**TRANSPORTATION POOLED FUND PROGRAM**

**QUARTERLY PROGRESS REPORT**

**Lead Agency: Utah Department of Transportation**

**INSTRUCTIONS:**

*Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.*

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| **Transportation Pooled Fund Program Project #**  **TPF-5(296)** | | **Transportation Pooled Fund Program - Report Period:**  \_ Quarter 1 (January 1 – March 31, 2015)  \_ Quarter 2 (April 1 – June 30, 2015)  \_ Quarter 3 (July 1 – September 30, 2015)  **x Quarter 4 (October 1 – December 31, 2015)** | |
| **Project Title:**  Simplified SPT Performance-Based Assessment of Liquefaction and Effects | | | |
| **Name of Project Manager(s):**  David Stevens | **Phone Number:**  801-589-8340 | | **E-Mail**  [davidstevens@utah.gov](mailto:davidstevens@utah.gov) |
| **Lead Agency Project ID:**  FINET 42065, ePM PIN 12436  UDOT PIC No. UT13.407 | **Other Project ID (i.e., contract #):**  UDOT Contract No. 148753 | | **Project Start Date:**  March 6, 2014 |
| **Original Project End Date:**  November 30, 2016 | **Current Project End Date:**  November 30, 2016 | | **Number of Extensions:**  1 |

Project schedule status:

\_ On schedule **X** On revised schedule \_ Ahead of schedule \_ Behind schedule

Overall Project Statistics:

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| **Total Project Budget** | **Total Cost to Date for Project** | **Percentage of Work**  **Completed to Date** |
| $149,500.00 (current contract)  $167,500.00 (total commitments) | $95,750 | 70% |

***Quarterly*** Project Statistics:

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| **Total Project Expenses**  **and Percentage This Quarter** | **Total Amount of Funds**  **Expended This Quarter** | **Total Percentage of**  **Time Used to Date** |
| 16% | $24,000 | 65% |

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| **Project Description**:  Liquefaction of loose saturated sands results in significant damage to buildings, transportation systems and lifelines in most large earthquake events. Liquefaction and the resulting loss of shear strength can lead to lateral spreading and seismic slope displacements, which often impact bridge abutments and wharfs, damaging these critical transportation links at a time when they are most needed for rescue efforts and post-earthquake recovery.  While most updated seismic provisions now adopt a risk-targeted approach to design ground motions for superstructures, other critical aspects of geotechnical engineering, such as liquefaction and ground deformation evaluation, are still based on the older concept of deterministic hazard evaluation. Recent advances in performance-based earthquake engineering (PBEE) in geotechnical engineering (e.g., Kramer and Mayfield 2007; Rathje and Saygili 2008; Bradley et al. 2011; Franke and Kramer 2013) have introduced probabilistic uniform hazard-based procedures for evaluating seismic ground deformations within a performance-based framework from which the likelihood of exceeding various magnitudes of deformation within a given time frame can be computed. However, the ability to apply these performance-based procedures on everyday projects is generally beyond the capabilities of most practicing engineers.  This study proposes to create and evaluate *simplified* performance-based design procedures for the *a priori* prediction of liquefaction triggering, lateral spread displacement, seismic slope displacement, and post-liquefaction free-field settlement using the standard penetration test (SPT).  Objectives for this study include:  1. Derive new simplified performance-based procedure for liquefaction triggering, lateral spread displacement, free-field post-liquefaction settlements, and Newmark seismic slope displacements.  2. Develop liquefaction parameter maps in GIS format associated with each of the hazards included in objective 1 at return periods of 475 years, 1033 years, and 2475 years for each of the states participating in the study.  3. Evaluate the new simplified performance-based liquefaction procedures against conventional (i.e., AASHTO) liquefaction analysis procedures.  4. Develop a simplified design procedure that will allow the designer to envelope the performance-based and conventional results to select which result will govern the design.  Tasks for this study include, regarding the participating states:  1. Derivation and validation of a new simplified liquefaction triggering model (Year 1).  2. Derivation and validation of simplified lateral spread displacement models (Year 1).  3. Derivation and validation of simplified post-liquefaction settlement models (Year 2).  4. Derivation and validation of simplified Newmark seismic slope displacement models (Year 2).  5. Assessment of grid spacing considerations in various seismic environments for map development (Years 1 & 2).  6. Development of liquefaction parameter maps at targeted return periods in GIS file format (Years 1 & 2).  7. Comparison of simplified, conventional, and deterministic analysis approaches (Years 1 & 2).  8. Development of a simplified design procedure and an analysis spreadsheet that incorporates both performance-based and conventional methods (Years 1 & 2).  9. Preparation of the annual and final reports (Years 1 & 2).  10. Dissemination of results in appropriate engineering journals and conferences (Years 1 & 2).  11. Technical Advisory Committee meetings (Years 1 & 2), including a final workshop to train partner states on the new performance-based liquefaction hazard methods.  Dr. Kevin Franke of BYU is the Principal Investigator for this research project. The technical advisory committee (TAC) for the study includes representatives from UT, AK, CT, ID, MT, OR, and SC state DOTs. |

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| **Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):**  Task 1 – 100% complete.  Task 2 – 100% complete.  Task 3 – 100% complete.  Task 4 – 100% complete. BYU updated the TAC quarterly update report for Tasks 3 and 4 based on TAC feedback.  Task 5 – 100% complete. BYU continued work on this task.  Task 6 – 80% complete. BYU continued work on this task and prepared the TAC quarterly update report and maps for Tasks 5 and 6 (Year 2) for participating states, except for Alaska and Oregon. The TAC reviewed this report. BYU had issues with the USGS deaggregation servers crashing when trying to complete maps for Alaska based on 1996 seismic hazard data.  Task 7 – 80% complete. BYU began the Year 2 work on this task.  Task 8 – 80% complete. BYU began the Year 2 work on this task. They also explored separate spreadsheet and web options for input of latitude/longitude coordinates and output of reference map values for a project site.  Task 9 – 60% complete.  Task 10 – 60% complete.  Task 11 – 60% complete. A TAC web-conference was held in December to review progress and provide feedback.  Contract – No adjustment this quarter. Due to the setback from the USGS deaggregation server crash, UDOT and the TAC verbally approved a no-cost time extension of about 3 months for BYU to complete the TAC quarterly update report for Tasks 7 and 8 (Year 2) and the updated analysis spreadsheet by March 2016, and the final report by June 2016. |
| **Anticipated work next quarter**:  Task 1 – Completed.  Task 2 – Completed.  Task 3 – Completed.  Task 4 – Completed.  Task 5 – Completed.  Task 6 – BYU will complete work on this task for the participating states, except for Alaska and Oregon. The TAC quarterly update report for Tasks 5 and 6 (Year 2) will be updated based on TAC feedback. BYU will pursue use of the new Uniform Hazard Tool from USGS to prepare reference parameter maps for Alaska based on 2008 USGS deaggregation data, and for Oregon based on 2014 USGS deaggregation data.  Task 7 – BYU will complete the Year 2 work on this task (comparison of analysis approaches).  Task 8 – BYU will complete the Year 2 work on this task (adding features to the analysis spreadsheet) and prepare the TAC quarterly update report for Tasks 7 and 8 (Year 2). BYU will continue creating tutorial videos to help TAC members with the use of GIS maps and the analysis spreadsheet.  Task 9 – TAC quarterly update reports will continue to be combined for final reports.  Task 10 – A paper is currently in review with the journal *Soil Dynamics and Earthquake Engineering* to clearly explain the differences between traditional liquefaction hazard maps and new performance-based reference parameter maps. Review comments and an editor decision regarding the manuscript should be received by next quarter.  Task 11 – A TAC web-conference will be held in March to review progress and provide feedback. Preparations will be made for a training workshop to be held around the end of April in Utah, for TAC members to learn more on how to use the maps and spreadsheet tool.  Contract – A plan will be made with BYU and Oregon DOT to generate maps and other deliverables for Oregon DOT as part of the study. This additional work and budget will be incorporated in a contract amendment. The no-cost time extension for the other study partners will also be incorporated in the contract amendment. Time extension for generating maps for Alaska will likely coincide with the estimated schedule for the Oregon scope of work. |

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| **Significant Results:**  Volumetric strain and Newmark seismic slope stability reference parameter maps were successfully completed for all of the states in the TPF Pooled Fund Study with the exception of Alaska (due to the crash of the USGS deaggregation server for Alaska) and Oregon (which desires to incorporate seismic hazard deaggregation data from the 2014 USGS update, which is not yet publically available). We have been in constant communication with the USGS, and have been informed that a new uniform hazard tool will be made available to the public in early 2016. The tool will allow the incorporation of the 2008 USGS seismic hazard data for Alaska and the 2014 USGS seismic hazard data for Oregon. Once the tool becomes available, the performance-based reference parameter maps for Alaska and Oregon will be completed and documented in an addendum report.  Incorporation of the simplified performance-based volumetric strain and Newmark seismic slope displacement models has begun for the simplified analysis spreadsheet (Task 8). In addition, comparisons between deterministic, pseudo-probabilistic, and performance-based post-liquefaction settlements and seismic slope displacements in select areas of varying seismicity have been initiated.  A simple data-querying spreadsheet/database was developed for the states in the study to interpolate reference parameter map values from a specified site (i.e., latitude and longitude). This tool will allow engineers to use the results of this research without needing to interpolate reference parameter values from a GIS raster. |
| **Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that**  **might affect the completion of the project within the time, scope and fiscal constraints set forth in the**  **agreement, along with recommended solutions to those problems).**  The permanent retirement of the seismic hazard deaggregation servers for the state of Alaska by the USGS in November 2015 introduced a significant setback to the project. At the time the servers were shut down, approximately 80% of the reference parameter maps for volumetric strain and seismic slope stability were completed for the state of Alaska. After deliberation with the TAC, it was decided to wait upon the USGS to release its new uniform hazard tool in early 2016 to complete the reference parameter maps for Alaska using the USGS 2008 seismic hazard update, as well as the reference parameter maps for Oregon using the USGS 2014 seismic hazard update. We anticipate this work can still be completed in 2016. |

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| **Potential Implementation:**  Completion of the simplified analysis spreadsheet will allow engineers to implement performance-based liquefaction hazard analysis (i.e., triggering, lateral spread displacement, settlement, and seismic slope stability) at return periods of 475, 1033, and/or 2475 years for all of the states in the study. Completion of the interpolation spreadsheet can be coupled with the simplified analysis spreadsheet to obtain the necessary reference parameter values to run the performance-based calculations. |