UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
National Park Service

Plate 2
Utah Geological Survey Special Study 133
Zion National Park Geologic-Hazard Study Area, Washington and Kane Counties, Utah

ROCK-FALL HAZARD
ZION NATIONAL PARK GEOLOGIC-HAZARD STUDY AREA

By

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2010

This geologic-hazard map was funded by the Utah Geological Survey and the U.S. Department of the Interior, National Park Service. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

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Base map consists of U.S. Department of Agriculture 2006 National Agricultural Imagery Program natural color aerial photography and shaded relief generated from digital elevation data acquired from the Utah Automated Geographic Reference Center.

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

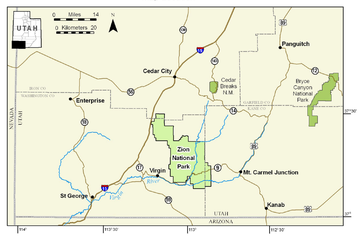
SYMBOLS

- Zion National Park Geologic-Hazard Study Area boundary
- Zion National Park boundary
- County boundary
- State highway
- Minor road
- Foot trail
- Existing park structure
- Area not studied

EXPLANATION

- High rock-fall hazard: Areas where steep slopes below resistant cliff-forming bedrock units provide acceleration and runout zones littered with abundant rock-fall boulders ≥1.5 feet in diameter. Such large boulders can damage property and threaten lives. Rock units in high-hazard areas include the Shinarump Member of the Chinle Formation, Springdale Sandstone Member of the Kayenta Formation, Navajo Sandstone, Lamb Point Tongue Member of the Navajo Sandstone, and Quaternary basalt flows. Where jointed or fractured, these rock units can produce large (>30 feet in long dimension) angular boulders.
- Moderate rock-fall hazard: Areas where (1) slopes provide sufficient relief to create an acceleration zone, but where only sparse rock-fall debris is present on slopes or in the runout zone at the base of the slope; typically bedrock units in these areas crop out in the slope instead of forming a capping unit; (2) talus/cliff-retreat deposits form steep slopes due to erosion and previous rock-fall boulders on those slopes may remobilize; or (3) resistant, cliff-forming bedrock units extend to the canyon floor with no underlying acceleration zone; rock falls in these areas tend to fall straight down and stop immediately at the base of the cliff.
- Low rock-fall hazard: Areas where fine-grained, comparatively soft bedrock units such as mudstone and shale crop out on steep slopes, or where rock units typical of moderate- or high-hazard categories crop out in areas of low to moderate relief. Low rock-fall hazard areas typically contain sparse rock sources of limited extent.
- Low probability, high hazard: Canyon bottoms subject to very large low-probability, high-hazard rock falls. These areas are typically bordered by towering, jointed Navajo Sandstone cliffs. The largest of these events (fin collapse/rock avalanche) may involve thousands of cubic yards of material, are typically sourced high on canyon walls, and have recurrence intervals likely measured in thousands of years. Runout zones can extend much farther than for the smaller, more frequent rock-fall events.

Map Location



SCALE 1:24,000

1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0.5 0 1 KILOMETER

12°9' TRUE NORTH / MAGNETIC NORTH
Approximate mean declination, 2009

DISCUSSION

Rock fall is a natural mass-wasting process that involves the dislodging and downslope movement of individual rocks and small rock masses (Varnes, 1978; Cruden and Varnes, 1996). Rock falls pose a safety threat because a falling or rolling boulder can cause significant damage to property, roadways, and vehicles as well as injury or even loss of life (see, for example, Hylland, 1995; Keller and Blodgett, 2006; Elliot and Giraud, 2009; Lund and others, 2009). Rock-fall hazards exist where a source of rock is present above slopes steep enough to allow rapid downslope movement of dislodged rocks by falling, rolling, and bouncing.

Rock-fall hazard is based on a number of factors including geology, topography, and climate. Rock-fall sources include bedrock outcrops or boulders on steep mountainsides or near the edges of escarpments such as cliffs, bluffs, and terraces. Talus cones and scree-covered slopes are indicators of a high rock-fall hazard, but other less obvious areas may also be vulnerable.

Rock falls are initiated by freeze/thaw action, rainfall, weathering and erosion of the rock and/or surrounding material, and root growth. Rock fall is also the most common type of mass movement caused by earthquakes. Keefer (1984) indicates that earthquakes as small as magnitude (M) 4.0 can trigger rock falls. All nine of Utah's historical earthquakes of M 5 or greater have caused rock falls. Sources of earthquake ground shaking that might produce rock falls in the Zion National Park Geologic-Hazard Study Area include a large earthquake on the Hurricane fault west of the study area, or a moderate earthquake (≤ M 6.5) within the study area itself (Ivan Wong, URS Corporation, written communication, 2008).

Slope modification, such as cuts for roads and building pads or clearing of slope vegetation for development, can increase or create a local rock-fall hazard. However, in many cases a specific triggering event is not apparent. Although not well documented, rock falls in Utah appear to occur more frequently during spring and summer months. This is likely due to spring snowmelt, summer cloudburst storms, and large daily temperature variations (Castleton, 2009).

Rock fall is the most common mass-movement type in the Zion National Park Geologic-Hazard Study Area. The combination of steep slopes capped by well-jointed, resistant bedrock formations provides ample opportunity to generate rock falls. Bedrock units particularly susceptible to rock fall in the study area include the Shinarump Member of the Chinle Formation; Springdale Member of the Kayenta Formation; Lamb Point Tongue Member of the Navajo Sandstone; other ledge- and cliff-forming strata in the Moenkopi, Moenave, and Kayenta Formations; and the massive, pervasively jointed, cliff-forming Navajo Sandstone. Rock falls are particularly prevalent and hazardous where softer, more easily eroded bedrock units crop out on slopes below stronger, more resistant bedrock formations. Erosion of the underlying soft units and subsequent undercutting of the more resistant bedrock formations triggers many rock falls.

Talus deposits blanket steep to moderate slopes throughout the study area. These deposits are derived from upslope ledges and cliffs and consist chiefly of accumulations of poorly sorted, coarse, angular blocks of various sizes. The boulders in talus deposits may exceed 30 feet in long dimension (Biek and others, 2003). The widespread distribution of talus and the direct relation of talus deposits to the rock-fall process attest to the widespread extent of the rock-fall hazard in the study area.

For additional information about the rock-fall hazard in the Zion National Park Geologic-Hazard Study Area, refer to the Rock-Fall Hazard chapter in this report.

USING THIS MAP

This map shows areas of relative rock-fall hazard in the Zion National Park Geologic-Hazard Study Area. Site-specific, rock-fall-hazard investigations should be performed for future development in the study area as recommended in the table below. Existing park facilities, campgrounds, and high-use trails should be evaluated as time and funding allow, also as recommended in the table below. A geotechnical consultant should provide design or site-preparation recommendations as necessary to reduce the rock-fall hazard. These investigations can resolve uncertainties inherent in generalized hazard mapping and help ensure safety by identifying the need for rock-fall-resistant design or mitigation.

For some areas, site-specific assessment may only require a field geologic evaluation to determine if a rock-fall source is present. However, if a source is identified, additional work to adequately assess the hazard is needed. Rock-fall sources should be evaluated for the following parameters: rock type, joints and other fractures, bedding planes, and potential clast size. Slopes below rock sources should be evaluated for slope angle, aspect, substrate, surface roughness, and vegetation. Previous rock-fall deposits should be evaluated for distribution, clast-size range, amount of embedding, and weathering of rock-fall boulders. In addition, evaluation of the runout zone below a source can be estimated using a simple two-dimensional model, such as the Colorado Rock Fall Simulation Program (Jones and others, 2000).

The hazard presented by large rock falls in areas designated "low probability, high hazard" is high, but the likelihood of such an event at any particular location is low. These areas are considered subject only to very infrequent events. Site-specific investigations are not recommended for future development in these areas.

Recommended Requirements for Site-Specific Investigations Related to Rock-Fall Hazards to Protect Life and Safety

Hazard Potential	Occupancy Category[1]				
	I	II		III	IV
	Buildings and Other Structures That Represent a Low Hazard to Human Life in the Event of Failure	Family Dwellings and Campgrounds	All Other Buildings and Structures Except Those Listed in Groups I, III, and IV	Buildings and Other Structures That Represent a Substantial Hazard to Human Life in the Event of Failure	Buildings and Other Structures Designated as Essential Facilities
High, Moderate	No[2]	Yes	Yes	Yes	Yes
Low	No[2]	Yes	Yes	Yes	Yes
None	No	No	No	No	No

[1]Modified from International Code Council (2009). [2]Property damage possible, but little threat to life safety.

MAP LIMITATIONS

The map boundaries between rock-fall-hazard categories are approximate and subject to change as new information becomes available. The rock-fall 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 map scale. Small, localized areas of higher or lower rock-fall hazard may exist within any given map area, but their identification is precluded because of limitations of the map scale. This map is not intended for use at scales larger than the published scale, and is designed for use in general planning and design to indicate the need for site-specific investigations.

HAZARD REDUCTION

Early recognition and avoiding areas subject to rock fall are the most effective means of reducing rock-fall hazard. However, avoidance may not always be a viable or cost-effective option, especially for existing facilities, and other techniques are available to reduce potential rock-fall damage. These may include, but are not limited to, rock stabilization, engineered structures, and modification of at-risk structures or facilities. Rock-stabilization methods are physical means of reducing the hazard at its source using rock bolts and anchors, steel mesh, or shotcrete on susceptible outcrops. Engineered catchment or deflection structures such as berms or benches can be placed below source areas, or at-risk structures themselves could be designed to stop, deflect, retard, or retain falling rocks. Conversely, after careful consideration of the hazard, it may be possible to conclude that the level of risk is acceptable and that no hazard-reduction measures are required.

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