Plate 6
Utah Geological Survey Special Study 148
State Route 9 Corridor Geologic-Hazard Study Area

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

EXPLANATION

Soil

GS — Includes gypsum-bearing soils mapped by the Natural Resources Conservation Service (NRCS) (Mortensen and others, 1977). The gypsum in the soils is largely pedogenic (formed by dissolution and re-precipitation at depth during the soil-forming process) and its presence may not be apparent at the ground surface.

Rock

GR_A — Bedrock units that contain abundant gypsum, often in laterally continuous horizons as much as several feet thick. These units and the soils derived from them are commonly associated with dissolution and collapse features. This category includes the Shnabkaib Member of the Moenkopi Formation and the Harrisburg Member of the Kaibab Formation.

GR_B — Bedrock units that lack massive gypsum horizons, but contain thin to medium beds and veins of gypsum interspersed with other rock types. These units and the soils derived from them may contain sufficient gypsum locally to cause foundation distress or other problems. This category includes the Timpoweap, Virgin Limestone, lower red, middle red, and upper red members of the Moenkopi Formation; the Kayenta Formation; and the Dinosaur Canyon Member of the Moenave Formation.

INTRODUCTION

Gypsum-bearing soil and rock are subject to dissolution of the gypsum ($CaSO_4 \cdot 2H_2O$), which causes a loss of internal structure and volume. Where the amount of gypsum is $\geq$10 percent, dissolution can result in localized land subsidence and sinkhole formation (Mulvey, 1992; Muckel, 2004; Santi, 2005). Dissolution of gypsum may lead to foundation collapse problems and may affect roads, dikes, underground utilities, and other infrastructure. Gypsum dissolution can be greatly accelerated by application of water, such as that provided by reservoirs; septic-tank drain fields; street, roof, or parking lot runoff; and irrigation (Martinez and others, 1998). Gypsum is also a weak material with low bearing strength and is not well suited as a foundation material. Additionally, when gypsum weathers it forms dilute sulfuric acid and sulfate, which can corrode and weaken unprotected concrete and metals. Type V or other sulfate-resistant cement is typically required in areas having abundant gypsum, as is corrosion protection for metals.

SOURCES OF INFORMATION

Sources of information used to evaluate gypsiferous soil and rock in the State Route 9 Corridor Geologic-Hazard Study Area (SR-9 study are) include (1) 40 geotechnical reports on file with the National Park Service (NPS), the Utah Department of Transportation (UDOT), and the towns of Springdale and Virgin, (2) Natural Resources Conservation Service (NRCS) (formerly Soil Conservation Service) *Soil Survey of Washington County Area, Utah* (Mortensen and others, 1977), (3) the four Utah Geological Survey (UGS) 1:24,000-scale geologic quadrangle maps that cover the study area (Virgin [Hayden and Sable, 2008], Springdale West [Willis and others, 2002], Springdale East [Doelling and others, 2002], and Smithsonian Butte [Moore and Sable, 2001]), (4) *Engineering Geology of the St. George Area, Washington County, Utah* (Christenson and Deen, 1983), (5) "Geologic Hazards of the St. George Area, Washington County, Utah" (Christenson, 1992), (6) *Engineering Geologic Map Folio, Springdale, Washington County, Utah* (Solomon, 1996), (7) *Geologic Hazards and Adverse Construction Conditions, St. George–Hurricane Metropolitan Area, Washington County, Utah* (Lund and others, 2008), and (8) *Geologic Hazards of the Zion National Park Geologic-Hazard Study Area, Washington and Kane Counties, Utah* (Lund and others, 2010).

DESCRIPTION

In the SR-9 study area, gypsum is an important component of the Shnabkaib Member of the Moenkopi Formation (figure 1) and the Harrisburg Member of the Kaibab Formation. Gypsum is present in lesser amounts in the Timpoweap, Virgin Limestone, lower red, middle red, and upper red members of the Moenkopi Formation; the Kayenta Formation; and the Dinosaur Canyon Member of the Moenave Formation. Additionally, residual and colluvial soils derived from these bedrock units may contain locally significant pedogenic gypsum. However, because gypsum is typically concentrated in subsurface horizons by soil-forming processes, problem soils may be difficult to recognize in the absence of subsurface exploration.

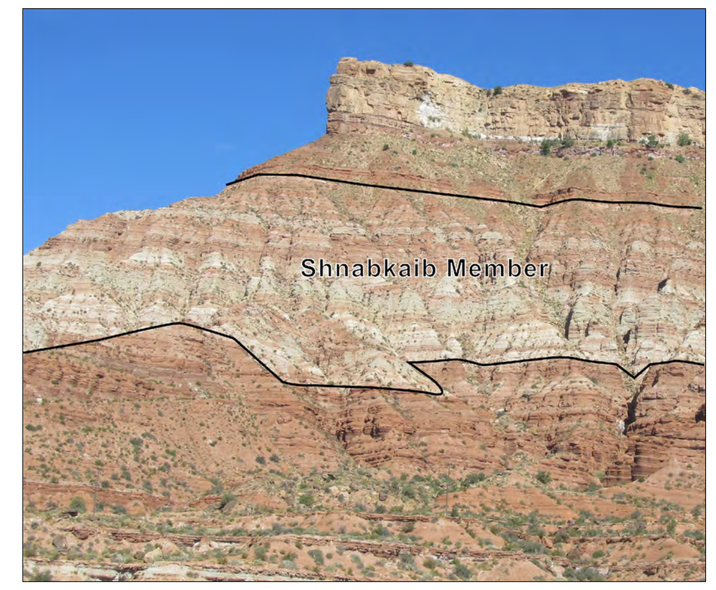


Figure 1. *Gypsum-rich Shnabkaib Member of the Moenkopi Formation near Virgin.*

GYPSUM DISSOLUTION

Gypsum dissolution in bedrock is common in southwestern Utah. Dissolution of gypsum (Shnabkaib Member of the Moenkopi Formation) was an important factor in the January 1, 1989, failure of the Quail Creek dike near Hurricane, Utah (figure 2; Gourley, 1992). Elsewhere in the region, gypsum solution caverns as much as several feet in diameter have formed in susceptible bedrock units. The entire flows of the Virgin River and La Verkin Creek have been captured by sinkholes that opened in their streambeds (Harrisburg Member of the Kaibab Formation) (Everitt and Einert, 1994; Lund, 1997). In St. George, a bulldozer broke through the roof of a cavern and was suspended by its front blade and back ripper (J and J Construction Company, personal communication, 1995, as reported in Higgins and Willis, 1995). David Black (Black, Miller, and Associates, personal communication, 1995, as reported in Higgins and Willis, 1995) reported honeycomb pedogenic gypsum with solution cavities as much as 2 feet wide in an excavation for a swimming pool in central St. George. Black (Rosenberg Associates, written communication, 2012) stated that honeycomb structure caused by gypsum dissolution in both rock and soil can extend to as much as 10 feet below the ground surface in gypsum-susceptible areas in southwestern Utah and may lead to collapse-prone foundation conditions.

Figure 2. *Quail Creek dike failure, January 1, 1989, in southwestern Utah was due in part to gypsum dissolution in the underlying Shnabkaib Member of the Moenkopi Formation (photo credit Ben Everitt).*

CORROSIVE SOIL AND ROCK

Gypsum is the most common sulfate mineral in soils in the western United States (Muckel, 2004). Gypsum is soluble and along with associated sulfates, such as sodium sulfate and magnesium sulfate, can dissolve in water to form a weak acid solution that is corrosive to concrete and metals in areas where the amount of soil gypsum is one percent or greater (Muckel, 2004). The ions within the acid react chemically with the cement (a base) in the concrete. Gypsum-induced corrosion of unprotected concrete slabs, walls, and masonry blocks is widespread in southwestern Utah (figure 3), and damage can become severe after just a few years of exposure (David Black, Rosenberg Associates, written communication, 2007). Precipitation of excess sulfate in soils can also cause foundation slabs to lift and crack (David Black, Rosenberg Associates, written communication, 2007).

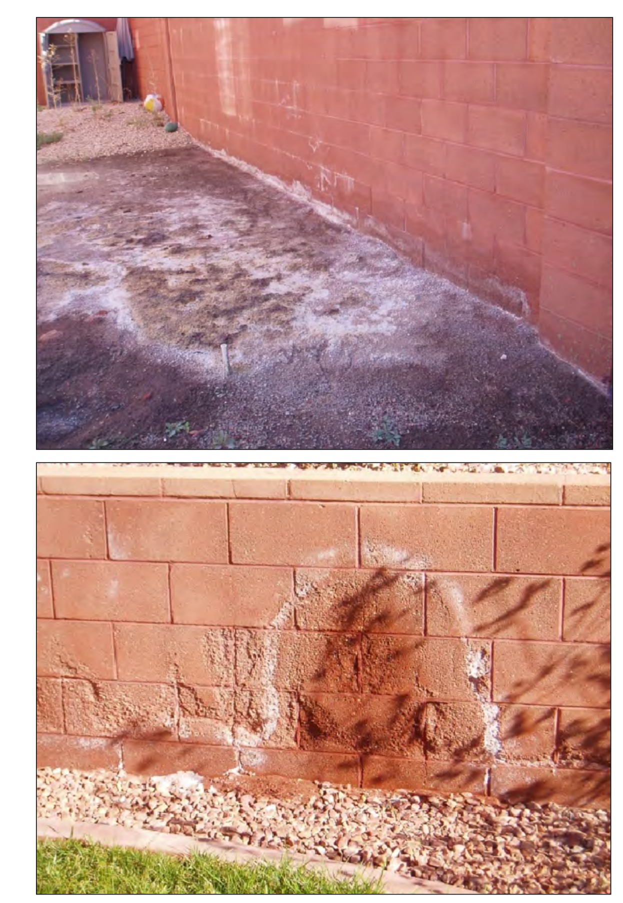


Figure 3. *Corrosion of masonry block walls in southwestern Utah due to the reaction of the non-Type V cement used in the masonry blocks with high-sulfate soils (photo credit David Black, Rosenberg Associates).*

HAZARD CLASSIFICATION

Soil

Information on gypsiferous soil in the study area is limited. We grouped unconsolidated gypsiferous deposits into a single susceptibility category (GS, see Explanation) based upon the origin and nature of the deposits. Gypsiferous soils may contain abundant gypsum (>10%), and may have significant potential for dissolution and collapse. Soils containing gypsum in concentrations of less than 10 percent are widespread in the study area, and while not presenting a soil collapse problem, they can corrode unprotected concrete and masonry structures. Data on the distribution of such soils are generally lacking.

Rock

We grouped gypsum-bearing bedrock units (table 1) into two susceptibility categories (GR_A and GR_B) based on the relative amount of gypsum present in the bedrock units that constitute each category. While there is a general decrease in the amount of gypsum present from GR_A to GR_B, both categories may contain abundant gypsum locally, and have a significant potential for dissolution and collapse. Therefore, the classification system presented below employs a relative susceptibility ranking as opposed to a hazard-severity ranking.

The gypsiferous-rock-susceptibility categories are described in the Explanation section.

Table 1. *Geologic units and NRCS soil categories known or likely to contain abundant gypsum.*

GYPSIFEROUS SOIL		
Gypsiferous Soil Category	**NRCS Map Symbols**[1]	**Unconsolidated Units**
GS	SH (Schmutz Loam), EA (Eroded Land-Shalet Complex	Alluvial-Fan Deposits
GYPSIFEROUS ROCK		
Gypsiferous Rock Category	**UGS Map Symbols**	**Bedrock Units**[2]
GR_A	TRms, Pkh	Shnabkaib Member, Moenkopi Formation; Harrisburg Member, Kaibab Formation
GR_B	TRmt, TRml, TRmv, TRmm, TRmu, Jk, JTRmd	Timpoweap, lower red, Virgin Limestone, middle red, upper red members, Moenkopi Formation; Kayenta Formation; Dinosaur Canyon Member, Moenave Formation

[1]Refer to NRCS soil maps (see Sources of Information section) for a description of map units.
[2]Refer to UGS geologic quadrangle maps (see Sources of Information section) for a description of map units.

USING THIS MAP

This map shows the location of known and suspected gypsiferous rock in the SR-9 study area. The map is intended for general planning and design purposes to indicate where gypsiferous rock conditions may exist and special investigations, including sodium sulfate testing to determine the presence of corrosive soil or rock, should be required. Site-specific investigations can resolve uncertainties inherent in generalized mapping and help identify the need for special design or mitigation techniques. The presence and severity of gypsiferous rock units and gypsum-rich soils derived from them, along with other geologic hazards, should be addressed in these investigations. If gypsiferous soil or rock is present at a site, appropriate design and construction recommendations should be provided.

HAZARD REDUCTION

Although potentially costly when not recognized and properly accommodated in project design and construction, problems associated with gypsiferous soil and rock rarely are life threatening. As with most geologic hazards, early recognition and avoidance are the most effective ways to mitigate potential problems. However, 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 Dwell-ings* (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 in doubt) 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. Where the presence of gypsiferous soil or rock is confirmed, possible hazard-reduction techniques include use of Type V or other sulfate-resistant cement for concrete; corrosion protection for metals; soil removal and replacement with noncohesive, compacted, non-gypsum-bearing backfill; and careful site landscape and drainage design to keep moisture away from concrete and gypsum-bearing deposits (Keller and Blodgett, 2006). Where gypsum problems are particularly acute, design recommendations should be provided by a qualified corrosion engineer.

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. Additionally, gypsum-bearing bedrock units are locally covered by a thin veneer of unconsolidated deposits. Such areas may be susceptible to sinkhole development or collapse; however, because subsurface information is generally unavailable, those areas are not identified on this map. 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.

REFERENCES

Christenson, G.E., 1992, Geologic hazards of the St. George area, Washington County, Utah, *in* Harty, K.M., editor, Engineering and environmental geology of southwestern Utah: Utah Geological Association Publication 21, p. 99–108.

Christenson, G.E., and Deen, R.D., 1983, Engineering geology of the St. George area, Washington County, Utah: Utah Geological and Mineral Survey Special Studies 58, 32 p.

Doelling, H.H., Willis, G.C., Solomon, B.J., Sable, E.G., Hamilton, W.L., and Naylor, L.P., II, 2002, Interim geologic map of the Springdale East quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report 393, 19 p., scale 1:24,000.

Everitt, B., and Einert, M., 1994, The 1985 slug test of Pah Tempe springs, Washington County, Utah, *in* Blackett, R.E., and Moore, J.N., editors, Cenozoic geology and geothermal systems of southwestern Utah: Utah Geological Association Publication 23, p. 189–194.

Gourley, C., 1992, Geologic aspects of the Quail Creek dike failure, *in* Harty, K.M., editor, Engineering and environmental geology of southwestern Utah: Utah Geological Association Publication 21, p. 17–38.

Hayden, J.M., and Sable, E.G., 2008, Geologic map of the Virgin quadrangle, Washington County, Utah: Utah Geological Survey Map 231, 2 plates, scale 1:24,000, CD.

Higgins, J.M., and Willis, G.C., 1995, Interim geologic map of the St. George quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report 323, 90 p., scale 1:24,000.

International Code Council, 2009a, International building code: Country Club Hills, Illinois, 678 p.

International Code Council, 2009b, International residential code for one- and two-family dwellings: Country Club Hills, Illinois, 870 p.

Keller, E.A., and Blodgett, R.H., 2006, Natural hazards—Earth's processes as hazards, disasters, and catastrophes: Upper Saddle River, New Jersey, Pearson Prentice Hall, 395 p.

Lund, W.R., 1997, La Verkin Creek sinkhole geologic investigation, Washington County, Utah, *in* Mayes, B.H., compiler, Technical Reports for 1996, Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 25–41.

Lund, W.R., Knudsen, T.R., and Sharrow, D.L., 2010, Geologic hazards of the Zion National Park geologic-hazard study area, Washington and Kane Counties, Utah: Utah Geological Survey Special Study 133, 95 p., 9 plates, GIS data, DVD.

Lund, W.R., Knudsen, T.R., Vice, G.S., and Shaw, L., 2008, Geologic hazards and adverse construction conditions, St. George–Hurricane metropolitan area, Washington County, Utah: Utah Geological Survey Special Study 127, 105 p., DVD.

Martinez, J.D., Johnson, K.S., and Neal, J.T., 1998, Sinkholes in evaporite rocks: American Scientist, v. 86, p. 38–51.

Moore, D.W., and Sable, E.G., 2001, Geologic map of the Smithsonian Butte quadrangle, Washington County, Utah: Utah Geological Survey Miscellaneous Publication 01-1, 30 p., scale 1:24,000.

Mortensen, V.L., Carley, J.A., Crandall, G.C., Donaldson, K.M., Jr., and Leishman, G.W., 1977, Soil survey of Washington County area, Utah: U.S. Department of Agriculture Soil Conservation Service and U.S. Department of the Interior Bureau of Land Management and National Park Service, 139 p., 95 plates, scale 1:24,000.

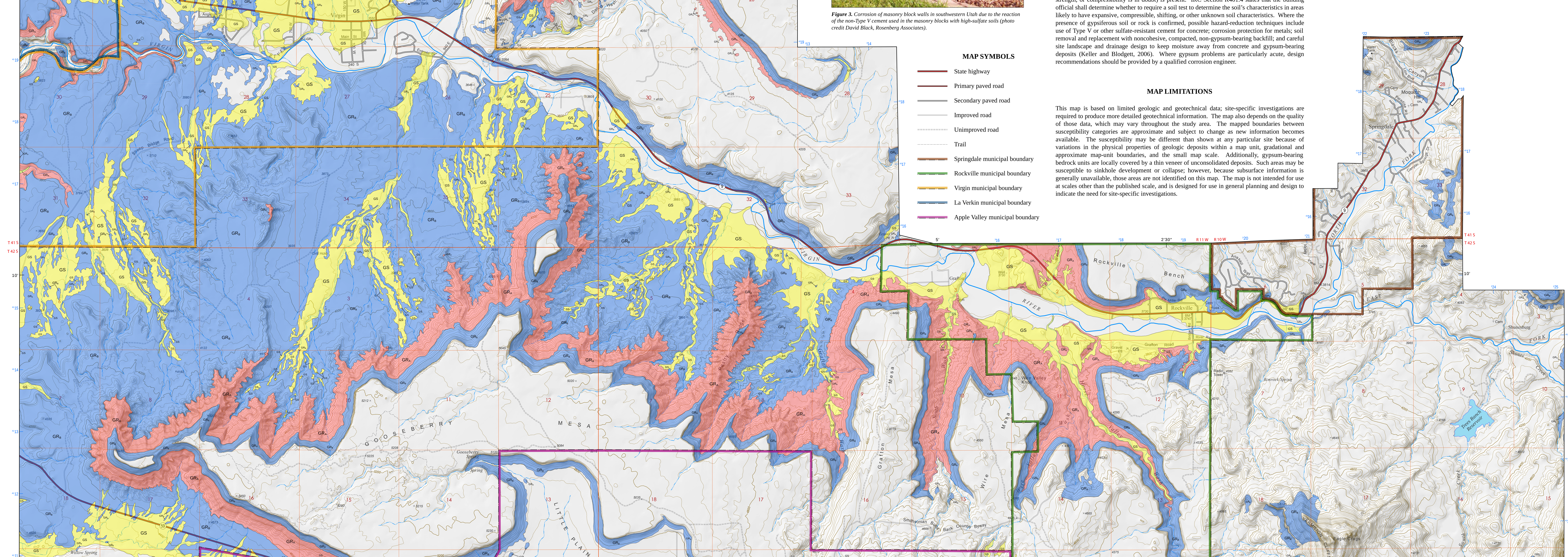
Muckel, G.B., 2004, Gypsum in excess, *in* Muckel, G.B., editor, Understanding soil risks and hazards—using soil survey to identify areas with risks and hazards to human life and property: Lincoln Nebraska, Natural Resources Conservation Service, National Survey Center, p. 58–59.

Mulvey, W.E., 1992, Soil and rock causing engineering geologic problems in Utah: Utah Geological Survey Special Study 80, 23 p., 2 plates, scale 1:500,000.

Santi, P., 2005, Recognition of collapsible soils based on geology, climate, laboratory tests, and structural crack patterns [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 7, p. 326.

Solomon, B.J., 1996, Engineering geologic map folio, Springdale, Washington County, Utah: Utah Geological Survey Open-File Report 340, 6 plates, scale 1:14,400.

Willis, G.C., Doelling, H.H., Solomon, B.J., and Sable, E.G., 2002, Interim geologic map of the Springdale West quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report 394, 20 p., scale 1:24,000.



MAP SYMBOLS

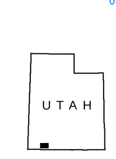
- State highway
- Primary paved road
- Secondary paved road
- Improved road
- Unimproved road
- Trail
- Springdale municipal boundary
- Rockville municipal boundary
- Virgin municipal boundary
- La Verkin municipal boundary
- Apple Valley municipal boundary

This geologic-hazard map was funded by the Utah Geological Survey, the Utah Permanent Community Impact Fund Board, and the municipalities of Springdale, Rockville, Virgin, and La Verkin. 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 governmental entities listed above.

For use at 1:24,000 scale only.

11°42'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2013

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
CONTOUR INTERVAL 40 FEET



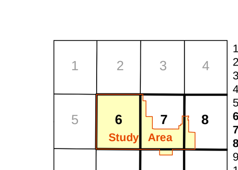
MAP LOCATION

GYPSIFEROUS SOIL AND ROCK
STATE ROUTE 9 CORRIDOR GEOLOGIC-HAZARD STUDY AREA, WASHINGTON COUNTY, UTAH

by

Tyler R. Knudsen and William R. Lund

2013



7.5' QUADRANGLE INDEX

1. Pintura
2. Smith Mesa
3. The Guardian Angels
4. Temple of Sinawava
5. Hurricane
6. **Virgin**
7. **Springdale West**
8. **Springdale East**
9. The Divide
10. Little Creek Mountain
11. **Smithsonian Butte**
12. Hildale

Base-map topographic contours and shaded relief derived from 10 meter U.S. Geological Survey National Elevation Dataset.

Geographic labels from U.S. Geological Survey 7.5-minute quadrangle maps acquired from the Utah Automated Geographic Reference Center.

Projection: UTM Zone 12
Datum: NAD 1983
Ellipsoid: GRS 80

GIS and Cartography: Tyler R. Knudsen

Utah Geological Survey
1594 West North Temple, Suite 3110
P.O. Box 146100, Salt Lake City, UT 84114-6100
(801) 537-3300
geology.utah.gov