UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 2
Utah Geological Survey Special Study 137
Geologic Hazards and Adverse Construction Conditions,
St. George–Hurricane Metropolitan Area, Washington County, Utah

PLATE 2

LIQUEFACTION-HAZARD MAP FOR THE ST. GEORGE–HURRICANE METROPOLITAN AREA

by

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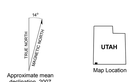

Approximate mean declination, 2007

Map Location

Basemap consists of National Agricultural Imagery Program natural color aerial photography.

Universal Transverse Mercator Projection, zone 12. North American Datum 1983.

Scale 1:24,000

1 0.5 0 1 2 Miles

1 0.5 0 1 2 Kilometers

SYMBOLS

- Municipality boundary
- Interstate Highway
- State Highway
- Major local surface street
- Other road

EXPLANATION

- **VH** – Very High – Geologic units that liquefied during the 1992 St. George, Utah, M_L 5.8 earthquake, and consist of well-sorted sands, silty sands, and gravels along modern stream drainages and young alluvial terraces where depth to ground water is ≤10 feet.
- **H** – High – Geologic units that consist of well-sorted sands, silty sands, and gravels where depth to ground water is ≤50 feet. None of these units are known to have liquefied during the 1992 St. George earthquake.
- **H_2** – High$_2$ – Geologic units with textural characteristics of the High category, but ground-water information is lacking.
- **M** – Moderate – Geologic units that consist of moderately sorted sands, silty sands, and gravels where depth to ground water is ≤50 feet.
- **M_2** – Moderate$_2$ – Geologic units with textural characteristics of the Moderate category, but ground-water information is lacking.
- **L** – Low – Geologic units that consist of moderately to poorly sorted sands and gravels where depth to ground water is ≤50 feet. Liquefaction hazard is considered low in these units because of their textural characteristics and/or degree of cementation.
- **L_2** – Low$_2$ – Geologic units with textural characteristics of the Low category, but ground-water information is lacking.

Liquefaction Susceptibility of Unconsolidated Geologic Units

Type of Deposit[1]	Geologic Unit[2]	Liquefaction Susceptibility	
		Ground Water ≤50 ft	Ground Water Depth Unknown
Stream and Terrace Alluvium	Qes, Qal,	VH	VH
	Qaes, Qae	H	H_2
Alluvial Deposits	Qli, Qlo, Qaec	M	M_2
	Qaqs, Qafi, Qafc, Qafy, Qao, Qaeo	L	L_2
Eolian Deposits	Qes, Qea, Qea, Qeq, Qed	H	H_2
Colluvial Deposits	Qc, Qca	L	L_2
Various	Remaining unconsolidated Quaternary and Tertiary units, bedrock, and areas where depth to ground water is >50 feet	None[3]	None[3]

[1]Some categories include mixed unit deposits. [2]Refer to UGS 1:24,000-scale geologic maps (see SOURCES OF DATA and REFERENCES in accompanying text) for a description of map units. [3]Not shown on map, although may contain small areas of liquefaction hazard too small to show at the scale of this study.

DISCUSSION

Liquefaction and liquefaction-induced ground failures are major causes of earthquake damage. Upon liquefaction, a soil loses its strength and ability to withstand the weight of overlying structures or support lateral loads. Liquefaction initially occurs in saturated, loose to moderately dense, cohesionless soil that is subjected to strong ground shaking. Cohesionless soils have loose grains that do not readily stick together and are typically sandy, with little clay, although some silty and gravelly soils are also susceptible to liquefaction. In general, an earthquake of magnitude 5 or greater is necessary to induce liquefaction. Larger earthquakes are more likely to cause liquefaction, and may result in liquefaction at greater distances from the earthquake epicenter. The September 2, 1992, M_L 5.8 St. George earthquake produced liquefaction in saturated sand deposits along the Virgin River. Liquefaction and liquefaction-induced ground failure can have four major adverse effects: (1) foundations may crack, (2) buildings may tip, (3) buoyant buried structures, such as septic tanks and storage tanks, may rise, and (4) liquefied soils and overlying materials may move down even gentle slopes. Structures that are particularly sensitive to liquefaction-induced ground failure include buildings with shallow foundations, railway lines, highways and bridges, buried structures, dams, canals, retaining walls, utility poles, and towers.

For additional information about the liquefaction hazard in the St. George – Hurricane metropolitan area, refer to the Liquefaction-Hazard text document in this report.

USING THIS MAP

The Liquefaction-Hazard Map shows areas of known or suspected liquefaction hazard in the St. George – Hurricane metropolitan area. The map does not integrate earthquake-ground motions with soil characteristics and depth to ground water, which is required to determine relative liquefaction potential (potential equals hazard plus opportunity) in susceptible soils. Consequently, this map does not differentiate ground-failure types or amounts, which are needed to fully assess the hazard and evaluate possible mitigation techniques.

This map is intended for general planning purposes to indicate where a liquefaction hazard may be present and to assist in regional-hazard evaluations. Requirements for liquefaction special studies are given in the International Building Code (IBC) (International Code Council, 2006a) and are implied in the International Residential Code (IRC) (International Code Council, 2006b), which applies to the design and construction of one- and two-family dwellings and townhouses. In Utah, both the IBC and IRC are adopted statewide. IBC Section 1802.2.6 (p. 343) requires a liquefaction evaluation if a structure is in Seismic Design Category C, and IBC Section 1802.2.7 (p. 343-344) requires a liquefaction evaluation and an assessment of potential consequences of any liquefaction if the structure is in Seismic Design Categories D, E, or F (see Earthquake-Ground-Shaking-Hazard text document, table 2). In general, seismic design categories in the St. George – Hurricane metropolitan area for structures built on unconsolidated materials fall into Seismic Design Categories C and D (see Earthquake-Ground-Shaking-Hazard text document), thus triggering the IBC requirement for a liquefaction evaluation. Although the IRC does not specifically mention liquefaction, IRC Section R401.4 (p. 67) leaves the need for soil tests up to the local building official in areas likely to have expansive, compressive, shifting, or other unknown soil characteristics, such as liquefiable soils.

IBC seismic design categories are determined on a site- or project-specific basis, and vary throughout the St. George – Hurricane metropolitan area depending on IBC site class, maximum considered earthquake ground motions, and the IBC Occupancy Category of the proposed structure (see Earthquake-Ground-Shaking Hazard text document). Occupancy categories are based on the nature of the structure's use and occupancy and are described in IBC Section 1604.5 (p. 280) and table 1604.5 (p. 281). The IBC specifies four occupancy categories (I, II, III, and IV). Occupancy Category I includes buildings and other structures that represent a low hazard to human life in the event of a failure. Occupancy Category II includes buildings and other structures except those listed in Occupancy Categories I, III, and IV. Occupancy Category III includes buildings and other structures that represent a substantial hazard to human life in the event of failure. Occupancy Category IV includes buildings and other structures designated as essential facilities.

Because the risk to human life and the requirement that certain essential structures remain functional during natural or other disasters varies by occupancy category, we recommend different levels of liquefaction evaluation for different occupancy categories based on mapped liquefaction susceptibility (see table below). We recommend detailed subsurface investigations for Occupancy Category II, III, and IV structures in moderate to very high liquefaction hazard areas; detailed subsurface investigations for Occupancy Category III and IV structures in low hazard areas; reconnaissance investigations for Occupancy Category II structures in low or not susceptible liquefaction areas, followed by a detailed investigation if the liquefaction hazard is determined to be moderate or greater; a reconnaissance evaluation only for Occupancy Category I structures in moderate to very high liquefaction areas; and no investigation for Occupancy Category I buildings in low or not susceptible areas. Martin and Lew (1999) provide guidelines for conducting both reconnaissance (screening) and detailed (quantitative) liquefaction evaluations.

Recommended Requirements for Liquefaction-Hazard Investigations

Liquefaction Susceptibility	IBC Occupancy Category			
	I	II	III	IV
	Buildings and Other Structures that Represent a Low Hazard to Human Life in the Event of Failure (IBC)	All Other Buildings and Structures (Occupancy Category II Structures and IV (Includes One- and Two-Family Dwellings and Townhouses) (IRC)	Buildings and Other Structures that Represent a Substantial Hazard to Human Life in the Event of Failure (IBC)	Buildings and Other Structures Designated as Essential Facilities (IBC)
Very High	Reconnaissance[1]	Detailed[2]	Detailed	Detailed
High, Moderate	Reconnaissance	Detailed	Detailed	Detailed
Low	No	Reconnaissance	Detailed	Detailed
Not Susceptible	No	Reconnaissance	Reconnaissance	Reconnaissance

[1]Reconnaissance evaluation; if a moderate to very high liquefaction susceptibility is found, at a minimum, disclosure is recommended and detailed evaluations may be performed at the discretion of the owner. [2]Detailed evaluation necessary; a detailed liquefaction evaluation should be interdisciplinary in nature and performed by qualified, experienced geotechnical engineers and engineering geologists working as a team.

MAP LIMITATIONS

The Liquefaction-Hazard Map is based on limited geological, geotechnical, and hydrological data; site-specific studies are required to produce more detailed information. The map also depends on the quality of those data, which varies throughout the study area. The mapped boundaries between liquefaction-hazard categories are approximate and subject to change with additional information. The liquefaction hazard at any particular site may be different than shown because of geological and hydrologic variations within a map unit, gradational and approximate map-unit boundaries, and the map scale. Small, localized areas of higher or lower liquefaction hazard may exist anywhere within the study area, but their identification is precluded because of limitations of either data or map scale. Seasonal and long-term fluctuations in ground-water levels can affect liquefaction hazard at any given site. The map is not intended for use at scales other than the published scale, and is designed for use in general planning to indicate the need for site-specific studies.

HAZARD REDUCTION

Although potentially costly when not recognized and properly accommodated in project design, problems associated with liquefaction rarely are life threatening. As with most geologic hazards, early recognition and avoidance is the most effective way to mitigate this hazard. However, avoidance may not always be a viable or cost-effective hazard-reduction option and other techniques are available to reduce liquefaction hazards (National Research Council, 1985).

Liquefaction damage may be reduced either by improving site conditions to lower liquefaction hazard (for example, compacting or replacing soil; installing drains or pumps to lower the water table) or by designing structures to withstand liquefaction effects (using deep foundations or structural reinforcement). Existing structures threatened by liquefaction may be retrofitted to reduce the potential for damage. Because the cost of reducing liquefaction hazards for existing structures may be high relative to their value, and because liquefaction is generally not a life-threatening hazard, the UGS considers it prudent, although not essential, to reduce liquefaction hazards for existing structures, unless significant ground deformation (lateral spreading) is anticipated and the structures fall into IBC Occupancy Categories III or IV, in which case we do recommend retrofitting. At a minimum, we recommend disclosure of study results if studies confirm a moderate to very high liquefaction potential. Disclosure allows prospective home buyers to make an informed decision on the amount of risk they are willing to accept.