Executive Summary

The February 27, 2010 Maule, Chile earthquake (M_w = 8.8) is the fifth largest earthquake to occur since 1900. Its effects were felt along 600 km of the central Chile coast. Initial field observations suggest that tectonic displacement of the hanging wall produced both uplift of over 2 m and subsidence of up to 1 m in coastal regions. The tsunami initiated by the rupture devastated parts of the coast and killed hundreds of people. Strong shaking lasted for over a minute in some areas, and widespread damage occurred in some cities. A large number of significant aftershocks contributed additional damage to an already fragile infrastructure.

The earthquake tested numerous modern structures and facilities. Most of these systems performed well, although some did not. Most often, poor performance resulted from construction deficiencies or oversights in the design process related to structural detailing or recognition of geotechnical effects, such as liquefaction.

This major earthquake was the subject of several post-earthquake reconnaissance efforts. This report presents the observations of the NSF-sponsored Geo-engineering Extreme Events Reconnaissance (GEER) team. GEER team members included engineers, geologists, and scientists from Chile and the United States. The GEER team worked closely with other reconnaissance teams, including EERI, USGS, NIST, FEMA, TOSG, PEER, and ASCE, amongst others, to document the geotechnical effects of this significant event so that our understanding of earthquakes can be improved and we may turn disasters such as this one into knowledge for advancing societal resilience.

In this report, key observations were carefully documented and geo-referenced with the use of GPS and other geospatial tools such as Google Earth. A selected number of critical sites were further characterized using advanced tools, such as LiDAR, SASW, and DCPT. Reconnaissance was performed remotely using satellite imagery, efficiently through aerial reconnaissance, and in detail through coordinated ground-based reconnaissance studies.

This report includes a brief summary of engineering seismology and earthquake ground motions for this event, a description of the use of remote sensing to provide insight into damage patterns, and an in-depth discussion of the important role of coastal uplift and subsidence resulting from the underlying tectonic movement. Localized damage patterns observed during the 2010 Chile earthquake and findings from previous earthquake studies indicate that seismic site effects were also important in this earthquake.

Soil liquefaction occurred at many sites, and often led to ground failure and lateral spreading. Of special interest are the effects of liquefaction on the built environment. Several buildings were damaged significantly due to foundation movements resulting from liquefaction. Liquefaction-induced ground failure displaced and distorted waterfront structures, which adversely impacted the operation of some of Chile's key port facilities. Critical lifeline structures, such as bridges, railroads, and road embankments, were damaged by ground shaking and ground failure. The damage to some sections of Ruta 5, the primary North-South highway in Chile, was pervasive, which disrupted the flow of supplies and traffic following the event.

Most dams, levees, and mine tailings dams performed well. However, several key earth structures experienced some distress, and in one case a liquefaction-induced tailings dam failure produced a flow slide that killed a family of four. Most earth retention systems, such as retaining walls and basement walls, proved to be inherently robust. Landsliding was not pervasive, which appears to have resulted from native slopes that are generally composed of competent earth materials and the relatively low groundwater levels present at the end of the dry season.

All of these consequences impact how society responds to, plans for, and rebuilds after a major earthquake, which will occur again in this region and other regions such as the Pacific Northwest. GEER team urban planners, geologists, and engineers documented the impacts of the geologic and tsunami hazards and identified the challenges and opportunities that will confront Chile as it rebuilds and addresses these hazards in the future. Careful documentation of the geotechnical effects of the 2010 Chile earthquake will enable advancements in the art and science of engineering that will save lives during the next major event.