UTAH GEOLOGICAL SURVEY
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COLLAPSIBLE-SOIL SUSCEPTIBILITY ZION NATIONAL PARK GEOLOGIC-HAZARD STUDY AREA

By

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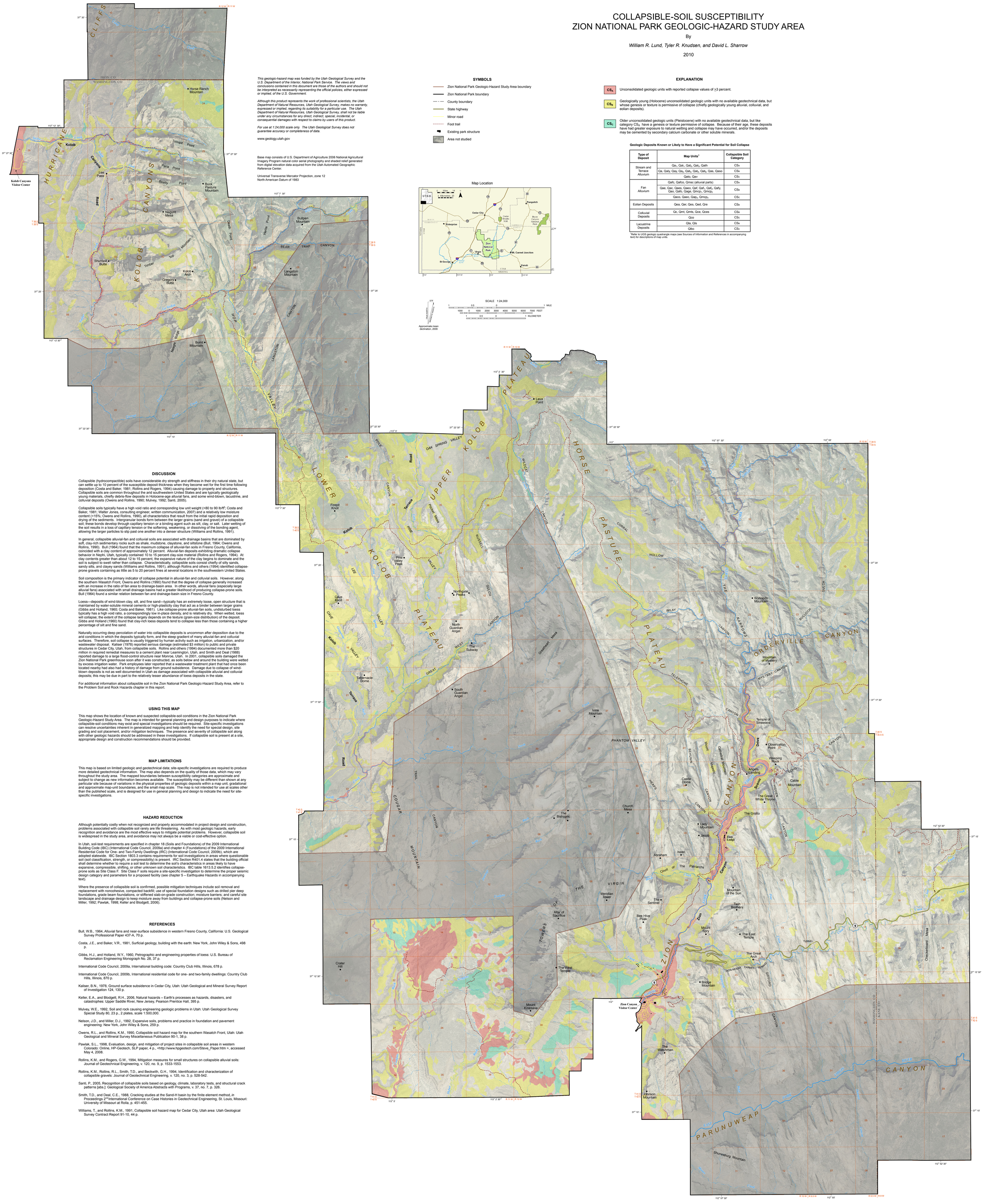

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Base map consists of U.S. Department of Agriculture 2006 National Agricultural Imagery Program natural color aerial photography and shaded relief generated from digital elevation data acquired from the Utah Automated Geographic Reference Center.

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

CS_A — Unconsolidated geologic units with reported collapse values of ≥3 percent.

CS_B — Geologically young (Holocene) unconsolidated geologic units with no available geotechnical data, but whose genesis or texture is permissive of collapse (chiefly geologically young alluvial, colluvial, and eolian deposits).

CS_C — Older unconsolidated geologic units (Pleistocene) with no available geotechnical data, but like category CS_B, have a genesis or texture permissive of collapse. Because of their age, these deposits have had greater exposure to natural wetting and collapse may have occurred, and/or the deposits may be cemented by secondary calcium carbonate or other soluble minerals.

Geologic Deposits Known or Likely to Have a Significant Potential for Soil Collapse

Type of Deposit	Map Units[1]	Collapsible Soil Category
Stream and Terrace Alluvium	Qa_1, Qal_1, Qat_2, Qat_3, Qath	CS_A
	Qa, Qaly, Qay, Qa_2, Qat_4, Qat_5, Qat_6, Qas, Qaso	CS_B
	Qato, Qav	CS_C
Fan Alluvium	Qafc, Qafco, Qmsc (alluvial parts)	CS_A
	Qae, Qac, Qaes, Qaeo, Qaf, Qaf_1, Qaf_2, Qafy, Qao, Qafo, Qagé, $Qmcp_1$, $Qmcp_2$	CS_B
	Qaco, Qaec, Qap_2, $Qmcp_3$	CS_C
Eolian Deposits	Qea, Qer, Qes, Qed, Qre	CS_B
Colluvial Deposits	Qc, Qmt, Qmts, Qce, Qces	CS_B
	Qco	CS_C
Lacustrine Deposits	Qla, Qls	CS_B
	Qlbc	CS_C

[1]Refer to UGS geologic quadrangle maps (see Sources of Information and References in accompanying text) for descriptions of map units.

DISCUSSION

Collapsible (hydrocompactible) soils have considerable dry strength and stiffness in their dry natural state, but can settle up to 10 percent of the susceptible deposit thickness when they become wet for the first time following deposition (Costa and Baker, 1981; Rollins and Rogers, 1994) causing damage to property and structures. Collapsible soils are common throughout the arid southwestern United States and are typically geologically young materials, chiefly debris-flow deposits in Holocene-age alluvial fans, and some wind-blown, lacustrine, and colluvial deposits (Owens and Rollins, 1990; Mulvey, 1992; Santi, 2005).

Collapsible soils typically have a high void ratio and corresponding low unit weight (<80 to 90 lb/ft^3; Costa and Baker, 1981; Walter Jones, consulting engineer, written communication, 2007) and a relatively low moisture content (<15%; Owens and Rollins, 1990), all characteristics that result from the initial rapid deposition and drying of the sediments. Intergranular bonds form between the larger grains (sand and gravel) of a collapsible soil; these bonds develop through capillary tension or a binding agent such as silt, clay, or salt. Later wetting of the soil results in a loss of capillary tension or the softening, weakening, or dissolving of the bonding agent, allowing the larger particles to slip past one another into a denser structure (Williams and Rollins, 1991).

In general, collapsible alluvial-fan and colluvial soils are associated with drainage basins that are dominated by soft, clay-rich sedimentary rocks such as shale, mudstone, claystone, and siltstone (Bull, 1964; Owens and Rollins, 1990). Bull (1964) found that the maximum collapse of alluvial-fan soils in Fresno County, California, coincided with a clay content of approximately 12 percent. Alluvial-fan deposits exhibiting dramatic collapse behavior in Nephi, Utah, typically contained 10 to 15 percent clay-size material (Rollins and Rogers, 1994). At clay contents greater than about 12 to 15 percent, the expansive nature of the clay begins to dominate and the soil is subject to swell rather than collapse. Characteristically, collapsible soils consist chiefly of silty sands, sandy silts, and clayey sands (Williams and Rollins, 1991), although Rollins and others (1994) identified collapse-prone gravels containing as little as 5 to 20 percent fines at several locations in the southwestern United States.

Soil composition is the primary indicator of collapse potential in alluvial-fan and colluvial soils. However, along the southern Wasatch Front, Owens and Rollins (1990) found that the degree of collapse generally increased with an increase in the ratio of fan area to drainage-basin area. In other words, alluvial fans (especially large alluvial fans) associated with small drainage basins had a greater likelihood of producing collapse-prone soils. Bull (1964) found a similar relation between fan and drainage-basin size in Fresno County.

Loess—deposits of wind-blown clay, silt, and fine sand—typically has an extremely loose, open structure that is maintained by water-soluble mineral cements or high-plasticity clay that act as a binder between larger grains (Gibbs and Holland, 1960; Costa and Baker, 1981). Like collapse-prone alluvial-fan soils, undisturbed loess typically has a high void ratio, a correspondingly low in-place density, and is relatively dry. When wetted, loess will collapse; the extent of the collapse largely depends on the texture (grain-size distribution) of the deposit. Gibbs and Holland (1960) found that clay-rich loess deposits tend to collapse less than those containing a higher percentage of silt and fine sand.

Naturally occurring deep percolation of water into collapsible deposits is uncommon after deposition due to the arid conditions in which the deposits typically form, and the steep gradient of many alluvial-fan and colluvial surfaces. Therefore, soil collapse is usually triggered by human activity such as irrigation, urbanization, and/or wastewater disposal. Kaliser (1978) reported serious damage (estimated $3 million) to public and private structures in Cedar City, Utah, from collapsible soils. Rollins and others (1994) documented more than $20 million in required remedial measures to a cement plant near Leamington, Utah, and Smith and Deal (1988) reported damage to a large flood-control structure near Monroe, Utah. In 2001, collapsible soils damaged the Zion National Park greenhouse soon after it was constructed, as soils below and around the building were wetted by excess irrigation water. Park employees later reported that a wastewater treatment plant that had once been located nearby had also had a history of damage from ground subsidence. Damage due to collapse of wind-blown deposits is not as well documented in Utah as damage associated with collapsible alluvial and colluvial deposits; this may be due in part to the relatively lesser abundance of loess deposits in the state.

For additional information about collapsible soil in the Zion National Park Geologic-Hazard Study Area, refer to the Problem Soil and Rock Hazards chapter in this report.

USING THIS MAP

This map shows the location of known and suspected collapsible-soil conditions in the Zion National Park Geologic-Hazard Study Area. The map is intended for general planning and design purposes to indicate where collapsible-soil conditions may exist and special investigations should be required. Site-specific investigations can resolve uncertainties inherent in generalized mapping and help identify the need for special design, site grading and soil placement, and/or mitigation techniques. The presence and severity of collapsible soil along with other geologic hazards should be addressed in these investigations. If collapsible soil is present at a site, appropriate design and construction recommendations should be provided.

MAP LIMITATIONS

This map is based on limited geologic and geotechnical data; site-specific investigations are required to produce more detailed geotechnical information. The map also depends on the quality of those data, which may vary throughout the study area. The mapped boundaries between susceptibility categories are approximate and subject to change as new information becomes available. The susceptibility may be different than shown at any particular site because of variations in the physical properties of geologic deposits within a map unit, gradational and approximate map-unit boundaries, and the small map scale. The map is not intended for use at scales other than the published scale, and is designed for use in general planning and design to indicate the need for site-specific investigations.

HAZARD REDUCTION

Although potentially costly when not recognized and properly accommodated in project design and construction, problems associated with collapsible soil rarely are life threatening. As with most geologic hazards, early recognition and avoidance are the most effective ways to mitigate potential problems. However, collapsible soil is widespread in the study area, and avoidance may not always be a viable or cost-effective option.

In Utah, soil-test requirements are specified in chapter 18 (Soils and Foundations) of the 2009 International Building Code (IBC) (International Code Council, 2009a) and chapter 4 (Foundations) of the 2009 International Residential Code for One- and Two-Family Dwellings (IRC) (International Code Council, 2009b), which are adopted statewide. IBC Section 1803.3 contains requirements for soil investigations in areas where questionable soil (soil classification, strength, or compressibility) is present. IRC Section R401.4 states that the building official shall determine whether to require a soil test to determine the soil's characteristics in areas likely to have expansive, compressible, shifting, or other unknown soil characteristics. IBC table 1613.5.2 identifies collapse-prone soils as Site Class F. Site Class F soils require a site-specific investigation to determine the proper seismic design category and parameters for a proposed facility (see chapter 5 – Earthquake Hazards in accompanying text).

Where the presence of collapsible soil is confirmed, possible mitigation techniques include soil removal and replacement with noncohesive, compacted backfill; use of special foundation designs such as drilled pier deep foundations, grade beam foundations, or stiffened slab-on-grade construction; moisture barriers; and careful site landscape and drainage design to keep moisture away from buildings and collapse-prone soils (Nelson and Miller, 1992; Pawlak, 1998; Keller and Blodgett, 2006).

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