PROJECT TITLE:

RPFP-16-MGS-2: Design Guidance for MGS Placed on or near Slopes (New Jersey)

STATE'S PROBLEM STATEMENT:

The MGS has shown to be a high performance, adaptable system that can be installed on or near slopes. Variations of the MGS have been tested under these conditions, with differing post spacing, post lengths, and blockout depths, depending on the degree of the slope and the guardrail offset in front of the slope. However, gaps in the guidance still exist for some ranges of slopes and offsets, and existing guidance is contained in various documents as well as on the Midwest Pooled Fund Q/A website.

The need exists to fill the gaps in guidance regarding MGS installed near slopes. For example, there is currently limited guidance for: (1) posts installed 1 ft to 2 ft adjacent to a 3H:1V or steeper slope; (2) posts installed less than 1 ft adjacent to a 3H:1V to 6H:1V slope; and (3) posts installed less than 1 ft adjacent to a 6H:1V or flatter slope. In addition, a single document that provides clear, concise guidance on all options available to designers when installing MGS near slopes would be extremely valuable.

BACKGROUND:

Guardrail placed adjacent to slopes has been a common concern for state DOT's. In the past, several states have requested guidance regarding safe guardrail offsets or modification to guardrail post spacing and/or embedment when placed directly adjacent to steep fill slopes. With respect to the MGS system, MwRSF has made conservative recommendations based on engineering judgment regarding placement of the MGS adjacent to slopes, as shown in Table 5. While these recommendations were based on the best available information at the time regarding the use of beam guardrail adjacent to slopes, they have not been updated to reflect more recent research nor do they cover the entire range of slope and barrier placement scenarios.

Slope	Offset	Post Configuration
Any Slope	2 ft	6-ft long W6x8.5 @ 6'-3" spacing
Slope ≤ 6H:1V	1 ft – 2 ft	6-ft long W6x8.5 @ 6'-3" spacing
3H:1V ≤ Slope < 6H:1V	1 ft – 2 ft	7-ft long W6x8.5 @ 6'-3" spacing
Slope > 3H:1V	≤ 1ft	8-ft or 9-ft long W6x8.5 or 7.5-ft long 6"x8" SYP @ 6'-3" spacing

Table 5. Previous Guidance for MGS Adjacent to Slopes

Over the past several years, variations of the MGS installed adjacent to steep slopes have been developed and full-scale crash tested. A modified version of the MGS was developed for use adjacent to steep slopes. This design consisted of 9-ft long, W6x9 steel post spaced 75 in. on center and was installed at the slope break point of a 2H:1V fill slope with a 31 in. top rail mounting height. This system was successfully crash-tested according to the TL-3 safety performance criteria of MASH. For this variation, either wood or steel post options are acceptable when installed at the slope break point. The wood post version consists of 7.5-ft long, 6-in. x 8-in. wood posts instead of the 9-ft long W6x9 steel posts. It should be noted that during the dynamic bogie testing, the 8-ft and 9-ft long W6x9 steel posts installed at the slope break point of a 2H:1V fill slope showed very similar behavior. In order to be conservative, the 9-ft long post was selected for the testing program. However, the 8-ft long steel post has been considered an acceptable option as well.

A non-blocked version of the MGS placed at the slope break point of a 3H:1V slope has been successfully tested according to the MASH TL-3 safety performance criteria. This design consisted of 6-ft

long, W6x9 steel posts spaced 75 in. on center and was installed at the slope break point of a 3H:1V fill slope with a 31-in. top rail mounting height. This system was installed in a very strong fill material in a wire-faced MSE wall, which limited post rotation and produced higher soil resistive forces when compared to a typical MGS installation. Based on these results and engineering judgment, a non-blocked, 31-in. tall MGS with back up plates, 8-ft or 9-ft long steel posts, and placed at the slope break point of a 2H:1V fill slope may possibly also be capable of meeting the TL-3 MASH impact safety standards. However, it should be noted that no crash tests have been performed on this exact variation and that the minimum recommended top mounting height would likely be affected, similar to the blocked version of the MGS adjacent to 2H:1V fill slopes. As such, it is recommended that a non-blocked version of the MGS adjacent to 2H:1V fill slopes utilize a minimum top mounting height of 31 in. in combination with longer steel posts.

Texas A&M Transportation Institute (TTI) successfully tested a 31-in. tall W-beam placed on a 2H:1V slope according to the MASH TL-3 safety performance criteria. This design consisted of 8-ft long W6x9 posts, with 8-in. deep blockouts, spaced 75-in. on center and was located such that the front face of the rail was placed at the slope break point. Since this system used shorter posts that were installed farther down the slope, it is reasonable to assume that 8-ft long posts installed at the slope break point would also work.

Most recently, MwRSF conducted a MASH TL-3 crash test of a MGS system with standard 6-ft 3-in. post spacing and 6-ft long posts installed at the slope-break-point of a 2H:1V slope. In test no. MGSS-1, a 2270P vehicle impacted the MGS system adjacent to slope at 61.6 mph and an angle of 26.2 degrees. The impacting vehicle was safely and smoothly redirected and the test met all of the MASH TL-3 safety criteria. Analysis of the test data found a peak dynamic deflection and working width of 72.9 in. and 77.4 in., respectively. These values were significantly higher than the deflections of the MGS system on level terrain and previously versions of the MGS adjacent to slope with longer posts, as shown in Table 6. Thus, the MGS with standard post lengths and spacing adjacent to slope may be near its limits of performance.

	2214MG-2	MGSSYP-1	MGS221-2	405160-20-1	MGSS-1
Post Type	**Steel W6x9**	**Wood 6”x8”**	**Steel W6x9**	**Steel W6x9**	**Steel W6x9**
Post Length	**6-ft**	**6-ft**	**9-ft**	**8-ft**	**6-ft**
Offset / Slope	**Level Terrain**	**Level Terrain**	**@ 2:1 SBP**	**1-ft down 2:1 slope**	**@ 2:1 SBP**
Dyn. Deflection	**43.9”**	**40.0”**	**57.6”**	**51.6”**	**72.9”**
Working Width	**48.6”**	**53.8”**	**64.2”**	**55.2”**	**77.4”**

Table 6. Comparison of Selected Successful MGS Crash Tests on Level Terrain and Slopes

OBJECTIVE:

The research objectives are to: (1) develop recommendations for MGS installed with slopes and offsets that have not been provided previously and (2) combine all recommendations regarding MGS installed near slopes into a selection guide which clearly presents all options available to designers when placing MGS near slopes.

RESEARCH PLAN:

The research effort will begin with a literature search to compile the existing full-scale and component test data related to the MGS installed adjacent to slopes as well as previous guidance that has been provided to the states for installing MGS in combination with slopes. MwRSF will compile and organize this data and identify areas that lack recommendation or need to be addressed. The proposed scope of the

guidance will be provided to the state DOTs for review in order to garner feedback regarding whether the needed guardrail on slope installations are covered. Once the range of guardrail and slope combinations has been identified, MwRSF will propose guidance for placement of the MGS adjacent to slopes based on viable post embedment, spacing, and offset options for a given slope condition. This guidance will be based on engineering judgment and the data on MGS adjacent to slopes complied during the literature search. A summary report will be completed that provides the recommended guidance in a clear format for states to refer to when designing for MGS adjacent to slopes.

Major Task List

Literature Review:	Review literature pertaining to MGS in combination with slopes.
Selection of Options:	Determine slope and barrier combinations requiring guidance, followed by sponsor review and feedback
Design and Analysis:	Determine guidance for MGS installed adjacent to various slopes.
CAD:	Prepare charts and CAD details as needed to document recommendations.
Summary Report:	Prepare summary report containing results of literature search, charts, guidelines, and recommendations regarding MGS installed near slopes.

BENEFITS:

This research would develop a selection guide that presents installation options of the MGS placed near a slope. It would be slope-based such that for a given slope, all allowable variations and locations of the MGS would be presented.