Top 10 Research Priorities on Cascadia Liquefaction & Lateral Spreading

Resulting from the Cascadia Liquefaction and Lateral Spreading Needs Meeting on August 30, 2013

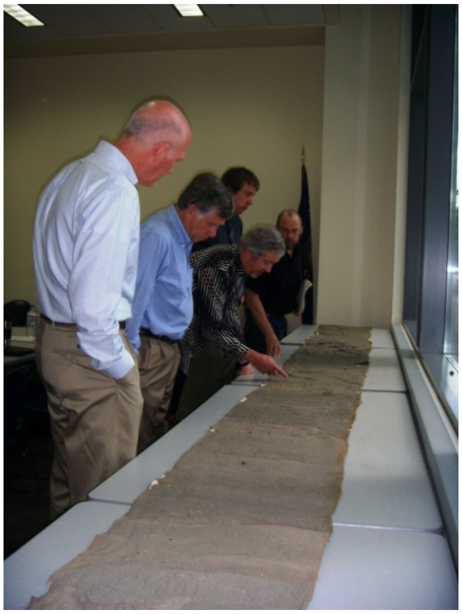
Sponsored by the
Oregon Department of Geology and Mineral Industries (DOGAMI)
and Oregon State University (OSU)

We believe a major earthquake on the Cascadia Subduction Zone will cause widespread liquefaction-induced ground deformations that will be severely damaging to the built environment in Oregon. We strongly advocate and encourage the following ten (10) efforts (in no particular order) to improve understanding of the liquefaction hazard and mitigate risk in Oregon:

1. **Developing a database of probabilistic seismic hazard analysis deaggregations from the USGS National Seismic Mapping Project (NSHMP).** Such a database of deaggregations (i.e., mean annual rates of exceedance at a site as a function of potential earthquakes of varying magnitudes and source-site distances) will allow more detailed evaluations of the probabilistic seismic hazard in Oregon. In addition, the database could be uploaded into *WSliq*, a public computer program developed by researchers at the University of Washington under support by the Washington State Department of Transportation (WSDOT). *WSliq* aids in performing several liquefaction hazard analyses, including evaluations of the susceptibility of the soil to liquefaction, liquefaction triggering analyses, and predictions of the effects due to liquefaction (e.g., settlement, lateral spreading). The program can be downloaded at: http://faculty.washington.edu/kramer/WSliq/WSliq.htm
2. **Updating and/or creating new liquefaction hazard maps in Oregon, especially in the highly urbanized Portland Metro Area.** The group believes such hazard maps could be improved by incorporating recently developed geology maps (e.g., 1:4000 – 1:8000 scale, 3D geology maps), seismic hazard data from the most-current NSHMP, digital elevation models from aerial Lidar studies, advances in liquefaction hazard assessment techniques, and available geotechnical data. Such maps should depict liquefaction potential as well as predictions of resulting liquefaction-induced ground deformations (e.g., lateral spreading, differential settlement).
3. **Identifying more geologic evidence of liquefaction and lateral spreading in Oregon during prehistoric, major earthquakes.** For example, the magnitude 9 January 26, 1700, Cascadia Subduction Zone earthquake should have produced widespread liquefaction-induced ground failures. However, to date, there have been few studies that have identified significant liquefaction features from this event. Searching for such evidence will improve understanding of the liquefaction hazard in Oregon and promote preparations for the next great earthquake.
4. **Performing additional shear wave velocity tests to further characterize the site amplification and liquefaction potential of sediments in Oregon.** Soft soils may amplify or deamplify the strong ground motion depending on the nature and frequency content of the strong motion, and the thickness and characteristics of the soil profile. Certainly, more shear

wave velocity tests will improve maps describing the geographic variation of the average shear wave velocity in the upper 30 meters of the site profile (V_{s30}). (Many ground motion attenuation relationships and building codes account for site amplification by using V_{s30}.) In addition to describing site amplification effects, results from shear wave velocity tests may be used in conjunction with recently published empirical models to describe the liquefaction triggering potential at a site or for a geologic unit.

5. **Developing a geospatial database of geotechnical investigations where the public can easily access, upload data, and download data.** For example, DOGAMI has compiled hard copies of over 8,000 geotechnical boreholes and over 400 cone penetration test soundings in the Portland Metro Area. Such a wealth of data needs to be digitized for further analysis of subsurface conditions. A readily-accessible geotechnical database could be used to develop correlations and distributions of soil properties for various geologic units, evaluate liquefaction potential, and improve liquefaction hazard maps.
6. **Evaluating the performance of published liquefaction triggering and lateral spread displacement empirical models against case studies where great and long-duration earthquakes occurred** (e.g., 2011 Tohoku Earthquake). Commonly, geotechnical engineers and geologists assessing liquefaction hazards use empirical models developed mostly from case studies of liquefaction from magnitude 6 to 8 earthquakes. However, geologic studies indicate the Cascadia Subduction Zone is capable of generating magnitude 9 earthquakes. Extrapolating these empirical models for such powerful and long-lasting earthquakes may underpredict (or overpredict) the liquefaction hazard.
7. **Characterizing the liquefaction potential of geologic units commonly encountered in Oregon, especially in the Willamette Valley and along the Coast.** For example, the Willamette Valley is filled with the Willamette Silt. Improved in-situ and laboratory testing is needed to assess the spatial variability (i.e., north to south along the valley) of the liquefaction potential of this widespread unit.
8. **Recommending and/or developing ground improvement methods for increasing the resistance of a site to liquefaction-induced ground failure.** Mitigation strategies need to be further investigated, and work flows need to be refined for how such strategies can be implemented for typical conditions in Oregon. Several mitigation strategies have been proposed in the past, such as installation of stone columns, vertical drains, and jet grouting, and use of deep soil mixing, dynamic compaction, and vibratory probes. Further developing criteria unique to Oregon for mitigating the liquefaction hazard will improve engineering design. For example, does vibro-densification adequately mitigate the liquefaction hazard in highly silty soils, such as the Willamette Silt?
9. **Developing fragility curves for common foundations and structures in Oregon.** Such "standard" curves can then be used in seismic vulnerability analyses, enabling improved estimates of potential damage and economic losses from major to great earthquakes.
10. **Informing emergency responders of the liquefaction hazard in Oregon.** By identifying and explaining critical information, emergency responders can develop and prioritize plans in preparation for a major seismic event.



Dr. Brian Atwater explaining the subsurface soil layers, including liquefaction features from the January 26, 1700 earthquake.

A close-up of a liquefaction feature discovered along the river banks of the lower Columbia River.

Meeting Participants

Yumei Wang, DOGAMI (co-organizer)
Daniel Gillins, Oregon State University (co-organizer)
Scott Ashford, Oregon State University
Brian Atwater, USGS
Bill Burns, DOGAMI
Scott Burns, Portland State University
Thomas Holzer, USGS
Bruce Johnson, ODOT
Leon Kempner, Bonneville Power Administration
Steve Kramer, University of Washington
Ian Madin, DOGAMI
Ben Mason, Oregon State University
Kate Mickelson, DOGAMI
Nancy Murphy, ODOT
Michael Olsen, Oregon State University
Tom Peterson, Port of Portland
Don Pettit, Department of Environmental Quality
Armin Stuedlein, Oregon State University
Mike Stuhr, Portland Water Bureau
Tom Wharton, Port of Portland
Tom Wiley, DOGAMI
Liam Wotherspoon, University of Auckland

For more information on the Cascadia Liquefaction and Lateral Spreading Needs Meeting held on August 30, 2013, please contact:

Yumei Wang, PE, Geotechnical Engineer
Oregon Dept. of Geology & Mineral Industries (DOGAMI)
Phone: 971-673-1551
Email: yumei.wang@dogami.state.or.us

and

Daniel Gillins, Ph.D., Assistant Professor
Oregon State University, School of Civil & Construction Engineering
Phone: 541-737-4865
Email: dan.gillins@oregonstate.edu

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Liquefaction and Lateral Spreading Flow Chart— August 2013