## Project overview

Liquefaction induced lateral spreading from earthquakes poses a significant hazard to the built environment and has severe consequences, as observed in Christchurch during the 2010 to 2011 Canterbury Earthquake Sequence (CES) (Cubrinovski, et al., 2014). It is critical for geotechnical engineers to be able to estimate lateral spread movements for design purposes. Published empirical and semi-empirical models are available to help predict the potential for damage and movements associated with liquefaction and lateral spreading (i.e. Tokimatsu & Asaka (1998), Youd et al. (2002) and Zhang et al. (2004)). However, the various models produce estimates that can vary by orders of magnitude for particular situations as demonstrated in studies by Bowen et al. (2012), Deterling (2015), Robinson (2015), amongst others, which compare predicted horizontal displacements withthe observed horizontal displacements for the main CES events at various study locations in the Christchurch area. Bowen et al. (2012) recognised that geologic and topographic features had a significant influence on the horizontal displacement pattern and extent of lateral spreading in Christchurch. Part of the variation between predicted and observed horizontal displacement likely results from geologic, geomorphologic and spatial variability in soil conditions which are not appropriately accounted for in the predictive models (Bastin et al., 2015; Cubrinovski and Robinson, 2015). In addition, some of the significant variation in the horizontal displacement estimates produced by the various published methods are due to the different assumptions regarding the mechanism causing lateral spreading.

The various published methods available for estimating displacements induced by lateral spreading are typically based on limited numbers of case histories and relatively small geotechnical investigation datasets (for example Tokimatsu & Asaka, 1998, Youd et al., 2002, Zhang et al., 2004, Jibson, 2007 and Bray and Travasarou, 2007). The researchers undertaking this work were frequently limited in the methods used to collect these case histories due to the limited resources available. As a result it is often difficult to estimate actual horizontal ground displacements, which results in additional uncertainty in the development of the prediction methodologies. Comprehensive, extensive, and detailed observations of lateral spreading displacements were made following the main CES earthquakes, and are available in GEER (2010 & 2011), Martin & Rathje (2014), Cubrinovski & Robinson (2015) and Bastin et al. (2015) among others. This data provide a high quality case history database spanning multiple events. A key strength of this case history database is that the measurements of lateral spreading are derived from multiple data sources and thus the accuracy of the measurements can be verified against one another. Internationally the CES lateral spreading dataset is of unparalleled quality and provides a unique opportunity to expand understanding of the mechanisms of lateral spreading and refine the existing methods used to estimate the magnitude of displacements.

The maximum extent of lateral spreading for the September 2010, February 2011, and across the CES was derived for the Avon River as part of the 2016 QuakeCoRE project (16056). This was completed using LiDAR and satellite displacements combined with the summation of measured crack widths along transects, LiDAR derived ground surface subsidence, documented land damage, and cracking observed from post-event aerial photography. Comparison of the maximum extent of spreading with geologic and geomorphic variability strongly supports that the distribution of lateral spreading and associated displacements is influenced by variability in the subsurface soils. Detailed geotechnical and geologic characterization of the subsurface soils where extensive, localized, or no displacement was observed would enable common factors within each area to be determined and examined in detail. In addition, collation of local resident observations during the earthquakes including the time cracks started to open, would enable the mechanism causing lateral spreading to be examined. Combining this observational data with detailed geotechnical characterization would enable the lateral spreading mechanism best supported by the CES to be determined. Additionally, comparison of the observed lateral spreading with that predicted by conventional analyses (Newmark method) would enable the applicability of the current methods recommended to geotechnical engineers to be scrutinized.

Key objectives:

The key objectives of this research proposal are as follows:

1. Examine the recorded depth of damage to wells, and explore possible links with spreading, depth affected by spreading, and whether it is consistent with LiDAR observations.
2. Following the methodology employed by Lai and Marshal (2015), perform detailed evaluation of the factors influencing lateral spreading, including the separation of topography-related and free-face related ground displacements, and summarize (quantify) the conditions for gravity-induced spreading displacements.
3. Undertake detailed geotechnical and geological characterization of the subsurface soil conditions for the different categories of observed lateral spreading, as identified in Cubrinovski and Robinson (2015) and 2016 QuakeCoRE project (16056).
4. Perform analysis and interpretation of temporal evolution of LS displacements using: (i) Analysis of ground motion records to separate earthquake loading into pre-triggering and post-triggering phases, (ii) Collate and examine anecdotal evidence regarding the timing of lateral spreading during the CES events.
5. Use simplified Newmark-type analysis to compare modelled displacements using the results from objective 4 with the recorded earthquake-induced ground displacements derived in objective 1, and the geotechnical and geological characteristics derived in objective 3.