Research Project Work Plan

for

IMPACTS OF POTENTIAL SEISMIC LANDSLIDES ON LIFELINE CORRIDORS

SPR-740

Submitted by

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for

Oregon Department of Transportation
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Research Project Work Plan
For

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ON LIFELINE CORRIDORS

1.0 Identification

1.1 Organizations Sponsoring Research
Oregon Department of Transportation (ODOT)
Research Section
200 Hawthorne Ave. SE, Suite B-240
Salem, OR  97301-5192   Phone: (503) 986-2700
Federal Highway Administration (FHWA)
Washington, D.C.  20590

1.2 Principal Investigator(s)
Michael J. Olsen, Assistant Professor
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1.3 Technical Advisory Committee (TAC) Members
Katie Castelli, ODOT Region 2
Greg Ek-Collins, ODOT Emergency Management
Matthew Mabey, ODOT Research, Chair
Curran Mohney, ODOT GeoEnvironmental
Nancy Murphy, ODOT Planning
Jan Six, ODOT Bridge

1.4 Project Coordinator

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Coastal communities depend on Highway 101 and the state highways crossing the Coast Range to connect them with the rest of the State of Oregon. Landslides have the potential to isolate these communities. The Oregon Coast Range is likewise home to weak soils, steep slopes, abundant groundwater, and substantial rainfall that can combine to produce landslides. “Sunken Grade” signs testify to the chronic nature of these slope movements throughout Western Oregon.

The eventual certainty of one or more large earthquakes striking, and triggering landslides, adds to the considerable existing hazard described above. Seismic events produce additional inertial loading, which may trigger landslides on slopes that are normally stable or reactivate dormant, pre-existing landslides. The geographic scope of these seismically-induced landslides will be particularly broad when the next Cascadia Subduction Zone earthquake occurs, shaking the state border to border. The disruption of state highway system by landslides will inhibit the response to the damage and disruption from strong ground shaking, liquefaction, and tsunami waves. The human and economic costs of earthquakes are multiplied by delayed response and recovery.

State leaders and the general public expect the state highway system to serve as an important lifeline, facilitating post-earthquake response and recovery. In order to effectively prepare for the post-shaking use of the highway system, the vulnerability of the various state highway routes must be objectively determined. This will help the Oregon Department of Transportation (ODOT) identify key sites for seismic retro-fit and to prioritize debris removal and repairs. In this way, ODOT can best ensure that lifeline corridors remain operational after a disaster and other parts of the highway system are restored as quickly and rationally as possible.

2.1 Background and Significance of Work

Figure 1 shows the extents of the study area, which is bounded by the northern and southern borders of the State of Oregon, the I-5 corridor on the east, and the Oregon Coast Range on the west. The current highway routes from I-5 to the coast consist of the following: US Routes 30, 26, and 20; and Oregon State Routes 6, 18, 22, 34, 126, 36, 38, and 42. There are some additional, minor routes to the coast. Highway 101, the only major north-south highway connecting coastal communities, is connected with the Willamette Valley through these corridors. It is absolutely critical that these routes be accessible following a potential earthquake and/or tsunami to allow vital supplies to reach the coast and allow people to escape, if needed. Recent landslides have caused major delays on these highways due to normal traffic conditions. Disaster conditions could create significant problems for this area.


3.0 Objectives of the Study

The objective of this research is to use geospatial data such as LIDAR, land-cover, and geologic materials to map potential seismically-induced landslides. These landslides pose a hazard to the state highway system in Oregon. These regional maps will be assembled based on probabilistic analyses. They can then be used for site to site comparisons of the hazard and risk at key locations identified by ODOT. This information would be developed using GIS technology to enable easy integration with other information to designate lifeline corridors and prioritize the restoration of the state highway system following a disaster.

3.1 Benefits

It is anticipated that this project will be of significant economic benefit to ODOT and the State of Oregon, including:

1. Cost savings by determining which lifelines corridors can be hardened with the least resources.
2. Improve post-disaster operations and damage assessment resulting in quicker emergency response and economic recovery.
3. The selection of sites for quantitative monitoring that cannot be safely accessed by conventional means.
4. Better understanding of the current, historic, and ancient landslides on the highway system so as to better manage their impacts on construction and maintenance.
5. Research project LIDAR data collected at sites can be used for future purposes, including routine monitoring of slopes and infrastructure, as well as supporting future roadway improvement projects.

6. Although the study will be in the coast range, the developed methodology will be applicable to other sections of Oregon.

4.0 Implementation

There are two initiatives already underway within ODOT that would be able to shape and improve their products by integrating landslide hazard maps into their work. The first is the Engineering and Asset Management Section’s Unstable Slope Program. The second is the update and revision of ODOT’s Lifeline Routes. Both of these programs see this project as providing essential information for the proper completion of their tasks. The GIS product proposed for this research would be filling an immediate and pressing need.

5.0 Research Tasks

Probabilistic slope stability analysis to predict potential landslides from seismic events will be performed using geospatial data along transportation corridors in Western Oregon. All this information will be packaged in GIS data format that can be readily accessed and utilized.

The estimated duration of this project, assuming a May 1, 2011 start date, is 26 months. The estimated cost to accomplish the tasks outlined is $265,000. A preliminary map will be completed within 12 months to meet ODOT’s immediate needs. The final map will be produced at the end of the second year and will reflect a refinement of the maps and models.

Key tasks are outlined as follows:

Task #1: Literature Review of probabilistic landslide models and mapping techniques

The focus of this effort will be to determine the advantages and disadvantages to current methodologies for seismically induced landslide hazard assessment and regional mapping. Particularly, different methods require different data sources as input. The investigators will compile a list of relevant, available methodologies, strengths, weaknesses, and data requirements for the TAC review to determine the optimal mapping methodology for the future tasks. Given that most probabilistic methods are developed for a site-specific analysis, many will require adaptation to be applied successfully on a regional scale. We will search for methodologies developed in regions with climates and seismicity similar to Oregon.

An additional component of this task will be to review previous seismic and landslide hazard mapping efforts in Oregon.

Time Frame: May – August 2011

Responsible Party: Michael J. Olsen, OSU Geomatics Lab

Cost: $ 6k

Deliverable: Summary of mapping methodologies
**TAC Decision/Action:** The TAC will assist in defining the appropriate methodology, or methodologies, to use for this effort.

**Task #2: Compile relevant GIS data**

In conjunction with the literature review, multiple data layers, including (but not limited to) LIDAR, DEM, geology, soil properties, land-cover, USGS ground acceleration predictions (de-aggregated seismic hazard curves), and hydrology will be integrated into a GIS database. Much of the data already exists from various sources, but will need to be combined for analysis. The model that is assembled will also include known landslides from current mapping efforts by ODOT and DOGAMI.

**Time Frame:** May – September 2011

**Responsible Party:** Michael J. Olsen, OSU Geomatics Lab

**Cost:** $15k

**Deliverable:** Compiled datasets and summary of acquired data

**TAC Decision/Action:** Assist with data collection, review gaps in data collection

**Task #3: Compile and Analyze Case History Data**

Case histories of landslides and slope failures in the Coast Range will be compiled to obtain estimated strength parameters. We will also acquire existing geotechnical data (e.g. previous boreholes) from the coast range to characterize soil properties within geologic units. These data will be analyzed for spatial trends and variability. The team will analyze select historical landslides, where possible, to determine the role of geologic material, inter-bedding, slope inclination, and dip angle on back-calculated strength parameters (e.g. $\phi$, $c$). As needed, ground based 3D laser scans may be performed to accurately capture site geometry and topography, if such information is not readily available in the case histories. Previous mapping by DOGAMI and ODOT also provides information about types of slope failures (landslides, rockfalls, etc.), which will be important to evaluate triggering mechanisms and extents of failures.

**Time Frame:** September - December 2011

**Responsible Party:** Michael J. Olsen, OSU Geomatics Lab

**Cost:** $10k

**Deliverable:** Summary of Case Histories

**TAC Decision/Action:** Provide input on historic landslides

**Task #4: Perform initial regional seismic slope stability analyses**

Workflows and code will be developed to process the acquired geospatial data in GIS to perform slope stability analyses to detect locations most likely to fail from seismic activity along transportation corridors.

**Time Frame:** December 2011 – April 2012

**Responsible Party:** Michael J. Olsen, OSU Geomatics Lab

**Cost:** $70k
Deliverable: GIS data showing the likelihood of slope failure

TAC Decision/Action: Review the workflow

Task #5: Produce Initial Lifeline Hazard Map
Using the results of the regional seismic slope stability analysis in Task 4, the team will produce a seismic-induced landslide map for the zone between Oregon’s coast and the I-5 corridor (Figure 1). This map will be a GIS layer, such that it can easily be integrated with other hazards for lifeline prioritization analysis.

Time Frame: April – May 2012

Responsible Party: Michael J. Olsen, OSU Geomatics Lab

Cost: $50k

Deliverable: Preliminary initial lifeline hazard map.

TAC Decision/Action: Review the initial hazard map. Make suggestions for refinements.

Task #6: Refine methodologies and hazard maps
Because of the urgency of a preliminary map completed within the first year (Tasks 5), the preliminary maps will require several refinements using advanced methods. For example, the interaction of the roadway with the potential slide will be considered. For this task we plan on doing more sophisticated modeling and analyses along three to four specific, representative routes. One of these will most likely be Highway 101. The others will be selected based on potential hazards, typical traffic loads, and data availability. Some of these routes will contain high resolution aerial LIDAR data, which will allow us to see more distinct surface features than available in typical lower resolution DEMs. This may help guide us in extracting more information from the lower resolution DEMs for use in mapping at the regional scale. Finally, for this task, we will evaluate the sensitivity of the models to the input data and assumptions needed for regional mapping.

Time Frame: May – December 2012

Responsible Party: Michael J. Olsen, OSU Geomatics Lab

Cost: $80k

Deliverable: Refined landslide maps.

TAC Decision/Action: Provide input on revised maps and representative sites.

Task #7: Perform analyses at representative sites identified from Tasks 5 and 6
The team will make preliminary recommendations regarding potential mitigation techniques at representative sites identified by this research to promote continued operation of lifeline
corridors immediately, or soon, after an earthquake event. This task will provide a preliminary discussion of costs and benefits of potential techniques.

Terrestrial and/or mobile LIDAR will be used to obtain higher resolution data in select locations for site-specific analysis and modeling. This valuable baseline data will be available to ODOT for future monitoring, repairs, and evaluating performance. Particularly, having the accurate baseline data will be critical for ODOT following a major seismic event to determine the extents and degree of damage.

**Time Frame:** December 2012 to April 2013

**Responsible Party:** Michael J. Olsen, OSU Geomatics Lab

**Cost:** $14k

**Deliverable:** Baseline scanning data and analysis for key sites

**TAC Decision/Action:**

**Task #8: Prepare final report, publications, and conference presentations**

The report for the project will be continually developed and refined throughout the entire project duration, as each task develops a key component of the final report. Additional literature review will be performed throughout the project. The final report will be completed by the end of the funding cycle (July 1, 2013) and delivered to ODOT along with supporting GIS and other data files. The final report sections of this report will also be further developed by the students for publication as theses and peer-reviewed journal papers. This research will fund 1 PhD student and partially fund a second graduate student. However, it is anticipated that the thesis and journal paper publications will require additional time beyond the project cycle to complete. We will also give presentations to ODOT personnel, as directed by the TAC.

**Time Frame:** April to June 2013.

**Responsible Party:** Michael J. Olsen, OSU Geomatics Lab

**Cost:** $5k

**Deliverable:** Final Report to ODOT, presentation to relevant ODOT personnel.

**TAC Decision/Action:** The TAC will assist in setting up the presentations and review the report.
## 6.0 Time Schedule

<table>
<thead>
<tr>
<th>Project Tasks</th>
<th>FY2011</th>
<th>FY2012</th>
<th>FY2013</th>
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<tr>
<td></td>
<td>Qtr 4</td>
<td>Qtr 2</td>
<td>Qtr 3</td>
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<tr>
<td></td>
<td>Apr - Jun</td>
<td>Jul - Sep</td>
<td>Oct - Dec</td>
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<tr>
<td>Task 1: Literature Review</td>
<td></td>
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<tr>
<td>Deliverable: Summary</td>
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<tr>
<td>Task 2: Compile GIS data</td>
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<tr>
<td>Deliverable: Organized GIS data, List of compiled data</td>
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<tr>
<td>Task 3: Compile and Analyze Case History Data</td>
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<tr>
<td>Deliverable: Summary report of case histories and soil strength</td>
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<tr>
<td>parameters</td>
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<tr>
<td>Task 4: Perform initial regional seismic slope stability analysis</td>
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<tr>
<td>Deliverable: Summary</td>
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<tr>
<td>Task 5: Produce Initial Lifeline Hazard Map</td>
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<tr>
<td>Deliverable: Preliminary Map</td>
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<tr>
<td>Task 6: Implement and refine advanced methodologies and maps</td>
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<tr>
<td>Deliverable: Updated maps</td>
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<td>Task 7: Perform analyses at representative sites identified from</td>
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<tr>
<td>Tasks 5 and 6</td>
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<tr>
<td>Deliverable: Baseline scan data</td>
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<td>Task 8: Dissemination</td>
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<tr>
<td>Deliverable: Final report</td>
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7.0 **Budget Estimate**

Below is the budget breakdown for the entire project.

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<th>Personnel</th>
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<th>FY2011</th>
<th>FY2012</th>
<th>Total</th>
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<td>Michael Olsen, OSU</td>
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<td>9000</td>
<td>17500</td>
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<td>Scott Ashford, OSU</td>
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<td>Graduate Student #1, OSU</td>
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<td>4986</td>
<td>5986</td>
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<td>DOGAMI –sub-award</td>
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<td><strong>Services and Supplies</strong></td>
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<td><strong>Total Direct Costs</strong></td>
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<td><strong>Total Project Costs</strong></td>
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<td>$135,097</td>
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