National Park Service
U.S. Department of the Interior

Denali National Park and Preserve
Long-Range Transportation Plan

Appendix C: Denali Park Road Risk Assessment Utilizing the Unstable Slope Management Program

Denali National Park and Preserve – Long Range Transportation Plan

Deterministic Geologic Risk Assessment of the Denali Park Road Utilizing the Unstable Slope Management Program

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Introduction and Project Status

The 92-mile Denali Park Road traverses a highly active geologic landscape and has experienced numerous documented mass wasting events throughout the history of the road. One of the most dramatic occurred in late October 2013 when a 600-ft-long, 110-ft-wide debris slide blocked the road near MP 38. Blocks of permafrost-frozen, unconsolidated debris up to 15 ft thick slid on weak, unfrozen clay. Frequent but less dramatic events: block traffic, undermine road surfaces, and may cause damage to vehicles or injuries. Many events, including the example above, are likely triggered or exacerbated by thawing permafrost and are consistent with the possible effects of anthropogenic climate change. With increases in road use, the uncertain effects of climate change, and possible changes to maintenance funding levels, National Park Service (NPS) and Federal Highway Administration (FHWA) staff identified the need for a comprehensive risk analysis of geologic hazards along the Denali Park Road.

The risk analysis is scheduled for completion by March, 2017 and includes five parts: (1) inventory maps and linked database that illustrate spatial/temporal distribution of geohazards, their relative activity, and geomorphic attributes; (2) beta testing and implementation of the Unstable Slope Management Program (USMP) rating criteria; (3) geohazard susceptibility models that estimate the spatial probability of occurrence; (4) geohazard risk models that illustrate the potential consequences; and (5) analyses/recommendations to park management regarding other risks the road will exhibit over the next decade (DENA-MOA-208813A/B). Currently, tasks 1 and 2 are predominately complete, tasks 3 and 4 are underway and task 5 will follow the completion of tasks 1-4. Although final results and recommendations are still forthcoming, the results of tasks 1 and 2, in particular the USMP ranking scores (discussed below), provide an inventory and a first-order, deterministic risk assessment of geologic hazards currently affecting the park road.

The results of the USMP rating criteria provide valuable information on the spatial distribution of geologic hazards, their severity, and the associated risk; however, they do not directly assess the possible impacts of climate change or provide a detailed outlook of possible future scenarios. We utilize these data to provide a preliminary identification of the areas with the highest relative risk and their spatial patterns. Consideration of this information should be valuable to this Long Range Transportation Plan (LRTP) and for park managers and planners as future infrastructure plans are being developed.

Unstable Slope Management Program Site Rankings

The USMP is a collaboration between the FHWA, many other federal agencies including the NPS, private geotechnical consultants, and the Alaska Department of Transportation & Public Facilities (AKDOT) that ranks geologically unstable slopes for the purpose of facilitating more effective long-term geotechnical asset management. USMP scores provide a deterministic ranking of agency risk associated with any particular geologic hazard site. These scores consider elements of both the severity and frequency/probability of a hazard and the exposure and vulnerability at each particular site. Example elements include: the amount of roadway affected by landslide events, the frequency of known hazard events, the impact of events on the use of the transportation corridor, the maintenance cost and complexity, and annual average daily traffic. For detailed information the USMP ranking criteria please see: (http://nl.cs.montana.edu/usmp/RatingManual.pdf).

We have currently completed a total of 141 USMP site rankings along the entire 92 miles of the DENA Park Road (Figure 1). These data represent the vast majority of known geologic hazard sites and include: landslides, debris flow drainages, rockfall areas, frost-heaves, and erosional undercutting due to fluvial processes. It should be noted, however, that these site rankings are not totally comprehensive; instead, they represent our most complete knowledge as of 06/29/2016. The DENA USMP rankings range from 164 to 948 with a mean value of 328 and more variance within higher ranking sites. To put these values in perspective immediately however, the USMP qualitatively defines sites that score less than 200 to be in “good” condition, sites that score between 200 and 399 to be in “fair” condition, and sites that score 400 or higher to be in “poor” condition.

In theory, sites in poor condition are more likely to pose persistent and/or more serious problems along the road and areas of higher risk density are more likely to see a higher concentration of problems. In DENA, the current majority of our sites, 67%, rank in fair condition, while only 9% are in good condition, and a relatively large number of sites, 24%, are in poor condition. The only significant outlier was the “Pretty Rocks” slump (Figure 3b) with a score of 948; 365 points higher than the next highest site. Spatially, regions of higher USMP risk density (Figure 2) are most pronounced along Polychrome Pass and the Eielson Bluffs areas. Individual USMP scores represent the relative risk associated with a hazard site and risk density represents the relative concentration of agency risk.

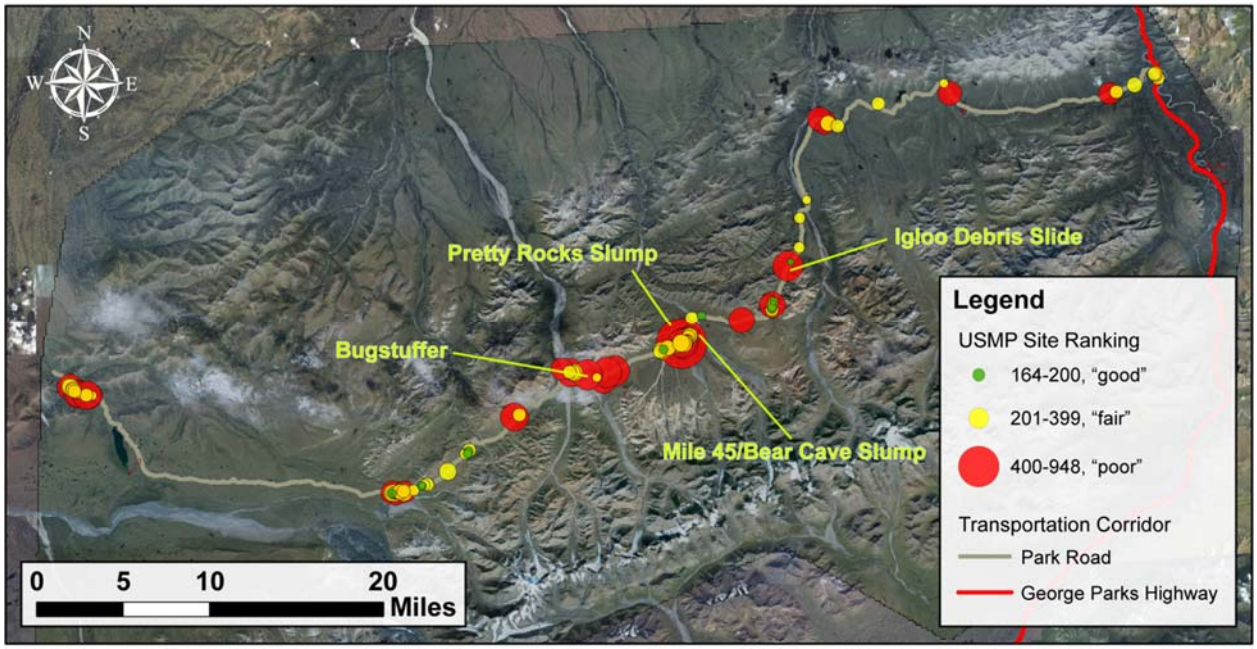

Figure 1. DENA USMP site rankings on IKONOS imagery. Icon sized is scaled by individual site rank and colored according to good, fair, or poor qualitative rank.

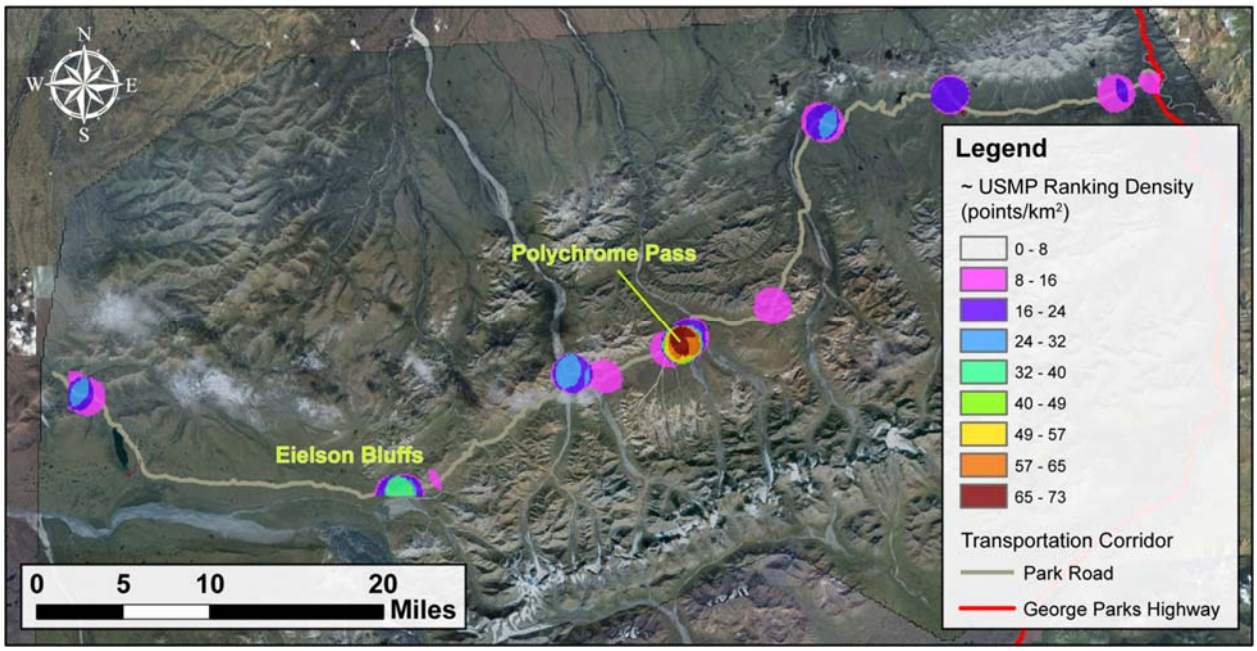

Figure 2. DENA USMP score density on IKONOS imagery. Density scaled by linear concentration and site ranking scores.

Of the sites ranked in poor in condition along the Park Road, many received prior mitigation, or were previously identified as areas of concern by maintenance or resource management personnel. Some previously noted severe geologic hazard sites in 'agreement' with poor USMP scores include: the "Pretty Rocks" slump (Figure 3a), debris flow activity at "Bugstuffer" creek (Figure 3b), the "Bear Cave/Mile 45" slump (Figure 3c), and the "Igloo Debris Slide" (Figure 3d). Additionally, Polychrome Pass is a known area of high geologic hazard occurrences. This general agreement of USMP scores and professional

judgement/institutional knowledge within DENA should be reassuring to park managers and help demonstrate that the USMP ranking scores represent useful information and are based off of many years of development from similar programs and expertise developed by FHWA, AKDOT, Oregon Dept. of Transportation, and private firms. The USMP provides an institutional framework for tracking these known problem areas and has identified other new examples.

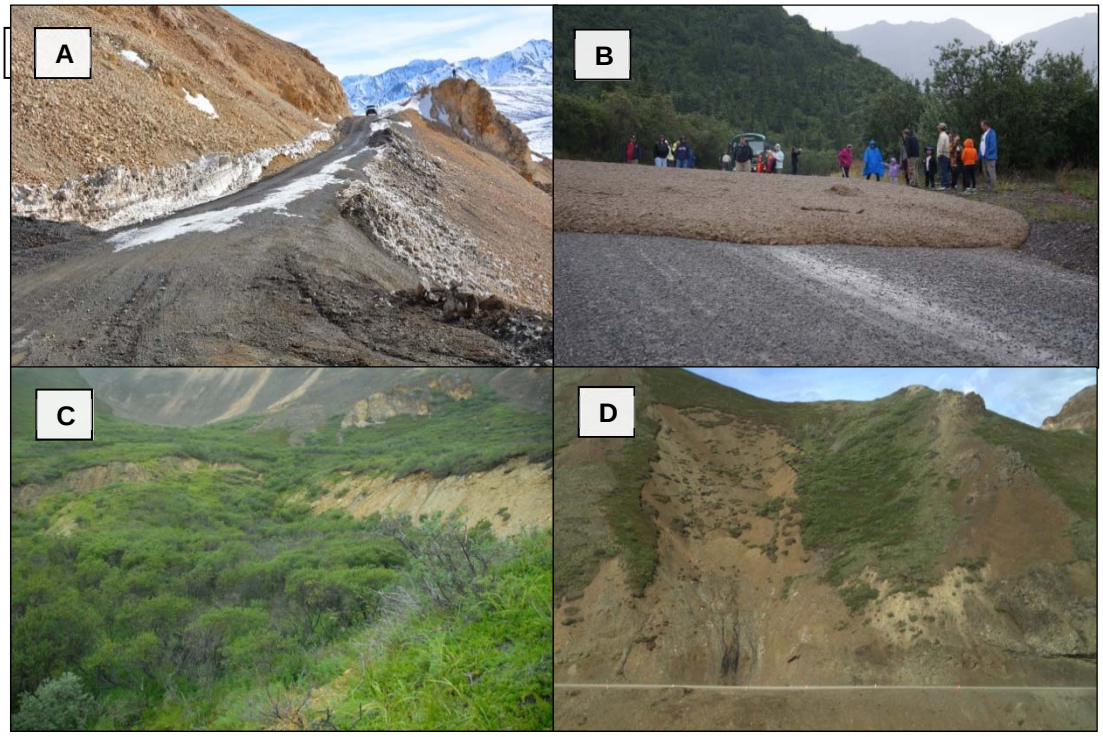

Figure 3. Previously recognized sites that rank in poor condition. A – Pretty Rocks Slump (mile 45.4, 948 points); B – Bugstuffer debris flow (mile 51.9, 575 points); C – Bear Cave Slump (mile 45, 411 points); D – Igloo Debris Slide (mile 37.7, 514 points).

Current Applications to the LRTP

The USMP rankings provide a preliminary framework for understanding the relative severity of risk associated with geologic hazards along the Park Road. Although we do not currently make recommendations tailored to specific sites or address possible future scenarios, we suggest that an awareness of the current results of the USMP rankings is beneficial to this LRTP. Likely applications of the USMP data to the LRTP would involve spatial analysis of USMP rankings as they relate to possible disruptions in traffic, programming of potential mitigation projects, and overlap with future infrastructure planning. In order to facilitate this analysis we submitted a spatial database of our USMP rankings to PaTINA (they are also available on request). We emphasize that these results are preliminary, yet they provide a method for understanding and considering geologic hazards in a broader context. Park planners and managers should continue to work with resource staff in understanding the

implications of these results; however, the following are potential applications to consider for the current LRTP:

- All geologic hazards sites, but in particular those in poor condition are more likely to pose persistent and/or serious problems along the Park Road. These are areas where the transportation corridor could experience interruptions, or incur high maintenance costs as a result of geologic activity. Sites in poor condition should be considered for mitigation and investigated in more scientific detail (see Future Work).
- The USMP rankings may help identify geotechnical assets where hazards do not appear extremely severe, but may be candidates for mitigation from a risk-based or cost-based perspective. Rockfall sites that are not capable of producing catastrophic roadway failure, but require very frequent maintenance are good examples of this. These sites also rank in poor condition, but may not otherwise receive attention from management.
- Density analysis of USMP site distribution identifies areas of non-discrete geologic hazard areas that may require alternate or more systematic mitigation efforts to increase cost effectiveness. The extreme concentration of hazard sites along Polychrome Pass is an example of such an area.

Future Applications to the LRTP

Both the LRTP and USMP have been designed to evolve as new information become available through time, thus allowing for future applications with as new data become available. Most transportation agencies apply transportation asset management (TAM) systems to transportation assets such as bridges and road surfaces; however, geotechnical assets such as rock slopes and embankments are unlikely to be considered with the same detail (Stanley, 2010). The USMP provides a system for geotechnical asset management by creating a framework to establish potential performance measures, and targets, for individual geologic hazards and the overall transportation corridor (Federal Highway Administration-DRAFT report, 2015). We plan to update USMP rankings for the DENA park road as more information is made available or new events occur, and to perform a systematic re-evaluation once every five years. By tracking USMP rankings over time the following performance measures could be considered by transportation planners and park managers:

- Establish targets to reduce the overall number of fair or poor ranking sites along the park road. This could represent a total percentage reduction, a maximum target number of poor/fair sites, or a certain number of poor/fair sites per unit distance along the road.
- Establish targets to reduce the risk at sites of particular concern (see Future Work)
- A benefit/cost analysis for all geotechnical assets along the transportation corridor could be undertaken. The USMP group is currently working on developing this tool and the effectiveness of programmed mitigation projects could be measured by tracking costs vs performance changes in geotechnical assets recorded by the USMP rankings.

- A method for tracking the performance of assets through time to establish a preferred course of action. As an example, USMP scores at the site of the October 2013 slide that blocked the road (Figure 3d), have been on a downward trend since May 2015 because of relative inactivity while scores at the Pretty Rocks slump (Figure 3a) have remained higher or increased slightly because of recent activity. Establishing trends in USMP scores through time could be useful for determining appropriate mitigation priority.

Future Work

The USMP risk matrix provides a relatively robust assessment of geotechnical assets based on their current condition and a way to track their performance through time. However, because of its deterministic nature, it does not directly consider possible or likely future conditions. We hope to address this limitation through the continued development of the geologic risk assessment. Completion of task 3-5 of the risk assessment will allow us provide data which will help determine the probability of future events based on geologic conditions and the associated risk based on transportation infrastructure and human exposure. The results of tasks 3-5 will allow us to assess the potential outlook of areas of the road based on their probability to experience new events. Additionally, we will expand on the results of the USMP to examine high ranking sites in more scientific depth. Examples of this may include: drilling bore holes at the Pretty Rocks slump to determine sub-surface conditions, examining the relative abundance of fine-grained sediment in debris flow watersheds, or repeat GPS surveys to ascertain motion rates, such as are currently ongoing at the Bear Cave/Mile 45 slump. By using all of these data sets in conjunction we plan to propose specific recommendations and mitigation considerations for sites of concern based on their current conditions and future outlook.

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