WASHINGTON STATE DEPARTMENT OF Natural Resources
Doug Sutherland - Commissioner of Public Lands
Division of Geology and Earth Resources
Ron Teissere - State Geologist

Department of Homeland Security
Federal Emergency Management Agency
Region 10

Washington Military Department
Emergency Management Division

Liquefaction Susceptibility Map of Whatcom County, Washington

by Stephen P. Palmer, Sammantha L. Magsino, Eric L. Bilderback, James L. Poelstra, Derek S. Folger, and Rebecca A. Niggemann

September 2004

WHAT IS LIQUEFACTION?

Liquefaction is a phenomenon in which strong earthquake shaking causes a soil to rapidly lose its strength and behave like quicksand. Liquefaction typically occurs in artificial fills and in areas of loose sandy soils that are saturated with water, such as low-lying coastal areas, lakeshores, and river valleys. When soil strength is lost during liquefaction, the consequences can be catastrophic. Movement of liquefied soils can rupture pipelines, move bridge abutments and road and railway alignments, and pull apart the foundations and walls of buildings. Ground movement resulting from liquefaction caused massive damage to highways and railways throughout southern Alaska during the 1964 Good Friday earthquake. During the 1989 Loma Prieta earthquake, liquefaction was a contributing factor to severe building damage in the Marina District of San Francisco. Liquefaction-induced ground movements also broke water lines, severely hampering control of the ensuing fires in the Marina District. Damage caused by liquefaction to the port area of Kobe, Japan during the 1995 earthquake resulted in billions of dollars in reconstruction costs and lost business.

WHAT IS A LIQUEFACTION SUSCEPTIBILITY MAP?

A liquefaction susceptibility map provides an estimate of the likelihood that soil will liquefy as a result of earthquake shaking. This type of map depicts the relative susceptibility in a range that varies from very low to high. Areas underlain by bedrock or peat are mapped separately as these earth materials are not liquefiable, although peat deposits may be subject to permanent ground deformation caused by earthquake shaking.

This map is based solely on surficial geology published at a scale of 1:100,000 by the Washington State Department of Natural Resources, Division of Geology and Earth Resources (Washington Division of Geology and Earth Resources staff, 2001). We have assigned liquefaction susceptibility based on published geologic correlations (Youd and Perkins, 1978) and similarity of the geologic units in the map area to units that have been subjected to a quantitative susceptibility analysis (Grant and others, 1998; Palmer, 1995; Palmer and others, 1994, 1995, 1999, 2002, 2003, *in press*). The assignment of liquefaction susceptibility represents our best professional judgment.

HOW CAN THIS MAP BE USED?

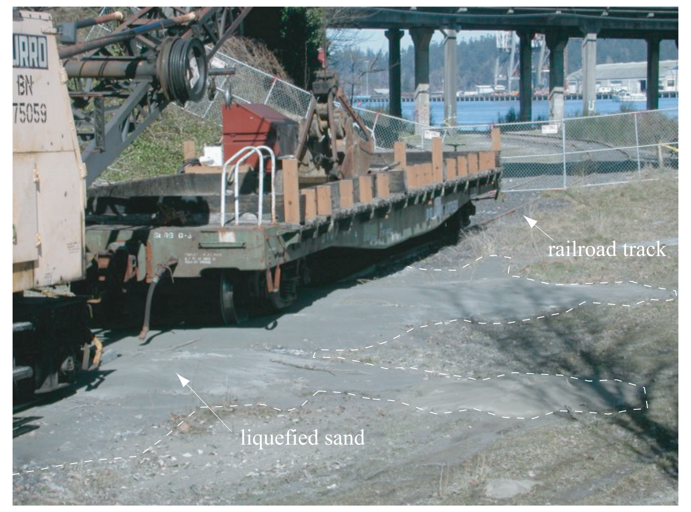
Liquefaction susceptibility maps such as this can be used for many different purposes by a variety of users. For example:

- Emergency managers can determine which critical facilities and lifelines are located in hazardous areas.
- Building officials and engineers can select areas where detailed geotechnical studies should be performed before new construction or retrofitting of older structures.
- Facilities managers can assess the vulnerability of corporate and public facilities, including schools, and recommend actions required to maximize public safety and minimize earthquake damage and loss.
- Insurance providers can determine relative seismic risk to aid in the calculation of insurance ratings and premiums.
- Land-use planners can reduce vulnerability by recommending appropriate zoning and land use in high hazard areas to promote long-term mitigation of earthquake losses.
- Private property owners can guide their decisions on purchasing, retrofitting, and upgrading their properties.

This map is meant only as a general guide to delineate areas prone to liquefaction. It is not a substitute for site-specific investigation to assess the potential for liquefaction for any development project. Because the data used in the liquefaction susceptibility assessment have been subdivided on the basis of regional geologic mapping, this map cannot be used to determine the presence or absence of liquefiable soils beneath any specific locality. This determination requires a site-specific geotechnical investigation performed by a qualified practitioner.

This map is intended to be printed at a scale of 1:175,000 in order to present the entire study area on a single standard-size plate. However, the map was generated using 1:100,000-scale digital coverages of the geologic mapping; therefore, the digital data reflect the original 1:100,000-scale of the hazard mapping. As with all maps, it is recommended that the user does not apply this map, either digitally or on paper, at scales greater than the source data.

Liquefaction during the 1965 SeaTac earthquake caused both lateral and vertical movement of the ground in the Port of Seattle. Cargo cranes such as the one in the background are vulnerable to liquefaction-induced ground displacement. Lateral spreading such as this can cause severe damage to both above-ground structures and underground utilities. Photo courtesy of the Karl V. Steinbrugge Collection, Earthquake Engineering Research Center [http://nisee.berkeley.edu/visual_resources/steinbrugge_collection.html].



During the 2001 Nisqually earthquake, liquefied sand was extruded onto the ground surface beneath the railroad tracks near Capitol Lake in Olympia. The vented sand is called a sand blow, and is clear evidence of liquefaction of the underlying soil. Photo by Stephen P. Palmer.

EXPLANATION

- Liquefaction susceptibility: HIGH
- Liquefaction susceptibility: MODERATE to HIGH
- Liquefaction susceptibility: MODERATE
- Liquefaction susceptibility: LOW to MODERATE
- Liquefaction susceptibility: LOW
- Liquefaction susceptibility: VERY LOW to LOW
- Liquefaction susceptibility: VERY LOW
- Bedrock
- Peat deposit — Peat is not susceptible to liquefaction but may undergo permanent displacement or loss of strength as a result of earthquake shaking.
- Water
- Ice

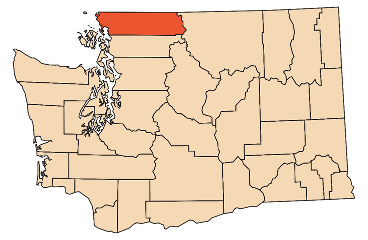
This explanation is standardized for this series of county-based liquefaction maps; some categories may not appear on this map.

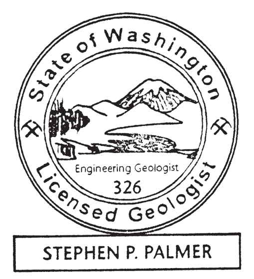
Lambert conformal conic projection
North American Datum of 1983 HARN
Shaded relief generated from U.S. Geological Survey 30-meter Digital Elevation Model, 2x vertical exaggeration
Production by Anne C. Heinitz, Rebecca A. Niggemann, and Jaretta M. Roloff
Editing by Karen D. Meyers

scale 1:175,000

2 1 0 2 4 6 8 Miles

2 1 0 2 4 6 8 Kilometers





Stephen P. Palmer
9/1/04

REFERENCES CITED

Grant, W. P.; Perkins, W. J.; Youd, T. L., 1998, Evaluation of liquefaction potential in Seattle, Washington. In Rogers, A. M.; Walsh, T. J.; Kockelman, W. J.; Priest, G. R., editors, Assessing earthquake hazards and reducing risk in the Pacific Northwest: U.S. Geological Survey Professional Paper 1560, v. 2, p. 441-473, 1 plate. [accessed Sep. 9, 2004 at http://greenwood.cr.usgs.gov/pub/ppapers/p1560/p1560po.pdf]

Palmer, S. P., 1995, Liquefaction analysis of soil deposits found in the Sumner quadrangle. In Dragovich, J. D.; Pringle, P. T., Liquefaction susceptibility for the Sumner 7.5-minute quadrangle, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-44, p. 13-26.

Palmer, S. P.; Evans, B. D.; Schasse, H. W., 2002, Liquefaction susceptibility of the Greater Eastside area, King County, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-48, 1 sheet, scale 1:36,000, with 14 p. text.

Palmer, S. P.; Magsino, S. L.; Poelstra, J. L.; Niggemann, R. A., *in press*, Liquefaction susceptibility map of Clark County, Washington: Washington Division of Geology and Earth Resources, 1 sheet, scale 1:100,000.

Palmer, S. P.; Perkins, W. J.; Grant, W. P., 2003, Liquefaction susceptibility of the greater Tacoma urban area, Pierce and King Counties, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-51, 1 sheet, scale 1:30,000 with 11 p. text. [accessed Sep. 9, 2004 at http://www.dnr.wa.gov/geology/pdf/gm51.zip]

Palmer, S. P.; Schasse, H. W.; Norman, D. K., 1994, Liquefaction susceptibility for the Des Moines and Renton 7.5-minute quadrangles, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-41, 2 sheets, scale 1:24,000, with 15 p. text.

Palmer, S. P.; Walsh, T. J.; Gerstel, W. J., 1999, Geologic folio of the Olympia-Lacey-Tumwater urban area, Washington-Liquefaction susceptibility map: Washington Division of Geology and Earth Resources Geologic Map GM-47, 1 sheet, scale 1:48,000, with 16 p. text.

Palmer, S. P.; Walsh, T. J.; Logan, R. L.; Gerstel, W. J., 1995, Liquefaction susceptibility for the Auburn and Poverty Bay 7.5-minute quadrangles, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-43, 2 sheets, scale 1:24,000, with 15 p. text.

Washington Division of Geology and Earth Resources staff, 2001, Digital geologic maps of the 1:100,000 quadrangles of Washington: Washington Division of Geology and Earth Resources Digital Report 2, June 2003 version, 1 CD-ROM disk.

Youd, T. L.; Perkins, D. M., 1978, Mapping liquefaction-induced ground failure potential: American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, v. 104, no. GT4, p. 433-446.