Emerging Data Collection Partnerships: FHWA and NHTSA develop the framework for the next generation In-Service Performance Evaluation of Guardrail End Terminals

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ABSTRACT

The Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA) have entered into an agreement to investigate crashes involving the most widely used energy absorbing guardrail end terminals in the United States. These include the ET-2000, ET-Plus, Flared Energy Absorbing End Terminal (FLEAT), Sequential Kinking Terminal (SKT), X-Lite, X-Tension, and Softstop. For each device, the evaluation will address:

- Crash performance in terms of vehicle occupant risk.
- The sensitivity to varying effects such as environmental conditions, site characteristics, and impact conditions.
- The degree of sensitivity to improper installation, maintenance, and repair.

Data is being collected at test sites in four States that have agreed to participate in this pilot study: Massachusetts, Pennsylvania, California, and Missouri. This work is being done in cooperation with NHTSA, the Resource Center - Safety Technical Services Team (TST), the Office of Safety, and the division offices in each of the data collection States.

The objective of this paper is to present preliminary results of a novel data collection partnership between FHWA and NHTSA to conduct a pilot In-Service Performance Evaluation (ISPE) of Guardrail End Terminals (GETs). It will discuss source materials developed for the ISPE of GETs; explain the data collection partnership, methodology and status; and introduce sample cases.

Although studies involving joint data collection by FHWA and NHTSA are not new, this is the first time that the data collection has been driven by and tailored specifically to the needs of FHWA. In the 1980's, the Longitudinal Barrier Special Study (LBSS) relied upon the National Automotive Sampling System Crashworthiness Data System (NASS CDS) data collectors to compile information relevant to FHWA. FHWA subject matter experts produced data collection documentation, forms, and training materials that supplemented the goals of LBSS established by NHTSA. The LBSS lasted for approximately five years. Over 30 years later, FHWA is partnering with the NHTSA Special Crash Investigation (SCI) Team to support the ISPE of GETs and explore the possibility of including several of the study variables as standard features of future NHTSA data collection efforts. This paper will review:

- the impact of the data to be collected;
- tools used to collect and share this data;
- data elements and attributes.

Discussion will include what data has been and will be collected and how the data will be used. Ultimately, results of the study will be used to identify replicable patterns in the data that might enhance the design and testing of GETs.

BACKGROUND

The Federal Highway Administration (FHWA) is conducting a pilot In-Service Performance Evaluation (ISPE) of selected Guardrail End Terminals (GETs) in Massachusetts, Pennsylvania, California and Missouri in response to growing concerns about the safety performance of these devices. The foundation of a successful ISPE is robust data collection. FHWA has vast experience and a well-established network in roadside safety and crash testing. The National Highway Traffic Safety Administration (NHTSA) has over four decades of crash investigation experience and a well-deveoped data collection infrastructure. Leveraging the expertise and resources of each agency helped establish a firm foundation for the detailed and timely data collection needed for this study.

In 1982, FHWA and NHTSA established a partnership to conduct the Longitudinal Barrier Special Study (LBSS) using NASS CDS data collectors. This special study was suspended in 1986due to smallsample size and a limited audience that primarilly included epidemiologists and vehicle safety experts. However, NASS CDS continued to report general data relevant to all damaged barriers, involved in vehicle tow-away crashes on public roadways.

In 2015, FHWA and NHTSA established a new data collection partnership to conduct the ISPE of GETs. This time the Special Crash Investigations (SCI) teams were enlisted to conduct detailed site investigations for serious injury and fatal crashes in specific study areas. Appendix A provides case counts, by crash severity and agency partner for each device type, through March 31, 2017.

What is an In-Service Performance Evaluation (ISPE)?

The expected safety performance of GETs is initially assessed through full-scale crash tests; however, developers of these tests have long recognized that they could not rely solely on a limited number of tests to represent the full range of crash types, impact speeds, vehicle types, environmental conditions, road alignments, and device maintenance that would affect the in-service performance of end treatments. Thus, they recommended that asset owners evaluate the performance of in-service devices to determine if the device performs as anticipated in its design; to assess the collision and injury severity rates associated with actual use of the device; and to reveal any unsuspected problems that were not evident during the design phase. These evaluations could also provide insights to determine whether the crash test criteria themselves should be revised accordingly.

ISPEs are generally the responsibility of asset owners. While FHWA has taken the lead on conducting this pilot study with support from NHTSA, a strong collaborative effort with AASHTO and the state DOTs in this study may help to institutionalize these processes in other states.

What is the scope of the Pilot ISPE of GETs?

The two-year pilot data collection effort includes the following activities:

- Develop a data collection plan with subject matter experts (SMEs) in the FHWA Office of Safety R&D, Office of Safety, and the Resource Center.
- In cooperation with NHTSA, identify crash and asset management data elements and the degree of certainty with which these could be measured.
- Develop data collection forms and crash notfication protocols.
- Collect Data – now underway.
- Develop database architecture.
- Prepare a final report, compiling study documents, populated database, and lessons learned.

Goal: to serve as a template for states and other asset owners to effectively and efficiently perform their own ISPEs.

METHODS AND SOURCES

In August 2015, FHWA started to build relationships with NHTSA and five data collection partners, who were selected for the study based on a number of factors such as: reported inventory of the selected GETs; crash history involving GETs; geographic diversity; existence of relevent asset management systems; intereste and willingness to participate in the study, etc.. These relationships gave rise to agreements to collect data in each state based upon prescribed resources, including: photographic guidelines, notification plans, data collection forms, and training.

Resource Development

An ISPE would be impossible without accurate and timely data.To that end, FHWA and NHTSA SMEs spent months developing the study resources. This included: photographic data collection guidelines, notification plans tailored to the needs of each state, data collection forms with variables and their associated attributes, and targeted training for SCI and state data collectors. The resource development was constrained by:

- what the ISPE was designed to collect,
- which determined what data would be collected,
- how the data would be acquired; and finally,
- the optimum storage architecture.

Photographic Guideline and Notification Plans
The photographic guideline was developed to support three distinct activities:

- notification of a serious injury orfatal crash
- collection of property damage only (PDO) or/minor crash data
- in-depth crash investigation.

. Photographs taken in accordance with the Photographic Guideline serve as the first level of documentation in the notification plan used by state agencies to alert FHWA of relevant crashes. The photographs serve to confirm the involement of a relevant end terminal, provide investigators with plannning details, and in the event of rapid repair, they document the crash site. The second level of documentation involves photographs taken by maintenance personnel. As seen in Appendix A, Figure 11, these photos taken from specified locations serve to document PDO and minor crashes. Minor crashes are crashes that produced an injury but did not merit ambulance transport. The third level of documentation is data collected by the SCI teams. This involves a full crash investigation with supplementary images, focusing on end terminal damage and performance. Based upon this information, FHWA SMEs assess whether GETs were subjected to conditions prescribed by the crash testing standard that governed their installation. The ISPE of GETs has evolved with the changing guidance climate. The originally prescribed devices, ET-2000, ET-Plus, FLEAT, SKT, X-Tension, and X-Lite, were National Cooperative Highway Research Program Report 350 (NCHRP, 2017) compliant. However many states are moving toward devices that meet the current standard established by the American Association of State Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH) testing (AASHTO, 2016). For example, in October 2015 Missouri adopted the SoftStop – a MASH-comliant GET – and began reporting crashes involving this device to FHWA. California has also begun installing the SoftStop and discussions are underway with Caltrans to start collecting data on this device.

Data Collection Forms The development of data collection forms was a multi-step process, that started with a large number of preferred data elements initially specified by researchers and was narrowed to a smaller analysis-ready data set that met the needs of the SME's. The data collection forms were then tailored to meet the needs of each agency.

A basic study form was developed which included a description of the crash environment, identification of the end terminal type, and measurements of damaged and undamaged elements. Some study partners are providing: photographs-only or a data collection form with photographs. Some cases also include additional state-provided materials. Agencies operating under rapid repair policies generally use a combination of data collection procedures, in which some information on damaged devices is collected by state personnel to be shared with NHTSA SCI investigators, who may not be able to arrive at the scene before the damage is cleared or repaired.

Training FHWA SMEs developed training to ensure appropriate data collection. SCI teams were the first to receive training on the characteristics of the devices in the study, which supplemented their crash investigation expertise. A similar format was used for training provided to the Collision Analysis Reporting Section (CARS) of the Massachusetts State Police. For state agencies, engaging in PDO/minor data collection, training was geared to their data collection preferences, i.e. photo-only or photo plus crash form.

EXEMPLAR DATA COLLECTION PRACTICES

The following example will review data collection prescribed by the Photographic Guideline, photo locations 1 though 6. (See Appendix A, Figure 11 for standard photo locations.) This section considers data collection design and data acquisition. The figures contrast traditional, photo location 1, and targeted data collection, photo locations 2 through 6, with the rectangular legends providing the location on a larger schematic (FHWA Safety R&D, 2016).

Figure 1 provides the first contrast of traditional (left) and targeted data collection (right). Traditionally, crashworthiness data sets offered images providing environmental context. For this reason, photo location 1 documents the approach to the damaged end terminal, from 150 to 200 feet. Photo location 2, provides a closer view allowing positive identification of the GET. Findings:

- positive idenfitication of butt-weld, indicative of an ET-PLUS with a five-inch channel.
- the kink appears to have been induced by moving the rail off the roadway and not by the impact event.

Figure 1. Traditional Photo Location 1 (left) and Targeted Photo Location 2 (right)

Figure 2 provides a supplemental positive head identification, from photo location 3 on the traffic side. This view also provides the context for guardrail, within the crash environment. Images are only taken if either the lane has been closed or the data collector has been cleared to safely enter the active travel lane. This view can be helpful for highly deformed GETs, as a comparison with Figure 1. Although Figure 2 shows a repaired end terminal, this image is used primarily to illustrate a photo taken from location 3. In most cases this would show a damaged end.

Figure 2. Traditional Photo Location 1 (left) and Targeted Photo Location 3 (right)

Figure 3 provides the back view of the GET taken from photo location 4. Findings:

- appears post 2 performed as intended.
- probable low speed impact, with extrusion of less than 1 panel length.
- device may have been moved from traffic side to field side by maintenance forces.

Figure 3. Traditional Photo Location 1 (left) and Targeted Photo Location 4 (right)

Figure 4 provides a look back toward the guardrail end terminal, from photo location 5 at 100 to 150 feet away. Photo location 5 complements the approach context, initially seen in photo location 1.

Figure 4. Traditional Photo Location 1 (left) and Targeted Photo Location 5 (right)

Figure 5 shows adjacent terminal displacement with length of need displacement behind guardrail. This is taken from photo location 6, on the field side looking toward the traffic side. Findings:

- no unusual folds or tears in the ribbon.
- condition suggests no existing damage to w-beam before impact event.

Figure 5. Traditional Photo Location 1 (left) and Targeted Photo Location 6 (right)

Figure 6 provides multiple examples of post damage captured above the location. Images of posts reamining in place are also instructive. The lower left image uses a measuring wheel to highlight location of post hole.

Figure 6. Traditional Photo Location 1 (left) and Targeted Photo Location A (right)

Although, the ISPE of GETs may rely on many different data sources, the photographs are the fundamental resource. This exemplar provided a contrast of traditional data collection versus targeted data collection and the difference in information that can be obtained from these images.

DATA STORAGE ARCHITECTURE

FHWA used the Highway Safety Information System (HSIS) Program to develop a data storage architecture based upon early cases submitted by MoDOT. The database will be anonymized to prevent disclosure of personally identifiable information, without losing its descriptive character. It will be searchable, with flexibility to view both coded and graphic data, and platform agnostic, allowing the data to eventually be made available to other interested researchers. This architecture is also meant to harmonize with eventual receipt of SCI data, which is currently unavailable as a result of the recent NHTSA data modernization.

Current Development

The current architecture was developed from baseline PDO/minor crash data collection forms. Although input from the participating states was used to improve the appearance of the forms and to add information, the architecture is based upon the baseline provided at the beginning of the study.

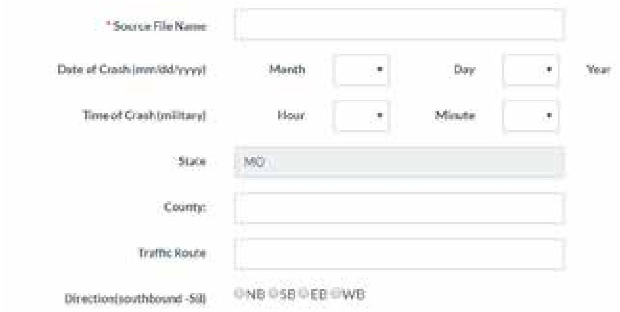

Figure 7. Electronic Data Input Form: Crash Time General Time and Location Data

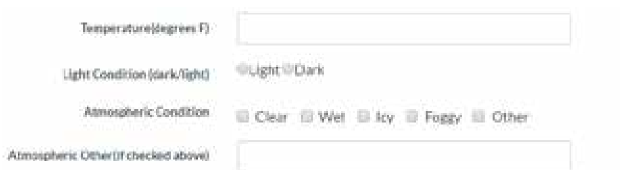

Figure 8. Electronic Data Input Form: Meteorological Data

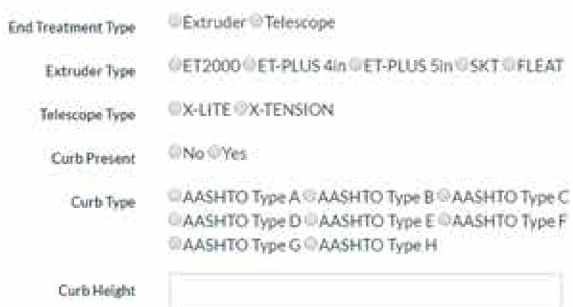

Figure 9. Electronic Data Input Form: General Installation information

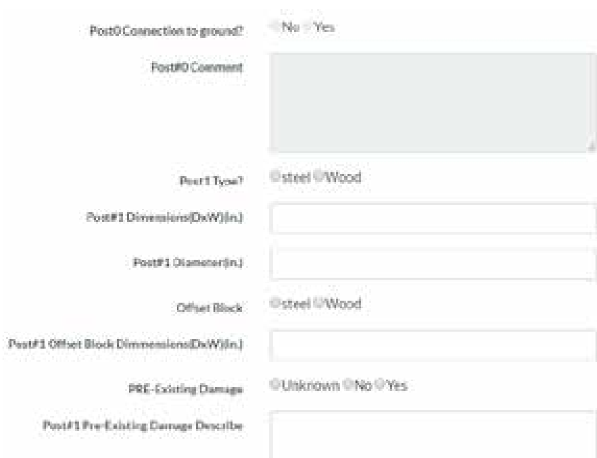

Figure 10. Electronic Data Input Form: Post Details

Database Content

The data architecture will accommodate coded and graphic data. For graphic data only, FHWA data coders will follow the crash form and enter observable information. No estimates will be made relative to measurements or meteorological conditions, unless supported by supplementary inputs. These inputs might include but not be limited to: maintenance summaries, police accident reports, maintenance inventories, and asset management systems.

Database Expansion

Not only will the database architecture incorporate the findings from five agencies, it will also serve as the repository for serious and fatal crashes. NHTSA will continue to publish SCI reports on their website. FHWA will publish searchable data for analysis purposes. NHTSA and FHWA are in early discussions to create a flexible data set that might be joined to the PDO/minor database, developed by the HSIS Program. NHTSA is slowly implementing their data modernization. FHWA will underwrite the development of the NHTSA SCI ISPE of GETs crash form. Future data collection is envisioned; however, the financial and resource allocation needs are still pending. Currently, SCI investigators are funded through an Inter-Agency Agreement to provide support for this study.

DISCUSSION

The ISPE of GETs is the first of its kind. The transition from crash test criteria defined in the NCHRP Report 350 (NCHRP, to MASH Guidance (AASHTO, 2016) required some changes in practice and highlighted the value of good data when it comes to evaluating overall safety performance of these devices.

What data has been and will be collected?

To date only measurable, repeatable, and verifiable data has been collected. Measurable data includes acceptable tolerances. Data categories include but are not limited to the following: measurements of crash scene, crash reports, installation and maintenance records, and interviews of occupants.

How will it be used?

The data will be used to develop a template for use by states and other asset owners to effectively and efficiently perform their own ISPEs. This will help with assessing the degree of data collection that might be reasonably expected given available resources and the expected quality and potential use of the findings. Finally, the data will be examined for trends and other factors that might inform new test procedures.

Study Limitations

ISPEs are normally conducted by states or local jurisdictions interested in evaluating the safety performance of devices installed on their system, but few have actually been carried out. The lack of data, especially for minor and PDO crashes, has been one of the major limiting factors. While this pilot study is one of the most comprehensive efforts to collect ISPE data on the full spectrum of crashes, historic crash trends suggest that a sufficient number of crashes may not occur during this two-year pilot study to draw statistically significant conclusions about the actual safety performance of each device. However, several data collection best practices will be identified that could inform longer studies to assess the in-service performance of roadside safety hardware. The pilot study will identify current challenges to conducting effective in-service performance evaluations and will recommend best practices for 1) the collection of real-time data on crashes involving roadside safety hardware, 2) interagency communication at the State level regarding crash reporting, and 3) data management regarding hardware maintenance and inventory.

Although small sample size is proving to be the biggest practical concern, the presence or lack of robust relationships among a variety of stakeholders has proven to be a foundational concern. When agencies are not already working with diverse elements required to undertake such a study such as asset management and maintenance personnel and safety organizations, such as local law enforcement, collecting sufficient and accurate data in a timely manner can be a challenge. Some agencies in this study have developed these relationships with great success. One agency continues to struggle with this issue, which has hampered the full development and progress of the study. Four of the five participating agencies have collected meaningful data, from which SMEs have been able to draw meaningful conclusions.

PRELIMINARY CONCLUSIONS

The first outcome of this study has been the creation of exemplar notification and data collection plans for five agencies, which could be used in whole or in part by other states to develop their own ISPEs. Replicable methodologies have been developed to ensure that data can be collected and coded using the asset owner's and stakeholder partners' existing personnel. This minimizes the need for specialized experience to conduct the ISPE and to analyze the resulting data. Fatal and serious injury cases are being analyzed as they are collected. Once the data collection is complete for this study, it will be assessed from a quantitative and qualitative perspective to identify lessons learned, good practices, and other findings relative to the safety performance of the devices in the study.

REFERENCES

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FHWA Office of Safety R&D, Abridged ISPE of GETs Photographic Guideline (version 112816), Washington, D.C., 2016.

NCHRP, Report 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_350-a.pdf, last accessed 19 January 2017.

APPENDIX

Table 1.
Case Counts by Agency Partner and Device Type, as of 31 March 2017

Agency/ Partner	Trinity Highway Products, LLC					Road Systems, Inc.		Lindsay Corporation		Total
	ET-2000	ET-Plus Unk	ET-Plus 4"	ET-Plus 5"	Soft Stop	FLEAT	SKT	X-LITE	X-Tension	
Caltrans/ SCI	0	0	0	0	0	0	0	0	0	0
Caltrans	0	0	7	1	0	2	2	6	0	18
MassDOT/ CARS	0	0	0	0	0	0	0	2	0	2
MassDOT	0	0	18	1	0	0	2	20	0	41
MoDOT/ SCI	4	0	8	0	2	0	8	3	0	25
MoDOT	7	1	32	11	6	0	12	0	8	77
PennDOT/ SCI	0	0	1	0	0	0	0	0	0	1
PennDOT	4	9	3	1	0	0	9	3	0	29
PTC/ SCI	0	0	2	0	0	0	1	0	0	3
PTC	0	0	0	0	0	3	5	0	0	8
Total	15	10	71	14	8	5	39	34	8	204
Usually, SCI and CARS perform serious and fatal crash investigations. MoDOT investigated a serious crash with repaired end terminal.										
State/Agency performs PDO and minor injury crash investigations.										

Table 2.
Case Counts by Crash Severity and Device Type

Crash Type	ET-2000	ET-Plus Unk	ET-Plus 4"	ET-Plus 5"	Soft Stop	FLEAT	SKT	X-LITE	X-Tension	Total
PDO/ minor	11	10	60	14	6	5	30	29	8	173
Serious/ fatal	4	0	11	0	2	0	9	5	0	31
Total	15	10	71	14	8	5	39	34	8	204

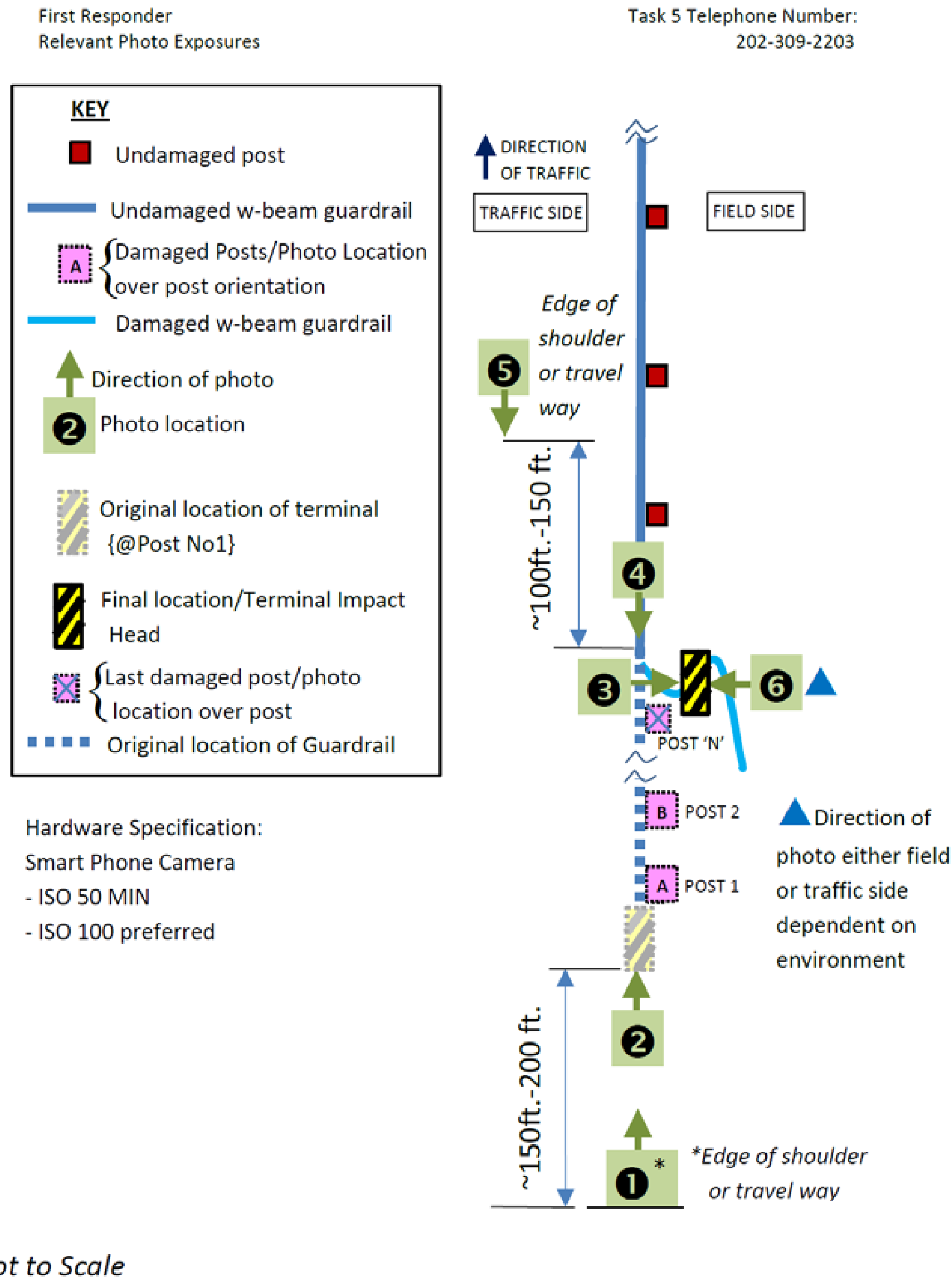

Figure 11. First Responder, Relevant Photo Exposures. FHWA, 2016.