1. INTRODUCTION

The 22 February 2011, M_w6.2-6.3 Christchurch earthquake is the most costly earthquake to affect New Zealand, causing 181 fatalities and severely damaging thousands of residential and commercial buildings, and a significant portion of the city lifelines and infrastructure. However, the scientific and engineering significance of this earthquake goes well beyond the effects of this event alone, because the same region was impacted by an M_w7.1 Darfield six months earlier. Accordingly, there is much that can be learned from comparing the different levels of soil liquefaction, differing magnitudes and seismic source distances, and variable performance of buildings, lifelines, and engineered systems during these two earthquakes, along with the many strong aftershocks. It is rare to have the opportunity to document the effects of one significant earthquake on a modern city with good building codes. It is extremely rare to have the opportunity to learn how the same ground and infrastructure responded to two significant earthquakes. This report presents an overview of observed geotechnical aspects of the Christchurch earthquake; a previous GEER report covers observations from the Darfield earthquake:
(http://www.geerassociation.org/GEER_Post%20EQ%20Reports/Darfield%20New%20Zealand_2010/Cover_Darfield_2010.html).

A unique aspect of the Christchurch earthquake is the severity and spatial extent of liquefaction occurring in native soils. Overall, both the spatial extent and severity of liquefaction in the city was greater than in the preceding Darfield earthquake, including numerous areas that liquefied in both events. Liquefaction and lateral spreading, variable over both large and short spatial scales, affected commercial structures in the Central Business District (CBD) in a variety of ways including: total and differential settlements and tilting; punching settlements of structures with shallow foundations; differential movements of components of complex structures; and interaction of adjacent structures via common foundation soils. Liquefaction was most severe in residential areas located to the east of the CBD as a result of stronger ground shaking due to the proximity to the causative fault, a high water table, and soils with composition and states of high susceptibility and potential for liquefaction. The effects of liquefaction and lateral spreading are estimated to have severely compromised 15,000 residential structures, the majority of which otherwise sustained only minor to moderate damage directly due to inertial loading from ground shaking. Liquefaction also had a profound effect on lifelines and other infrastructure, particularly bridge structures, and underground services. Minor damage was also observed at flood stopbanks to the north of the city, which were more severely impacted in the Darfield earthquake. Due to the large high-frequency ground motion in the Port Hills numerous rockfalls and landslides also occurred, resulting in several fatalities and rendering some residential areas uninhabitable.

Following the earthquake, a geotechnical reconnaissance was conducted by a joint NZ-US team. The NZ and US members worked as one team and shared resources, information, and logistics in order to conduct a thorough and efficient reconnaissance covering a large area over a very limited time period. The observations presented in this report resulted from reconnaissance efforts that started immediately following the earthquake by the NZ team members and by US team members over a period of six days (2–8 March 2011). However, because access to the CBD was limited during the time of the US main contingent's visit, two US members performed a reconnaissance visit at a later date, with the main focus of the visit being the performance of lifelines and building foundation systems in the CBD. The team included the following members:

- **Assoc. Prof. Misko Cubrinovski** – NZ Lead (University of Canterbury, Christchurch, New Zealand)
- **Assoc. Prof. Russell A. Green** – US Lead (Virginia Tech, Blacksburg, VA, USA)
- **Mr. John Allen** – (TRI/Environmental, Inc., Austin, TX, USA)
- **Dr. Brendon Bradley** – (University of Canterbury, Christchurch, New Zealand)
- **Assist. Prof. Aaron Bradshaw** – (University of Rhode Island, Kingston, RI, USA)
- **Prof. Jonathan Bray** – (UC Berkeley, Berkeley, CA, USA)
- **Mr. Greg DePascale** – (Fugro/WLA, Christchurch, New Zealand)
- **Mr. Duncan Henderson** – (University of Canterbury, Christchurch, New Zealand)
- **Mr. Lucas Hogan** – (University of Auckland, Auckland, New Zealand)
- **Mr. Patrick Kailey** – (University of Canterbury, Christchurch, New Zealand)
- **Dr. Rolando Orense** – (University of Auckland, Auckland, New Zealand)
- **Prof. Thomas O'Rourke** – (Cornell University, Ithaca, NY, USA)
- **Prof. Michael Pender** – (University of Auckland, Auckland, New Zealand)
- **Prof. Glenn Rix** – (Georgia Tech, Atlanta, GA, USA)
- **Ms. Kelly Robinson** – (University of Canterbury, Christchurch, New Zealand)
- **Mr. Merrick Taylor** – (University of Canterbury, Christchurch, New Zealand)
- **Mr. Donald Wells** – (AMEC Geomatrix, Oakland, CA, USA)
- **Ms. Anna Winkley** – (University of Canterbury, Christchurch, New Zealand)
- **Mr. Clint Wood** – (University of Arkansas, Fayetteville, AR, USA)
- **Dr. Liam Wotherspoon** – (University of Auckland, Auckland, New Zealand)

ACKNOWLEDGEMENTS

Support for the GEER participants in this work was provided from grants from the U.S. National Science Foundations (NSF) as part of the Geo-engineering Extreme Event Reconnaissance (GEER) Association activity through an NSF RAPID GRANT and CMMI-00323914. The GEER Team reconnaissance was performed in coordination with teams from EERI. (Note that Thomas O'Rourke was a member of both the GEER and EERI Teams, with his travel support coming from both organizations). Primary support for the New Zealand participants was provided by the University of Canterbury, the University of Auckland, and the New Zealand Earthquake Commission (EQC). However, any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the associated organizations and funding agencies.

We particularly appreciate Mike Jacka from Tonkin and Taylor, Christchurch, who provided valuable information related to liquefaction-induced damage to residential properties and CPT data. Josh Zupan, University of California, Berkeley, CA, Sam Lasley, Virginia Tech, Blacksburg, VA, and Brady Cox, Fayetteville, AR, assisted the reconnaissance, data management and preparation of this report. Josh Zupan (University of California, Berkeley) and Dr. Bruce Deam (University of Canterbury) assisted with posting of the report.