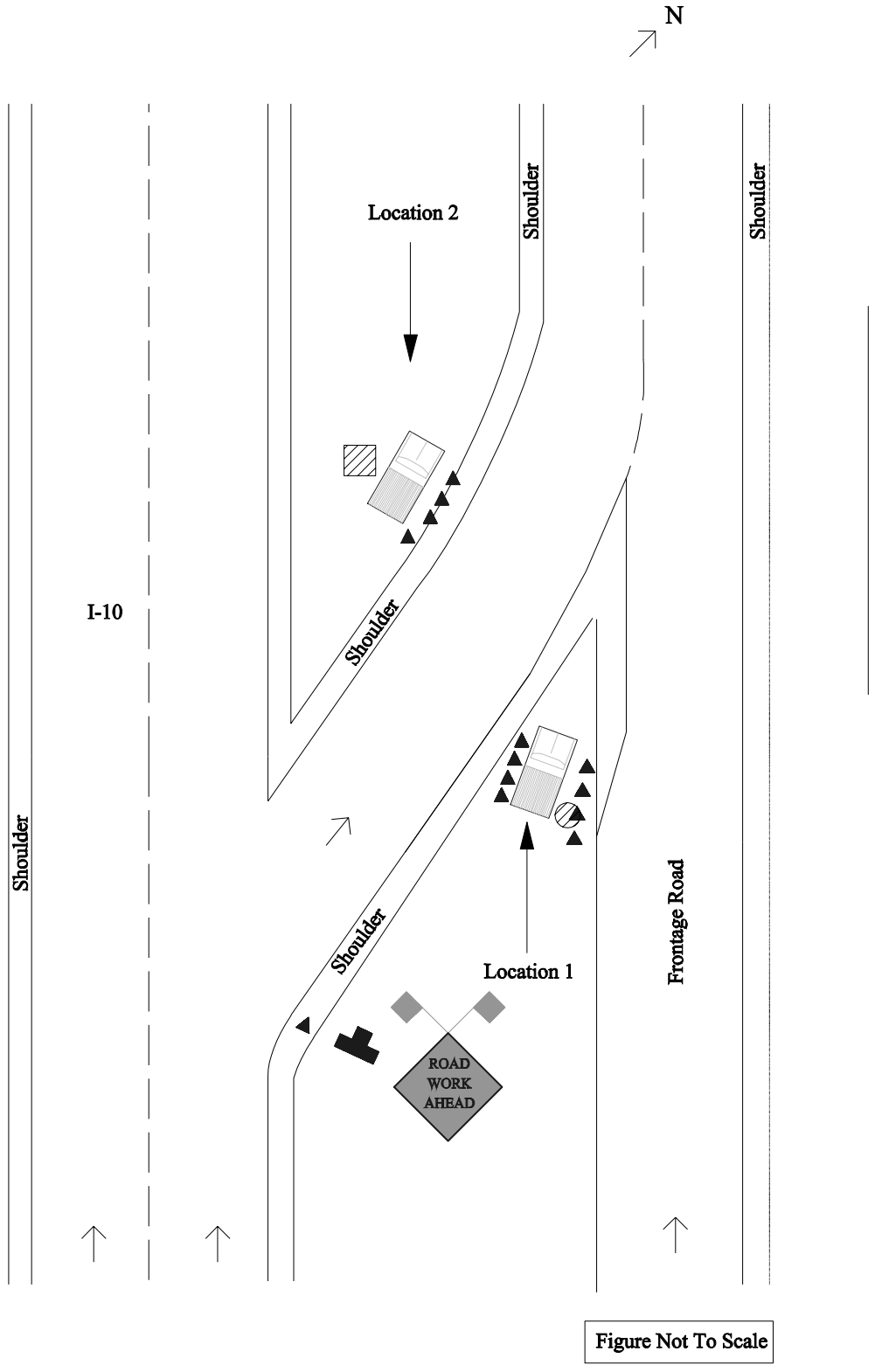

Figure D9. Sign Maintenance on I-10.

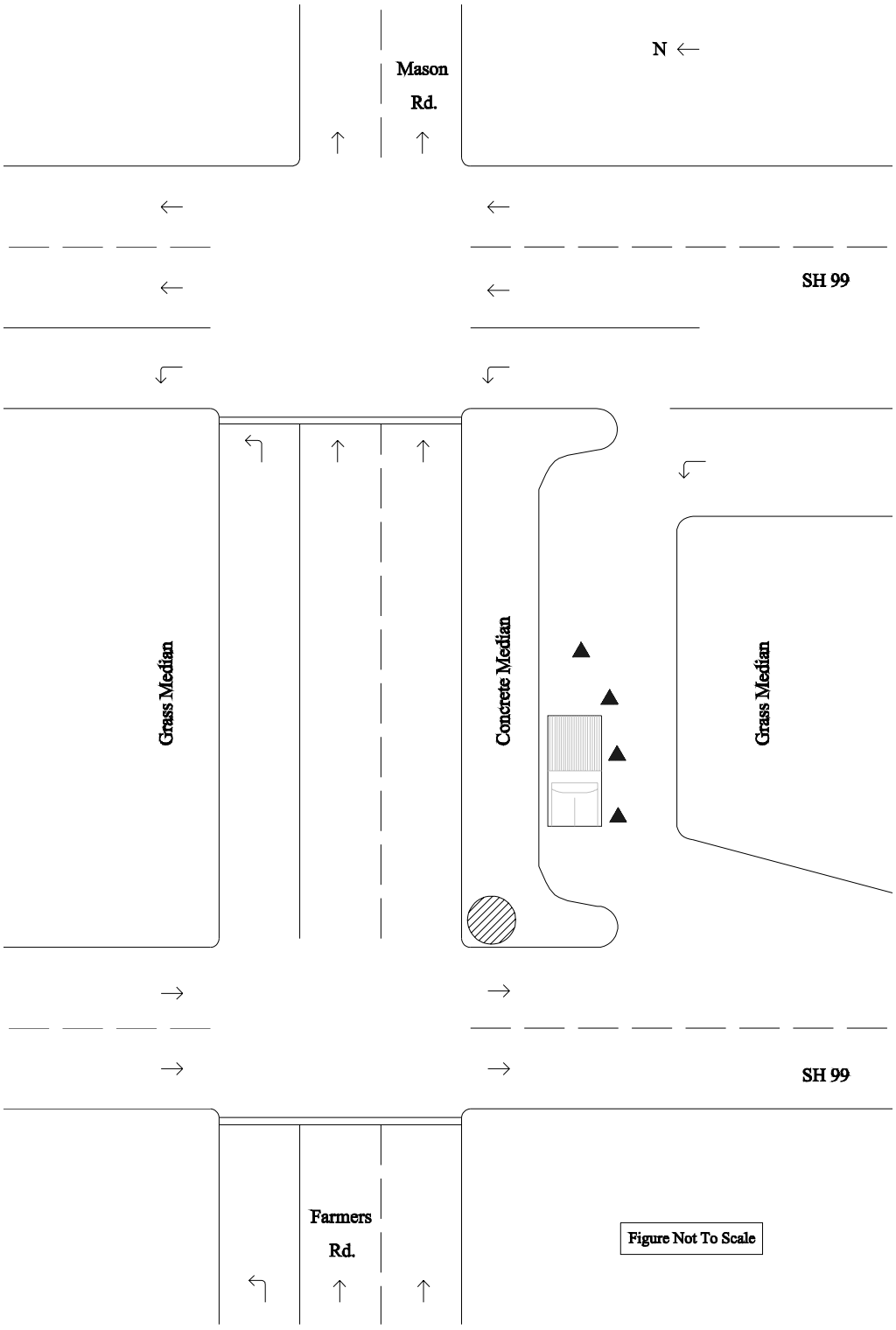

Figure D10. Sign Maintenance on SH 99.

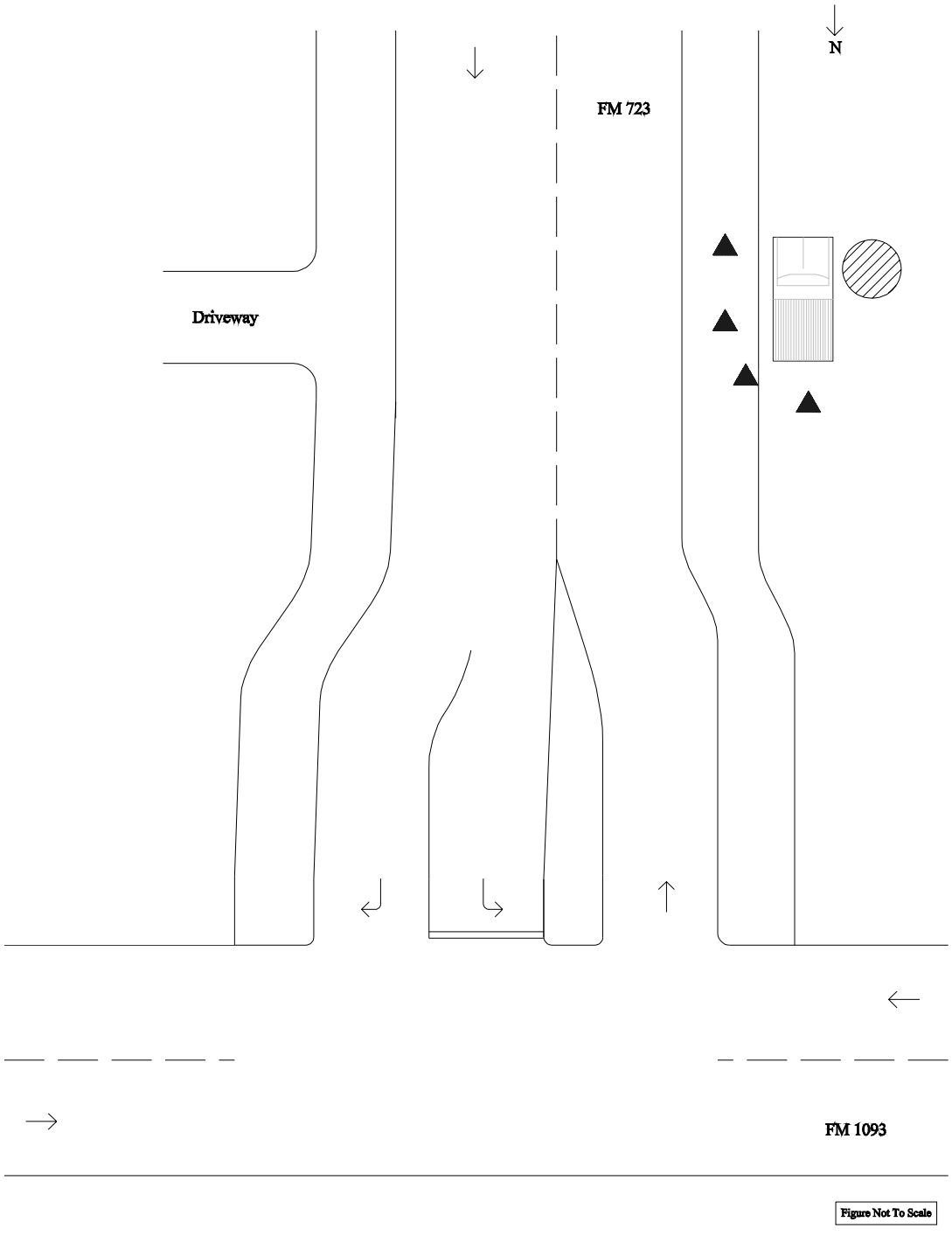

Figure D11. Sign Maintenance on FM 723.

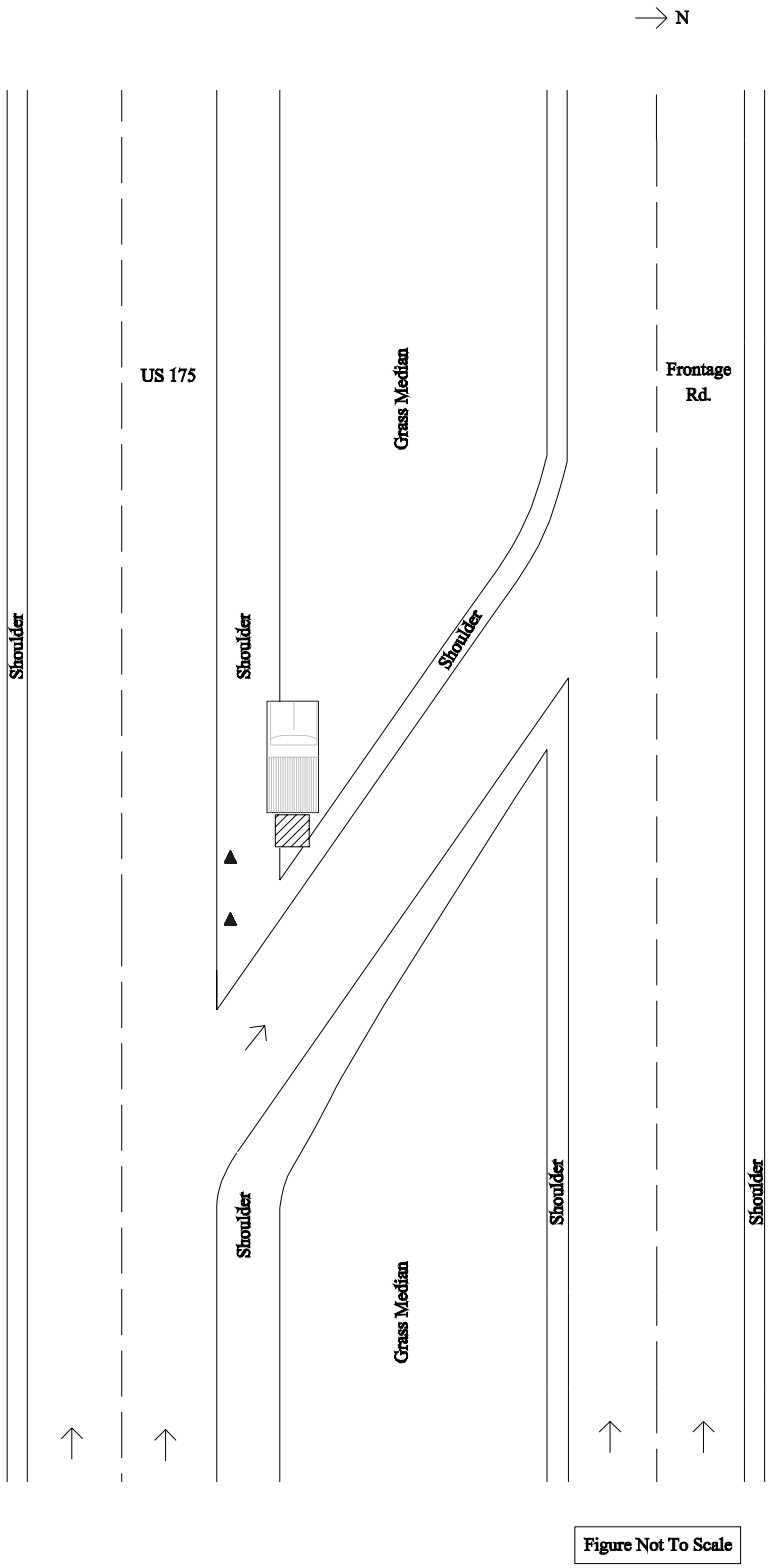

Figure D12. Sign Maintenance on US 175.

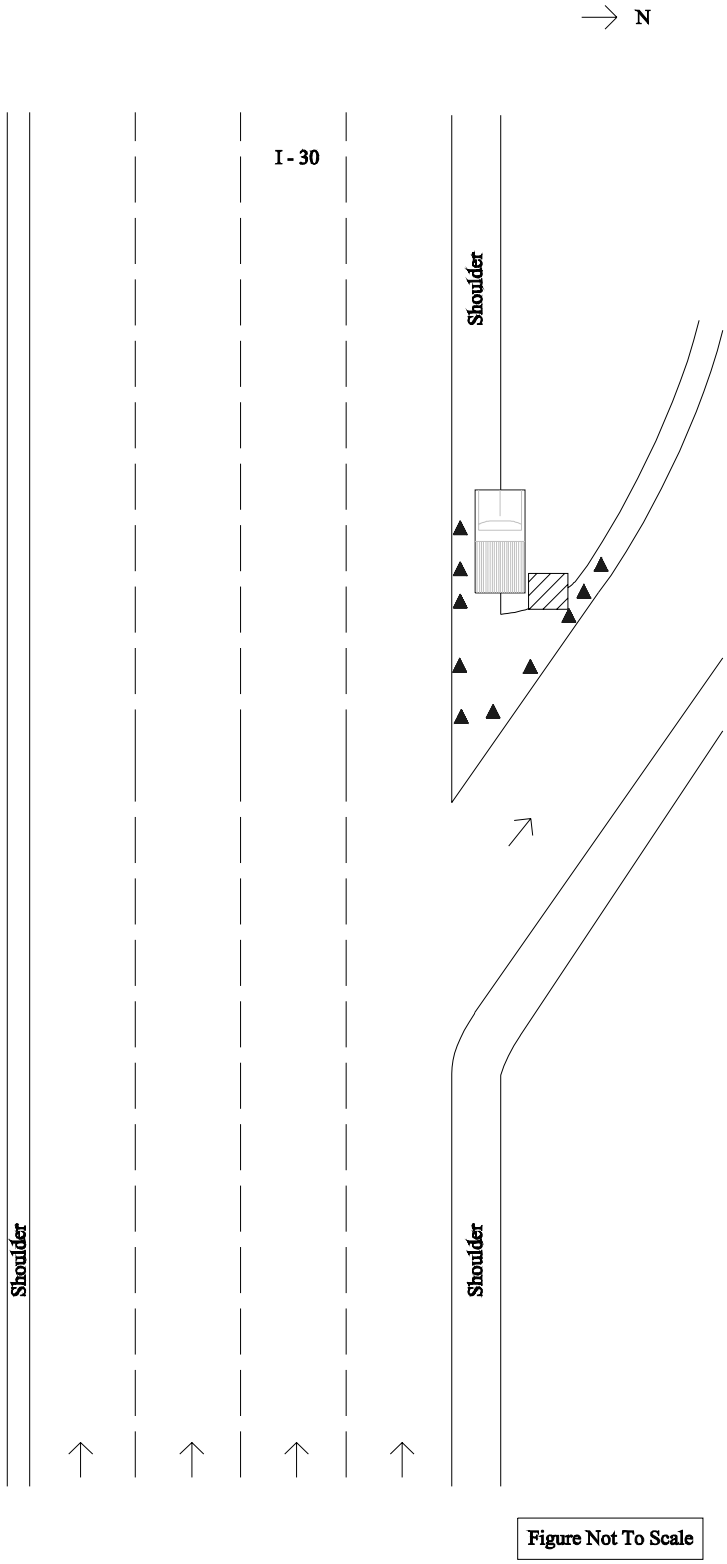

Figure D13. Sign Maintenance on I-30.

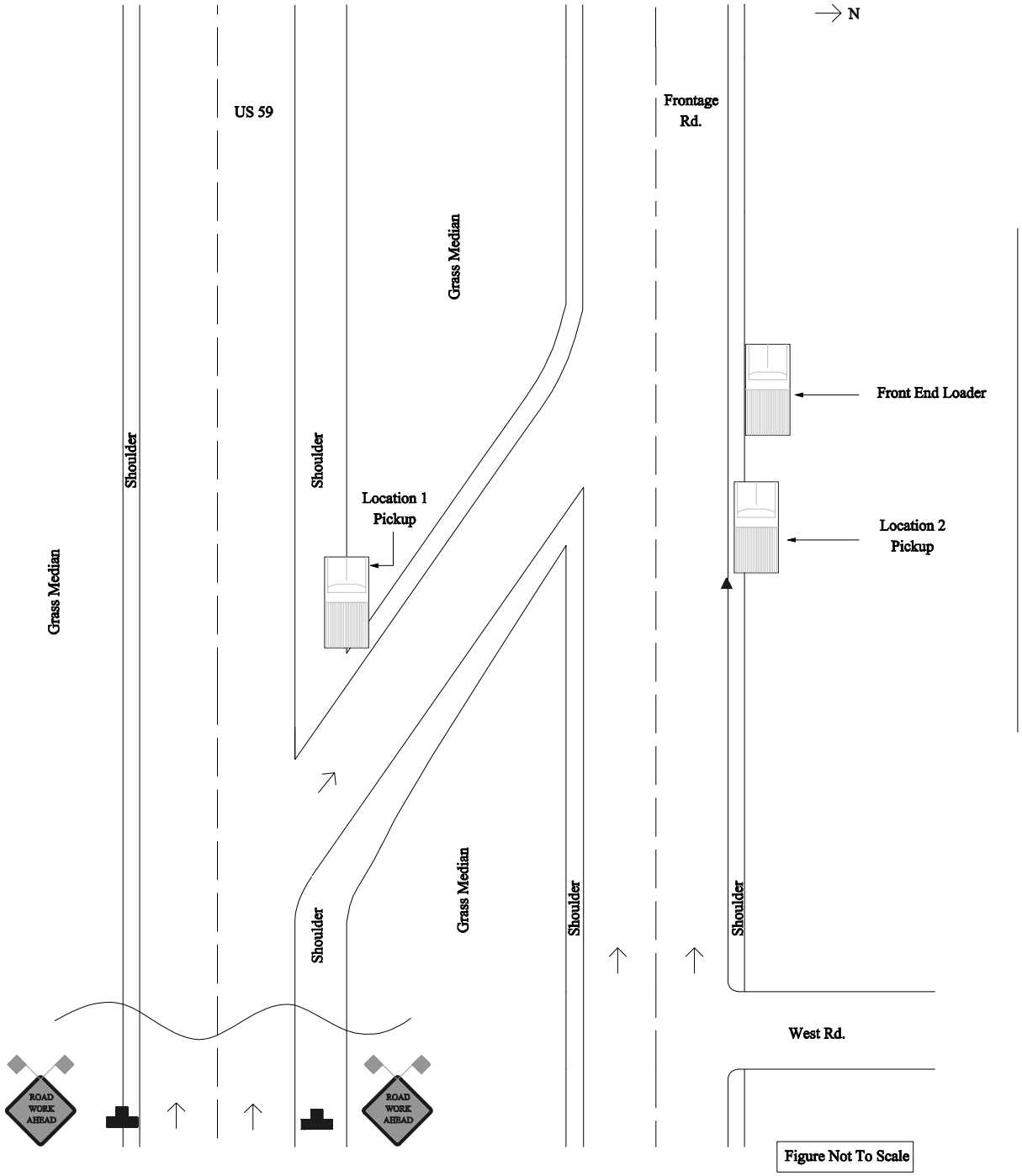

Figure D14. Delineator Maintenance on US 59.

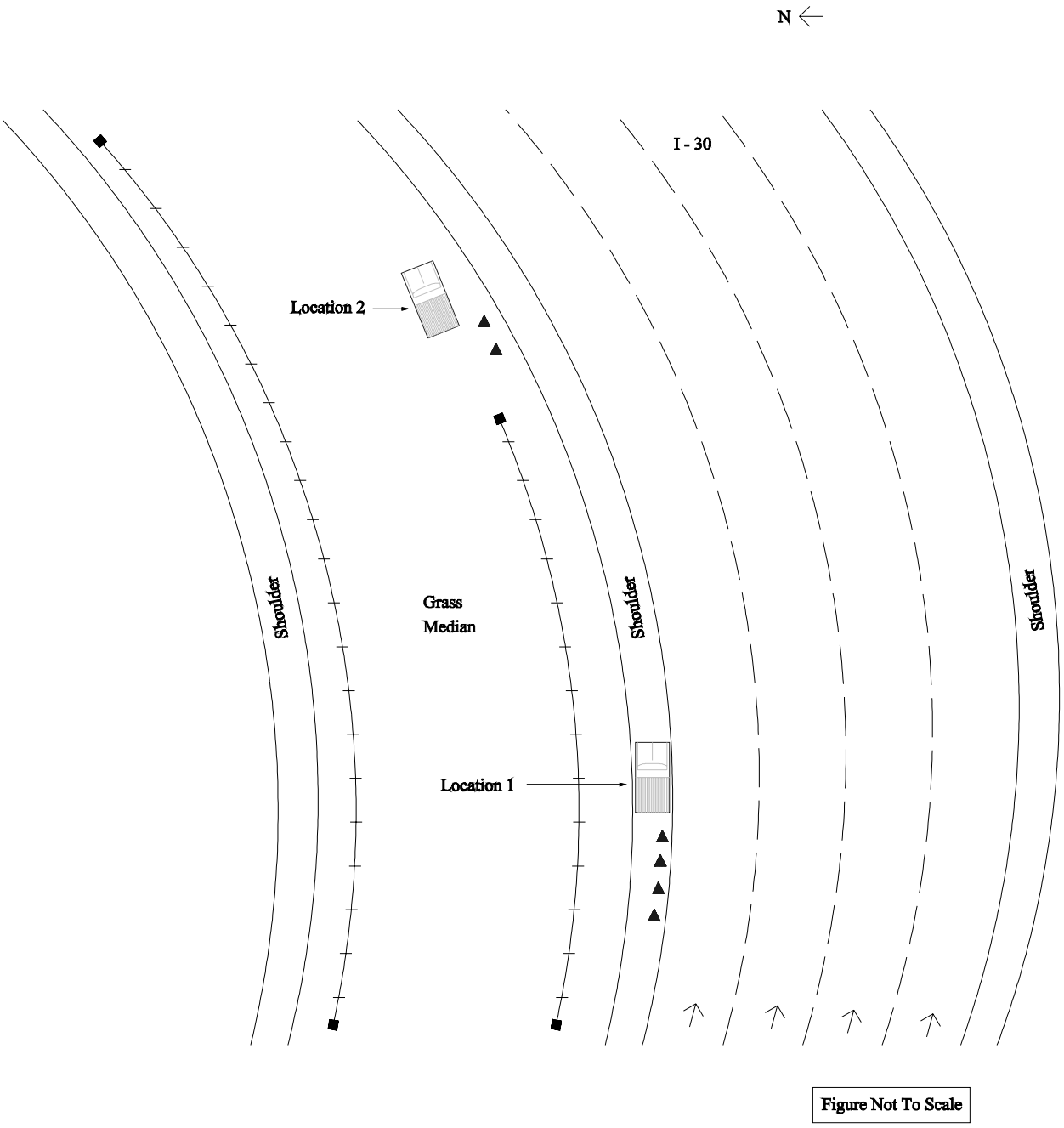

Figure D15. Delineator Maintenance on I-30 (Site 1).

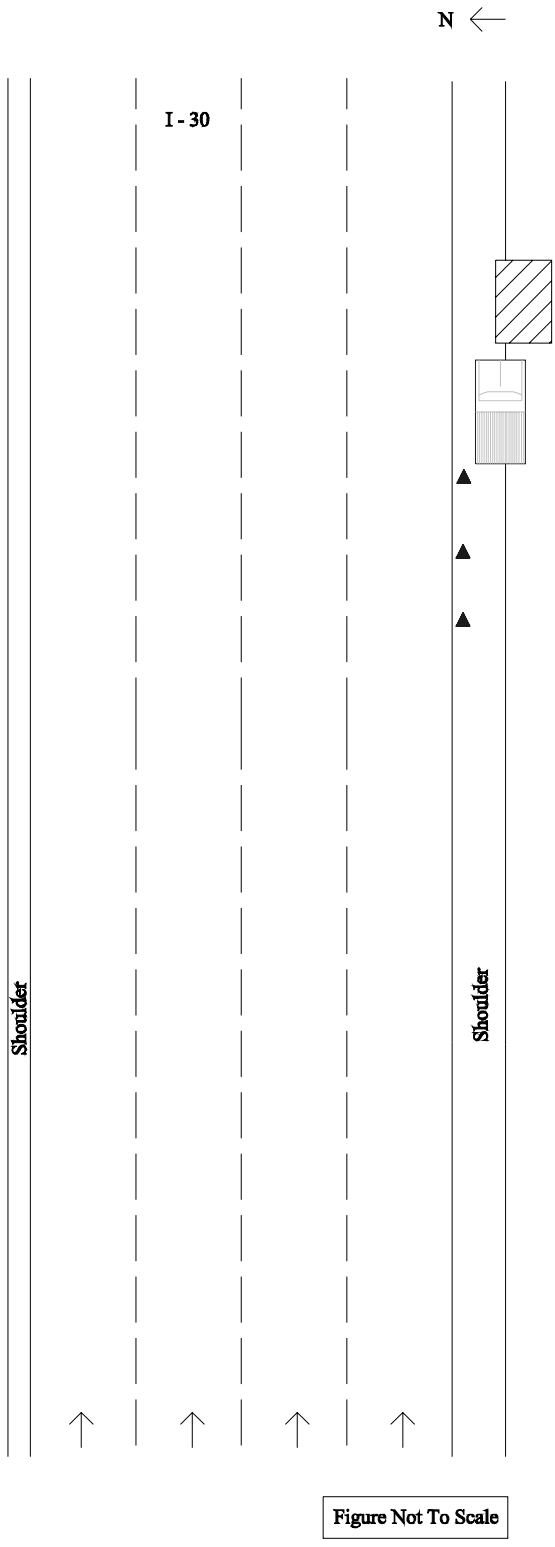

Figure D16. Delineator Maintenance on I-30 (Site 2).

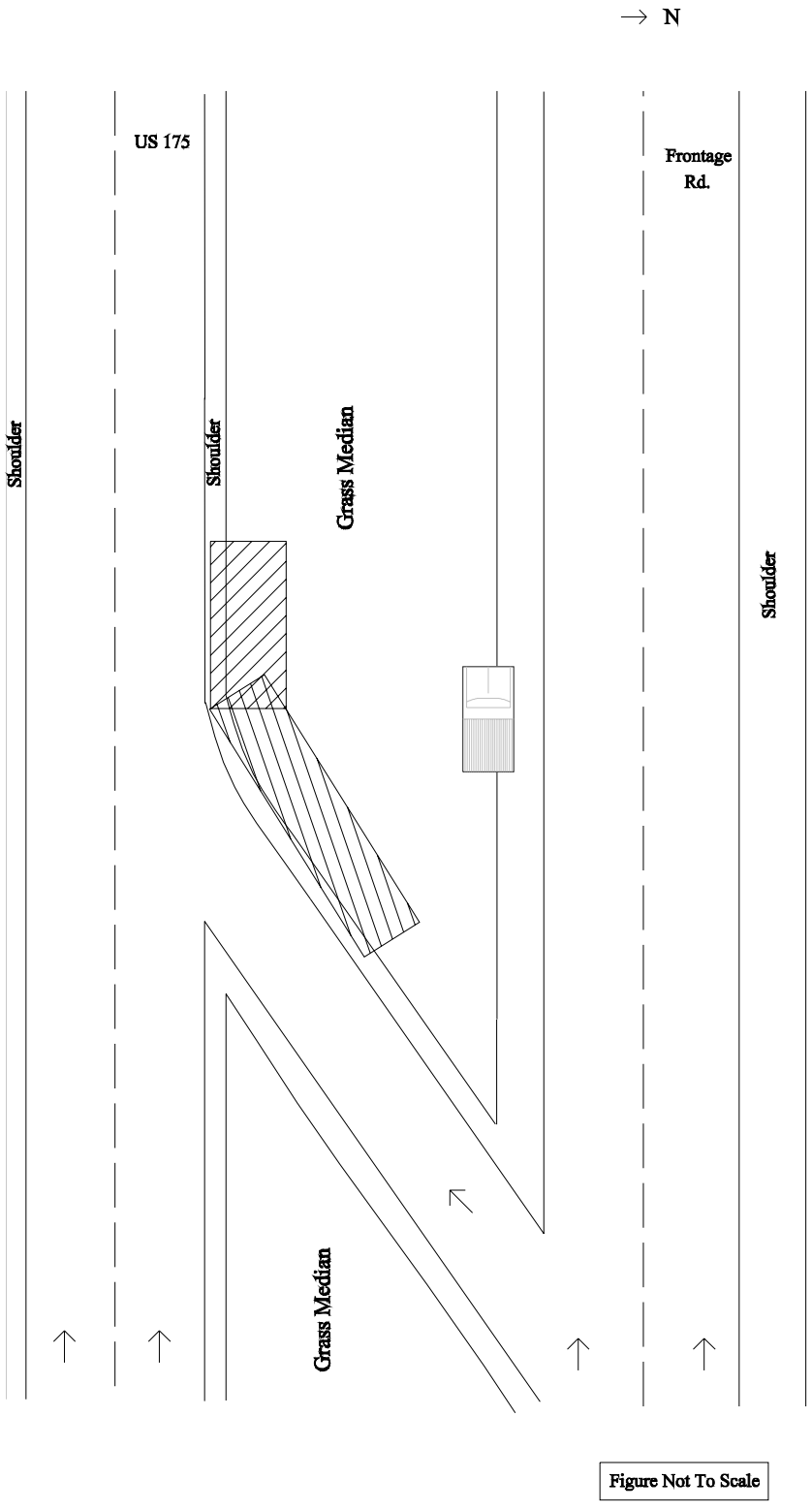

Figure D17. Delineator Maintenance on US 175 (Site 1).

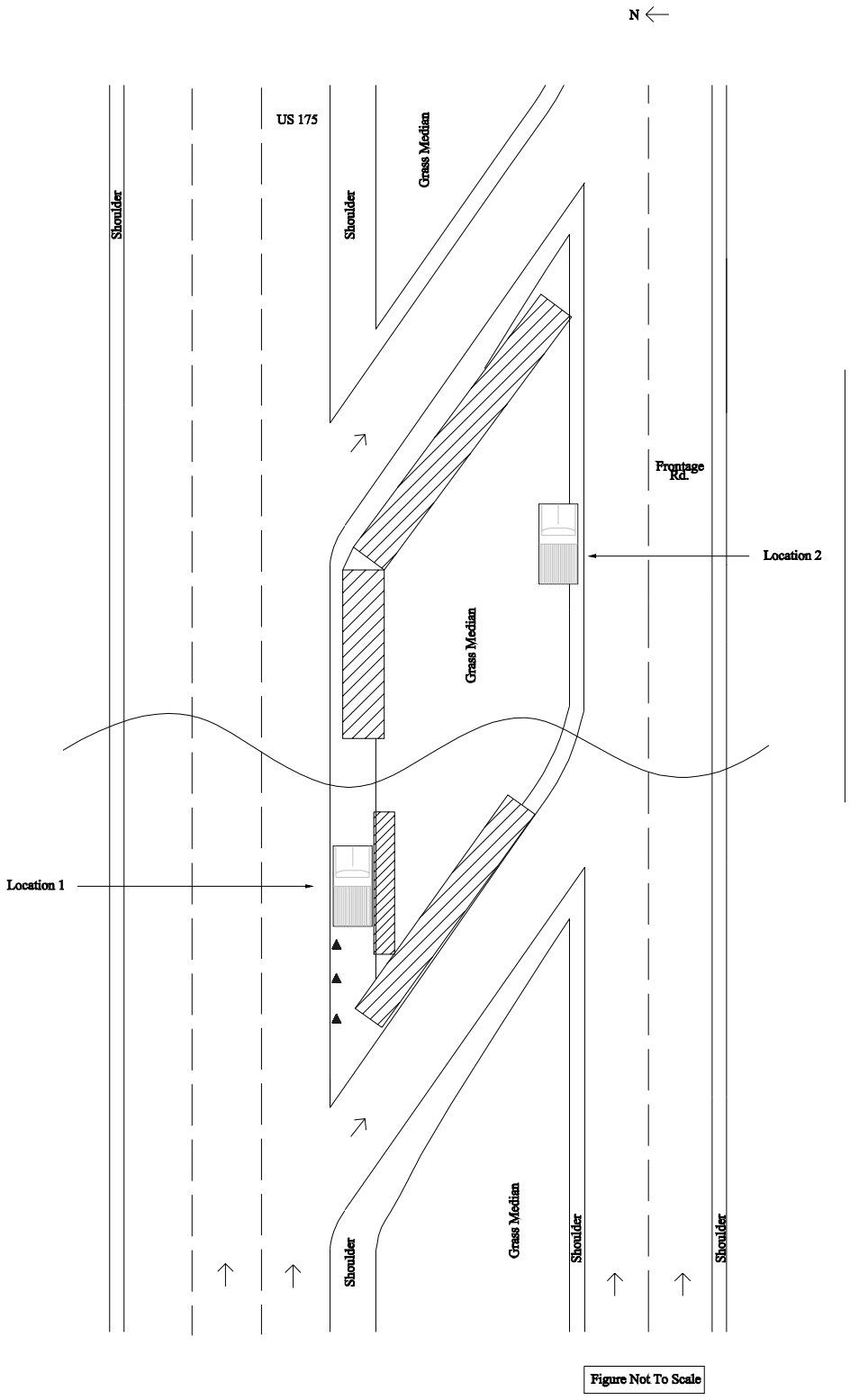

Figure D18. Delineator Maintenance on US 175 (Site 2).