Wyoming Department of Transportation

TECHNICAL PROPOSAL: FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS

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**It should be noted that all bogie and full-scale vehicle crash tests noted within this research program will be conducted according to MwRSF's list of accredited testing services granted by the A2LA laboratory accreditation body. MwRSF's certificate number is 2937.01.

EXECUTIVE SUMMARY

The Wyoming Department of Transportation (WYDOT) seeks to design, develop, and full-scale crash test a box-beam guardrail system to shield fixed objects and bridge ends in narrow medians. Proposed design concepts provided by WYDOT are composed of roadside and median box-beam guardrails, a roadside box beam end terminal, and box beam approach guardrail transitions. In order to limit the overall length of the installation, it is proposed to flare the installation. This type of barrier configuration poses several challenges that have not been addressed in previous testing of box-beam systems including non-traffic side or backside impacts on roadside box-beam guardrail and box-beam end terminals as well as impacts on flared box-beam systems. WYDOT is requesting assistance in developing an effective configuration for shielding of fixed objects and bridge ends in narrow medians and evaluation of the system in critical areas where the performance of the box beam barriers is currently undefined. WYDOT desires that the box-beam guardrail configuration be designed and evaluated to the Manual for Assessing Safety Hardware (MASH) Test Level 3 (TL-3) criteria.

The Midwest Roadside Safety Facility (MwRSF) at the University of Nebraska – Lincoln is a long-standing research group focused on roadside safety and has come to be recognized as a global leader in the development of crashworthy safety structures and roadside safety guidance for over 30 years. Numerous safety features developed at the facility have been adopted nationwide, including many of the most common and successful barrier systems in use on roads today. These systems include the Midwest Guardrail System (MGS), the thrie beam bullnose, the F-shape portable concrete barrier, various bridge rails and approach guardrail transitions, and other devices. These new safety features have saved the lives of countless motorists across the nation. MwRSF is also a full-service testing laboratory that offers compliance testing, design, redesign, failure analysis, and component testing of roadway and roadside appurtenances. MwRSF's testing experience includes performance testing of guardrail, bridge rails, noise walls, concrete barriers, delineators, luminaries, mailboxes, work zone sign supports, and component testing of post designs, break-away and slip bases, as well as materials testing. MwRSF is an ISO/IEC 17025:2005 Accredited Laboratory. In 2009, MwRSF was approved for accreditation by the American Association for Laboratory Accreditation (A2LA) in the field of safety performance evaluation of highway features and vehicle testing of crash barriers for the tests identified in the Scope of Accreditation. Finally, MwRSF is the home of the Midwest Pooled Fund Program. The Midwest Pooled Fund Program is a collaborative program between state DOTs and MwRSF dedicated to fostering roadside safety research.

MwRSF has prepared a research proposal in response to Wyoming Request for Proposal (RFP): Development and Evaluation of a Box-Beam Barrier Configuration for Shielding Fixed Objects and Bridge Ends in Medians. MwRSF proposes to conduct a detailed literature review of current box-beam barrier options for use in the system development. MwRSF will then develop a proposed design configuration to meet WYDOT needs. MwRSF will then full-scale crash test and evaluate the WYDOT narrow-median box-beam guardrail to MASH TL-3 through a series of six full-scale crash tests, detailed herein. MwRSF researchers will identify critical impact conditions for the evaluation of the narrow-median box-beam guardrail, install sections of the narrow-median box-beam guardrail at the MwRSF Outdoor Test Site and Proving grounds, and conduct six full-scale crash tests on the system. MwRSF researchers will analyze, document, and summarize the test results and provide evaluation of the narrow-median box-beam guardrail performance in summary reports. In the event of failure of one of the crash tests, MwRSF will review the failed test and provide potential design modifications to improve the device performance and recommend additional research needs for further study.

The research effort to evaluate the WYDOT narrow-median box-beam guardrail will be performed over a three-year time period. The work will be completed by June 30, 2026. The proposed budget for this research effort to evaluate the WYDOT narrow-median box-beam guardrail is $799,998.00.

FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS

STATE'S PROBLEM STATEMENT

The Wyoming Department of Transportation (WYDOT) is seeking to fund the development and testing of a box-beam guardrail system to shield hazards, such as bridge ends and other fixed hazards, in narrow medians with a 10:1 slope per side where independent runs of shoulder barrier would not be an option. The current WYDOT box-beam guardrail standards for shielding hazards are in Figure 1 and 2. As is the case with narrow medians, however, this would require a barrier that could be impacted on either side (e.g. box beam median barrier), a crashworthy approach terminal which can be impacted on either side, and a downstream terminal which would be shielded from upstream impacts.

A proposed design for shielding hazards in narrow medians is in Figure 3. In that design, the sections tangent to the roadway are roadside box-beam guardrail while the middle section is the median box-beam guardrail flared at a rate of 15:1. The upstream roadside box-beam guardrail near the center of the median and the approach terminal would be subject to impact by traffic from both sides of the median. To date, the roadside box-beam guardrail and approach terminal have not been evaluated for backside impacts. The median guardrail isn't feasible for use in the upstream portion of the system near the center of the median as an approach terminal has not been evaluated for that system with current full-scale crash test guidelines. The proposed system in Figure 3 was detailed for hazards such as sign supports or bridge columns in which the guardrail shields the hazard but doesn't attach directly to it. A scenario in which the guardrail would attach to a bridge end, for example, would require an approach guardrail transition (AGT) along with the other components discussed in the proposed design.

BACKGROUND STATEMENT

The system will be comprised of four main components: median box-beam guardrail, roadside box-beam guardrail, a box-beam end terminal, and a box-beam approach guardrail transition (AGT). The median box-beam guardrail was approved under NCHRP Report 350 criteria, however NCHRP Report 350 has since been replaced by MASH. NCHRP Report 350 test level 3 (TL-3) required that longitudinal barriers be subjected to two tests: (1) Test designation no. 3-10 with the 820C small car weighing 1810 lbs impacting the barrier at 62 mph and at an impact angle of 20 degrees; (2) Test designation no. 3-11 with the 2000P pickup truck weighing 4410 lbs impacting the barrier at 62 mph and at an impact angle of 25 degrees (2). Under MASH, those criteria were updated: (1) MASH test designation no. 3-10 with the 1100C small car weighing 2425 lbs impacting the barrier at 62 mph and at an impact angle of 25 degrees; (2) MASH test designation no. 3-11 with the 2270P pickup truck weighing 5000 lb impacting the barrier at 62 mph and at an impact angle of 25 degrees (2). As compared to NCHRP Report 350 criteria, MASH criteria requires heavier vehicles and an increased impact angle for the small car. Moreover, in the proposed configuration, the median box-beam guardrail is flared at a rate of 15:1, making the impact angle 28.1 degrees rather than 25 degrees. The AASHTO Roadside Design Guide (RDG) provides flare rate guidance that has been used previously, but that guidance was based on NCHRP Report 350 guidelines (3). As such, the RDG flare rate guidance does not take into account the heavier MASH vehicles and the increase in the small car impact angle under MASH. There are inherent issues associated with testing flared barriers given the additional energy imparted into the system. For the small car, vehicle capture and underride, occupant impact velocity (OIV), and occupant ride down accelerations (ORA) are of concern. For the pickup truck, increased barrier impact loading and vehicle capture are potential concerns. The combination of heavier vehicles in the current MASH test vehicle fleet along with the increase in small car impact angle warrant full-scale crash testing.

The roadside box-beam guardrail has been tested to MASH criteria. However, testing was conducted with impacts to the traffic side and not the backside. In the proposed design, the roadside box-beam guardrail will be subjected to backside impacts. That system is asymmetric with posts on the backside only. Vehicle interaction with a post prior to loading a rail element could lead to improper capture of the vehicle or wheel snag which can cause excessive OIVs, ORAs, or occupant compartment intrusion. As the roadside

box-beam guardrail has not been tested on the backside, full-scale crash testing of that system is required to evaluate crashworthiness in that loading scenario. Note that current WYDOT box-beam standard plans include flared roadside box-beam guardrail, however, flared roadside box-beam guardrail has not been evaluated to MASH TL-3 criteria.

Lastly, the box-beam end terminal selected for the proposed design has been MASH-tested, however, all impacts were on the traffic side and not the backside. In the proposed design, the terminals will be subjected to backside impacts. That end terminal is asymmetric with a breaker bar on the traffic side and all posts are on the backside other than the first two posts. Vehicle interaction with a post prior to loading a rail element could lead to improper capture of the vehicle or wheel snag which can cause excessive OIVs, ORAs, or occupant compartment deformation. Further, the impact head and cable anchor release may be affected in a negative manner by backside loading. As such, the end terminal requires full-scale crash testing prior to installation in a narrow median.

Current WYDOT box-beam guardrail standard plans in Figure 1 and 2 have not been evaluated for narrow median applications, and in some cases, were tested and evaluated to full-scale crash test standards that are now outdated. Successful completion of proposed research tasks would provide WYDOT a MASH-tested system that can be implemented into box-beam standard plans.

Research outlined herein will focus on developing a configuration that limits potential unknowns within the system. Full-scale testing will be used to evaluate potential concerns with the flared median box beam guardrail and backside impacts on roadside box beam and the MBEAT. Further details on the testing of these devices are in the Literature Review section of this proposal.

LITERATURE REVIEW

The median box-beam system is constructed with S3x5.7 steel posts spaced 6 ft on center, with an embedment depth of 30 in. (Figure 4). The 6-in. tall x 8-in. wide box beam mounts centered above the posts with the beam top mounting heights ranging from 26 to 30 in (4-7). The WYDOT median box-beam system has not yet been tested to MASH criteria, although, the system was issued an FHWA eligibility letter based on NCHRP Report 350 criteria (8). However, the State of New York is preparing to test the current median box-beam system used by WYDOT. The impact angle for that test series will be 25 degrees, however, and will not be sufficient to deem the median box beam system crashworthy when impacted with a flare rate of 15:1.

MwRSF successfully tested the Midwest Guardrail System (MGS) at flare rates of 13:1, 7:1, and 5:1, under NCHRP Report 350 TL-3 criteria (9). Those flare rates were effective impact angles of 29.4, 33.2, and 36.5 degrees respectively for the pickup truck and 24.4, 28.2, and 31.5 degrees, respectively for the small car. TTI has an ongoing study in which several flare rates have been tested on the MGS to MASH TL-3 but have yet to achieve a successful 11:1 flare-rate crash test. An 11:1 flare rate is an effective impact angle of 30.2 degrees. Successful crash tests at a flare rate of 5:1 under NCHRP Report 350 criteria and unsuccessful crash tests at a flare rate of 11:1 under MASH criteria underscores the increase in impact severity caused by differences between NCHRP Report 350 and MASH vehicle weights and the small car impact angle.

TTI has completed the testing of the roadside box-beam system to MASH TL-3 criteria. For MASH test no. 3-11, the weak-post box-beam guardrail system was constructed with S3x5.7 steel posts spaced 6 ft on center, with an embedment depth of 36 in. (10). The box beam was 6 in. x 6 in. x $^{3}/_{16}$ in. supported by angle brackets bolted to posts. The box beam had a top mounting height of 27 in. A cross-section schematic of the system is in Figure 5. This system is asymmetric with posts on the backside only. The system tested to MASH 3-10 was similar to the one tested to MASH 3-11 criteria, except the box beam had a top mounting height of 28 in., as opposed to 27 in. Both tests conducted on the traffic side of the system. An FHWA eligibility letter was issued for this system (11). To date, the roadside box beam system has only been tested on the traffic side.

End treatment hardware for the roadside box-beam section near the center of the median will be the MBEAT box-beam approach terminal (Figure 6). This end terminal is currently the only MASH-compliant box-beam end treatment (12). The MBEAT terminal was designed and tested for 6-in. tall x 6-in. wide box-beam end treatment, and not for 6-in. tall x 8-in. wide box beam. The impact head is 20 in. x 20 in. It is supported by two breakaway posts that are connected by a strut, and S3x5.7 posts. The terminal is 15 ft in length with a top rail height of 28 in and is asymmetric with a breaker bar on the traffic side and all posts are on the backside other than the first two posts. This system was only tested with traffic-side impacts, and not backside impacts. As the MBEAT is proprietary, the test report was not readily available. Recall that the median slopes are typically 10:1 per side. Note that a 10:1 slope is typically considered equivalent to level terrain for barrier performance. Initial efforts would focus on level terrain for testing and evaluation; however, additional efforts may be warranted to confirm system crashworthiness at a slope of 10:1.

OBJECTIVES

The objective of this research effort is to develop, crash test, and evaluate the WYDOT narrow-median box-beam guardrail system according to the TL-3 safety performance criteria found in MASH. The outcome of this study will be a flared, minimal-length, cost-effective, narrow-median box-beam guardrail system. The system will be available for WYDOT and other state DOTs to implement into box-beam standard plans immediately upon project closing.

Funding of this research effort will bolster two of the goals listed in the WYDOT Guiding Principles. One WYDOT goal achieved by completion of this study is to provide safe, reliable, and effective transportation systems. Installation of the WYDOT narrow-median box-beam barrier system on the roadway will improve occupant safety in two ways. First, the proposed system is flared, which not only reduces the overall length of the system but also moves the system away from the roadway, decreasing the frequency of impact from errant vehicles. Second, if an impact does occur, the system will be designed, tested, and evaluated in a narrow-median configuration to current MASH TL-3 crash test safety criteria. This system will serve as a crashworthy option that currently isn't included in WYDOT box-beam standard plans.

The second goal achieved by completion of this study is to encourage and support innovation. Research detailed herein will require the integration of four different roadside safety devices into a single, crashworthy system. This type of barrier configuration poses several challenges that have not been addressed in previous testing of box-beam systems including backside impacts on roadside box-beam guardrail and box-beam end terminals as well as impacts on flared box-beam systems. Innovation will be required to not only to ensure the crashworthiness of these systems tested in different configurations, but also to ensure the transition from one system to another is also crashworthy.

To reiterate, flared barriers reduce the overall system length and amount of barrier immediately adjacent to the roadway when compared to tangent systems. As such, a flared system improves installation time and efficiency while minimizing labor and material cost. Moreover, because flared systems decrease the frequency of impacts, accident costs and repair costs are also reduced.

BENEFITS

The successful testing and evaluation of the WYDOT narrow-median box-beam guardrail would provide Wyoming and other state DOTs with a MASH-tested option for shielding hazards in narrow medians. Completion of research efforts detailed herein will provide a minimal-length, cost-effective, narrow-median box-beam guardrail system that will reduce frequency of impacts and increase occupant safety. Once all reports have been finalized and distributed, WYDOT can integrate system drawings into box-beam guardrail standards plans.

APPLICABLE QUESTIONS

- Are there any potential barriers to implementation (e.g. material, technology, vendors, legal/regulatory, public perception)? For each potential barrier, identify strategies to mitigate these potential barriers.
    - **No**
- What is the expected period for implementation?
    - **Upon successful completion of the project, WYDOT will have the ability to implement this system immediately.**
- Does the project involve action on Federal lands or other conditions that will require National Environmental Policy Act (NEPA) documentation (e.g. Categorical Exclusion or Environmental Assessment), and/or forest service or other permits?
    - **No**
- What are the major uncontrollable factors and/or unknowns in the project such as weather, wildlife, material properties, traffic, etc.? For each uncontrollable factor, address whether there could be additional costs or delays.
    - **None that MwRSF is currently aware of.**
- Should the project be segmented into phases with go/no-go decision points based on known unknowns (e.g. technology, partnerships, regulatory)?
    - **Yes. Separating the project into phases allows the project to be halted or modified based on the results of each phase. For example, a test failure in Phase II may result in rescoping of the effort to address the failure or halting of the research.**
- If the project involves evolution of one or more technologies, is a technology road map provided showing how these technologies fit together?
    - **This project does not involve the evolution of one or more technologies.**
- Will a Buy American Waiver be necessary?
    - **No**
- Will any data produced by this project be considered confidential or sensitive?
    - **No**
- Will the data and/or report from the final project be copyrighted, patented, or trademarked?
    - **No**

STATEMENT OF WORK

WORK PLAN/SCOPE

Research efforts detailed herein were divided into three phases. Separating the project into phases allows the project to be halted or modified based on the results of each phase. For example, a test failure in Phase II may result in rescoping of the effort to address the failure or halting of the research. Phase I involves a literature review, development and selection of a barrier design configuration for further evaluation, and a summary report. Phase II would entail the testing of the median box-beam guardrail at a flare rate of 15:1 and a summary report. Lastly, Phase III includes full-scale backside crash testing of the roadside box-beam guardrail and MBEAT and a summary report.

All full-scale crash tests outline in this proposal will be conducted according to MwRSF's list of accredited testing services granted by the A2LA laboratory accreditation body (A2LA Cert. No. 2937.01).

MwRSF will follow the requirement for Final Reports set out in the *Research Development, Technology Transfer, and Data Management Guidelines for the Wyoming Department of Transportation*, Chapter 10, Subsection 10.1.3, Final Report.

<u>Phase I</u>

Research efforts to develop a MASH TL-3 narrow-median box-beam guardrail will begin with a literature review. Literature of interest will involve roadside and median box-beam guardrail, MBEAT terminal, box-

beam AGTs, flared barrier, and backside barrier testing. Also included in the literature review is a search for existing roadside-to-median and flared-to-tangent box-beam transitions. The goal of the literature review is to evaluate lengths of need, flare rates, working widths, barrier component placement, ability to transition to other barrier types such as cable barriers, and barrier and end terminal crashworthiness on slopes. WYDOT currently requires 50 ft of additional guardrail to be placed downstream of approach terminals when the flare rate exceeds 25:1. This will also be investigated during the literature review. If it is determined upon review of the MBEAT that certain modifications are evident that would improve the backside impact performance of the MBEAT, MwRSF would attempt to work with the MBEAT manufacturers to address those modifications and implement them into the system prior to testing. Potential transitions between the tangent and flared box beam will also be included in the literature review to determine if recommendations could be made regarding those areas or if further study may be needed. These transitions may pose concerns due to the local change in the angle of the system. Evaluation of the angled transitions through full-scale crash testing, if needed, is outside of the scope of the current proposal, however the review of background material and potential concerns will be a part of the study.

Following the literature review, design criteria will be established and will aid in developing preliminary design concepts. Preliminary design concepts developed in the study will likely assume a similar configuration as the proposed design in Figure 3. However, WYDOT has expressed interest in a “closed loop” design in which the shielded hazard is fully enclosed by guardrail. The closed loop design would include the development of a Y-type connection between sections of roadside and median box-beam systems, or a design for the lapping of a downstream terminal with an upstream terminal. The closed loop type of design will be considered in research efforts outlined herein; however, the main focus of this work will be on the proposed design configuration.

Simplified CAD drawings of the preliminary concepts will be compiled and presented to WYDOT for feedback and selection of a preferred concept. Once the preferred concept is selected, full-scale crash testing needs will be determined, and the simplified drawings will then be used to create detailed CAD drawings. Upon completion of detailed CAD drawings, a report including the literature search, CAD details, and recommendations for full-scale crash testing and/or further research will then be compiled and disseminated.

Major Task List – Phase I

1. Project Planning and Correspondence
    a. General project planning and documentation
    b. Literature search of roadside box beam, median box beam, MBEAT, box-beam AGTs, flared barrier testing, backside barrier testing, and roadside-to-median and flared-to-tangent box-beam transitions
    c. WYDOT review and selection of a concept for further development
    d. Develop CAD details of the final system design for fabrication and testing
    e. Sponsor correspondence and update presentations

2. Design and Analysis
    a. Design narrow-median box beam guardrail options/configurations based on WYDOT criteria
    b. Modify the MBEAT design to improve backside impact performance
    c. Simplified 3-D CAD details of preliminary design concepts
    d. Detailed 3-D CAD drawings of the preferred concept selected for further development
    e. Selection of system configuration, test matrix, and CIPs

3. Reporting and Project Deliverables
    a. Compile summary report to document research effort, including literature review, CAD details, crash testing, and recommendations for implementation and/or further research
    b. Report editing (internal and sponsor review)

c. Final report submittal for 508 compliance conversion and review
d. Project closing (printing, dissemination, accounting)

Phase II

After the narrow-median box-beam guardrail configuration is developed in Phase I of the study, full-scale crash testing will be conducted on critical portions of the selected configuration to as part of the MASH evaluation. Without Phase I being completed, the desired test configuration and impact conditions remain unknown. However, it is assumed that the final barrier configuration will include flared median box-beam, similar to the proposed design in Figure 3. As such, Phase II will involve full-scale crash testing the 15:1 flared median box-beam guardrail. Although the State of New York is currently planning to crash test the median box-beam guardrail at 25 degrees, it will need to be tested in a flared orientation for use in the proposed design. MASH requires that longitudinal barriers be subjected to two tests: (1) MASH test designation no. 3-10 with the 1100C small car impacting the barrier at 62 mph and at an impact angle of 25 degrees; (2) MASH test designation no. 3-11 with the 2270P impacting the barrier at 62 mph and at an impact angle of 25 degrees. As the system is flared at a rate of 15:1, the impact angle is increased to 28.8 degrees. Concerns with the flared impact angle for the small car are vehicle capture and system underride and excessive OIVs, and ORAs. For the pickup truck, barrier loading and vehicle capture are of concern. Recall that the median slopes are typically 10:1 per side. Note that this is typically considered equivalent to level terrain for barrier performance. Initial efforts would focus on level terrain for testing and evaluation; however, additional efforts may be warranted to confirm system crashworthiness at a slope of 10:1.

Upon completion of the full-scale crash tests, test data and videos will be analyzed, and results will be compared against the MASH requirements. All photos, videos, and other test data will be provided to WYDOT following the crash testing. A summary report will be written to document all design, testing, analysis, conclusions, and implementation recommendations pertaining to the WYDOT MASH TL-3 narrow-median box-beam guardrail. A rough draft for the final report will be sent to WYDOT's Research Manager no later than six (6) weeks prior to the expiration date of the Contract. If full-scale crash testing of the WYDOT narrow-median box-beam guardrail is unsuccessful, MwRSF researchers will review the possible causes of the device failure, suggest potential modifications for improving performance, and recommend additional research needed to further the design and evaluation of the WYDOT narrow-median box-beam guardrail.

Major Task List – Phase II

1. Project Planning and Correspondence
    a. General project planning and documentation
    b. Sponsor correspondence and update presentations

2. Full-Scale Crash Testing of the Median Box-Beam Guardrail Flared at a Rate of 15:1 to MASH TL-3
    a. Construction of the test article – Procure hardware for and assembly of the median box-beam guardrail at MwRSF's Outdoor Testing Facility
    b. Full-scale testing of median box beam at a 15:1 flare rate
        i. 3-10
        ii. 3-11
    c. Data analysis - Transducer and video analysis for each crash test
    d. System removal - Removal and disposal of system components upon completion of test matrix

3. Reporting and Project Deliverables
    a. Compile summary report to document research efforts, including CAD details, crash testing, and recommendations for implementation and/or further research
    b. Report editing (internal and sponsor review)
    c. Final report submittal for 508 compliance conversion and review

d. Project closing (printing, dissemination, accounting)

Phase III

To reiterate, without the completion of Phase I, the desired test configuration and impact conditions remain unknown, although it is assumed that the final barrier configuration will include roadside box beam and the MBEAT, similar to the proposed design in Figure 3. Upon successful completion of Phase II, Phase III will involve MASH test designation nos. 3-10 and 3-11 full-scale crash tests to the backside of the roadside box-beam guardrail.

Additionally, the MBEAT terminal will be tested in the reverse direction on the backside to MASH test designation nos. 3-37a and 3-37b. MASH does not require testing of the backside of end terminals in reverse direction, therefore, these tests are modified versions of test designation nos. 3-37a and 3-37b. The vehicles for test designation nos. 3-37a and 3-37b are the pickup truck and small car, respectively.

Upon completion of the full-scale crash tests, test data and videos will be analyzed, and results will be compared against the MASH requirements. All photos, videos, and other test data will be provided to WYDOT following the crash testing. A summary report will be written to document all design, testing, analysis, conclusions, and implementation recommendations pertaining to the WYDOT MASH TL-3 narrow-median box-beam guardrail. A rough draft for the final report will be sent to WYDOT's Research Manager no later than six (6) weeks prior to the expiration date of the Contract. If full-scale crash testing of the WYDOT narrow-median box-beam guardrail is unsuccessful, MwRSF researchers will review the possible causes of the device failure, suggest potential modifications for improving performance, and recommend additional research needed to further the design and evaluation of the WYDOT narrow-median box-beam guardrail.

Major Task List – Phase III

1. Project Planning and Correspondence
    a. General project planning and documentation
    b. Sponsor correspondence and update presentations

2. Full-Scale Crash Testing of the Backside of the Roadside Box-Beam Guardrail to MASH TL-3
    a. Construction of the test article – Procure hardware for and assembly of the roadside box-beam guardrail at MwRSF's Outdoor Testing Facility
    b. Full-scale testing of roadside box beam on the backside
        i. 3-10
        ii. 3-11
    c. Data analysis - Transducer and video analysis for each crash test
    d. System removal - Removal and disposal of system components upon completion of test matrix

3. Full-Scale Crash Testing of the Backside of the MBEAT in Reverse Direction to MASH TL-3
    a. Construction of the test article – Procure hardware for and assembly of the MBEAT terminal at MwRSF's Outdoor Testing Facility
        i. Modified 3-37a
        ii. Modified 3-37b
    b. Data analysis - Transducer and video analysis for each crash test
    c. System removal - Removal and disposal of system components upon completion of test matrix

4. Reporting and Project Deliverables
    a. Compile summary report to document research efforts, including CAD details, crash testing, and recommendations for implementation and/or further research
    b. Report editing (internal and sponsor review)
    c. Final report submittal for 508 compliance conversion and review

d. Project closing (printing, dissemination, accounting)

Future Research Needs

To date, a downstream terminal for box beam has not been tested to MASH. WYDOT has used two terminals: a 24-ft turned down terminal anchored to a concrete block and an 8-ft long anchorage, secured to a post. The State of New York has conducted testing with the latter terminal, to be used in upstream conditions in which the terminal would be located outside the clear zone and not vulnerable to end on impacts. WYDOT expressed interest in developing a downstream terminal which could be used with either roadside or median box-beam guardrails. The design of said terminal would need to be able to withstand the amount of load generated in an end on impact to the upstream end of a minimal-length guardrail installation. It is preferred that the terminal does not require a concrete anchor block.

WYDOT also seeks to develop a transition from roadside to median box-beam guardrail. It is desirable that this transition involves only a connection sleeve from 6 in. x 6 in. to 6 in. x 8 in. box beam.

WORK SCHEDULE

The research effort to design and evaluate the WYDOT narrow-median box-beam guardrail will be performed over a three-year time period. The work is currently scheduled to begin July 1, 2023, and it will be completed by June 30, 2026. If the actual start date of the research effort is altered, the start and end dates would shift accordingly. The schedule of the major tasks outlined in the statement of work is outlined in the Gantt Charts shown in Table 1 through Table 3. Note that MwRSF will provide quarterly progress reports every quarter until termination of the project.

BUDGET

The Midwest Roadside Safety Facility (MwRSF) of the University of Nebraska-Lincoln (UNL) conducts roadside safety research with the Nebraska Department of Transportation (NDOT), the Midwest Pooled Fund Program (30 years active), as well as many other State Departments of Transportation. Under these scenarios, the Nebraska Department of Transportation serves as the lead agency due to their long-standing agreement with the University of Nebraska-Lincoln and the use of a simplified, general agreement and requirements that are not cumbersome for pre-award and post-award personnel at UNL's Office of Sponsored Programs. State DOT agencies that are willing to work through NDOT and follow the general terms of the NDOT-UNL agreement, then one potential benefit to the sponsors is the use of a reduced overhead rate equal to 10%. If the lower overhead rate is desired, the WYDOT would need to comply with the NDOT-UNL contractual requirements, have NDOT serve as the lead agency contracting with UNL, and follow the noted NDOT contracting method that 21 other State DOTs currently utilize, which then would result in a reduced overhead rate on the proposed research project detailed herein.

If the general and simplified NDOT-UNL agreement will not work for a State agency, then that State agency would need to contract directly with UNL and comply with UNL's Office of Sponsored Programs requirements and contractual language. As a result of this direction, the research project would then be subject to UNL's approved overhead rates. Depending on the percentage of the research effort classified as off-campus (MwRSF outdoor testing site) or on-campus (MwRSF headquarters), the overhead rates would either be 26% or 55.5%, respectively, as determined on the entire effort based on which campus made up more than 50% of the research study. The budget proposed for the research detailed herein assumes that WYDOT agrees to conduct the research within the terms of the UNL-NDOT agreement and utilizes an overhead rate of 10%.

The proposed budget for this research effort to evaluate the WYDOT MASH TL-3 narrow-median box-beam guardrail is $799,998.00. Detailed budget information is shown in Table 4 through Table 9.

IMPLEMENTATION PLAN

MwRSF will work closely with WYDOT representatives throughout the evaluation of the narrow-median box-beam guardrail to ensure that the system evaluation meets the needs of WYDOT. Once the WYDOT narrow-median box-beam guardrail has been crash tested and evaluated, summary reports detailing research efforts outlined herein, including detailed CAD drawings of the system and test setups, will be provided to WYDOT. WYDOT can determine the means of integrating the system into standard plans. MwRSF will continue to provide guidance on various implementation scenarios and will field any questions that WYDOT may have beyond project closing.

TECHNOLOGY TRANSFER

Once the research effort is completed and the final summary report is supplied to the sponsor, copies of the photo, video, and sensor data will be provided to the sponsor as digital files in standard formats. The summary report is supplied in a digital format as well. If the WYDOT agrees, portions of the test data and the summary report are archived on the MwRSF website for access to the roadside safety community at large. The publication and dissemination of the research results and demonstration program, in the form of newsletters, research reports, and refereed journal papers, will aid the rapid transfer of this new technology to all interested organizations. Study findings will be presented at MwRSF Pooled Fund Meetings. Other potential venues for formal presentations on study findings include, but are not limited to, Task Force 13, AKD 20, and TRB.

DATA MANAGEMENT PLAN

The Data Management Plan is provided in the attached Appendix.

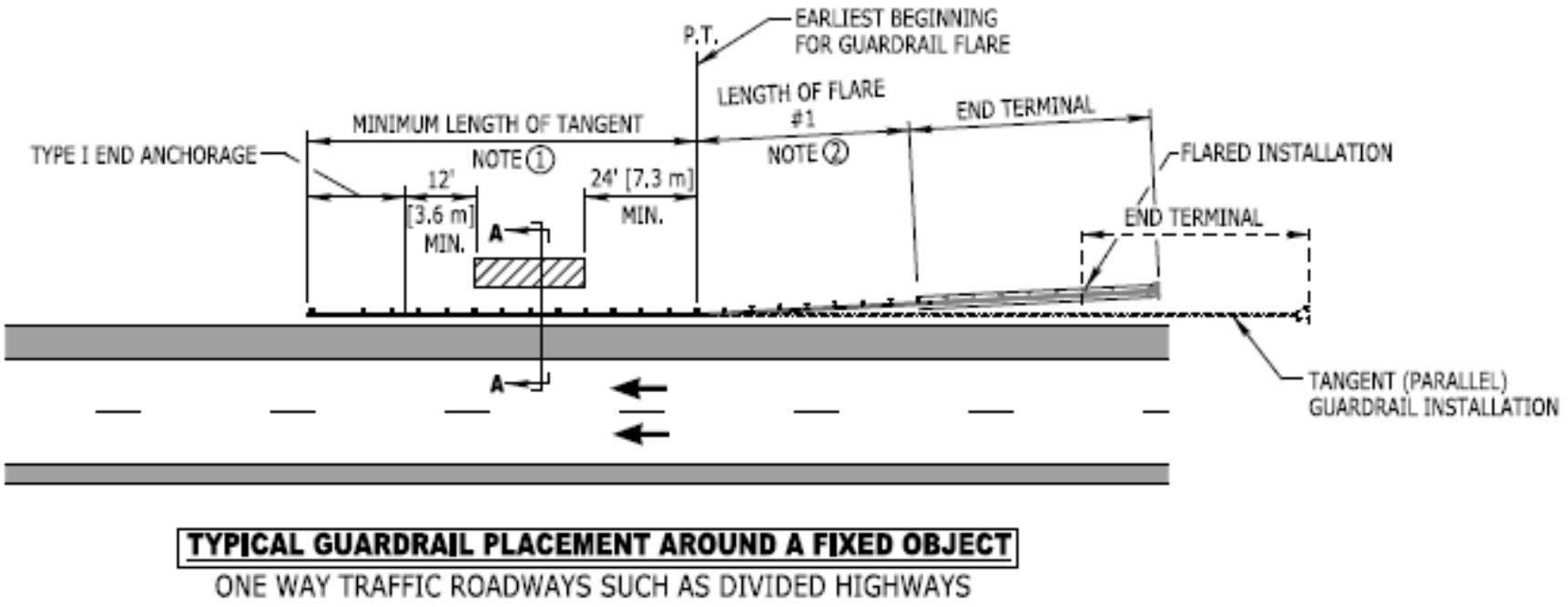

Figure 1. WYDOT box-beam guardrail standard plan for shielding hazards.

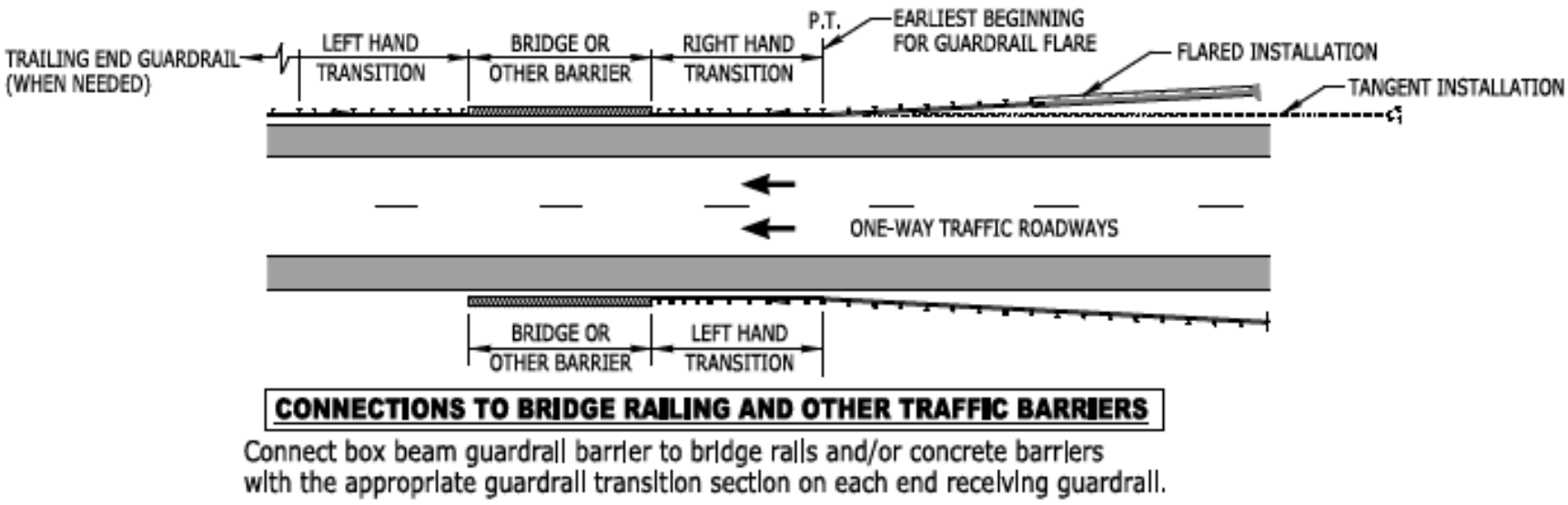

Figure 2. WYDOT box-beam guardrail standard plan for shielding bridge ends.

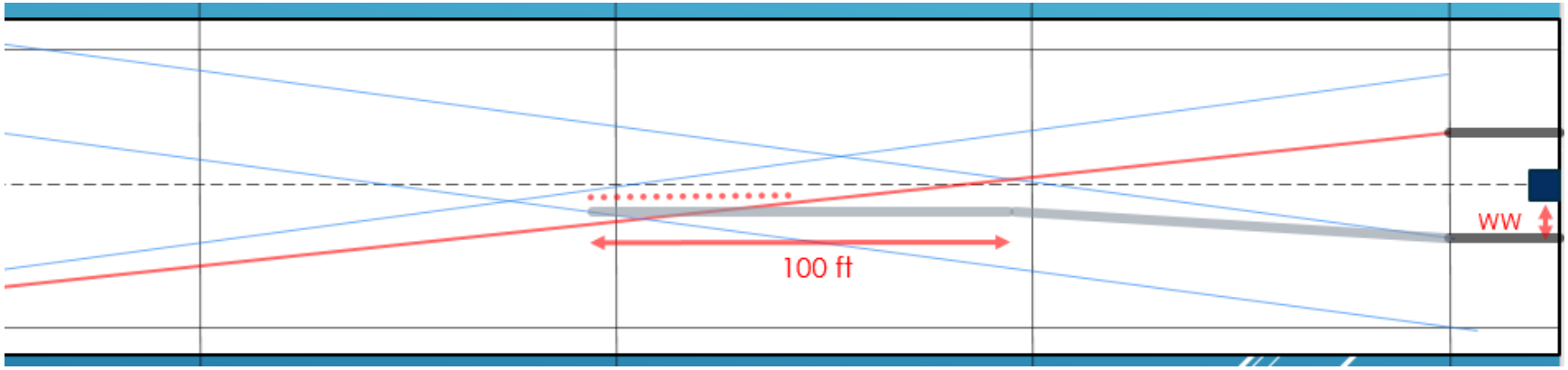

Figure 3. Schematic of the proposed box-beam system used for shielding hazards in the median.

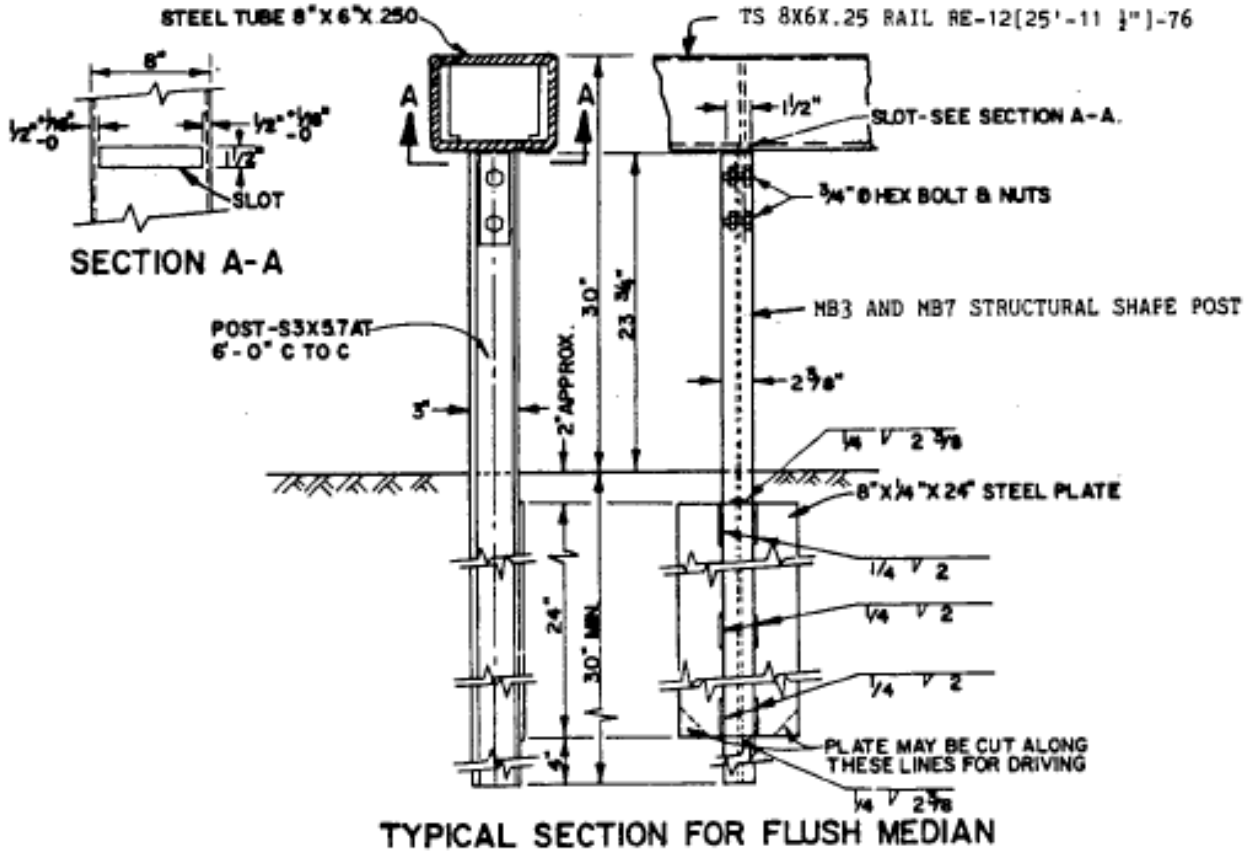

Figure 4. Median box-beam guardrail details.

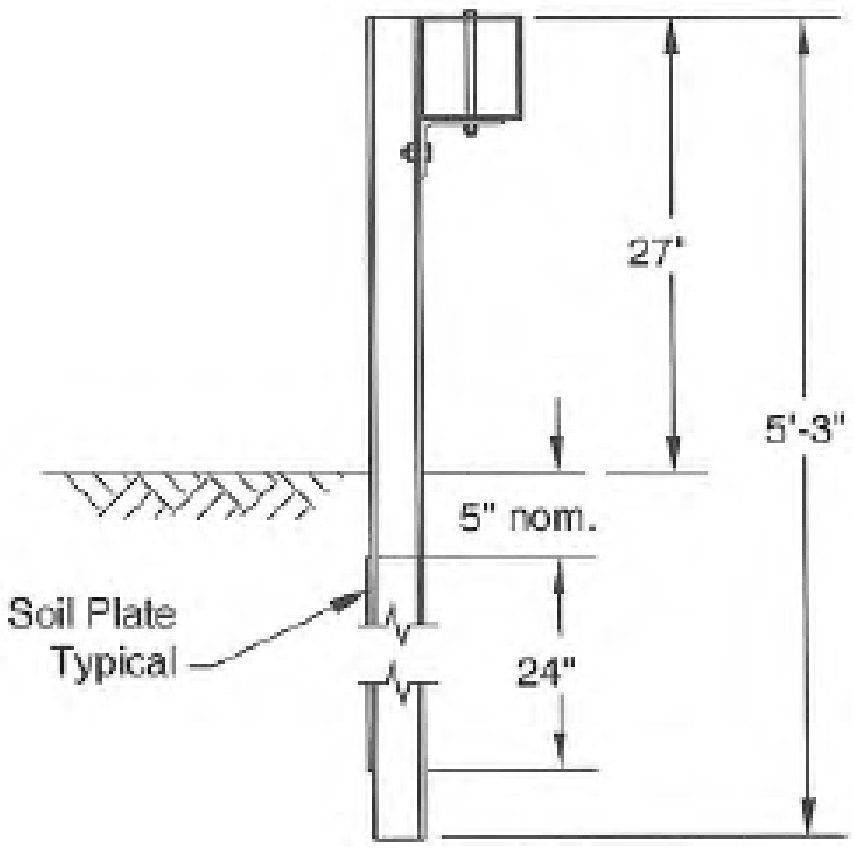

Figure 5. Roadside box-beam guardrail tested by TTI.

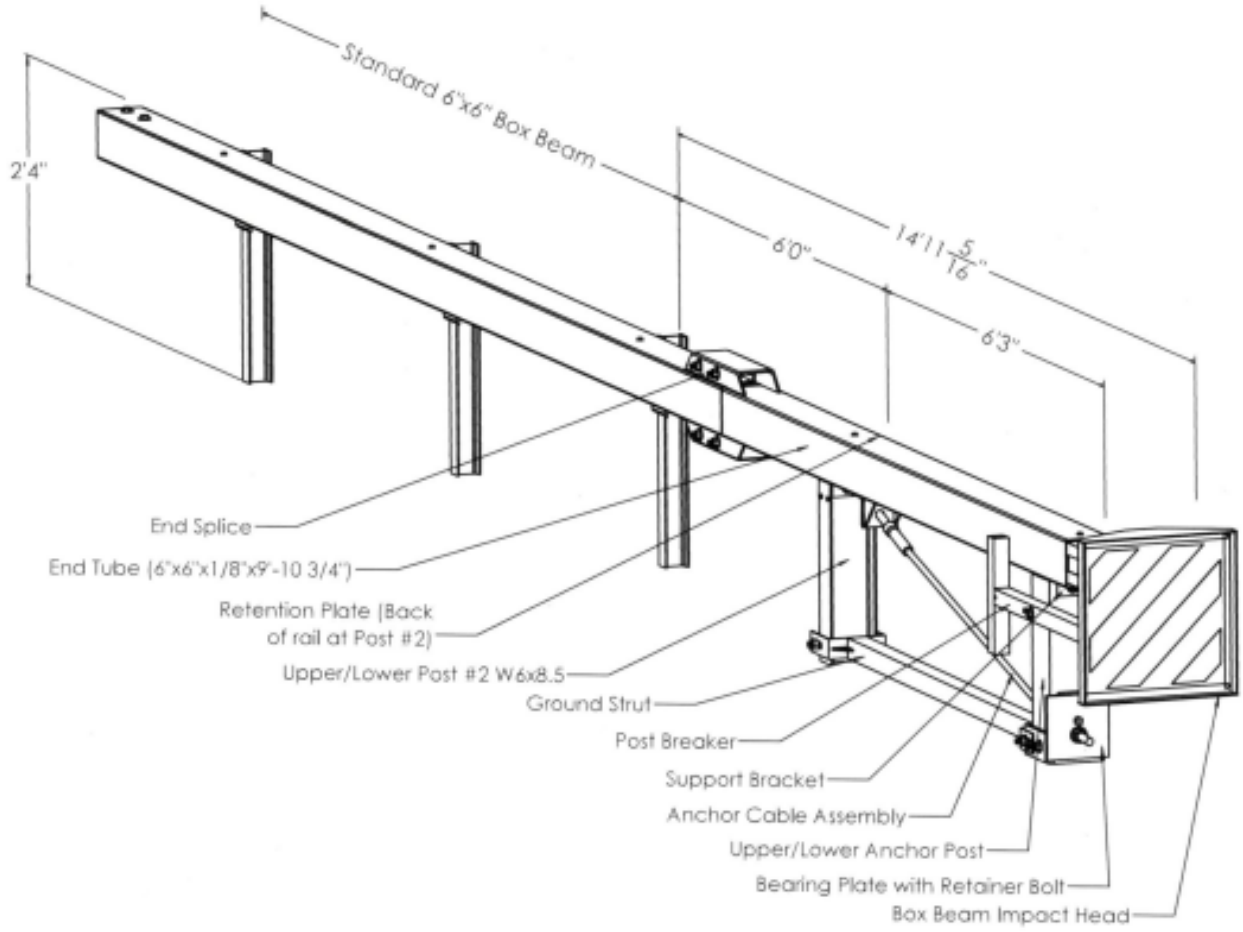

Figure 6. MBEAT box-beam terminal details.

Table 1. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – GANTT CHART, PHASE I

Task No.	Task	Description	2023 QTR 3	2023 QTR 4	2024 QTR 1	2024 QTR 2
1	Project Planning and Correspondence	General Project Planning and Documentation	X			
1	Project Planning and Correspondence	Literature Search	X	X		
1	Project Planning and Correspondence	WYDOT Review and Selection of Preferred Concept		X		
1	Project Planning and Correspondence	Develop CAD Details for Fabrication and Testing			X	
1	Project Planning and Correspondence	Sponsor Correspondence / Update Presentations		X		X
2	Design and Analysis	Brainstorming and Design	X	X		
2	Design and Analysis	Modify MBEAT Design		X		
2	Design and Analysis	Simplified 3D CAD of Preliminary Design Concepts	X	X		
2	Design and Analysis	Detailed 3D CAD of selected concepts			X	
2	Design and Analysis	Selection of System Configuration, Test Matrix, and CIPs			X	
3	Reporting and Project Deliverables	Research Report - First Draft		X	X	X
3	Reporting and Project Deliverables	Report Editing (internal and sponsor)			X	X
3	Reporting and Project Deliverables	508 Compliance				X
3	Reporting and Project Deliverables	Project Closing (printing, dissemination, accounting)				X

Table 2. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – GANTT CHART, PHASE II

Task No.	Task	Description	2024 QTR 3	2024 QTR 4	2025 QTR1	2025 QTR 2
1	Project Planning and Correspondence	General Project Planning and Documentation	X			
1	Project Planning and Correspondence	Sponsor Correspondence / Update Presentations		X		X
2	Full-Scale Crash Test	Construction of Test Article	X	X		
2	Full-Scale Crash Test	Full-scale Crash Test No. 3-10		X		
2	Full-Scale Crash Test	Crash Test No. 3-10 Data Analysis		X	X	
2	Full-Scale Crash Test	Full-scale Crash Test No. 3-11			X	X
2	Full-Scale Crash Test	Crash Test No. 3-11 Data Analysis			X	
2	Full-Scale Crash Test	System Removal				X
3	Reporting and Project Deliverables	Research Report - First Draft		X	X	X
3	Reporting and Project Deliverables	508 Compliance				X
3	Reporting and Project Deliverables	Report Editing (internal and sponsor)			X	X

Table 3. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – GANTT CHART, PHASE III

Task No.	Task	Description	2025 QTR 3	2025 QTR 4	2026 QTR 1	2026 QTR 2
1	Project Planning and Correspondence	General Project Planning and Documentation	X			
1	Project Planning and Correspondence	Sponsor Correspondence / Update Presentations		X		X
2	Full-Scale Crash Test	Construction of Test Article	X	X		
2	Full-Scale Crash Test	Full-scale Crash Test No. 3-10		X		
2	Full-Scale Crash Test	Crash Test No. 3-10 Data Analysis		X		
2	Full-Scale Crash Test	Full-scale Crash Test No. 3-11		X		
2	Full-Scale Crash Test	Crash Test No. 3-11 Data Analysis		X		
3	Full-Scale Crash Test	Full-scale Crash Test No. 3-37A			X	
3	Full-Scale Crash Test	Crash Test No. 3-37A Data Analysis			X	
3	Full-Scale Crash Test	Full-scale Crash Test No. 3-37B			X	
3	Full-Scale Crash Test	Crash Test No. 3-37B Data Analysis			X	
3	Full-Scale Crash Test	System Removal				X
4	Reporting and Project Deliverables	Research Report - First Draft		X	X	X
4	Reporting and Project Deliverables	Report Editing (internal and sponsor)			X	X
4	Reporting and Project Deliverables	508 Compliance				X
4	Reporting and Project Deliverables	Project Closing (printing, dissemination, accounting)				X

Table 4. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – BUDGET: WYDOT RFP FORMAT

Description	Budgeted Amount	Explanatory Note
Direct Cost		
Total Personnel Costs		
Principal Investigator		
Other Personnel		
Fringe Benefits		
Research Travel		
Report Generation		
Equipment		
Other	$727,271	See budget details below. Although costs are broken out in multiple categories below, MwRSF is an approved service center and costs are charged as other direct costs.
Technical Transfer		
Conferences/Report Presentation		
Miscellaneous Travel		
Indirect Costs		
Project Administration		
Overhead		
Indirect Costs	$72,727	Indirect costs calculated at 10% of Total Direct Costs since project is proposed under NDOT-UNL agreement.
In-Kind Match		
TOTAL	$799,998	

Table 5. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – BUDGET: MwRSF FORMAT – SUMMARY

Item	PHASE I Development and Evaluation of Box-Beam Barrier for Shielding Fixed Objects and Bridge Ends in Medians Costs($)	PHASE II Development and Evaluation of Box-Beam Barrier for Shielding Fixed Objects and Bridge Ends in Medians Costs ($)	PHASE III Development and Evaluation of Box-Beam Barrier for Shielding Fixed Objects and Bridge Ends in Medians Costs ($)	Total Costs ($)
Labor Operating Costs (1)	$56,510	$145,680	$287,483	$489,672
Testing Costs	$0	$42,221	$84,442	$126,663
Operating	$1,441	$2,336	$4,548	$8,325
Materials & Supplies	$441	$29,318	$58,502	$88,261
508 Compliance	$2,000	$5,750	$6,600	$14,350
Travel	$0	$0	$0	$0
Subtotal Costs	$60,392	$225,305	$441,575	$727,271
Overhead Costs (10%)	$6,039	$22,530	$44,157	$72,727
Total Project Costs	$66,431	$247,835	$485,732	$799,998

Note (1) - Administrative labor costs are calculated as 2.4% of direct costs.
Note (2) - Service center rates are estimates only; the actual rates in effect during the project period will be charged.

Table 6. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – BUDGET: MwRSF FORMAT – PHASE I

Item	Project Setup, Planning & Management; Client Correspondence; Status/Progress Updates; Literature Review; Selection of Systems, Prepare 3-D SolidWorks Models and 2-D Construction Details with Material Specifications for **Three** Systems, and Documents Mill Certifications and Certificates of Compliance Costs ($)	Brainstorming, Analysis, Design, and Modifications for MBEAT, Roadside Box Beam, Median Box Beam, Flares, and Transitions, Identify Critical Impact Points for Backside, Flared, and Transition Impacts, and Develop Final Test Matrices for **Three** Systems Costs ($)	Prepare Draft & Final Research Report with Summary, Conclusions, & Recommendations Costs ($)	Total Costs ($)
Labor Operating Costs (1)	$31,484	$16,188	$8,838	$56,510
Testing Costs	$0	$0	$0	$0
Operating	$200	$1,000	$241	$1,441
Materials & Supplies	$100	$200	$141	$441
508 Compliance	$0	$0	$2,000	$2,000
Travel	$0	$0	$0	$0
Subtotal Costs	$31,784	$17,388	$11,220	$60,392
Overhead Costs (10%)	$3,178	$1,739	$1,122	$6,039
Total Project Costs	$34,962	$19,127	$12,342	$66,431

Note (1) - Administrative labor costs are calculated as 2.4% of direct costs.
Note (2) - Service center rates are estimates only; the actual rates in effect during the project period will be charged.

Table 7. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – BUDGET: MwRSF FORMAT – PHASE II

Item	Project Setup, Planning & Management; Client Correspondence; and Status/Progress Updates Costs($)	Site Preparation, Acquisition, Fabrication, & Installation of MBEAT, Roadside Box Beam, and Median Box Beam Systems Costs ($) (2-4)	Test No. 1 - System No. 1 Box Beam Barrier Systems MASH TL-3 Designation No. 3-10 1100C Small Car @ CIP 2,425 lb - 62 mph - 25 degrees Costs ($)	Remove, Repair, Install MBEAT, Roadside Box Beam, and Median Box Beam Systems Costs ($) (5-8)	Test No. 2 - System No. 1 Box Beam Barrier Systems MASH TL-3 Designation No. 3-11 2270P Pickup Truck @ CIP 5,000 lb - 62 mph - 25 degrees Costs($)	Full System Removal, Debris Disposal, Soil Placement & Compaction, & Restore Testing Site Costs ($) (9)	Prepare Draft & Final Research/Crash Test Report with Summary, Conclusions, & Recommendations Costs $)	Total Costs ($)
Labor Operating Costs (1)	$4,014	$33,485	$38,851	$13,740	$41,913	$3,723	$9,954	$145,680
Testing Costs	$0	$0	$15,246	$0	$26,975	$0	$0	$42,221
Operating	$158	$500	$386	$300	$482	$200	$310	$2,336
Materials & Supplies	$200	$18,000	$300	$8,800	$300	$1,300	$418	$29,318
508 Compliance	$0	$0	$0	$0	$0	$0	$5,750	$5,750
Travel	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal Costs	$4,372	$51,985	$54,783	$22,840	$69,670	$5,223	$16,432	$225,305
Overhead Costs (10%)	$437	$5,199	$5,478	$2,284	$6,967	$522	$1,643	$22,530
Total Project Costs	$4,809	$57,184	$60,261	$25,124	$76,637	$5,745	$18,075	$247,835

Note (1) - Administrative labor costs are calculated as 2.4% of direct costs.
Note (2) - The cost estimate assumes that the MwRSF will purchase all materials for the MBEAT, roadside box beam, and median box beam barriers with end anchgorage systems and have them delivered to MwRSF's Outdoor Testing Facility.
Note (3) - MwRSF will acquire, fabricate, and install the MBEAT, roadside box beam, and median box beam barriers with end anchorage sysems at MwRSF's Outdoor Testing Facility.
Note (4) - Construction Materials and Equipment Usage, Maintenance, Repair, and Rental Costs for Testing Program - $18,000 - Test 1 - System No. 1
MBEAT End Terminal Hardware - Estimate $3,500
Roadside and/or Median Box Beam Barrier Hardware - Estimate $8,000
Trailing-End Box Beam Barrier Anchorage Hardware - Estimate $1,000
Crushed Limestone Soil Material (MASH Strong Soil) for Posts and Anchorages - Estimate $1,500
Miscellaneous Materials - Estimate $500
Construction Equipment Usage, Maintenance, Repair, & Rental - Estimate $1,500
Shipping Costs - Estimate $2,000
Note (5) - Demolition, Removal, Disposal, and Restoration Equipment Usage, Maintenance, Repair, and Rental Costs and Trash Fees - Test 1 - $500
Note (6) - The cost estimate assumes that the MwRSF will purchase all materials for the MBEAT, roadside box beam, and median box beam barriers with end anchorage systems and have them delivered to MwRSF's Outdoor Testing Facility.
Note (7) - MwRSF will acquire, fabricate, and install the MBEAT, roadside box beam, and median box beam barriers with end anchorage systems at MwRSF's Outdoor Testing Facility.
Note (8) - Construction Materials and Equipment Usage, Maintenance, Repair, and Rental Costs for Testing Program - $8,300 - Test 2 - System No. 1
MBEAT End Terminal Hardware - Estimate $1,000
Roadside and/or Median Box Beam Barrier Hardware - Estimate $4,000
Trailing-End Box Beam Barrier Anchorage Hardware - Estimate $0
Crushed Limestone Soil Material (MASH Strong Soil) for Posts and Anchorages - Estimate $800
Miscellaneous Materials - Estimate $500
Construction Equipment Usage, Maintenance, Repair, & Rental - Estimate $1,000
Shipping Costs - Estimate $1,000
Note (9) - Demolition, Removal, Disposal, and Restoration Equipment Usage, Maintenance, Repair, and Rental Costs and Trash Fees - Test 2 - $1,300
Note (10) - Service center rates are estimates only; the actual rates in effect during the project period will be charged.

Table 8. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – BUDGET: MwRSF FORMAT – PHASE III

Item	Project Setup, Planning & Management; Client Correspondence; and Status/Progress Updates Costs ($)	Site Preparation, Acquisition, Fabrication, & Installation of MBEAT, Roadside Box Beam, and Median Box Beam Systems Costs ($) (2-4)	Test No. 3 - System No. 2 Box Beam Barrier Systems MASH TL-3 Designation No. 3-10 1100C Small Car @ CIP 2,425 lb - 62 mph - 25 degrees Costs ($)	Remove, Repair, Install MBEAT, Roadside Box Beam, and Median Box Beam Systems Costs ($) (5-8)	Test No. 4 - System No. 2 Box Beam Barrier Systems MASH TL-3 Designation No. 3-11 2270P Pickup Truck @ CIP 5,000 lb - 62 mph - 25 degrees Costs ($)	Full System Removal, Debris Disposal, Soil Placement & Compaction, & Restore Testing Site Costs ($) (9)	Prepare Draft & Final Research/Crash Test Report with Summary, Conclusions, & Recommendations Costs ($)
Labor Operating Costs (1)	$5,655	$33,485	$38,851	$12,988	$41,913	$3,723	$9,954
Testing Costs	$0	$0	$15,246	$0	$26,975	$0	$0
Operating	$192	$500	$386	$300	$482	$200	$310
Materials & Supplies	$266	$18,000	$300	$8,800	$300	$1,300	$418
508 Compliance	$0	$0	$0	$0	$0	$0	$3,300
Travel	$0	$0	$0	$0	$0	$0	$0
Subtotal Costs	$6,113	$51,985	$54,783	$22,088	$69,670	$5,223	$13,982
Overhead Costs (10%)	$611	$5,199	$5,478	$2,209	$6,967	$522	$1,398
Total Project Costs	$6,724	$57,184	$60,261	$24,297	$76,637	$5,745	$15,380

Note (1) - Administrative labor costs are calculated as 2.4% of direct costs.
Note (2) - The cost estimate assumes that the MwRSF will purchase all materials for the MBEAT, roadside box beam, and median box beam barriers with end anchgorage systems and have them delivered to MwRSF's Outdoor Testing Facility.
Note (3) - MwRSF will acquire, fabricate, and install the MBEAT, roadside box beam, and median box beam barriers with end anchorage sysems at MwRSF's Outdoor Testing Facility.
Note (4) - Construction Materials and Equipment Usage, Maintenance, Repair, and Rental Costs for Testing Program - $18,000 - Test 3 - System No. 2
MBEAT End Terminal Hardware - Estimate $3,500
Roadside and/or Median Box Beam Barrier Hardware - Estimate $8,000
Trailing-End Box Beam Barrier Anchorage Hardware - Estimate $1,000
Crushed Limestone Soil Material (MASH Strong Soil) for Posts and Anchorages - Estimate $1,500
Miscellaneous Materials - Estimate $500
Construction Equipment Usage, Maintenance, Repair, & Rental - Estimate $1,500
Shipping Costs - Estimate $2,000
Note (5) - Demolition, Removal, Disposal, and Restoration Equipment Usage, Maintenance, Repair, and Rental Costs and Trash Fees - Test 3 - $500
Note (6) - The cost estimate assumes that the MwRSF will purchase all materials for the MBEAT, roadside box beam, and median box beam barriers with end anchgorage systems and have them delivered to MwRSF's Outdoor Testing Facility.
Note (7) - MwRSF will acquire, fabricate, and install the MBEAT, roadside box beam, and median box beam barriers with end anchorage sysems at MwRSF's Outdoor Testing Facility.
Note (8) - Construction Materials and Equipment Usage, Maintenance, Repair, and Rental Costs for Testing Program - $8,300 - Test 4 - System No. 2
MBEAT End Terminal Hardware - Estimate $1,000
Roadside and/or Median Box Beam Barrier Hardware - Estimate $4,000
Trailing-End Box Beam Barrier Anchorage Hardware - Estimate $0
Crushed Limestone Soil Material (MASH Strong Soil) for Posts and Anchorages - Estimate $800
Miscellaneous Materials - Estimate $500
Construction Equipment Usage, Maintenance, Repair, & Rental - Estimate $1,000
Shipping Costs - Estimate $1,000
Note (9) - Demolition, Removal, Disposal, and Restoration Equipment Usage, Maintenance, Repair, and Rental Costs and Trash Fees - Test 4 - $1,300

Table 9. FY2024-WY-1-BOX: DEVELOPMENT AND EVALUATION OF BOX-BEAM BARRIER CONFIGURATION FOR SHIELDING FIXED OBJECTS AND BRIDGE ENDS IN MEDIANS – BUDGET: MwRSF FORMAT – PHASE III (CONTINUED)

Item	Site Preparation, Acquisition, Fabrication, & Installation of MBEAT, Roadside Box Beam, and Median Box Beam Systems Costs ($) (10-12)	Test No. 5 - System No. 3 Box Beam Barrier Systems MASH TL-3 Designation No. 3-37a 2270P Pickup Truck @ CIP 5,000 lb - 62 mph - 25 degrees Costs ($)	Remove, Repair, Install MBEAT, Roadside Box Beam, and Median Box Beam Systems Costs ($) (13-16)	Test No. 6 - System No. 3 Box Beam Barrier Systems MASH TL-3 Designation No. 3-37b 1100C Small Car @ CIP 2,425 lb - 62 mph - 25 degrees Costs ($)	Full System Removal, Debris Disposal, Soil Placement & Compaction, & Restore Testing Site Costs ($) (17)	Prepare Draft & Final Research/Crash Test Report with Summary, Conclusions, & Recommendations Costs ($)	Total Costs ($)
Labor Operating Costs (1)	$33,485	$41,913	$12,988	$38,851	$3,723	$9,954	$287,483
Testing Costs	$0	$26,975	$0	$15,246	$0	$0	$84,442
Operating	$500	$482	$300	$386	$200	$310	$4,548
Materials & Supplies	$18,000	$300	$8,800	$300	$1,300	$418	$58,502
508 Compliance	$0	$0	$0	$0	$0	$3,300	$6,600
Travel	$0	$0	$0	$0	$0	$0	$0
Subtotal Costs	$51,985	$69,670	$22,088	$54,783	$5,223	$13,982	$441,575
Overhead Costs (10%)	$5,199	$6,967	$2,209	$5,478	$522	$1,398	$44,157
Total Project Costs	$57,184	$76,637	$24,297	$60,261	$5,745	$15,380	$485,732

Note (10) - The cost estimate assumes that the MwRSF will purchase all materials for the MBEAT, roadside box beam, and median box beam barriers with end anchgorage systems and have them delivered to MwRSF's Outdoor Testing Facility.
Note (11) - MwRSF will acquire, fabricate, and install the MBEAT, roadside box beam, and median box beam barriers with end anchorage sysems at MwRSF's Outdoor Testing Facility.
Note (12) - Construction Materials and Equipment Usage, Maintenance, Repair, and Rental Costs for Testing Program - $18,000 - Test 5 - System No. 3
- MBEAT End Terminal Hardware - Estimate $3,500
- Roadside and/or Median Box Beam Barrier Hardware - Estimate $8,000
- Trailing-End Box Beam Barrier Anchorage Hardware - Estimate $1,000
- Crushed Limestone Soil Material (MASH Strong Soil) for Posts and Anchorages - Estimate $1,500
- Miscellaneous Materials - Estimate $500
- Construction Equipment Usage, Maintenance, Repair, & Rental - Estimate $1,500
- Shipping Costs - Estimate $2,000

Note (13) - Demolition, Removal, Disposal, and Restoration Equipment Usage, Maintenance, Repair, and Rental Costs and Trash Fees - Test 5 - $500
Note (14) - The cost estimate assumes that the MwRSF will purchase all materials for the MBEAT, roadside box beam, and median box beam barriers with end anchorage systems and have them delivered to MwRSF's Outdoor Testing Facility.
Note (15) - MwRSF will acquire, fabricate, and install the MBEAT, roadside box beam, and median box beam barriers with end anchorage systems at MwRSF's Outdoor Testing Facility.
Note (16) - Construction Materials and Equipment Usage, Maintenance, Repair, and Rental Costs for Testing Program - $8,300 - Test 6 - System No. 3
- MBEAT End Terminal Hardware - Estimate $1,000
- Roadside and/or Median Box Beam Barrier Hardware - Estimate $4,000
- Trailing-End Box Beam Barrier Anchorage Hardware - Estimate $0
- Crushed Limestone Soil Material (MASH Strong Soil) for Posts and Anchorages - Estimate $800
- Miscellaneous Materials - Estimate $500
- Construction Equipment Usage, Maintenance, Repair, & Rental - Estimate $1,000
- Shipping Costs - Estimate $1,000

Note (17) - Demolition, Removal, Disposal, and Restoration Equipment Usage, Maintenance, Repair, and Rental Costs and Trash Fees - Test 6 - $1,300
Note (18) - Service center rates are estimates only; the actual rates in effect during the project period will be charged.

REFERENCES

1. Ross, H.E., Sicking, D.L., Zimmer, R.A., and Michie, J.D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Research Program (NCHRP) Report No. 350, Transportation Research Board, Washington, D.C., 1993.

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APPENDIX - DATA MANAGEMENT PLAN

Data Management Plan

Name of Contractor: Midwest Roadside Safety Facility
Name of the Project: Development and Evaluation of Box-Beam Barrier Configuration for Shielding Fixed Objects and Bridge Ends in Medians
Project Duration: Start Date: July 1, 2023 End Date: June 30, 2026
DMP Version: 1
Date Amended, if any: NA
Name of all authors, and ORCID number for each: Brandon Perry - 0000-0001-9172-5979
WYDOT Project Number: TBD

- **Name of all peer reviewed publications, which have been generated using data from this project to include:**

- **Any Digital Object Identifier (DOI), assigned to any peer reviewed publication or data generated by this project:**

- **URLs for all peer reviewed publications which have been generated using data from this project:**

- **Dataset URL, if available:**

What constitutes data will be determined by the Principle Investigator, Project Champion, and the Research Manager. In general, your plan should address final research data. This includes recorded factual material commonly accepted in the scientific community as necessary to validate research findings. Final research data do not include laboratory notebooks, partial datasets, preliminary analyses, drafts of scientific papers, plans for future research, peer review reports, communications with colleagues, or physical objects, such as gels or laboratory specimens. As part of your research, you may also generate unique data, which are data that cannot be readily replicated. Your DMP should also address unique data that may arise from your research.

WYDOT expects the timely release and sharing of data to be no later than the acceptance for publication of the main findings from the final dataset, unless the Principle Investigator will be embargoing the data. In such a case, the data cannot be embargoed for a period longer than 12 months. See Chapter 11 for information on retention and embargos.

1. Introduction

The purpose of this research project is to:

The objective of this research effort is to develop, crash test, and evaluate the WYDOT narrow-median box-beam barrier configuration for shielding fixed objects and bridge ends in

medians according to the TL-3 safety performance criteria found in MASH. If crash testing is unsuccessful, recommendations would be made regarding potential modifications to the design and future research needs.

2. Definitions

a. Code or scripts include code used in the collection, manipulation, processing, analysis or visualization of data, but may also include software developed for other purposes.
b. Copyright is a set of legal rights extended to copyright owners that govern such activities as reproducing, distributing, adapting, or exhibiting original works fixed in tangible forms.
c. Data means the recorded factual material commonly accepted in the scientific community as necessary to validate research findings, but not any of the following: preliminary analyses, drafts of scientific papers, plans for future research, peer reviews, communications with colleagues. Recorded material excludes physical objects (e.g. laboratory samples). Research data also does not include trade secrets, commercial information, materials necessary to be held confidential; and personnel and medical information and similar information the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.
d. Data Archive is a site where machine-readable materials are stored, preserved or possibly redistributed to individuals interested in the materials.
e. Data Management Plan is a document that specifies your plans for managing your data and files for a research project.
f. Dataset means collection of data.
g. Metadata refers to structured data about data that helps define administrative, technical, or structural characteristics of the digital content.

3. Data Types and Storage

The types of data and/or datasets generated and/or used in this project include …

The full-scale crash testing of the box-beam barrier configuration will generate digital video, digital photos, acceleration and angular rate transducer data, speed trap data, 3-D CAD, and a summary report.

Provide a description of the data that you will be gathering in the course of your project. You should address the nature, scope, and scale of the data that will be collected. Describe the characteristics of the data, their relationship to other data, and provide sufficient detail so that reviewers will understand any disclosure risks that may apply. Discuss value of the data over the long-term. Please provide the name of all repositories where the data will be housed during the lifetime of the project.

Checklist

- What type of data will be produced?

- How will data be collected? In what formats?
- How will the data collection be documented?
- Will it be reproducible? What would happen if it got lost or became unusable later?
- How much data will it be, and at what growth rate? How often will it change?
- Are there tools or software needed to create/process/visualize the data?
- Will you use pre-existing data? From where?
- Storage and backup strategy?

4. Data Organization, Documentation, and Metadata

The plan for organizing, documenting, and using descriptive metadata to assure quality control and reproducibility of these data include …

MwRSF collects and analyzes all of the test data collected. The test data is processed and stored digitally as part of the full-scale test documentation. Test data is typically stored in native formats for the software used to acquire the datasets. Processed data is transferred to standard software programs such as Microsoft Office, pdf formats, or CAD formats such as SolidWorks or AutoCAD. Video and photo data is accessible through standard Microsoft photo and video software. All of the data is stored on the MwRSF Data Server at UNL. This server is secure with access limited to MwRSF personnel. Once the research effort is completed and the final summary report is supplied to the sponsor, copies of the digital files are provided to the sponsor. The summary report is supplied in a digital format as well. If the sponsor agrees, portions of the test data and the summary report are archived on the MwRSF website for access to the roadside safety community at large.

Your DMP should describe the anticipated formats that your data and related files will use. To the maximum extent practicable, and in accordance with generally accepted practices in your field, your DMP should address how you will use platform-independent and non-proprietary formats to ensure maximum utility of the data in the future. If you are unable to use platform-independent and non-proprietary formats, you should specify the standards and formats that will be used and the rationale for using those standards and formats.
NOTE: Attach the Metadata Schema, URL for data generated, and all peer reviewed publications from this project.

Checklist

- What standards will be used for documentation and metadata?
- Is there good project and data documentation format/standard?
- What directory and file naming convention will be used?
- What project and data identifiers will be assigned?
- Is there a community standard for metadata sharing/integration?

5. Data and/or Database Access and Intellectual Property

What access and ownership concerns are there …

There are no proprietary or IP issues associated with the data collected in this effort. MwRSF does take the sponsors wishes with respect to distribution of the data into account. However, as

the project is funded with public funds, there are no set restrictions on the data. None of the data is tied directly to a single person or entity.

Data is stored on the MwRSF Data Server which has controlled access limited to MwRSF personnel. MwRSF is ISO17025 accredited and follows procedures for control and access to the test data.

Protecting research participants and guarding against the disclosure of identities and/or confidential business information is an essential norm in scientific research. Your DMP should address these issues and outline the efforts you will take to provide informed consent statements to participants, the steps you will take the protect privacy and confidentiality prior to archiving your data, and any additional concerns. If necessary, describe any division of responsibilities for stewarding and protecting the data among Principal Investigators.

If you will not be able to deidentify the data in a manner that protects privacy and confidentiality while maintaining the utility of the dataset, you should describe the necessary restrictions on access and use. In general, in matters of human subject research, your DMP should describe how your informed consent forms will permit sharing with the research community and whether additional steps, such as an Institutional Review Board (IRB), may be used to protect privacy and confidentiality.

Checklist

- What steps will be taken to protect privacy, security, confidentiality, intellectual property or other rights?
- Does your data have any access concerns? Describe the process someone would take to access your data.
- Who controls it (e.g., PI, student, lab, University, funder) ?
- Any special privacy or security requirements (e.g., personal data, high-security data) ?
- Any embargo periods to uphold?

6. Data Sharing and Reuse

The data will be released for sharing in the following way …

MwRSF shares the data directly with the sponsors in the form of email updates, sponsor presentations, summary reports, and any journal papers published regarding the research. As this is publicly funded research on a non-proprietary roadside hardware system, there are no specific concerns on the sharing or reuse of the data.

Describe who will hold the intellectual property rights for the data created by your project. Describe whether you will transfer those rights to a data archive, if appropriate. Identify whether any copyrights apply to the data, as might be the case when using copyrighted instruments. If you will be enforcing terms of use or a requirement for data citation through a license, indicate as much in your DMP. Describe any other legal requirements that might need to be addressed.

Checklist

- If you allow others to reuse your data, how will the data be discovered and, shared?
- Any sharing requirements (e.g., funder data sharing policy) ?
- Audience for reuse? Who will use it now? Who will use it later?
- When will I publish it and where?
- Tools/software needed to work with data?

7. Data Preservation and Archiving

The data will be preserved and archived in the following ways …

MwRSF archives all test data and final reports on the MwRSF Data Server. This server has secure limited access and the data is archived indefinitely. Additionally, the server is backed up regularly with copies of the data backups stored at multiple locations. Use of the server allows MwRSF to maintain a large database of test data for future research and to support sponsors in their research and educational needs. The dataset will be archived under in a specific location on the server for this research effort.

Note that the data is archived for MwRSF use. The sponsor may maintain their own archive of the data provided as part of the research as well.

Describe how you intend to archive your data and why you have chosen that particular option. You may select from a variety of options including, but not limited to:

- Use of an institutional repository.
- Use of an archive or other community-accepted data storage facility.
- Self-dissemination.

You must describe the dataset that is being archived with a minimum amount of metadata that ensures its discoverability. Whatever archive option you choose, that archive must support the capture and provision of the National Transportation Library metadata requirements. In addition, the archive you choose must support the creation and maintenance of persistent identifiers and must provide for maintenance of those identifiers throughout the preservation lifecycle of the data. Your plan should address how your archiving and preservation choices meet these requirements.

Checklist

- How will the data be archived for preservation and long-term access?
- How long should it be retained (e.g., 3-5 years, 10-20 years, permanently) ?
- What file formats? Are they long-lived?
- Are there data archives that my data is appropriate for (subject-based? Or institutional)?
- Who will maintain my data for the long-term?

NOTE:
Researchers evaluating data repositories as the option(s) for storing and preserving their data should examine evidence demonstrating that the repository:

a. Promotes an explicit mission of digital data archiving.

b. Ensures compliance with legal regulations, and maintains all applicable licenses covering data access and use, including, if applicable, mechanisms to protect privacy rights and maintain the confidentiality of respondents.
c. Has a documented plan for long-term preservation of its holdings.
d. Applies documented processes and procedures in managing data storage.
e. Performs archiving according to explicit workflows across the data life cycle.
f. Enables the users to discover and use the data, and refer to them in a persistent way through proper citation.
g. Enables reuse of data, ensuring appropriate formats and application of metadata.
h. Ensures the integrity and authenticity of the data.
i. Is adequately funded and staffed, and has a system of governance in place to support its mission.
j. Possesses a technical infrastructure that explicitly supports the tasks and functions described in internationally accepted archival standards like Open Archival Information System (OAIS).

NOTE: This DMP is created as a derivative from the DMP belonging to the University of Minnesota and can be found at https://www.lib.umn.edu/datamanagement/DMP

Metadata Schema

Elements	Example of what is expected for each element
Title[1]	Human-readable name of the asset. Should be in plain English and include sufficient detail to facilitate search and discovery. A name given to the publication or data element. All substitute or alternative titles must have a different Metadata Transmittal Schema.
Creator/contact point	An entity/person(s) primarily responsible for making the content of the resource. Contact person's name, ORCID number, and email for the asset.
Publication Date(s)	The date associated with the final report/dataset.
Description/Abstract	Human-readable description (e.g., an abstract) with sufficient detail to enable a user to quickly understand whether the asset is of interest. May include abstract, table of contents, reference to a graphical representation of content or a free text account of the content.
Subject and Keywords	The topic of the content of the resource. Tags (or keywords) help users discover your dataset; please include terms that would be used by technical and non-technical users.
Identifier[2] **and/or source**	A unique identifier for the dataset/publication. Examples: URI, URL, DOI, ISNB, ISSN.
Collection and Related Documents	If there is a secondary dataset, cite source. The collection of which the dataset is a subset should be listed. Include all identifiers and/or sources.
Edition	Most recent date on which the dataset was changed, updated or modified.
Related Documents	Related documents such as technical information about a dataset, developer documentation, etc.
Coverage	Spatial location, temporal period, jurisdiction.
Language	The language of the dataset/publication.

[1] *To include alternate title; conference title; and journal title, if they are different.*

[2] *To include record numbers; report numbers; NTIS number; TRIS Accession Number; OCLC Number; ISBN; ISSN; contract number; and DOI if available.*

Elements	Example of what is expected for each element
Publisher/Distributor	FHWA and Wyoming Department of Transportation List all other publishing companies that this publication has been sent to.
Funding agency	FHWA and Wyoming Department of Transportation
Access Restrictions	The degree to which this dataset could be made publicly available, *regardless of whether it has been made available*. Choices: public (Data asset is or could be made publicly available to all without restrictions), restricted public (Data asset is available under certain use restrictions), or non-public (Data asset is not available to members of the public).
Intellectual Property and Other Rights	This may include information regarding access or restrictions based on privacy, security, or other policies. This should also serve as an explanation for the selected "accessLevel" including instructions for how to access a restricted file, if applicable, or explanation for why a "non-public" or "restricted public" data asset is not "public," if applicable.
License	The license or non-license (i.e. Public Domain) status with which the dataset or API has been published.
Code and software needs	List all code specific information. Is there specific software needed to run the database or data.
Format	The machine-readable file format. May include media type or dimensions. Used to determine the software, hardware or other equipment needed to display or operate the resources.
Choice of Repository	If you have a preference, list the repository where you will archive your data/datasets.

NOTE: Each separate report, dataset, collection, existing collection, and software developed must have its own table. All fields in this Schema must be completed at the time of the final report.
NOTE: This Metadata Schema is created as a derivative from the Common Core required fields which can be found at https://project-open-data.cio.gov/schema/.