UTAH GEOLOGICAL SURVEY
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PLATE 4

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

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For use at 1:24,000 scale only. The Utah Geological Survey does not guarantee accuracy or completeness of data.

14°
TRUE NORTH
MAGNETIC NORTH
Approximate mean declination, 2007

UTAH
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: Existing landslides (Category A).

H High: Areas where Category B geologic units crop out on slopes greater than 15 percent (8.5º).

M_C Moderate C: Areas where Category C geologic units crop out on slopes greater than 20 percent (11.3º).

M_B Moderate B: Areas where Category B geologic units crop out on slopes less than 15 percent (8.5º).

L Low: Areas where Category D geologic units crop out on slopes greater than 30 percent (16.7º).

Landslide Susceptibility of Geologic Units

Susceptibility Category	Geologic Units [1]	Comments
A	Existing landslides	Existing slope failures are considered the most likely units in which landsliding may initiate.
B	Petrified Forest Mbr., Chinle Fm.	This rock unit consists chiefly of bentonitic clay, which is highly expansive and has low shear strength especially when wet. This unit includes the greatest number of landslides mapped in the study area.
C	Woods Ranch Mbr., Toroweap Fm.; Harrisburg Mbr., Kaibab Fm.; Shinarump Mbr. and red members, Moenkopi Fm.; Whitmore Point Mbr., Moenave Fm.; Temple Cap Fm.; Carmel Fm.; Cretaceous bentonitic beds; Iron Springs Fm.	These bedrock units contain varying amounts of gypsum, shale, claystone, mudstone, siltstone, or a combination of the above that imparts weak shear strength characteristics to the units, at least locally, and makes them susceptible to slope failure. These units contain the second greatest number of landslides in the study area.
D	Remaining bedrock and unconsolidated geologic units in the study area.	These geologic units either contain a higher percentage of stronger rock types, crop out on slopes too low to generate slope failures, or generate failures that are too small to map at 1:24,000-scale. As a result, they exhibit few or no mapped landslides. Some landslides identified within these units are likely the result of failures in underlying, weaker geologic units.

[1] Refer to UGS 1:24,000-scale geologic maps (see SOURCES OF DATA and REFERENCES in accompanying text) for a description of map units.

DISCUSSION

Landslide is a general term that refers to the gradual to rapid movement of a mass of rocks, debris, or earth down a slope under the force of gravity. Landslides can be both damaging and deadly. The U.S. Geological Survey estimates that in the United States, landslides on average cause $1-2 billion in damages and more than 25 deaths annually. In the St. George – Hurricane metropolitan area, landslides have disrupted transportation routes, houses, and commercial sites, and public utilities. Rock and soil units susceptible to slope failure underlie parts of the study area, as evidenced by the number of landslides identified there. As defined for this study, landslides are either rotational or translational. Rotational slides have curved, concave rupture surfaces, which may be either shallow or deep seated, along which the slide mass may move with little internal disruption. Translational slides move along planar or gently undulating shear surfaces and typically slide out over the original ground surface. Translational slides commonly utilize discontinuities such as bedding planes, joints, or faults as a surface of rupture. Both rotational and translational slides may range from very slow to rapid.

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

USING THIS MAP

The Landslide-Hazard Map shows areas of relative landslide hazard, and provides a basis for requiring site-specific hazard studies. Site-specific studies can resolve uncertainties inherent in generalized geologic-hazard mapping and help ensure safety by identifying the need for hazard mitigation.

The Landslide-Hazard Map identifies areas based on previous landslide history, material characteristics, and slope where site-specific, slope-stability conditions (material strength, orientation of bedding or fractures, ground-water conditions, erosion or undercutting) should be evaluated prior to development. The level of investigation needed at a given site depends on the relative hazard and the nature of the proposed development (structure size and placement, required cutting and filling, and changes in ground-water conditions). A valid landslide-hazard evaluation must address all pertinent conditions that *could* affect, or be affected by, the proposed development, including earthquake ground shaking. This can only be accomplished through the proper identification and interpretation of site-specific geologic conditions and processes (Hylland, 1996). Such conditions in areas near to the site that may affect the site must also be considered.

Landslide-hazard studies must be interdisciplinary in nature and performed by qualified, experienced geotechnical engineers and engineering geologists working as a team. Utah Geological Survey Circular 92 Guidelines for Evaluating Landslide Hazards in Utah (Hylland, 1996) presents minimum standards for performing landslide-hazard evaluations in Utah. Circular 92 outlines a phased approach to slope-stability studies beginning with a geologic evaluation and progressing through reconnaissance and detailed geotechnical-engineering evaluations, as needed, to mitigation design and construction monitoring. Lund and others (2002) and Black and others (1998) provide additional guidance for evaluating landslide hazards. Local jurisdictions may adopt more stringent requirements for slope-stability evaluations, as they deem necessary, to meet local needs and conditions. For example, the City of St. George requires studies on all slopes greater than 15 percent that lie within designated Hillside Development Overlay Zones, and that requirement takes precedence over the recommendations in this report. The UGS recommends that the following site-specific investigations be conducted for each of the landslide-hazard categories.

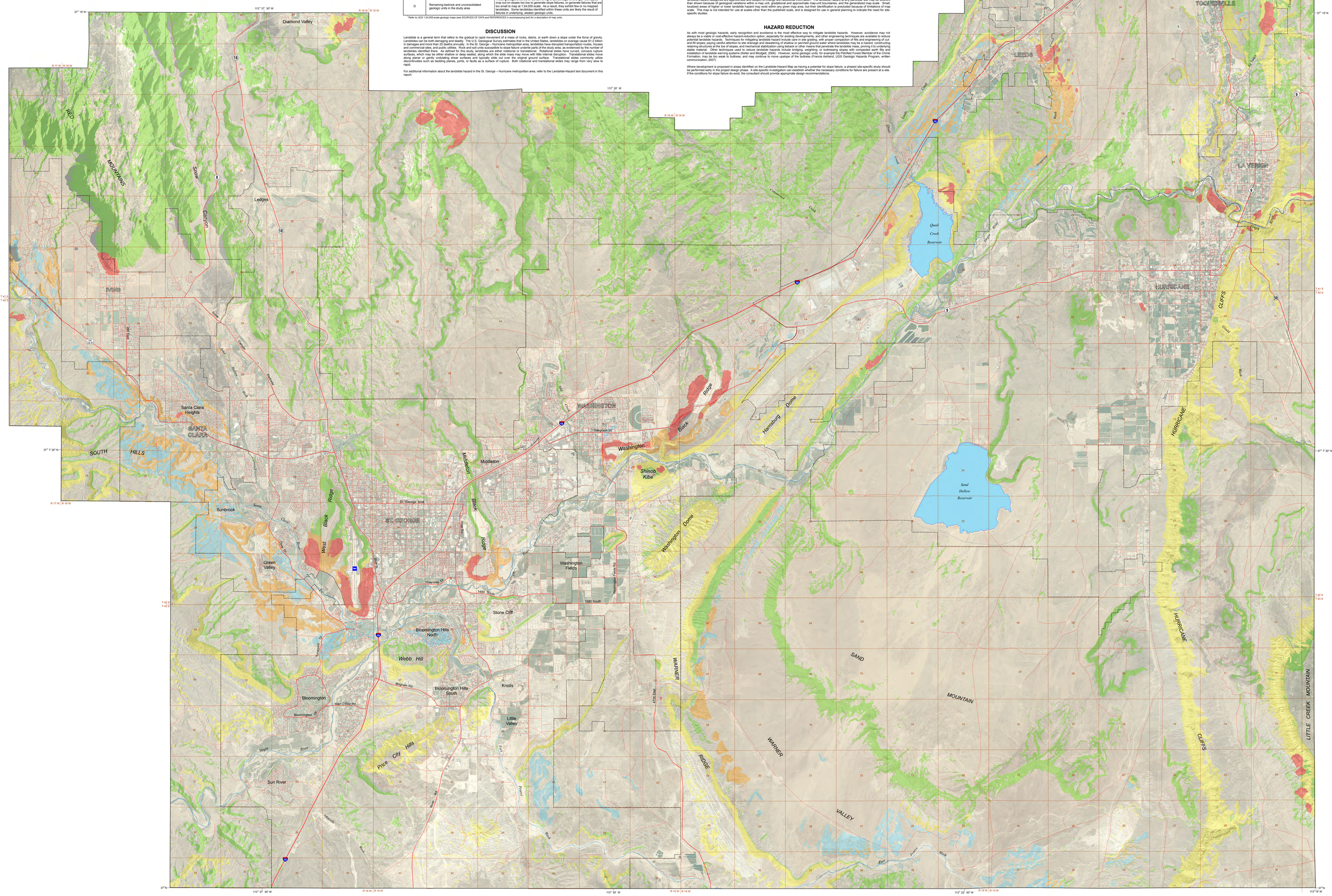
Recommended Site-Specific Study

Map Unit	Hazard Category	
VH	Very High	Detailed engineering geologic and geotechnical-engineering evaluation necessary. Predevelopment stabilization recommended for historical and geologically young (late Pleistocene) landslides.
H	High	Detailed engineering geologic and geotechnical-engineering evaluation necessary.
M	Moderate	Geologic evaluation and reconnaissance geotechnical-engineering evaluation necessary; detailed engineering geologic and geotechnical-engineering evaluation may be necessary.
L	Low	Geologic evaluation and reconnaissance geotechnical-engineering evaluation necessary, detailed geotechnical-engineering evaluation generally not necessary.

MAP LIMITATIONS

The Landslide-Hazard Map is based on limited geological, geotechnical, and hydrological data; site-specific studies are required to produce more detailed geotechnical information. The map also depends on the quality of the data used in the analysis throughout the study area. The indicated boundaries of the landslide-hazard categories are approximate and subject to change with additional information. The landslide hazard at any particular site may be different than shown because of geological variations within a map unit, gradational and approximate map-unit boundaries, and the generalized map scale. Small, localized areas of higher or lower landslide hazard may exist within any given map area, but their identification is precluded because of limitations of map scale. This 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

As with most geologic hazards, early recognition and avoidance is the most effective way to mitigate landslide hazards. However, avoidance may not always be a viable or cost-effective hazard-reduction option, especially for existing developments, and other engineering techniques are available to reduce potential landslide hazards. Techniques for mitigating landslide hazard include care in site grading, with proper compaction of fills and engineering of cut-and-fill slopes; paying careful attention to site drainage and dewatering of shallow or perched ground water where landslides may be a hazard; constructing retaining structures at the toe of slopes; and mechanical stabilization using tieback or other means that penetrate the landslide mass, pinning it to underlying stable material. Other techniques used to reduce landslide hazards include bridging, weighting, or buttressing slopes with compacted earth fills and installation of landslide warning systems (Keller and Blodgett, 2006). However, some geologic units, for example the Petrified Forest Member of the Chinle Formation, may be too weak to buttress, and may continue to move upslope of the buttress (Francis Ashland, UGS Geologic Hazards Program, written communication, 2007).

Where development is proposed in areas identified on the Landslide-Hazard Map as having a potential for slope failure, a phased site-specific study should be performed early in the project design phase. A site-specific investigation can establish whether the necessary conditions for failure are present at a site. If the conditions for slope failure do exist, the consultant should provide appropriate design recommendations.