**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, 2014) \_ Quarter 2 (April 1 – June 30, 2014)**x Quarter 3 (July 1 – September 30, 2014)**\_ Quarter 4 (October 1 – December 31, 2014) |
| **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 |
| **Lead Agency Project ID:**FINET 42065, ePM PIN 12436UDOT 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:** |

Project schedule status:

 **X** On schedule \_ 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** |
| $88,000.00 (current contract)$148,000.00 (total committed) | $48,000 | 30% |

***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** |
| 15% | $24,000 | 18% |

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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). (Not funded in original contract.)4. Derivation and validation of simplified Newmark seismic slope displacement models (Year 2). (Not funded in original contract.)5. Assessment of grid spacing considerations in various seismic environments for map development (Years 1 & 2). (Partially funded in original contract.)6. Development of liquefaction parameter maps at targeted return periods in GIS file format (Years 1 & 2). (Partially funded in original contract.)7. Comparison of simplified, conventional, and deterministic analysis approaches (Years 1 & 2). (Partially funded in original contract.)8. Development of a simplified design procedure and an analysis spreadsheet that incorporates both performance-based and conventional methods (Years 1 & 2). (Partially funded in original contract.)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, 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 – Not funded currently.Task 4 – Not funded currently.Task 5 – 50% complete. BYU assessed grid spacing for development of the first set of liquefaction parameter maps.Task 6 – 50% complete. BYU developed liquefaction parameter maps for liquefaction triggering and lateral spread displacement for the partner states. The TAC quarterly update report for initial portions of Tasks 5 and 6 was prepared and shared with the TAC, along with liquefaction parameter maps.Task 7 – 30% complete. BYU began work on this task.Task 8 – 30% complete. BYU began work on this task.Task 9 – No work yet.Task 10 – 30% complete. Two journal manuscripts are in preparation for submission to the ASCE Journal of Geotechnical and Geoenvironmental Engineering.Task 11 – 15% complete. Preparations were made for an October TAC web-conference to review progress.Contract – No changes were made. |
| **Anticipated work next quarter**:Task 1 – Completed.Task 2 – Completed. An addendum to the TAC quarterly update report for Tasks 1 and 2 will be prepared and shared with the TAC.Task 3 – None.Task 4 – None.Task 5 – See Task 6.Task 6 – The TAC quarterly update report and maps for initial portions of Tasks 5 and 6 will be updated based on TAC review comments, and then shared with the TAC.Task 7 – BYU will continue funded work on this task.Task 8 – BYU will continue funded work on this task. The TAC quarterly update report for initial portions of Tasks 7 and 8 will be prepared and shared with the TAC, along with the draft analysis spreadsheet.Task 9 – BYU will begin preparation of the annual report.Task 10 – Two journal manuscripts currently under preparation will be submitted for review. We will look into additional opportunities for disseminating the research results via technical papers.Task 11 – A web-conference will be held in October with the TAC to review progress on Tasks 5 and 6.Contract – FFY 2015 funding transfers will be requested from the partner states, and this additional funding will be added to the research contract to fully fund the planned scope of work. |

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| **Significant Results:**The research activities this quarter focused on applying the simplified performance-based liquefaction triggering and lateral spread displacement models to the states funding this research project. Specifically, liquefaction parameter/loading maps were developed for the states, as well as lateral spread displacement reference maps.The development of the reference maps this quarter required greater understanding of how the grid spacing used to develop the contour maps can bias the simplified results. If the grid spacing is too small, then the map developing will be analytically expensive and time-consuming. If the grid spacing is too large, then the maps will introduce bias in the computed liquefaction hazards, particularly in areas of higher seismicity. A grid spacing study was performed to correlate the length of the grid spacing required to achieve  5% bias in  and  and mapped probabilistic peak ground acceleration (*PGA*) hazard. Multiple cities across the U.S. were evaluated in developing these correlations. The recommended correlation for developing liquefaction triggering parameter/loading maps are presented in Fig. 1 and Table 1. The recommended correlation for developing lateral spread displacement reference maps are presented in Fig. 2 and Table 2. **Figure 1. Recommended grid spacing correlation for developing liquefaction parameter/loading maps. These correlations should result in  absolute error in computing  and/or .****Table 1. Recommended grid spacing correlation for developing liquefaction parameter/loading maps. Interpreted from the hand-drawn correlations presented in Fig. 1.**

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| Mapped *PGA (g)* | Recommended Spacing (km) | Recommended Spacing (mi) |
| 0 - 0.04 | 50 | 31.1 |
| 0.04 - 0.08 | 50 | 31.1 |
| 0.08 - 0.16 | 30 | 18.6 |
| 0.16 - 0.32 | 20 | 12.4 |
| 0.32 - 0.48 | 12 | 7.5 |
| 0.48 - 0.64 | 8 | 5.0 |
| 0.64+ | 4 | 2.5 |

**Figure 2. Grid spacing correlations for developing lateral spread displacement reference maps. The solid line should result in  absolute error in computing .****Table 2. Recommended grid spacing correlation for developing lateral spread displacement reference maps.**

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| *PGA* | Recommended Spacing(km) | Recommended Spacing (mi) |
| 0 - 0.04 | 25 | 15.6 |
| 0.04 - 0.08 | 20 | 12.5 |
| 0.08 - 0.16 | 15 | 9.4 |
| 0.16 - 0.32 | 12 | 7.5 |
| 0.32 - 0.48 | 10 | 6.3 |
| 0.48 - 0.64 | 7 | 4.4 |
| 0.64+ | 4 | 2.5 |

Using the correlations presented above, liquefaction triggering parameter/loading maps were developed using the Cetin et al. (2004) and Boulanger and Idriss (2014) probabilistic models for the states supporting the study. Maps were developed at three target return periods: 475, 1033, and 2475 years. Lateral spread displacement reference maps were also developed using the Youd et al. (2002) empirical model for the states supporting the study. These maps were also developing at the target return periods of 475, 1033, and 2475 years. Both hard (pdf) and soft (ArcGIS raster shapefiles) were provided to the TAC. Samples of these developed maps can be obtained from the TAC quarterly update report for the project and its corresponding appendices.  |
| **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).**None.  |

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| **Potential Implementation:** With the simplified performance-based liquefaction triggering and lateral spread displacement procedures and the developed reference maps, engineers can now immediately implement these procedures into practice for their site(s) of interest. Future tasks in this project will investigate how deterministic evaluation may provide a liquefaction hazard “cap” in areas of high seismicity, and will begin development of a simplified user spreadsheet to implement these simplified performance-based methods.  |