Research Project Work Plan

for

ENHANCED ASSESSMENT OF PROJECTED LANDSLIDE ACTIVITY UNDER PRECIPITATION AND SEISMICITY

SPR 808

Submitted by

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Revised: N/A

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1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301 Phone: (503) 986-2700

Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator (ODOT requests only one per institution or firm)

Ben Leshchinsky, Assistant Professor
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1.1 Associate Investigator(s)

Michael Olsen, Associate Professor
School of Civil and Construction Engineering
Department of Forest Engineering, Resources and Management

Adam Booth, Assistant Professor
Department of Geology
Portland State University

1.2 Technical Advisory Committee (TAC) Members

Curran Mohney (Engineering Geology Program Leader, ODOT), *Project Champion*
Geoff Crook (Sustainability Manager, ODOT), *Project Champion*
Kira Glover-Cutter (Research Coordinator), *Chair*
Susan Ortiz (Senior Bridge Geotechnical Engineer, ODOT)
Tom Braibish (Geo-Hydro Manager Region 1, ODOT)
Phil Wurst (Senior Geotechnical Engineer Region 2, ODOT)
Nick Testa (Biologist Region 2, ODOT)
Pete Castro (Senior Geotechnical Engineer Region 3, ODOT)
Emily Cline (Environmental Specialist, FHWA)

1.3 Friends of the Committee (if any)

Bernie Kleutsch (Geo/Hydro/HazMat Manager Region 2, ODOT)
Jim Collins (Geo/Environmental Manager Region 3, ODOT)
Becky Knudson (Senior Transportation Economist, ODOT)

1.4 Research Coordinator

Kira Glover-Cutter, ODOT Phone: 503-986-2851

1.5 Project Champion

Curran Mohney, ODOT
Geoff Crook, ODOT

2.0 Problem Statement

With thousands of active landslides saturating lifeline routes and overwhelming ODOT's mitigation capacity, the development of a new tool to prioritize landslides is imperative for maintaining the safest and most efficient transportation system possible. Landslides are frequent hazards that affect the operation, maintenance, and construction of Oregon highways, resulting in negative economic, environmental, and social impacts for Oregon communities. To fully support optimized resiliency efforts, focused risk mapping that integrally considers landslide recurrence intervals, geotechnical properties, potential seismic events, and projections of extreme precipitation events *is critical* for informed selection of priority areas.

2.1 Background and Significance of Work

Predictive factors such as landslide activity, precipitation projections, and geotechnical properties can be integrated together with seismic models to specifically filter and select for seismic landslide "hot spots" localized along lifeline corridors for targeted mitigation. In general, large, young landslides are most likely to move during an earthquake or climatic event. Until recently, comprehensive corridor assessment of landslide age has been field intensive, subjective, and cost prohibitive. This research proposes to apply a new, lidar-based technique to remotely estimate landslide ages over large swaths of terrain by calibrating a relationship between landslide age and the "roughness" of the landslide deposit. Because the technique enables dating large numbers of landslides over timescales of hundreds to thousands of years, it can be used to calculate landslide recurrence intervals, as well as to identify the youngest, most active slides. This data will be coupled with observed geometric properties, seismic modeling inputs representative of possible earthquake scenarios, and site-specific, back-calculated geotechnical and hydrological properties to optimize landslide susceptibility models for "hot spot" risk mapping along emergency routes.

When considering long-term resiliency planning, seismic landslide projections must also

be weighed in context with risks associated with extreme precipitation and seismic events. Over the next few decades, precipitation events are projected to increase in both magnitude and frequency across western Oregon over the course of this century. As water is a major driver of slope failures, increased precipitation will not only drive yearly winter landslides along critical routes, but also increase the potential impacts of a seismic event. The Pacific Northwest has historically been subject to the effects of long-duration, high amplitude shaking from the offshore Cascadia Subduction Zone. The rupture of this fault is expected to generate peak ground accelerations (Figure 1) of approximately 1g over broad areas of the coast, decreasing to 0.1g by ~ 100 km inland, which would be sufficient to trigger numerous landslides in the western part the state, particularly in the Oregon Coast Range. The resilience of these lifeline highways is critical as they accommodate much of the commercial and emergency access to the Coastal communities, which are expected to be most severely affected. Therefore, it is critical to pursue integration of precipitation projections that incorporate the increasingly extreme precipitation events, coupled with refined susceptibility mapping focused along lifeline corridors will enable targeted selection of "hot spots" for mitigation and inform planning for both climatic and seismic events.

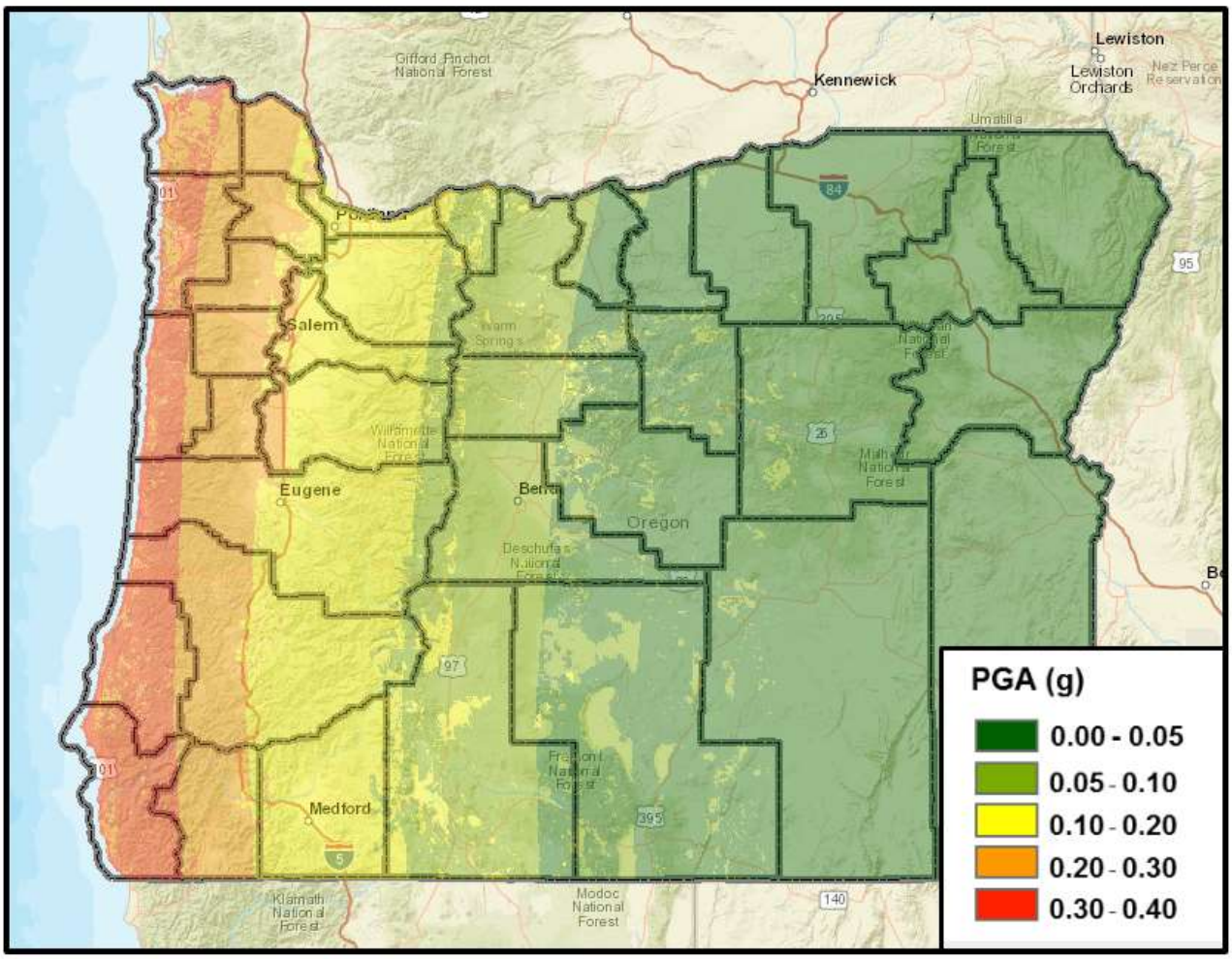

Figure 1. Peak ground acceleration estimates for a M9.0 scenario earthquake from the Oregon Resilience Plan (data available at http://ohelp.oregonstate.edu).

3.0 Objectives of the Study

This proposed research study aims to identify landslide hot spots along lifeline routes to maximize long-range planning efforts in consideration of seismic and climatic events and focus mitigation accordingly. This proposed work is unique and builds upon previous advances in assessing landslide hazards by coupling consideration of extreme precipitation events and emerging methods for landslide age dating, forensic analyses, and seismic modeling. The synthesis of these Oregon-specific components enables development of a hot spot mapping procedure that identifies landslide activity in context of their seismic and climactic history. Specific objectives include:

1. ***Date and heavily instrument an active landslide*** (Hooskanaden) to provide a baseline for current activity and paleoseismic context. Use existing and ongoing data collection procedures along the HWY20/PME corridor to supplement activity monitoring.
2. ***Develop a process*** to quantify relationships between topographic indices and landslide age or activity based on instrumented landslides and traditional geologic dating.
3. ***Develop a management framework*** for an advanced landslide risk system in a webGIS platform that merges large-scale forensic analyses of ODOT, DOGAMI and OSU landslide inventories using high-resolution lidar. Couple these analyses with refined age models and historical records for Cascadia Subduction Zone (CSZ) events to infer site-specific, spatially-variable geotechnical and hydrological thresholds for seismic- and precipitation-induced landslide susceptibility mapping.
4. ***Provide a guidance manual and training*** for identifying hot spots for prioritized mitigation and resiliency planning based on landslide activity from past and potential future CSZ events.
5. ***Provide risk maps*** of selected lifeline corridors identifying hot spots that integrate projected impacts of seismic and climactic scenarios for precipitation-triggered landslide risks and in consideration of multiple combined hazards.

3.1 Benefits

The primary benefit from this research is the development of a proactive, science-based procedure for resiliency planning that can be used to prioritize mitigation and budget for resiliency at the corridor to project level. This research would benefit and complement existing resiliency efforts at ODOT including the Seismic Lifelines, Unstable Slopes Program and Climate Change Adaptation initiatives. This information would also enable ODOT to work with other agencies to assess the overall risk to infrastructure on a regional scale, enabling projection of future impacts from landslide activity from current baseline risk. This research could enable enhanced evaluation of climate impacts on future performance measures to assess management costs, prioritize areas of concern, provide a process for project selection, and assess potential future corridor planning. Furthermore, it will produce projections for seismic and precipitation-triggered landslides during seismic or extreme weather emergencies on ODOT's lifelines.

4.0 Implementation

The results from this work will prioritize geohazards for more informed ODOT corridor resiliency planning. Specifically, landslide activity identification will provide support for:

1) STIP spending justification for unstable slope mitigation,

2) Seismic lifeline repair funding packages, and

3) Future climate change adaptation funding packages.

To support implementation, ODOT Research will work closely with ODOT's Unstable Slopes Program Manager, Sustainability Manager, and the Asset Management Integration Division to potentially incorporate these findings for future analysis and planning. Research products include:

1) Development of a framework that analyzes Digital Elevation Models (DEMs), Contour Connection Method (CCM)-derived landslide inventories, seismic and age models, precipitation data, and climate change projections to evaluate seismic or climatic landslide risk.

2) Production of risk maps that highlight landslide activity as areas of current and future concern.

3) Delivery of a short course and associate materials to ODOT personnel, and

4) Several peer-reviewed journal articles related to the technical aspects of the work.

5.0 Research Tasks

5.1 Expected tasks:

Task 1: TAC Meeting #1

Project kick off meeting, discussion of existing instrumentation by ODOT, and instrumentation plan for Hooskenaden. Select critical stretches from three to five corridors for age-roughness relationships, susceptibility mapping, and risk mapping.

Time Frame: August 2017 – September 2017
Responsible Party: PIs, ODOT Research Coordinator, TAC
Cost: $2,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes.
TAC Action: Review instrumentation plan. Review and understand project research problem statement, research question, limits of the proposed research, and the project schedule. Review site selections for instrumentation and mapping. Advise ODOT Research Coordinator regarding any critical issues with the project's scope or schedule. Advise PI's regarding related professional practices, standards, methods and context for the project. Discuss feasibility of drilling for soil sampling and instrumentation installation at selected site.

ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 2: Drilling and Instrumentation at Hooskanaden Landslide

The Hooskanaden Landslide (MP 344.1) will be instrumented as it is an actively moving slide with exposed, previously buried organics presented in it basal deposits that provide data for quantifying its history of movement in relation to past seismic events. The main subtasks in the subsurface investigation and instrumentation of this landslide include (a) Drilling Planning and Contract Preparation, (b) Drilling Coordination, Instrumentation Installation and On-site Project Management, and (c) Drilling Contract Payment.

Time Frame: August – December 2017
Responsible Party: PIs, ODOT Research Coordinator, ODOT Champion
Cost: $63,904 (OSU), $45,000 (ODOT)
Deliverable: Drilling plan, bidding document, instrumentation purchase and installation, and summary report of equipment installation.
TAC Action: Read summary report. Provide assistance with drilling contracting.
ODOT Action or Decision: Assess project potential for successful completion. If necessary direct PI to make changes to project documents. Provide formal acceptance of summary report of instrumentation.

Task 2a: Drilling Planning and Contract Preparation

Preparation for drilling will consist of boring plan preparation, bidding of proposed drilling work, purchase of instrumentation and coordination of all responsible parties (selected drilling contractor, ODOT, OSU and PSU). Drilling plan preparation will be completed by the PIs prior to bid in coordination with ODOT personnel. Upon completion of a drilling plan, bidding of the contract will be performed through the ODOT R3 office. Concurrent to bidding, purchasing and assembly of a MEMs (microelectromechanical systems)-piezometer-rainfall-data collection system will be completed. This system will be calibrated and its FTP cloud storage destination configured. The instrumentation system will measure rainfall, pore pressures pre-specified depths and the three-dimensional, real-time hydrogeologic response of the actively moving landslide (e.g. the displacement and velocity).

Time Frame: August – December 2017.
Responsible Party: PIs and ODOT Research Coordinator.
Deliverable: Preparation of bidding document and drilling plan.
TAC Action: Review bidding document and drilling plan. Provide assistance with drilling contracting.
ODOT Action or Decision: Assess project potential for successful completion. If necessary direct PI to make changes to project documents. Provide formal acceptance of planned drilling.

Task 2b: Drilling Coordination, Instrumentation Installation and On-site Project Management

Coordination with the drilling contractors, instrumentation and on-site project management will be handled by the PIs (OSU). Equipment will be transported and prepared to the site by OSU personnel. Installation will occur in conjunction with the drilling contractor. Safety briefings will be initiated by OSU PIs.

Time Frame: August – December 2017
Responsible Party: PI, ODOT Champion, R3 Personnel and Research Coordinator.
Deliverable: Summary report of equipment installation.
TAC Action: Read summary report. Provide assistance with drilling contracting.
ODOT Action or Decision: Connect PIs with permitting agencies and relevant ODOT R3 personnel. Provide an on-site ODOT representative when possible.

Task 2c: Drilling Contract Payment

Upon completion of boring and instrument installation at the Hooskanaden site, payment will be made to the drilling contractor based on the scope of completed work and the original bidding estimate. This payment will be disbursed by ODOT, but will be based on the scope of the drilling plan scope developed by OSU.

Time Frame: December 2017–January 2018
Responsible Party: ODOT Research Coordinator
Cost: $45,000 *(not included in the OSU budget).*
Deliverable: Payment.
TAC Action: N/A
ODOT Action or Decision: Provide payment to drilling contractor based upon successful completion of proposed work.

Task 3: HWY20/PME Data Transfer Meeting

OSU will coordinate necessary meetings with ODOT personnel with access to data from instrumented landslides along the Highway 20 Pioneer Mountain-Eddyville realignment. During these meetings, the PIs and ODOT personnel will discuss:

- Types of data available.
- Instrumentation location and condition.
- Data collection frequency.
- Site landslides and geology.
- Carbon dating and buried organics on site.
- Logistics of data transfer and storage.
- Logistics of future data collection.

The aforementioned data sets will be used to support Tasks 6, 8, 9 and 10, particularly as a means of defining activity and incipient conditions at failure.

Time Frame: October 2017 to March 2018
Responsible Party: PIs and ODOT Research Coordinator
Cost: $5,000
Deliverable: Establish protocol for past and future data transfer, data storage.

TAC Action: Approve proposed data management plan.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to data management plan.

Task 4: Draft Literature Review

A brief literature review will be compiled, focusing on the following elements:

- Geologic context of landslide hazards in Oregon.
- Landslide monitoring techniques.
- Landslide activity and types of movements.
- Use of dendrochronology and radiocarbon dating of landslide activity.
- Use of lidar or topographic data for inventorying and classifying landslide type, age and size.
- Geotechnical slope stability analysis in theory and application.
- Remediation of active landslides.
- Background for seismic and climatic parameters used in susceptibility analysis.

Time Frame: September 2017 to March 2018
Responsible Party: PIs and Co-PIs
*Cost: $*25,482
Deliverable: Draft Literature Review.
TAC Action: Read Draft Literature Review and advise ODOT Research Coordinator regarding any gaps in the literature.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 5: Draft Research Methodology.

The draft research methodology will expand on the specific research direction of Tasks 6, 8, 9, 10 and 12– all of which are interconnected and will be based on data from the available instrumentation of various landslide locations throughout Oregon. This document will highlight the protocols for data collection, storage, dissemination and analysis. We anticipate the following documentation for each of the specific tasks:

- **Task 6:** Describe the calibration of age-roughness relationships based on inventoried landslides and the implication regarding either seismic- or precipitation-induced conditions at incipient failure.
- **Task 8:** Describe forensic framework based on geotechnical slope stability analysis. Describe coupling of landslide inventories with age-roughness relationships – specifically, the use of age-roughness relationships to determine the age and potential causative events for past landslides (a critical component for forensic slope stability analyses).
- **Task 9:** Describe how forensic analyses will be performed and translated to susceptibility in consideration of geotechnical shear strength properties. Establish relevant extreme event inputs, both seismic and climactic, for assessing landslide susceptibility.
- **Task 10:** Describe how risk will be quantified in context of landslide susceptibility and ODOT prioritization (traffic, emergency access, economic input, repair considerations).

- **Task 12:** Describe sources of both seismic inputs and climactic projections and their integration into susceptibility and risk mapping for selected corridors.

Time Frame: January 2018 to July 2018
Responsible Party: PIs and Co-PIs
Cost: $15,081
Deliverable: Draft Research Methodology Report Section.
TAC Action: Read Draft Research Methodology.
ODOT Action or Decision: Schedule TAC Meeting #2

Task 6: Define Age-Roughness Relationships for Landslides in select Oregon Corridors.

The existing approach for assessing age-roughness relationships using lidar and radiocarbon dating will be expanded to Oregon-specific landslides where buried organics have been discovered (e.g., Pioneer Mountain, Hooskanaden Slide, and beyond). A field campaign that involves strategically accessing parts of landslides likely to contain buried organics from the time of failure will be performed to find additional, supporting dateable materials. We anticipate dating 4-6 landslides in each corridor, which is sufficient to define an age-roughness model that is calibrated to corridor-specific geologic units, climate, landslide style, and other environmental factors that may affect landslide roughness. The developed age-roughness curves will be used to assess absolute age (and primary cause) of inventoried landslides in selected corridors. Particular attention will go towards active landslides that demonstrate seasonal movements or creep. Corroborating the geologic and geomorphic properties of these landslides will enable potential corroboration of anticipated movement activities of similar slides.

Time Frame: August 2017 to September 2019
Responsible Party: PIs and Co-PIs
Cost: $112,322
Deliverable: A memo summarizing: (1) the collected C14 samples and associated landslide characteristics, (2) age-roughness curves for Oregon-specific geologic units, and (3), relative ages and causes for inventoried landslides along selected corridors, particularly with slides that exhibit movement.
TAC Action: None.
ODOT Action or Decision: Schedule TAC Meeting #2.

Task 7: TAC Meeting #2

In this TAC meeting, the results of Tasks 2-6 will be discussed as well as the preliminary progress on Task 6 to date. This TAC meeting will set the course for the completion of the next phase of the project, particularly forensic analyses and susceptibility mapping.
Time Frame: July 2018
Responsible Party: PIs, ODOT Research Coordinator, TAC
Cost: $2,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes, TAC meeting agenda

TAC Action: TAC review of Draft Research Methodology and Draft Literature Review. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. If possible, reach consensus regarding the content and methods contained in the draft research design. Advise ODOT Research Coordinator regarding project next steps.
ODOT Action or Decision: Review TAC advice. Assess project potential for successful completion. If necessary, direct PI to make changes to project documents. Provide formal acceptance of Draft Research Methodology. Authorize PI to proceed with subsequent steps, notify by memo or email.

Task 8: Develop Forensic Framework from Landslide Inventories/Age-Roughness Analysis.

The research team will develop a framework that uses landslide inventories to establish regional distributions of potential geotechnical shear strength properties based on topography, landslide geometry and observed landslide kinematics. The platform will use inventoried landslides and their likely conditions at failure (inferred from age-roughness relationships) to back-calculate the relative shear strength properties tailored to specific geologic and topographic regimes. These spatial distributions in shear strength will be assigned to specific units along selected corridors for use in assessing susceptibility under various seismic and projected climactic conditions.

Time Frame: April 2018 to June 2019
Responsible Party: PIs
Cost: $42,193
Deliverable: A memo summarizing the process used to back-calculate shear strength based on landslide drivers, topography and slope stability kinematics. Draft maps of relative shear strength for given corridors.
TAC Action: None.
ODOT Action or Decision: Review memo.

Task 9: Develop Susceptibility from Forensic Exploration.

Based on the aforementioned age-roughness relationships and back-calculated shear strength properties, the research team will develop a systematic framework for assessing landslide susceptibility. Using digital elevation models (DEMs) of selected corridors and changing seismic or precipitation inputs, we will extend an array of geotechnical slope stability analysis techniques that are typically implemented for a single slope to operate across a regional scale. To better capture the unique nature of different slope failures, both rotational and translational kinematics will be implemented into the DEM-based stability map. The effects of pixel size (resolution) and landslide shape will be investigated through a sensitivity analysis. The results will be compared to observed spatial characteristics of localized landslide inventories for validation. The susceptibility results will be presented as a map of failure probability under a variety of potential input conditions.

Time Frame: October 2018 to October 2019
Responsible Party: PIs and Co-PIs

Cost: $41,564
Deliverable: A memo outlining the process and technical specifications of stability analysis implementation, data used in the analysis and draft susceptibility maps of selected corridors.
TAC Action: None
ODOT Action or Decision: Review memo and susceptibility maps.

Task 10: Develop Hazard/ Risk Framework from Susceptibility Analysis.

The research team will further develop the susceptibility framework presented in Task 9 towards hazard mapping by coupling probabilities for potential seismic or precipitation events with the susceptibility analyses. Integrating age-roughness relationships, inferred landslide causative events, and observed activity from instrumented landslides will further provide quantitative metrics for assessing the connection between earthquakes and heavy precipitation on projected landslide activity. Finally, in consultation with ODOT, risk will be assessed by analyzing the spatial correspondence of ODOT right-of-way with landslide hazard and estimated corridor closure costs, emergency access considerations, and infrastructure repair costs. The resulting framework will enable the creation of a landslide risk mapping process with the flexibility to account for various potential extreme event scenarios, providing critical data for planning, prioritization and infrastructure resilience.

Time Frame: January 2019 to March 2020
Responsible Party: PIs, Co-PIs, and ODOT Research Coordinator
Cost: $36,934
Deliverable: A memo outlining the process and technical specifications of hazard and risk analysis implementation, data used in the analysis and draft susceptibility maps of selected corridors.
TAC Action: None
ODOT Action or Decision: Review memo and maps.

Task 11: TAC Meeting #3

In this TAC meeting, the results of Tasks 8 and 9 will be discussed as well as the preliminary progress on Tasks 10 and 12 to date. This TAC meeting will set the course for the completion of the final phase of the project, particularly assessment of risk and projection of potential extreme seismic and precipitation events.
Time Frame: July 2019
Responsible Party: PI, ODOT Research Coordinator, TAC
Cost: $3,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes, meeting agenda
TAC Action: TAC review of progress to date. Advise ODOT Research Coordinator regarding any potential obstacles for final phase of project. If possible, reach consensus regarding the relevant extreme precipitation and seismic events for projections. Advise ODOT Research Coordinator regarding project next steps.

ODOT Action or Decision: Review TAC advice. Assess to-date potential for successful completion. If necessary, direct PI to make changes to project documents. Authorize PI to proceed with subsequent steps, notify by memo or email.

Task 12: Climactic and Seismic Projections Based on Risk Framework.

The research team will use the risk framework to assess the probabilities of landsliding due to earthquakes and heavy precipitation events to produce risk maps for the selected corridors. For seismic projections, estimated peak ground accelerations (PGAs) from CSZ events, available on the OSU-hosted *Oregon Hazard Explorer for Lifelines Program* (OHELP) database or from other publically available databases (ex. ODOT SPR770), will be utilized. These PGA maps enable regional estimates of PGA (30 m pixels) for various potential CSZ earthquake (M8.1, 8.4, 8.7, 9.0) scenarios, providing estimates of seismic landslide risk for the aforementioned CSZ scenarios, hosted through an interactive webGIS-based viewer. Precipitation projections will be based off available NOAA data and OCCRI forecasts for the Pacific Northwest. Selection of 2-, 5-, 10-, 20-year storms will be used as the inputs for the risk mapping. Projections for precipitation-induced landsliding will be mapped for selected corridors considering the near term (current precipitation data), intermediate-term (10 years, 2027) and long-term (50 years, 2067), provided in the same webGIS platform. Further attention will be given to active and historic landslides, which will be assessed based on age-roughness signatures determined to better identify landslide masses that present more likelihood of activity. Along with risk maps of infrastructure, landslide hazard and susceptibility maps will be provided for the selected corridors in the interactive webGIS platform.

Time Frame: July 2019 to May 2020
Responsible Party: PIs and Co-PIs
Cost: $37,688
Deliverable: A memo outlining the map creation process. Risk maps of projected seismic- and precipitation-induced landsliding for selected corridors.
TAC Action: None
ODOT Action or Decision: Review

Task 13: Draft Final Report and Guidance Manual

The team will produce a publication ready Draft Final Report in the prescribed ODOT report format. (Formatting includes correct fonts, spacing, citations and graphics). The pretext pages will include an abstract, acknowledgement, table of contents, and disclaimer. The report will contain three principal parts:

- **Part 1:** This part of the report will contain an executive summary/technical note.
- **Part 2:** This part of the report will contain the Guidance Manual, which will describe how to implement the results of the research for ODOT planning.
- **Part 3:** This part of the report will consist of the main body of the report summarizing the overall research effort. Contents include: Introduction, Updated Literature Review (Task 4), Final Research Methodology (Task 5), use of age-roughness curves (Task 6), development of regional forensic analyses (Task 8),

susceptibility framework (Task 9), hazard and risk framework (Task 10), projections using climate and seismic data (Task 12), a discussion of results, conclusions/ recommendations, and potential for future research, application, or technology transfer.

Time Frame: January 2020 to June 2020
Responsible Party: PIs
Cost: $21,256
Deliverable: Draft Final Report using ODOT's report template
TAC Action: TAC review and feedback to the ODOT Research Coordinator
ODOT Action or Decision: Review and counsel prior to TAC meeting

Task 14: Draft ODOT Research Note

Review and edit a provided ODOT Research Note draft prepared by the research coordinator and select TAC members after final TAC meeting. The note will concisely document the research findings, value of the research to the agency, science, and society, as well as any limitations on the use of the findings.

Time Frame: April 2020 to June 2020
Responsible Party: PIs
Cost: $2,000
Deliverable: Draft ODOT Research Note using ODOT's report template
TAC Action: None
ODOT Action or Decision: Review and advise

Task 15: TAC Meeting #4 / Short Course

This TAC meeting will include a review of the Draft Final Report. Prior to the TAC meeting, the TAC will offer advice on the content and clarity of these work products. The TAC will also advise on post research implementation. Upon review and approval of the final report, the findings will be presented at an ODOT short course at the project close.

Time Frame: July 2020 to October 2020
Responsible Party: PI, Co-PIs, ODOT Research Coordinator, TAC
Cost: $5,000
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes
TAC Action: TAC review of Draft Final Report, and Draft Research Note. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. Advise ODOT Research Coordinator regarding any required final edits to the Draft Final Report, and Draft Research Note.
ODOT Action or Decision: Review TAC advice. If necessary, direct PI to make changes to project documents.

Task 16: Revise Final Report.

Edit Draft Final Report and Final Research Note to incorporate edits and comments identified by the ODOT Research Coordinator and TAC after the last TAC meeting (Task 15).

Time Frame: July 2020 to October 2020
Responsible Party: PI and Co-PIs
Cost: $9,666
Deliverable: Final Report
TAC Action: None
ODOT Action or Decision: Review. Provide formal acceptance of Final Report. Publish Final Report on ODOT's research website.

5.2 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigator shall be responsible for submitting deliverables as professional-level written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT in electronic format the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

5.3 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

6.0 Schedule

	CALENDAR YEAR	2017		2018				2019				2020			
	FISCAL YEAR	2018				2019				2020				2021	
	QUARTER	Q0	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
	START	8/1/17	10/1/17	1/1/18	4/1/18	7/1/18	10/1/18	1/1/19	4/1/19	7/1/19	10/1/19	1/1/20	4/1/20	7/1/20	10/1/19
TASK	DESCRIPTION END	9/30/17	12/31/17	3/31/18	6/30/18	9/30/18	12/31/18	3/31/19	6/30/19	9/30/19	12/31/19	3/31/20	6/30/20	9/30/20	12/31/20
1	TAC Meeting 1/Corridor Selection	*													
2	Drilling/Instrumentation at Hooskanaden Landslide		*												
3	HWY20/PME Data Transfer Meeting			*											
4	Draft Literature Review			*											
5	Draft Research Methodology					*									
6	Modification of Age-Roughness Relationships									*					
7	TAC Meeting 2					*									
8	Forensic Tools from Landslide Inventories/Age-Roughness Analysis								*						
9	Susceptibility Framework Based on Forensic Analyses										*				
10	Risk/Hotspot Framework Based on Susceptibility Analyses											*			
11	TAC Meeting 3									*					
12	Climate and Seismic Projections based on Risk Framework												*		
13	Draft Final Report												R		
14	Draft Technical Note												*		
15	TAC Meeting 4\Short Course													*	*
16	Revise Final Report														F

*Deliverables

R - Draft report submitted for ODOT review; F - Revised report submitted to ODOT for publication. End of contract.

7.0 Budget Estimate

TASK	DESCRIPTION	FY18	FY19	FY20	FY21	TOTAL
1	TAC Meeting 1/Corridor Selection	$2,000	$ -	$ -	$ -	$2,000
2	Drilling/Instrumentation at Hooskanaden Landslide	$63,904	$ -	$ -	$ -	$63,904
3	HWY20/PME Data Transfer Meeting	$5,000	$ -	$ -	$ -	$5,000
4	Draft Literature Review	$25,482	$ -	$ -	$ -	$25,482
5	Draft Research Methodology	$12,678	$2,403	$ -	$ -	$15,081
6	Modification of Age-Roughness Relationships	$48,927	$55,604	$7,791	$ -	$112,322
7	TAC Meeting 2	$ -	$2,000	$ -	$ -	$2,000
8	Forensic Tools from Landslide Inventories/Age-Roughness Analysis	$7,856	$34,337	$ -	$ -	$42,193
9	Susceptibility Framework Based on Forensic Analyses	$ -	$27,990	$13,574	$ -	$41,564
10	Risk/Hotspot Framework Based on Susceptibility Analyses	$ -	$13,715	$23,219	$ -	$36,934
11	TAC Meeting 3	$ -	$ -	$3,000	$ -	$3,000
12	Climate and Seismic Projections based on Risk Framework	$ -	$ -	$37,688	$ -	$37,688
13	Draft Final Report	$ -	$ -	$21,256	$ -	$21,256
14	Draft Technical Note	$ -	$ -	$2,000	$ -	$2,000
15	TAC Meeting 4 / Short Course	$ -	$ -	$ -	$5,000	$5,000
16	Revise Final Report	$ -	$ -	$ -	$9,666	$9,666
		$165,847	$136,049	$108,528	$14,666	$425,090
	Support/Management/Task 2C	$53,000	$3,000	$6,000	$3,000	$65,000
	Total for ODOT	$218,847	$139,049	$204,528	$17,666	$490,090