REGIONAL LIQUEFACTION SUSCEPTIBILITY ASSESSMENTS: DATA COLLECTION NEEDS AND A FOCUS ON THE CENTRAL AND EASTERN U.S.

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CURRENT STATE-OF-THE-PRACTICE AND LIMITATIONS

Liquefaction susceptibility assessments can be performed at the site-specific or regional scale. Site-specific assessments typically utilize quantitative methods that rely on geotechnical data from laboratory testing of soil samples retrieved in-situ (e.g., Bray and Sancio 2006, Boulanger and Idriss 2006). Regional assessments are generally more qualitative in nature and are based on factors that influence susceptibility such as groundwater level, geology and depositional environment, age of deposit, and fabric, or are based on applying site-specific methodologies at a regional scale (e.g., Youd and Perkins 1978, FEMA 2020).

Regional liquefaction susceptibility assessments are critical to improving the seismic resilience of communities and infrastructure systems across the country. However, there exists a technical gap between the detailed, quantitative site-specific studies carried out using laboratory testing data, and qualitative, often proxy-based, regional studies. This extended abstract discusses two aspects of regional susceptibility assessments: data collection needs to advance or improve existing assessment methods, and limitations in applying existing state-of-the-practice methods, with a focus on the Central and Eastern U.S. (CEUS).

DATA RESOURCES TO HELP IMPROVE UNDERSTANDING

Liquefaction susceptibility assessment methods are derived primarily from post-earthquake field case histories and laboratory testing. Case histories require an observation, a ground motion recording or estimate, and geotechnical data. However, immediately after an earthquake it is not feasible to visit and photograph the entire affected area in person, due to time and safety constraints. Developing the next generation of liquefaction susceptibility assessment methods, including quantitative regional assessment methods, requires regional data collection and selection of meaningful case history sites for detailed investigations. Extensive high-resolution aerial photography after an earthquake event can provide essential data needed to meet these goals. Consider the 2010-2011 Canterbury earthquake sequence (CES), which led to unprecedented research advances. Within two days after major earthquake events in the CES, the New Zealand government collected extensive aerial imagery throughout Christchurch and the surrounding communities. The imagery was then made publicly available, accessible via Google Earth, and maintained for over a decade following the events (NZGD 2022). Figure 1 shows the extent of aerial imagery coverage and the imagery resolution at the ground scale. Extensive regional coverage with high-resolution aerial imagery has enabled research investigations of CES post-earthquake observations to continue to this day.

In addition to providing regional coverage, extensive aerial imagery allows researchers to "revisit" sites years later and select critical, impactful case history sites for further investigation and collection of quantitative geotechnical data. This is especially important for selecting sites that perform well (i.e., where no ground failure is observed). For example, to investigate observations of "no liquefaction" at silty soil sites in Christchurch, over 30 candidate sites were initially selected and then narrowed down to 8 sites for development of detailed case histories (Beyzaei et al. 2018). High resolution aerial images across the region enabled a large pool of candidate sites from which the most impactful sites could be selected for further investigations. Aerial imagery of this extent ensures that the ephemeral data from post-event observations are not lost and can later be used for either regional or site-specific quantitative analysis.

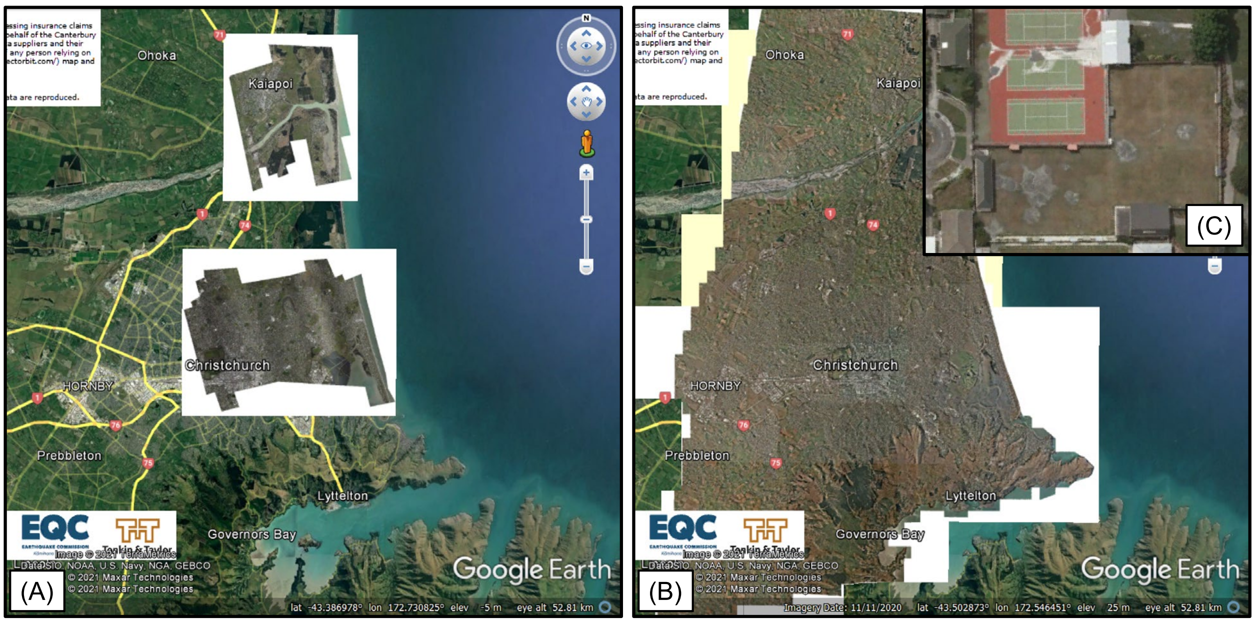

Figure 1. Extent of aerial imagery commissioned by the New Zealand Ministry of Civil Defence and Emergency Management: (A) 4 Sept 2010 Darfield earthquake, acquired on 5 Sept 2010; and (B) 22 Feb 2011 Christchurch earthquake, acquired on 24 Feb 2011 (NZGD 2022). (C) Inset showing resolution of imagery at the ground level.

CHALLENGES WITH CURRENT METHODS AND POTENTIAL CONSEQUENCES

Existing methods and proposed frameworks for regional liquefaction susceptibility assessments are typically based on examples from the Western U.S. and other areas of high seismic hazard. However, there are several challenges in applying existing assessment methods to the CEUS or other areas of low to moderate seismic hazard: 1) limited regional data availability (i.e., publicly available subsurface geotechnical and groundwater data), 2) practitioner and stakeholder liquefaction hazard awareness, and 3) fewer earthquake events leading to the perception of liquefaction hazard not being a "local" issue.

Improving practitioner and stakeholder awareness of liquefaction hazards and existing liquefaction susceptibility assessment methods should be a primary goal, alongside research, to advance technical knowledge and assessment models. Improving awareness and addressing the perception of liquefaction not being a "local" issue increases the opportunities for stakeholder buy-in and higher quality assessments in seismic or multi-hazard resilience planning.

It is critical to get stakeholders onboard now to start planning for climate change impacts affecting liquefaction susceptibility. Sea level rise has the potential to create larger or new areas of susceptible soils, with studies demonstrating the effects of sea level rise on liquefaction vulnerability for the Bay Area in California (USGS 2022) and Charleston, South Carolina (Ghanat 2021). A potential acute consequence of climate change impacts on liquefaction susceptibility is that a region becomes more vulnerable to liquefaction hazard due to sea level rise. In areas of low to moderate seismic hazard, if there is a lack of awareness or view that liquefaction is not a "local" problem, communities may not have mitigation strategies in place and are then unprepared when an earthquake occurs and damage ensues.

CONCLUDING REMARKS AND RECOMMENDATIONS

The next generation of liquefaction susceptibility models should close the gap between current state-of-practice quantitative site-specific methods and qualitative regional methods. Extensive aerial photography is key during post-earthquake reconnaissance and will allow for selection of impactful case histories in the years after an event. Limited regional data availability and practitioner and stakeholder awareness in low-to-moderate seismicity areas are challenges related to the use of existing methods.

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REFERENCES

Beyzaei, C. Z., Bray, J. D., Cubrinovski, M., Riemer, M., and Stringer, M.E. (2018). Laboratory-based characterization of shallow silty soils in southwest Christchurch. *Soil Dynamics and Earthquake Engineering*, 110(2018), 93-109.

Boulanger, R. W. and Idriss, I. M. (2006). Liquefaction susceptibility criteria for silts and clays. *Journal of Geotechnical and Geoenvironmental Engineering*, 132(11), 1413-1426.

Bray, J. D. and Sancio, R. B. (2006). Assessment of the liquefaction susceptibility of fine-grained soils. *Journal of Geotechnical and Geoenvironmental Engineering*, 132(9), 1165-1177.

FEMA (2020). Hazus earthquake model technical manual: Hazus 4.2 SP3. *Federal Emergency Management Agency (FEMA)*, October.

Ghanat, S. T. (2021). Impact of projected climate-driven sea level rise on liquefaction vulnerability in Charleston, SC. *EERI Annual Meeting*, virtual poster session.

NZGD (2022). Canterbury Maps, Collated Investigation Data: Aerial Photography. *New Zealand Geotechnical Database*, www.nzgd.org.nz [accessed March 2022].

USGS (2022). Liquefaction and sea-level rise. *United States Geological Survey*, story map created by T. Poitras, A. Grant, A. Wein, K. Knudsen, K. Befus, M. Erdman, K. Petersen, https://www.usgs.gov/tools/liquefaction-and-sea-level-rise [accessed July 2022].

Youd, T. L. and Perkins, D. M. (1978). Mapping liquefaction-induced ground failure potential. *Journal of the Geotechnical Engineering Division*, 104(No. GT4), 433-446.