

## **Executive Summary for the Unstable Slope Management Program for Federal Land Management Agencies (USMP for FLMA)**

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Transportation corridors consisting mainly of roads and trails within federally managed lands contain numerous unstable and potentially unstable slopes and slope failures. A variety of slopes including natural and constructed rock slopes, soil cut slopes and soil embankments are all subject to failures occurring as rockfall, landslides, debris flows, creep settlement, etc. These instabilities range in severity from maintenance nuisances that generally go unnoticed by the traveling public, to those that can block traffic or trail usage, or to those that cause injury and/or property damage. Although slope failures that cause significant blockages, property loss, or loss of life are not common at any given location, unstable slopes along a transportation corridor are a problem for the agency responsible for providing and maintaining safe and efficient transportation for people and goods. Consistent with the federal efforts for overall disaster preparedness and risk reduction, many state transportation agencies are moving toward proactive risk management strategies to help mitigate unstable slopes; however, there has been little information to guide federal land management agencies (FLMAs), tribes, and local state agencies (such as counties, cities, state parks, and metropolitan parks) with low to very low traffic volumes and various levels of trail usage on how to manage slopes using asset and performance management principles. This project was created to provide guidance to manage one of the geotechnical assets by developing and implementing an asset and performance management-based unstable slope management program (USMP) for FLMAs and tribes that can be adopted by other local state agencies with similar assets and infrastructure assessment needs.

Under the first phase of this project, two primary road corridors with known unstable slopes were identified for use in the field demonstration of the USMP. The road corridors were in the Gifford Pinchot National Forest on Forest Service Roads 25 and 99. The first task of this first phase included identifying stakeholders in partnering agencies, and providing, developing, and presenting geotechnical asset management materials to educate the team about unstable slope asset and performance management. Input from the stakeholders was used to refine the Alaska DOT's unstable slope rating criteria for FLMAs with very low to low volume roads and significant trail network usage. FLMAs also requested development of a brief video about development of the USMP and its value to managing slope assets and meeting the Moving Ahead for Progress in the

21st Century Act (MAP-21) requirements. A draft USMP rating form, calculations, and rating criteria definitions were produced prior to demonstrating the field inventory and condition survey at approximately 20 unstable slopes consisting of both, soil and rock unstable slopes of varying condition and severity. Following the field demonstration with the partnering agencies, the standardized unstable slope rating forms, calculations, and rating criteria definitions were finalized and presented in a report that included maps of the demonstration corridors with completed rating forms, site photographs, and a ranked list of the unstable slopes with their slope ratings.

Inventorizing and assessing the condition of unstable slopes is the first step in managing them; however, understanding the magnitude of the problems associated with unstable slopes requires more than identifying them. Successful management also includes an understanding of the costs associated with maintaining, fixing, and replacing such assets. Asset management is being used with increasing frequency as a means of reducing overall life-cycle costs. Geotechnical Asset Management (GAM) is in its infancy within most public agencies, and specifically within FLMAs, while assets such as pavements, bridges, and some larger culverts are usually more commonly inventoried and managed. Geotechnical assets (slopes, retaining walls, embankments, rock guardwalls, etc.) are typically handled using a reactive approach when a slope failure closes a trail or roadway. Emergency funds, often from other road and trail maintenance funds, are used to mitigate unstable slopes, thereby shortchanging the intended use of those funds for other programmed maintenance needs. GAM tools such as the USMP provide a proactive approach to inventorizing, assessing, prioritizing, and requesting proactive, dedicated funds for mitigation efforts. In addition, asset management under the MAP-21, and now the Fixing America's Surface Transportation (FAST) Act, mandates that asset and performance management tools be developed and utilized to manage our assets, provide transparency to the public, and determine strategic infrastructure needs to most efficiently use the limited and uncertain funding sources for these types of safety improvement projects.

The value of asset and performance management is to base decision-making on a proactive, strategic approach that takes a long view of performance and cost using analytical tools to allow for alternative comparisons. Accurate and effective asset management is founded on a database of relevant information collected during routine or periodic inventories and condition assessments. Agency performance goals and standards are needed to evaluate the asset and to determine whether to abandon, repair, or replace the asset.

The USMP is innovative and unique because of its application of the principles of asset and performance management to geotechnical assets. As part of the implementation process, the USMP will provide guidance on setting and validating performance goals and standards for unstable slope assets. This work will benefit all partnering agencies by providing them significant cost saving through applying asset and performance management principles for unstable slopes. The program will also provide policy statement examples about safety and service life goals for managing unstable slope assets.

One significant method of incorporating asset and performance management principals and meeting the MAP-21 and FAST Act requirements is to implement an USMP in FLMAs. Asset management for unstable slope assets covers four general areas, 1) building an inventory of unstable slope assets that includes their condition, 2) developing performance standards and service life criteria, 3) identifying corrective actions, and 4) taking corrective actions.

The second phase of this project was to develop, verify and demonstrate a database for unstable slopes that could be populated using a web-based electronic form or via iOS-based and Android-based applications that function off-line and upload when back in wireless locations. Data generated from USMP ratings is displayed graphically on a map to facilitate simple and quick visual assessments. Additional development under this phase also includes creating a form to document new unstable slopes that occur, a maintenance form to track deterioration of unstable slopes to stage risk reduction work or mitigation, and a search and reporting tool that allows users to harvest the data as they see fit. The quantitative risk analysis (QRA) tool is included in the USMP work to provide risk assessments for unstable slopes that may not have data in an USMP already, or it can be used to help quantify the risk associated with a given unstable slope as it relates to comparisons with societal risks; such as, being killed in an auto accident in the US, being struck by lightning, being murdered in the US, etc. All accomplishments from this second phase are documented in a field manual for users, and a number of free seminars will be held around the U.S. to train potential users of the program. The following tasks were undertaken as part of the second phase of this project to develop and execute a robust and useful USMP for FLMAs.

#### Task 1 – Develop Examples of Performance Measures

Task 1 is to develop performance measures for the USMP based on the system used by the Forest Service, which manages its roadway system by utilizing five distinct Maintenance Levels, each with their own usage goals and objectives. Performance Measures are divided into two general categories, Condition Performance Measures and Management Performance Measures. The Performance measurements based on condition follow and expand upon examples outlined in an FHWA Office of Transportation Performance Management factsheet describing a Notice of Proposed Rulemaking (NPRM)<sup>1</sup> for pavements and bridges. Performance measures based on management are intended to track how well the Agency is proactively managing and improving their unstable slope assets over time using data obtained during the slope rating procedures, and tracking of maintenance records for road-closing unstable slope events, as well as mitigation and risk reduction projects.

#### Task 2 – Database Development

Task 2 is to develop a searchable database based on open-source technologies (e.g., Postgres, MySQL) that is appropriate for the USMP management needs. The database accepts input from field ratings and measurement using web forms, or direct input through an application programming interface (API). The database is integrated with the GIS platform developed in Task

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<sup>1</sup> <http://www.fhwa.dot.gov/tpm/rule/pmfactsheet.pdf>

3. Stored data is available to future applications of USMP data through read-only SQL queries (Task 10).

#### Task 3 – GIS Platform Development

Task 3 is to develop a maps-based GIS platform that presents the information from the USMP database. It provides users with a graphical method for data query and content creation. Stored USMP data can be displayed on an interactive map through interactive icons and callouts. Content creation is supported through web forms available to field operators, or through an API. The web forms also support uploading of scanned documents and photographs to be associated with the rated unstable slopes.

#### Task 4 – Input Phase I Unstable Slope Inventory Data

Task 4 is to test the USMP database with the maps-based GIS platform using the Phase I unstable slope inventory condition information and the US Forest Service’s preliminary service life estimates for slopes, and set performance standards based on service life (based on Task 1) to determine what slopes are identified for corrective action. Ten slopes were prioritized for conceptual design and cost estimating in the field.

#### Task 5 – Site Visits

Task 5 is to rate ten additional unstable slopes in the field within the demonstration corridor to test the field data collection and GIS-based platform developed under Task 2 and 3, and to further test the USMP database and the maps-based GIS platform. The 10 unstable slopes used to assess conceptual design alternatives and cost estimating will be used to develop the benefit-cost alternatives under Task 6.

#### Task 6 – Cost-Benefit Formulation

Task 6 is to write a summary document to summarize a series of alternative approaches for benefit/cost prioritization of slope preservation, mitigation, and reconstruction. The alternative approaches will focus on differing levels of available Agency data to feed the benefit cost formulations. All of the approaches are based on widely-accepted principles of risk management and asset management, with varying levels of data requirements. The approaches are meant to provide an objective and consistent means of summarizing the degree to which each project may contribute to agency objectives while minimizing long-term cost and risk. An accompanying spreadsheet program is included to provide the necessary benefit factors for use in the formulas, and demonstrates their use.

#### Task 7 – Database and GIS Map Integration

Task 7 is to create a single platform to deliver a fully functional open source database, web form, and map-based GIS platform based on the work accomplished in Tasks 2 and 3. The database and GIS-based map will be available for use on desktop computers, iOS, and Android applications (Task 13).

#### Task 8 – Development of Field Manuals

Task 8 is to produce a brief and simple manual to outline the procedure for planning and rating unstable slopes and to describe the use of the database and associated map-based GIS platform.

#### Task 9 – Produce a Training Video on How to Rate Unstable Slopes

Task 9 is to produce a video training tool to aid deployment of the USMP to FLMAs. The training tool focuses on planning field work, rating unstable slopes, and accessing and using the database, web forms, and map-based GIS platform in the office and field.

#### Task 10 – Develop a Searching and Reporting Tool for the USMP Database

Task 10 is to develop a front-end web form to allow searching the contents of the USMP database by multiple categories and allow refined searches in at least three sub-categories. Reporting of the tabular data resulting from the searches will be presented in a spreadsheet-type format containing the categories and search ranges used for the search criteria and the resulting data. The “search and report” web form is linked to the USMP web-based GIS platform developed in Task 7 to illustrate the results of the search criteria geographically.

#### Task 11 – Maintenance Tracking Form

Task 11 is to develop a web form that can be used in the field by maintenance crews (even in the absence of an internet connection). Off-line data will be automatically downloaded into the USMP database upon reconnecting to the internet. This tracking form is intended to be used for normal, scheduled maintenance activities associated with known unstable slopes. The form will be used to capture the level of effort and associated costs required to maintain the roadway or trail, re-open the road or trail, or preserve the integrity of the roadway through specialized maintenance projects.

#### Task 12 – New Slope Form

Task 12 is to develop a web form that can be used in the field by FLMA personnel (even in the absence of an internet connection). Off-line data will be automatically downloaded into the USMP database upon reconnecting to the internet. This form is intended for new unstable slopes not already in the USMP inventory. When information for a new unstable slope form is added to the USMP database, an email may be automatically generated to a designated FLMA agency official to trigger a possible field visit and/or full unstable slope rating.

#### Task 13 – iOS and Android Application Development

Task 13 is to develop iOS-based and Android-based applications as alternatives to the PC platform developed as part of Tasks 2, 3, 7, 10, 11 and 12 described above. Application platform choices will encourage more usage by FLMA agency users and is less costly for FLMAs to implement.

#### Task 14 – Develop Quantitative Risk Analysis Module

Task 14 is to develop a Quantitative Risk Analysis (QRA) module as a graphical user interface implementation of the four factor QRA equation used by National Parks Service Geologic Resources Division. Probability factors and items affecting probability factors such as rock size and number of boulders for rockfall, speed limit in a hazard, and stopping distance required to avoid the hazard will be used to generate an annual or daily individual risk of death or injury. Risk probability could then be compared with other societal risks in an output comparison graph. Risk of death or injury occurrence and societal costs could also be estimated through input of the number of people exposed to the risk and an implementation of the USDOT’s Value of Statistical Life guidance.

### Task 15 – USMP Technology Deployment and Training Course

Task 15 is to develop and deliver up to four two-day training courses across the United States to educate potential users how to use the USMP rating tools and associated software. This training will help facilitate implementation of the USMP for FLMAs. Training will consist of one-day of office level instruction and one-day of field training. Students will learn how to prepare for rating slopes, input data into the various web forms, interact between the USMP database and map-based GIS platform, and download the collected field data when returning to the office.

### Task 16 – Present USMP to FHWA Performance Management Team and FLMA Leadership

Task 16 is to present the USMP to the FHWA Performance Management Team, and also to the FLMA Performance Management Leadership Team. This will help inform upper management of the unstable slope management program and its benefits to many FLMAs.

### Task 17 – Provide Marketing Materials for Technology Deployment and Training Courses

Task 17 is to develop an electronic brochure describing the benefits of unstable slope asset management through the free training course offered as part of Task 15. The brochure will also describe how the training course will prepare an attendee to collect and manage data collection and analysis in the USMP database and GIS map-based platform. The electronic brochure will target FLMA personnel, road managers, trail managers, federal geotechnical consultants, municipalities, counties or metro parks personnel, and consultants.

The value of asset and performance management is utilizing a proactive, strategic approach to make decisions that takes a long view of performance and cost, and is based on accurate information using analytical tools to allow for alternative comparisons. Asset and performance management are founded on accurate data in asset inventories and condition assessments. Agencies employing this system are able to set performance standards to determine the optimal approach once the service life of the asset is understood. This work will benefit all partnering agencies by providing them significant cost savings through applying asset management principles for geotechnical assets. It can also result in providing policy statements about safety and service-life goals for managing geotechnical assets, such as, unstable slopes.

The third phase of this project, which is currently unfunded, entails providing a stable, long-term information technology environment for the USMP database. This includes the following proposed IT solutions.

- Locating a cost-effective location(s) to house the USMP data for all FMLAs (e.g., with the RIP, GIP, and WIP databases in Eastern Federal Lands; at each agency)
- Updating the operation and maintenance of the database and web-based map platform to ensure the platform is stable and functional
- Establishing data quality control and assurance to ensure database integrity
- Performing database cleanup and IT projects to ensure compatibility and connectivity with other FMLA corporate databases

- Ensuring data are available in a timely fashion to provide more transparent decision making that translates to more effective and efficient management of FLMA roads and trail networks.

Overall, the third phase of the project seeks to provide longevity of this USMP asset and performance management program decision support tool by performing regular maintenance and providing operational support from IT staff so that the data remains available, error-free, and centralized for continued use by FLMA personnel.