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ET-2000
END TREATMENT FOR GUARDRAIL

FINAL REPORT

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16. Abstract

The Trinity Industries, Inc. ET-2000 is a guardrail end treatment designed to absorb the kinetic energy of a vehicle upon impact. Forty-three ET-2000 systems were installed at sites along I-94 and I-894 in Milwaukee County, Wisconsin. Performance of the systems was evaluated after five years in service. Vehicle impacts with the ET-2000 systems were generally not severe. Only minor injuries were reported in several cases, and no fatalities occurred. No impact resulted in vehicle vaulting or spearing, problems that were noted with traditional guardrail designs. After an impact, repair to an ET-2000 system was relatively simple and did not require a high number of labor-hours. Maintenance crews did note a deficiency in the temporary reinstallation of extruder head terminals; however, it appears from current detail drawings that this problem has been resolved. The initial installation cost of the ET-2000 system is higher than traditional guardrail systems, but that cost is offset by improvements in safety offered by the ET-2000. In addition, the ET-2000 can be installed without embankment widening and other right of way constraints that are required with traditional systems. The ET-2000 has performed well in Wisconsin, and many of these models have been installed since the start of this research project. Continued use is recommended for the ET-2000 and subsequent Trinity Industries, Inc. models that conform to NCHRP Report 350.

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INTRODUCTION

The use of roadside safety devices to reduce the severity of injuries due to off-road accidents has been a standard practice in the nation for many years. While these devices have been responsible for saving numerous lives, some have not performed as expected or hoped. In an effort to achieve a safe, cost-effective transportation system, research of roadside safety devices has been an ongoing process throughout the nation for many years. Research has lead to the development and improvement of many safety devices available today, with new or improved designs continually being developed and researched. The Wisconsin Department of Transportation (WisDOT) has been involved in a number of research studies aimed at evaluating these safety devices. Some of the devices have been accepted for use in Wisconsin. In 1994, WisDOT initiated this particular research study to evaluate the ET-2000 guardrail end treatment.

PRODUCT DESCRIPTION

The ET-2000, developed and manufactured by Trinity Industries, Inc., is a guardrail end treatment that is designed to absorb kinetic energy generated upon vehicular impact, while preventing spearing, vaulting, and rollovers, thus reducing the severity of collisions. The design, solely intended for use on roadside shoulders, consists of a guardrail extruder terminal, a cable assembly with cable anchor, a framework of W-beam steel guardrail panels, and breakaway wooden posts, of which the first four at minimum are secured to steel foundation tubes (Figure 1).

Figure 1. The ET-2000 guardrail end treatment.

Upon a head-on impact, the guardrail extruder terminal is designed to move rearward along the guardrail, shearing the wooden posts and bending the end of the guardrail away from the colliding vehicle and away from traffic. This process is intended to absorb kinetic energy of the impact while bringing the vehicle to a controlled stop. In the event of a side angle impact, the unit is designed to redirect the vehicle back into the traffic lane.

The ET-2000 guardrail end treatment does not require that the guardrail ends be flared away from the edge of the shoulder. This aspect makes the ET-2000 ideal for use in locations where geometry prevents a standard flare, where right of way widths are restricted, or where the flare can be achieved but the cost of embankment widening would be too high.

PRODUCT HISTORY

The ET-2000 was approved by the Federal Highway Administration in 1989 and has been in use in numerous states since 1990. Some states adopted this system as a standard for use where the flare for a breakaway cable terminal (BCT) cannot be achieved. It has also been used as an equal alternative for a BCT when the flare can be achieved but use of the ET-2000 would eliminate the cost of embankment widening.

The ET-2000 has undergone testing and certification for roadside safety hardware under the guidelines contained in the National Cooperative Highway Research Program (NCHRP) Report 350. Slight design modifications have been made to the ET-2000 since the 1990s. The currently available model uses a taller, more narrow impact head, which improves performance upon impact and also reduces the likelihood of the head being snagged by snowplow blades.

Prior to 1994, WisDOT primarily used the BCT and the Modified Eccentric Loader Terminal (MELT), both of which required embankment widening. WisDOT regional offices were initially not in favor of the ET-2000 because its initial cost was higher than a standard BCT end. However, in the years following this study, the use of ET-2000 (and other later models) has increased significantly in Wisconsin.

OBJECTIVES

This research effort initiated with WisDOT Southeast Region's interest in installing the ET-2000 units along the interstate. The objectives of this study were to evaluate and analyze the performance of the ET-2000 for five years with respect to:

Construction

- Ease of installation
- Efficiencies and deficiencies

Product Performance

- Improved safety
- Resistance to adverse weather conditions

Maintenance

- Ease of repair and replacement

Costs

- Initial
- Maintenance and replacement

INSTALLATION SITES

In 1994, the FHWA Wisconsin Division approved the use of this proprietary product for a test installation. WisDOT Southeast Region installed forty-three ET-2000 units in Milwaukee County at numerous test sites along I-894 and at one location on I-94. The terminals were erected on roadside shoulders, and were located at the ends of guardrail barriers to potential hazards such as bridge piers and steep embankments. A general site map and a test installation location map are provided in Figures A-1 and A-2 in the Appendix. Table A-1 in the Appendix lists specific installation locations.

CONSTRUCTION

The units were installed according to WisDOT Standard Specifications, WisDOT Special Provisions, product drawings, and manufacturer recommendations. A representative of the manufacturer was present during initial installations to ensure proper installation procedures were followed. The units consisted of a guardrail extruder head terminal, a cable assembly and cable anchor bracket, a framework of W-beam steel guardrail panels, breakaway wooden posts, and steel foundation tubes (Figure 2). Each ET-2000 package contained all materials required for installation.

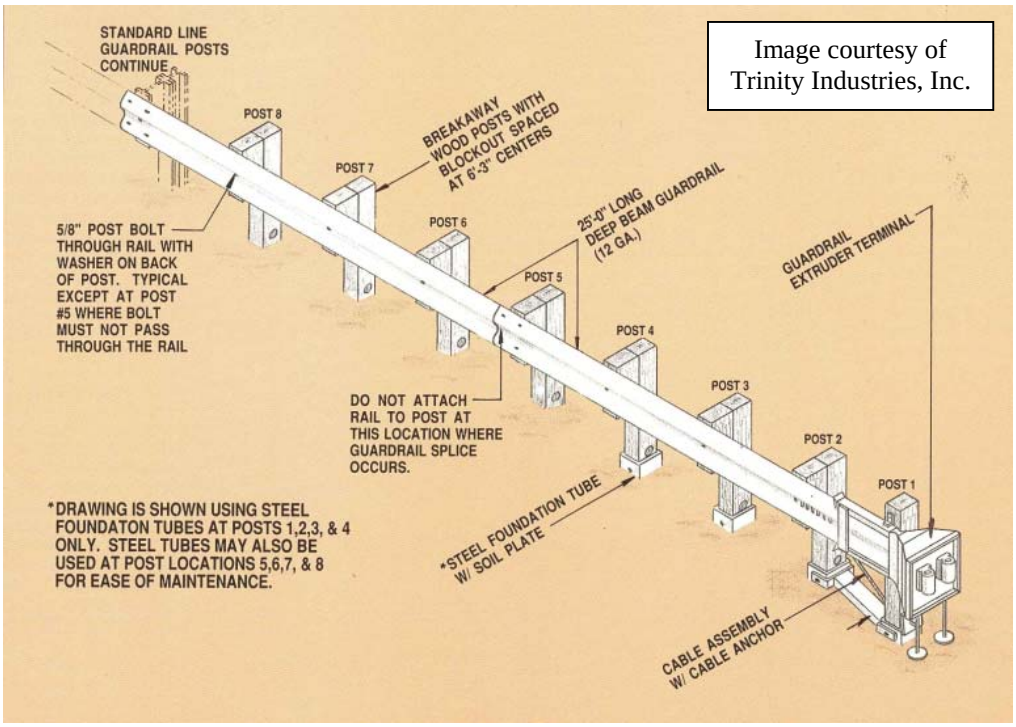

Figure 2. Components of the ET-2000 System.

No major earthwork or embankment widening was required for installation, although minor site grading may have been necessary to maintain consistent post elevations. Soil plates were bolted to foundation tubes, and this assembly was driven into the ground with an approved driving head. Augured pilot holes were necessary in cases where the soil was impermeable, but the driving method resulted in a better installation. Foundation tubes were required at post locations

one through four but could also have been installed at the remaining four post locations to make future post replacement operations easier.

Wood posts were installed in the steel foundation tubes at post locations one through four, or driven into the ground at post locations five through eight. Wood blockouts were attached at post locations two through eight. The first guardrail panel was attached at post locations eight through five, and the second guardrail panel was attached at post locations five through one. The cable strut and anchor bracket assembly was installed. Finally, the guardrail extruder was attached by placing it over the end of the guardrail panel and pushing it on as far as possible. To improve visibility, a high intensity reflector was installed on the front face of the extruder.

The ET-2000 units were relatively easy to install, requiring few workers and little time. On average, one unit took two workers approximately two hours to install. Required tools included sockets and wrenches, a post driver, and, if the soil was stiff, an auger. The units were installed along the edge of the roadway rather than on a flare as required for many gating type terminals. This greatly reduced the amount of earthwork required for embankment widening to provide the required four-foot offset flares necessary for non-energy absorbing systems.

PRODUCT PERFORMANCE

During the study period, there were approximately twenty police-recorded collisions with ET-2000 guardrail end terminals. Of the recorded incidents, two-thirds of the impacts were side-angle hits and one-third were direct head-on hits. The collisions resulted in a total of four reported injuries, two from side-angle impacts and two from head-on impacts. None of the impacts resulted in fatalities.

The side-angle impacts caused the guardrail to bend and, in some cases, resulted in broken posts. Most of the vehicles came to a stop either directly or shortly after hitting the guardrail. None of those cases resulted in an injury. Several of the side-angle hits resulted in the vehicle striking the guardrail at least twice before coming to a rest in one of the driving lanes. Two of those incidents resulted in injuries.

Half of the vehicles that directly hit the ET-2000 terminal extruder were brought to a stop directly after impact. Of those incidents, one of the vehicles had first struck a concrete barrier on the opposite side of the road prior to hitting the ET-2000; that incident resulted in an injury. The other half of the vehicles that directly hit the ET-2000 traveled a short distance, either down a grassy incline or into a travel lane, before coming to a stop. One of those resulted in an injury.

Maintenance personnel did not keep track of the number of units that were repaired during the five-year study period, so it is very likely that more impacts with the ET-2000 occurred than were reported. If incidents were not reported, they were likely not very severe and probably didn't result in injuries since the drivers were able to drive away. It is also important to note that searches of accident databases may not find all incidents.

FHWA's current procedure for testing and evaluating roadside safety hardware is based on the results of multiple crash tests conducted in compliance with the guidelines established in the NCHRP Report 350. Crash testing of the ET-2000 was conducted by the Texas Transportation Institute. The results indicated that the ET-2000 met the NCHRP Report 350 criteria for impact performance at Test Level 3. This test requires adequate performance in seven crash scenarios that evaluate vehicle occupant risk, energy absorption of the system, and vehicle trajectory.

It was noted that reflectors mounted to the guardrail at bolt locations acted as washers and prevented the bolt heads from pulling through the guard rail slot upon impact, as intended. This caused the guardrail to bend at the bolt rather than pull away from the post. Therefore, these reflectors were removed from the units.

The units withstood the impact of snow and ice, and the unit components did not show any indication of damage or corrosion due to snow, ice, or road salt. The units seemed to function properly in adverse weather conditions, even with snow piled up against them. If the snow piled high enough, however, the extruder head could be obscured, and, if frozen, the snow piles could potentially ramp vehicles over the ET-2000.

MAINTENANCE

Manufacturer Instructions

For temporary repairs, debris should be cleared from the roadway and shoulder. The extruded portion of the guardrail ahead of the displaced extruder head should be removed next, and a truck and chain hook-up is recommended to pull the extruder head off of the remaining undeformed guardrail. The extruder head is normally reusable. The guardrail panel should be cut off six inches ahead of the first undamaged post. The extruder head should then be reinstalled at this location by attaching it to a post with lag bolts.

For permanent repairs, the extruder head and anchor cable assembly should be checked for damage and inventory taken on the number of replacement posts and length of replacement guardrail that is necessary. All damaged parts should then be removed and replaced.

Field Notes

County maintenance forces were asked to provide input on the frequency and ease of maintenance operations for the ET-2000. The following is a summary of comments and observations.

The units were relatively easy to repair, but slightly more difficult than a Type I anchorage system. Most extruder heads remained intact after impact and were remounted and reused, minimizing maintenance costs. To make repairs to the system, a cutting torch was necessary to remove the extruder from the guardrail. Typically, 25 feet of damaged guardrail and two wooden posts required replacement. This type of repair required about four workers. The time required to repair the guardrail end terminal varied with the extent of damage and the location on the interstate.

During maintenance activities, minimal traffic control was necessary and was generally provided from the shoulder; thus traffic flow was not disrupted. If, however an auger was required to pull posts or re-auger holes, one lane of traffic had to be closed. If extensive damage had occurred, one lane of traffic was closed for safety and to park equipment.

There were numerous “nuisance” hits to extruder heads by snowplows, automobiles, and trucks, possibly due to the lack of set back from the shoulder that is required with other systems. These hits usually caused minimal damage but generally required maintenance. Slight impacts to the extruder head would cause post one to split at the connection to the guardrail (Figure 3). Because there was only one hole in the bracket that connects the post to the extruder, the extruder could only be mounted in one location, i.e. where the post had split and could no longer adequately support the extruder. Post 1 would then need to be replaced. If the bracket were designed wider and with additional mounting holes, the extruder could be remounted to the remaining solid section of the post. Post replacement would not be necessary.

Figure 3. Split in post at location one.

The units were often difficult to repair or replace during cold weather conditions. Ground water would build up inside the steel foundation tubes to a height that, under freezing temperatures, caused the wooden posts to freeze and bond to the steel tubes.

After a hit and prior to maintenance, the exposed steel guardrail became a hazard. If the extruder was detached from the guardrail, the exposed end of the guardrail would act as a spear if another impact occurred. For temporary repairs, product specifications indicated removing the extruder, cutting the guardrail six inches ahead of the first undamaged post, remounting the extruder head at this location, and attaching it with lag bolts to the undamaged post. This fix would have

worked well, but posts two through eight were too short to accommodate the extruder bracket lag bolts (see Figure 2 on page 4). Post one was designed several inches taller than the others so that it could accept the extruder bracket, but posts two through eight were only tall enough to support the guardrail. Therefore, short-term fixes usually required replacing at least one post to reattach the extruder.

COSTS

At the onset of this study, the initial cost of an ET-2000 system was $2750. The cost of site and grading work added about $600 per site, bringing the total cost of a completely installed unit to $3350. This cost was slightly higher than that of the commonly used BCT.

The maintenance and replacement costs of an ET-2000 terminal varied with the extent of damage. Because many of the extruder heads were reusable, the replacement costs were often limited to only the guardrail and post components. In addition, the labor required for small repairs was minimal.

CONCLUSIONS AND RECOMMENDATIONS

The ET-2000 systems installed as part of this research study have performed well. Vehicles that collided with the end terminals were safely brought to a stop, and very few injuries were reported. No vehicle vaulting or spearing was reported, which were problems noted with other guardrail designs. The ET-2000 meets the rigorous crash test requirements of NCHRP Report 350, as well as WisDOT requirements for barrier terminals.

The systems were relatively simple to repair, although potential modifications that would make repairs even easier were noted by maintenance crews. It was often possible to reuse the extruder head, which saved on the cost of replacement parts. The manufacturer noted that temporary repairs to the systems were possible by simply moving the extruder head back to the point where the guardrail and posts were undamaged. However, maintenance crews indicated that post

design did not allow for this type of temporary repair. It appears in current detail drawings that this design problem has been modified.

While the initial cost of the ET-2000 system was higher than traditional guardrail designs, the ET-2000 was competitive with other energy absorbing systems. In addition, use of the ET-2000 system reduced or eliminated the cost that would have been required for embankment widening with other guardrail designs. Reduced repair costs and added safety features also justify the higher initial cost of the ET-2000.

Use of the ET-2000 has increased in the state of Wisconsin since the onset of this research project. Because of the success that has been demonstrated with this system, the ET-2000 and subsequent models in the Trinity Industries, Inc. ET series are recommended for continued use as guardrail end treatments. No further research of this system is necessary.

APPENDIX

(a)

(b)

Figure A-1. Project location: (a) State of Wisconsin with Milwaukee County highlighted; (b) Milwaukee County, with project area denoted by box.

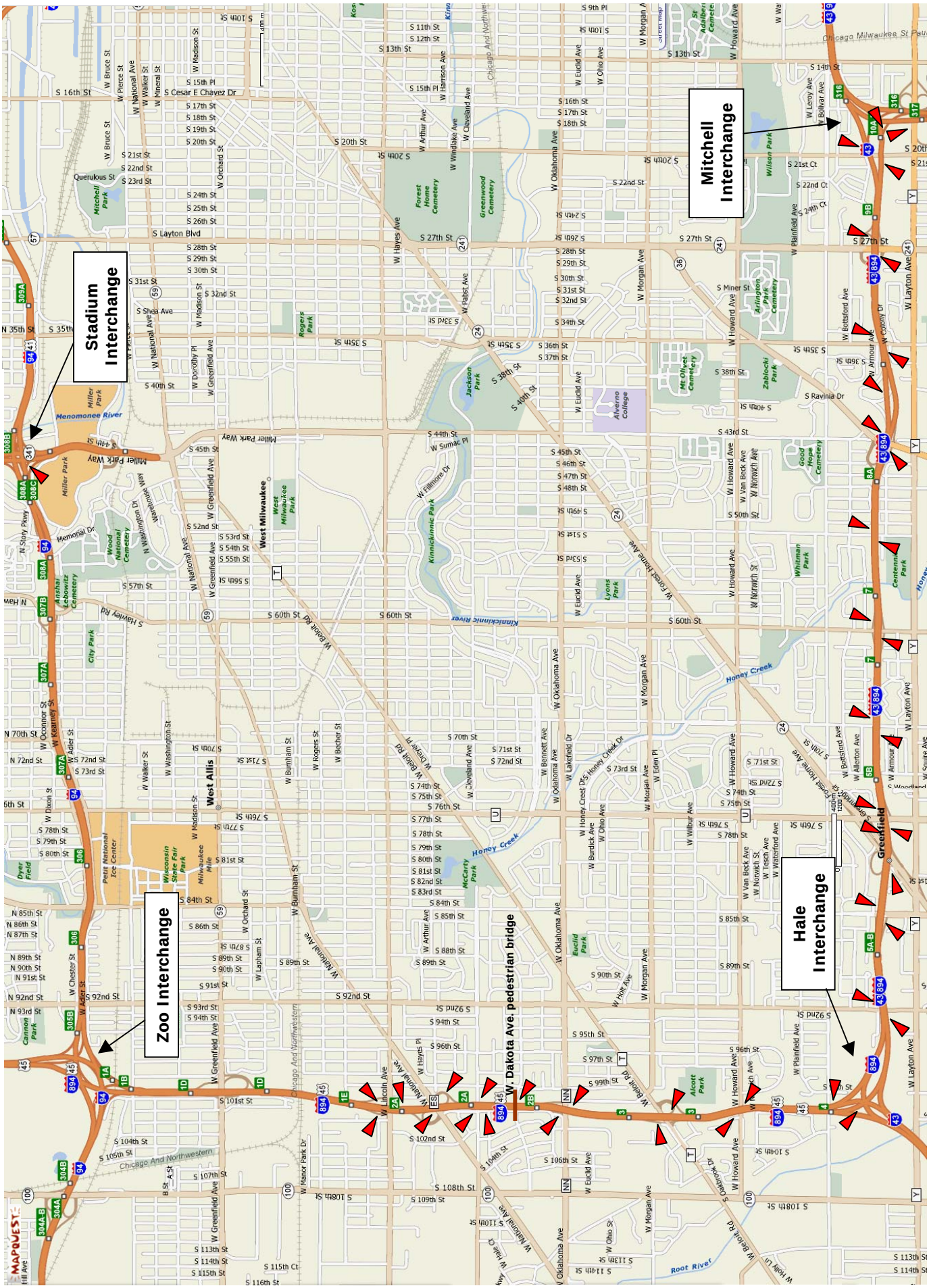

Figure A-2. Test site locations.

Table 1. ET-2000 Installation Locations

I-43/I-894 Airport Freeway (Hale Interchange to Mitchell Interchange)

LOCATION	# OF UNITS	DIRECTION
92nd Street Overpass	2	EB & WB
84th Street Underpass	2	EB & WB
Forest Home Avenue Overpass	2	EB & WB
76th Street Overpass	2	EB & WB
68th Street Overpass	2	EB & WB
60th Street Overpass	2	EB & WB
51st Street Underpass	2	EB & WB
Loomis Rd. Overpass	2	EB & WB
B-40-200 Approach	1	WB
35th Street Overpass	2	EB & WB
27th Street Overpass	2	EB & WB
20th Street Underpass	2	EB & WB
EB I-894 to SB I-94 Ramp, Mitchell I/C Underpass	1	EB/SB
Layton Avenue Overpass	1	SB

I-894/USH 45 Zoo Freeway (Hale Interchange to Zoo Interchange)

LOCATION	# OF UNITS	DIRECTION
Hale I/C, SB I-894 to EB I-894 Overpass	1	SB/EB
Coldspring Road Overpass	1	NB
Howard Avenue Overpass	2	NB & SB
Beloit Road Overpass (NB on-ramp)	2	NB & SB
Oklahoma Avenue Underpass	2	NB & SB
West Dakota Avenue Pedestrian Bridge	2	NB & SB
Cleveland Avenue Overpass	2	NB & SB
National Avenue Underpass (NB off-ramp)	2	NB & SB
Lincoln Avenue Overpass	2	NB & SB
C&NW RR Underpass	1	NB

I-94 Stadium Interchange

LOCATION	# OF UNITS	DIRECTION
Story Parkway Underpass	1	WB