**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.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Transportation Pooled Fund Program Project #**  **TPF-5(338)** | | **Transportation Pooled Fund Program - Report Period:**  \_ Quarter 1 (January 1 – March 31, 2021)  **x Quarter 2 (April 1 – June 30, 2021)**  \_ Quarter 3 (July 1 – September 30, 2021)  \_ Quarter 4 (October 1 – December 31, 2021) | |
| **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](mailto:davidstevens@utah.gov) |
| **Lead Agency Project ID:**  FINET 42074, ePM PIN 14239  UDOT 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:**  August 31, 2021 | | **Number of Extensions:**  6 |

Project schedule status:

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

Overall Project Statistics:

|  |  |  |
| --- | --- | --- |
| **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) | $134,500.00 | 97% |

***Quarterly*** Project Statistics:

|  |  |  |
| --- | --- | --- |
| **Total Project Expenses**  **and Percentage This Quarter** | **Total Amount of Funds**  **Expended This Quarter** | **Total Percentage of**  **Time Used to Date** |
| 0% | $0.00 | 97% |

|  |
| --- |
| **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 procedure  2. Develop full performance-based lateral spread procedure  3. Develop full performance-based post-liquefaction, free-field settlement procedure  4. Develop a numerical tool that will allow the calculation of performance-based liquefaction triggering, post-liquefaction settlement, and lateral spread displacement  5. Derivation and validation of a new simplified liquefaction triggering procedure  6. Derivation and validation of a new simplified lateral spread displacement procedure  7. Derivation and validation of simplified post-liquefaction free-field settlement procedure  8. Development of liquefaction reference parameter maps  9. Comparison of simplified, conventional (AASHTO), and deterministic analysis methods  10. Development of a simplified design procedure that incorporates both performance-based and conventional methods  11. Preparation of the Annual and Final Reports  12. Dissemination of Results  13. Technical Advisory Committee (TAC) Meetings  Dr. 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. |

|  |
| --- |
| **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** – 100% complete.  **Task 10** – 99% complete. Completed development of the analysis spreadsheet tool, CPTLiq. Shared the updated version 1.41 of CPTLiq with UDOT for review.  **Task 11** – 95% complete. Previously shared the 2-part draft final report with the TAC for review.  **Task 12** – 25% complete. Journal papers have begun development. Following Covid-19, abstracts will be submitted to share results at targeted professional conferences.  **Task 13** – 80% complete.  **Contract** – Extended the contract end date to August 2021 to allow time for completion of training videos and addressing TAC comments in finalized versions of reports. |
| **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.  **Task 9** – Completed.  **Task 10** – Receive and incorporate feedback from UDOT and the TAC on CPTLiq v1.41. Finalize CPTLiq and the User’s Manual.  **Task 11** – Update and publish the 2-part Final Report for the project based on feedback from the TAC.  **Task 12** – One journal paper is underway. Begin preparation on one or two more journal papers.  **Task 13** – Record training videos and post to YouTube. Consider following up with a practice workshop/interactive live session online with each TPF state and interested neighboring states.  **Contract** – No changes are planned. |

|  |
| --- |
| **Significant Results:**  The simplified performance-based CPT liquefaction hazard analysis spreadsheet CPTLiq has been improved and optimized in the new version 1.41.  In this version of CPTLiq: An error in the settlement plot was corrected; Corrected an error in the deterministic calculation of lateral spread with Ku et al. model; Corrected error with MSF for Boulanger and Idriss; Added a maximum number of 100 iterations for cases where CN does not converge for Boulanger and Idriss method (....only happens with very large tip resistances).  In this version of CPTLiq, all models and CPT correction options are running properly. An analysis now takes less than 5-10 seconds to perform. All reference parameter values have been incorporated into a beta version of the Liquefaction Hazard App on the BYU Tethys server and is currently undergoing testing. Upon approval by the TAC, this beta version will replace the current Tethys Liquefaction Hazard App. PowerPoint slides are being developed for a series of online recorded trainings on the simplified performance-based liquefaction hazard analysis method and the use of CPTLiq. |
| **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. |

|  |
| --- |
| **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 (CPTLiq) has been developed as part of the research, and will be useful for practical implementation of the performance-based methods in engineering practice. The procedures that were developed in this research have been implemented in this spreadsheet. |