**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(338)** | **Transportation Pooled Fund Program - Report Period:** \_ Quarter 1 (January 1 – March 31, 2019) \_ Quarter 2 (April 1 – June 30, 2019)**x Quarter 3 (July 1 – September 30, 2019)**\_ Quarter 4 (October 1 – December 31, 2019) |
| **Project Title:**Simplified CPT 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 42074, ePM PIN 14239UDOT PIC No. UT15.402 | **Other Project ID (i.e., contract #):** UDOT Contract No. 169826  | **Project Start Date:** May 17, 2016 |
| **Original Project End Date:**November 30, 2018 | **Current Project End Date:** December 31, 2019 | **Number of Extensions:**2 |

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** |
| $142,000.00 (current contract)$142,000.00 (total commitments) | $94,250.00 | 80% |

***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** |
| 0% | $0.00 | 93% |

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| **Project Description**:Conventional “pseudo-probabilistic” procedures to evaluate liquefaction triggering and its effects have been shown through recent research to produce estimates of liquefaction factor of safety at inconsistent and often unacceptable levels of risk. These errors are introduced through the incorrect assumption that using probabilistic ground motions in a deterministic liquefaction analysis will yield a probabilistic estimate of liquefaction factor of safety. The inconsistent consideration of liquefaction risk could contribute to undesirable performance or even collapse of various important structures such as bridges or retaining walls in the event of an earthquake. Conversely, the inconsistent consideration of liquefaction risk could also potentially contribute to the unnecessary and expensive over-design of liquefaction mitigation alternatives. Utilization of a fully-probabilistic or performance-based liquefaction triggering procedure, which considers both uncertainty in the seismic loading and the liquefaction triggering relationship, could effectively solve these problems. Furthermore, probabilistic evaluation of liquefaction triggering could potentially be taken into account when considering liquefaction effects such as lateral spreading or free-field liquefaction settlements. However, current performance-based liquefaction procedures (e.g. Kramer & Mayfield 2007) are quite complex and beyond the level of practical application for most practicing engineers. Additionally, available performance-based methods generally focus on using the standard penetration test (SPT). Increasingly, the cone penetration test (CPT) is becoming a preferred instrument for performing in-situ assessment of liquefaction hazard. Development of code-compatible simplified approximations of performance-based analysis methods for the CPT to assess liquefaction triggering and its effects could be a viable solution to overcome these challenges.Objectives for this study include: 1. Develop performance-based procedures for the CPT modeled after recent performance-based procedures for the SPT to compute the hazard from liquefaction triggering, lateral spread displacement, and post-liquefaction free-field settlement at select return periods (475, 1033, and 2475 years).2. Develop simplified performance-based procedures for the CPT modeled after recent simplified performance-based procedures for the SPT to closely approximate the performance-based analysis results for liquefaction triggering, lateral spread displacement, and post-liquefaction free-field settlement at select return periods (475, 1033, and 2475 years).3. Develop liquefaction triggering, lateral spread displacement, and post-liquefaction reference parameter maps in GIS format at return periods of 475 years, 1033 years, and 2475 years for each of the states participating in the study.Contract tasks for this study include, regarding the participating states: 1. Develop full performance-based liquefaction triggering procedure2. Develop full performance-based lateral spread procedure3. Develop full performance-based post-liquefaction, free-field settlement procedure4. Develop a numerical tool that will allow the calculation of performance-based liquefaction triggering, post-liquefaction settlement, and lateral spread displacement5. Derivation and validation of a new simplified liquefaction triggering procedure6. Derivation and validation of a new simplified lateral spread displacement procedure7. Derivation and validation of simplified post-liquefaction free-field settlement procedure8. Development of liquefaction reference parameter maps9. Comparison of simplified, conventional (AASHTO), and deterministic analysis methods10. Development of a simplified design procedure that incorporates both performance-based and conventional methods11. Preparation of the Annual and Final Reports12. Dissemination of Results13. Technical Advisory Committee (TAC) MeetingsDr. Kevin Franke of BYU is the Principal Investigator for this research project. The technical advisory committee (TAC) for the study currently includes representatives from UT, CT, 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.**Task 5** – 100% complete.**Task 6** – 100% complete.**Task 7** – 100% complete.**Task 8** – 100% complete. **Task 9** – 95% complete. Submitted TAC update report on Tasks 8-10, including liquefaction reference parameter maps, for review by the TAC.**Task 10** – 85% complete. Continued development of analysis spreadsheet tool.**Task 11** – 75% complete.**Task 12** – 25% complete.**Task 13** – 75% complete.**Contract** – No changes this quarter. |
| **Anticipated work next quarter:****Task 1** – Completed.**Task 2** – Completed.**Task 3** – Completed.**Task 4** – Completed.**Task 5** – Completed.**Task 6** – Completed.**Task 7** – Completed.**Task 8** – Completed. Need review from TAC.**Task 9** – Completed. Need review from TAC.**Task 10** – Continue developing simplified design procedure and analysis spreadsheet tool.**Task 11** – Continue report preparation.**Task 12** – One journal paper underway. Begin preparation on one or two more journal papers.**Task 13** – Hold a TAC web-conference in October 2019 to review and discuss additional results from the study.**Contract** – Consider extending the contract end date to allow sufficient time for completion of tasks by the research team and review of deliverables by the TAC. |

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| **Significant Results:**Our team completed the liquefaction reference parameter maps for the participating states. Significant improvements were made to the simplified performance-based analysis methods for CPT-based liquefaction triggering, volumetric strain, and lateral strain computation. New correction functions were developed specifically for areas of lower seismicity (e.g., PGA<0.2g) to provide a better fit to the validation data that was used in our study. Recognizing that different correction functions can be developed and beneficial for regions of different seismicity has been observed before by us and other researchers. Progress continues to be made on the development of the analysis spreadsheet for the implementation of these simplified performance-based methods.  |
| **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).**Unanticipated bias in the simplified performance-based results was observed when using the Boulanger and Idriss (2014) triggering model. We wanted to understand the source of this non-linearity and its limitations. We discovered that it relates to the magnitude scaling factor (MSF) recommended by Boulanger and Idriss (2014). To remove the bias, correction functions incorporating mean magnitude were developed and tested. This project has also been affected by several delays in the availability and the functionality of the new USGS Uniform Hazard Tool used to obtain deaggregation values, thus the change in contract end date. Now that the tool is available, the study is progressing at a good pace. However, we discovered a bug in our analysis towards the end of January 2018 in the USGS offline deaggregation tool which required attention from the USGS to fix. We have received word that the bug is fixed, and we are in the process of modifying CPTLiquefY to be able to process the new USGS deaggregation output files. Finally, one of the BYU graduate students on this project has had some health issues, and this has substantially slowed down our progress on the project. However, the other graduate student assigned to this project is working hard to make up for lost time, and overall, we are seeing great results with the CPT liquefaction assessment method.During summer 2019, we identified that the simplified performance-based correction functions originally developed did not adequately meet the accuracy requirements for the full performance-based methods in the funding states when tested. We re-formulated the correction functions for triggering, settlement, and lateral spread displacement to account for different levels of ground motions. Doing so has significantly reduced the scatter in the simplified performance-based results and increased the accuracy of the methodology.  |

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| **Potential Implementation:** While CPTLiquefY could be implemented in design, it is not recommended because it was developed to serve as a research tool. A simplified spreadsheet will be developed as part of the research later in the study, and will be useful for practical implementation of the performance-based methods in engineering practice. The procedures that are currently being developed will be those that will be implemented in this spreadsheet.  |