Deep-Seated Landslide Mapping and Classification Study Design

Answers to Prospective Six Questions from the CMER / Policy Interaction Framework Document

April 23, 2024
Approved by CMER on: TBD
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Brief Project Description: This is the study design for the Deep-Seated Landslide Mapping and Classification Project, two of the successive and interrelated projects that comprise the 12 projects listed in the Deep-Seated Landslide Research Strategy (Strategy, 2019) (See question 5 for list of projects). The Study Design is a combination of the Deep-Seated Landslide Mapping Project (4.5) and the Landslide Classification Project (4.6), listed in the Strategy. The Study Design is meant to inform the Research Strategy. It is intended to provide a classification of DSLs inferred to represent a range of potential landslide responses to natural and forest practice changes. This effort will provide the framework needed to pursue the subsequent projects in the Strategy which are designed to specifically investigate landslide mechanics and hydrology based on the landslide classification. This pilot study is proof-of-concept project that utilizes remotely sensed data in an effort to characterize several thousand landslides within a portion of NW Washington study area.

1. **Will the study inform a rule, numeric target, Performance Target, or Resource Objective?**
   Yes, indirectly. The Landslide Mapping and Classification Project will develop a protocol to identify DSL classes that may better inform rules, numeric targets, Performance Targets and Resource Objectives. The baseline classification data produced by this project will inform the design and landslide site selection for the more detailed empirical research to follow in the Strategy.

2. **Will the study inform the Forest Practices Rules, the Forest Practices Board Manual guidelines, or Schedules L-1 or L-2?**

   Washington Administrative Code (WAC) 222-16-050 addresses forest practices conducted on unstable slopes or landforms with the potential to deliver sediment or debris to a public resource or that have the potential to threaten public safety. These activities are evaluated as a Class IV-Special forest practice and undergo State Environmental Policy Act (SEPA) review. This project may inform Forest Practice Rules, the Board Manual and Schedule L-1, and the Forest Practices Board and Policy in the 2016 Proposal Initiation (WFPB 2016).

   - Deep-seated landslides are included in DNR's Forest Practices Application (FPA) approval process to evaluate a timber harvest's likelihood of accelerating or reactivating landslides that could deliver sediment or debris to a public resource or in a manner that would threaten

public safety (see WAC 222-10-030: SEPA policies for potentially unstable slopes and practices). While this project by itself is unlikely to directly change the Forest Practices Rules, it may inform the policy interpretation of the unstable slopes rules.

- This project will develop a protocol and identify landslide classes that may inform the CMER Work Plan Unstable Slopes Rule Group 5.5 and the Forest Practices Board Manual Section 16.
- The project will address the Schedule L-1 Priority Effectiveness Monitoring and Research directive that states "Develop a screen for deep-seated landslides."
- It will begin to answer a Critical Question posed by the Forest Practices Board and Policy in the 2016 Proposal Initiation (WFPB 2016), now included in the CMER Work Plan of "Can relative levels of response to forest practices be predicted by key characteristics of glacial deep-seated landslide and/or their groundwater recharge areas?"

The sequence of twelve studies specified for the Deep-Seated Landslide Research Strategy, of which this Study Design addresses Projects 4.5 and 4.6, has a goal of delivering data and analyses to provide a basis for differentiating between those situations where timber harvest could potentially reactivate or accelerate deep-seated landslides and those situations where DSLs are not likely to move. The Study Design offers a proof-of-concept application to identify landslide classes based on remotely sensed velocity trend data and assess where the specific groupings of DSLs (classes and clusters) are most sensitive to external drivers. This information will support a better understanding of landslide types and characteristics that are sensitive to disturbance from forestry activities.

3. Will the study be carried out pursuant to CMER scientific protocols (i.e., study design, peer review)?

Yes, this study design has been developed as the next step in the implementation of the Deep-Seated Landslide Strategy (Projects 4.5 & 4.6). The Deep-Seated Landslide Research Strategy has gone through UPSAG, CMER, and ISPR evaluation and approval (2019) and the Deep-Seated Landslide Mapping and Classification Study Design has gone through UPSAG, CMER, and ISPR evaluation and approval (2024). All deliverables from the study will also be subject to UPSAG, CMER, and ISPR evaluation and approval.

4. a. What will the study tell us?

This study is a Pilot project that will explore the benefits of using velocity trend data from InSAR and LiDAR Change Detection technologies, in addition to more traditional data such as geology/lithology, to classify deep-seated landslides at a regional scale across portions of three counties in Western Washington. A goal is to evaluate if certain classes of landslides, within the limited temporal range of the technology, have a high or low potential for instability from forest practices and rank classes based on multiple sources of empirical evidence.

This study will help us empirically define and characterize classes of DSLs based on critical

variables that influence the occurrence and type of landslide failure. In the process, it will help us understand the variables, best remote sensing tools, and field data needed to define DSL classes and estimate the relative sensitivity of DSLs within a class. This effort will provide the framework needed to pursue additional related projects as described in the Strategy. In particular, this information will allow us to better understand the influence of forest practices on DSL activity and guide our future modeling and monitoring efforts.

The project will develop data sets that will be used in future phases of the research strategy. These data sets may allow us to develop a data-driven understanding of the linkages between velocity trends and extrinsic factors (such as hydroclimatic influences and human disturbance) in future phases of the research strategy.

b. What will the study not tell us?

- This project by itself will not provide quantitative evidence about the influence of forest practices on landslide reactivation. The mechanistic and hydrologic details of the influence of forest practices on different classes of DSLs will only be illuminated in future research as described in the Strategy.

- The tools and map products generated by this Study Design are not intended to substitute for site-specific investigations or factors that locally affect landslide potential. Instead, the study will provide landscape-scale information on DSL sensitivity stratified into classes and clusters.

- This study represents a trade-off between landscape-scale, remotely sensed landslide data and detailed, site-specific landslide studies. The remote sensing data covers large areas, but landslide movement trends from InSAR and LiDAR Change Detection data are only available for approximately the last two decades and many landslides have not moved during the last few decades.

- The study design methods and technologies are not meant to identify the specific causal mechanisms of landslide movement due to internal hydrologic differences associated with elevated pore pressures and the stratigraphy and material properties within individual landslide masses. This study does not address the internal perturbations that often control individual landslide sensitivity and are only resolvable by subsurface study.

- The study is not designed to provide insight into potential future changes in hydroclimatic conditions and how those changes might affect landslide sensitivity. Identification of landslide activity change drivers is based on spatially continuous data sets that characterize historical displacement trends within a limited time period.

- This is a pilot study that uses emerging science and data sets focused on an area in northwest Washington with an existing landslide inventory, a range in DSL characteristics, and high-quality lidar and InSAR data. We do not know the degree to which the findings will be applicable to other areas in Washington.

5. What is the relationship between this study and any others that may be planned, underway, or recently completed?

This is the study design for the combined projects 4.5 and 4.6 in the series of 12 projects that are described in the Deep-Seated Landslide Research Strategy (2018) document. These projects include:

- 4.1 - Model Evapotranspiration in Deep-Seated Landslide Recharge Areas
- 4.2 - Literature Synthesis of the Effects of Forest Practices on Glacial Deep-Seated Landslides and Groundwater Recharge
- 4.3 - Literature Synthesis of the Effects of Forest Practices on Non-Glacial Deep-Seated Landslides and Groundwater Recharge
- 4.4 - Board Manual Revision
- 4.5 - Deep-seated Landslide Mapping
- 4.6 - Landslide Classification
- 4.7 - GIS-Based Landslide Stability and Sensitivity Toolkit
- 4.8 - Groundwater Recharge Modeling
- 4.9 - Physical Modeling of Deep-Seated Landslides
- 4.10 - Landslide Monitoring
- 4.11 - Evapotranspiration Model Refinement
- 4.12 - Empirical Evaluation of Deep-Seated Landslide Density, Frequency, and Runout by Landform

Projects 4.1 through 4.4 have been completed, projects 4.5 and 4.6 are addressed in this study design. The design and site selection of landslides for the next projects in the DSL Strategy will rely on the results from projects 4.5 and 4.6.

6. What is the scientific basis that underlies the rule, numeric target, performance target, or resource objective that the study will inform? How much of an incremental gain in understanding will the study results represent?

Traditionally, DSLs have been studied individually due to their high variability. They occur within diverse lithologies, climate regimes, and timescales and exhibit a plethora of failure types. In addition, geologists have lacked the tools/technologies necessary to gather information about DSLs at regional or landscape scales (Miller, 2017). The scientific purpose of this project is to evaluate the potential differences and similarities between DSL classes and possible correlations between landslide characteristics and the forest management activities that may affect landslide sensitivity. While there is extensive research about the influence of forestry activities on shallow landslides, Miller (2017) found that no work has been published to date on the influence of timber harvest activities on DSL activity, nor have subsequent studies been identified. This work is a critical step towards a better understanding of this relationship.

Geospatial information on past forestry operations is available through records of forest permit applications provided by the DNR Forest Practices Division (2022). Information from this

database will be compared with the presence or absence of DSL acceleration within the same area. However, the results of this research will not answer all facets of the critical questions posed for this study. If the current coverage of the InSAR and LCD technologies prove to be sufficiently robust within the pilot project study area, this will provide an important incremental gain in understanding DSL sensitivity. Learning to deploy these valuable technologies combined with currently available data on regional landslide characteristics, will significantly improve our ability to survey and explain landslide activity at the landscape scale. In addition, the temporal and spatial extents of these technologies continue to expand rapidly.