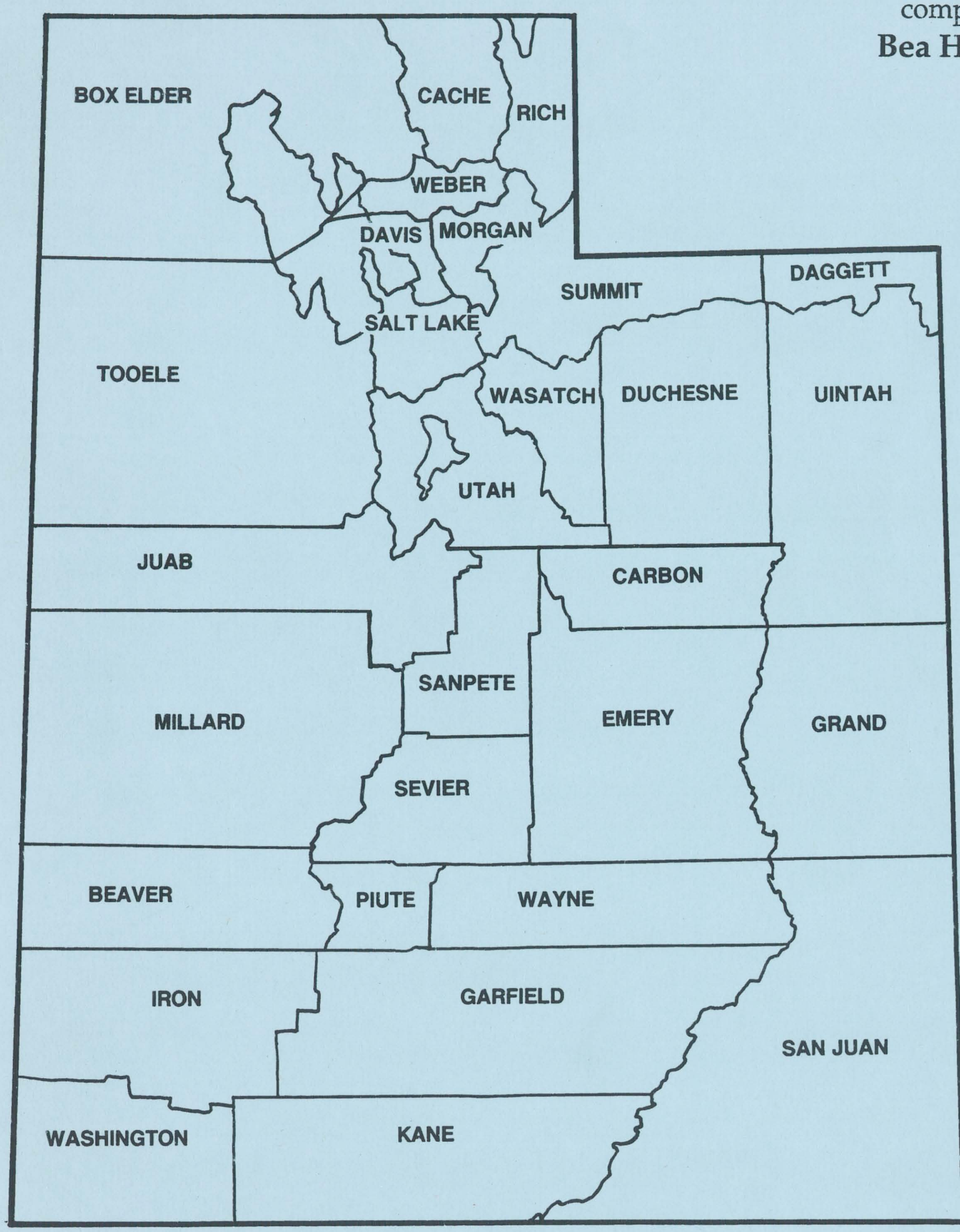
TECHNICAL REPORTS FOR 1994 - 1995
APPLIED GEOLOGY PROGRAM

compiled by
Bea H. Mayes



REPORT OF INVESTIGATION 228 February 1996
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

UTAH CENTENNIAL 1896-1996

TECHNICAL REPORTS FOR 1994 - 1995
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BEA H. MAYES

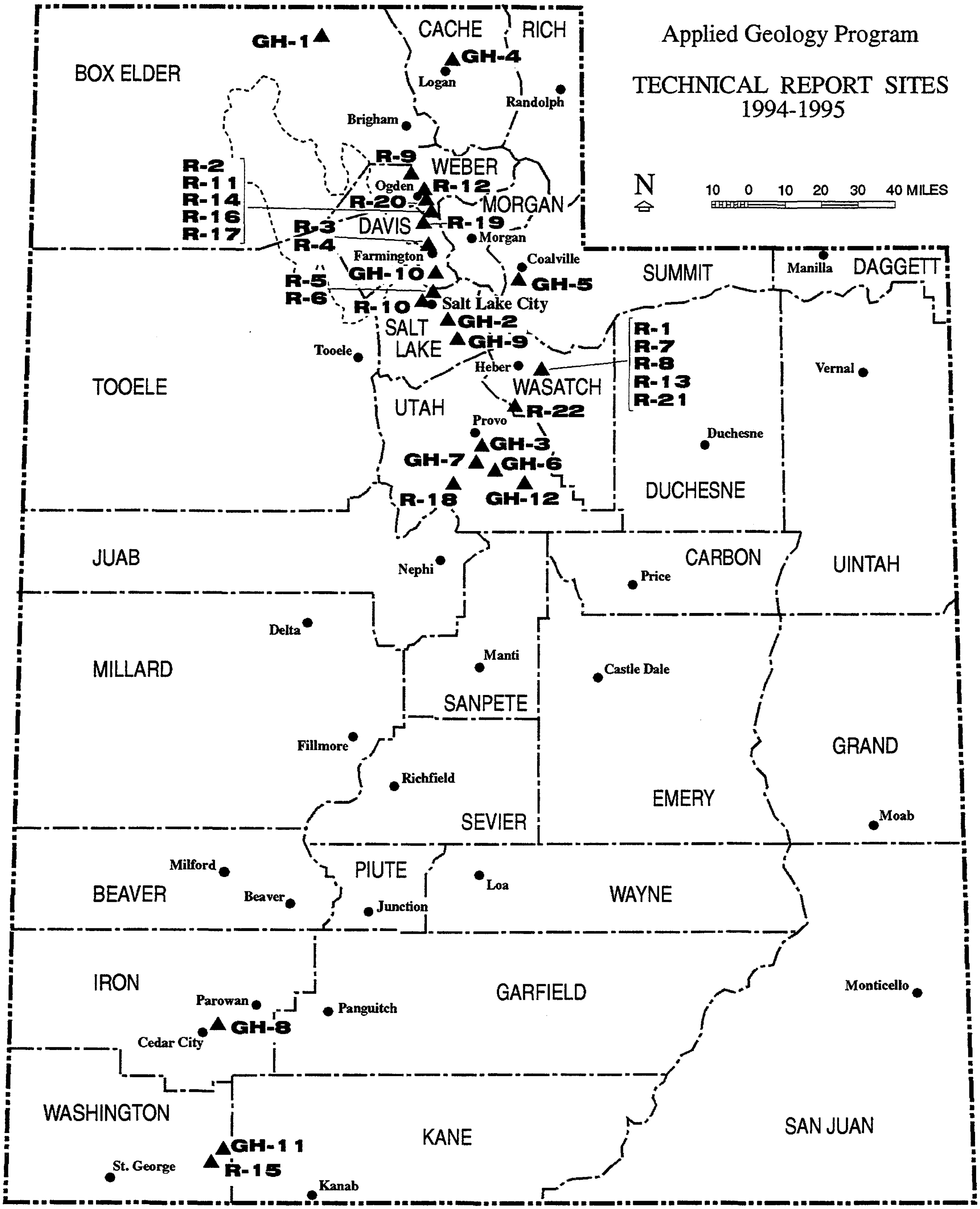
PREFACE

The Applied Geology Program of the Utah Geological Survey (UGS) maps and defines geologic hazards in the state and provides assistance to tax-supported entities (cities, towns, counties, and their engineers, planning commissions, or planning departments; associations of governments; state agencies; and school districts). We perform site evaluations of geologic-hazard potential for critical public facilities such as public-safety complexes, fire stations, waste disposal sites, water tanks, and schools. In addition, we respond to emergencies such as earthquakes, landslides, and wild fires (where subsequent debris flows are a hazard) with a field investigation and a report of the geologic effects and potential hazards. We also conduct investigations to answer specific geologic or hydrologic questions from state and local government agencies, such as geologic investigations of slope stability, evaluation of soil problems in developing areas, and evaluation of hazards from debris flows, shallow ground water, rock falls, landslides, and earthquakes. In addition to performing engineering-geologic studies, we review and comment on geologic reports submitted by consultants to state and local government agencies, such as those dealing with sites for residential lots, subdivisions, and private waste-disposal facilities.

Information dissemination is a major goal of the UGS. Studies of interest to the general public are published in several UGS formats. We present projects that address specific problems of interest to a limited audience in a technical-report format, which we distribute on an as needed basis. We maintain copies of these reports and make them available for inspection upon request.

This Report of Investigation presents, in a single document, the Applied Geology Program's 34 technical reports completed in 1994 and 1995 (figure 1). The reports are grouped by topic, and each report identifies the author(s) and requesting agency. Minor editing has been performed for clarity and conformity, but I have made no attempt to upgrade the original graphics, most of which were produced on a copy machine. This is the ninth compilation of the Applied Program's technical reports.

Bea H. Mayes
January 17, 1996



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GEOLOGIC HAZARDS

Project: A short summary of the geology, hydrology, and geologic hazards of the Whites Valley area, Box Elder County, Utah.			Requesting Agency: Representative Eli H. Anderson, House District 1
By: Mike Lowe	Date: Jan. 28, 1994	County: Box Elder	Job No: 94-02 (GH-1)
USGS Quadrangle: Blind Springs (1473), Limekiln Knoll (1498)			

SUMMARY

This report presents a review of published information regarding the Whites Valley area. Much of this information is 20-years old or more and needs to be updated, particularly the ground-water studies.

Whites Valley is a small intermontane valley set in a dissected plateau formed by the West Hills and Blue Springs Hills. Unconsolidated deposits in Whites Valley include Lake Bonneville deposits and alluvium. These deposits are underlain by the Oquirrh Formation. The West and Blue Springs Hills are also composed of Oquirrh Formation, which consists of limestone, sandy limestone, and sandstone. Ground water is found between rock particles in the unconsolidated sediments, and in fractures in bedrock, both beneath Whites Valley and in the surrounding hills. This water is of high quality. Water percolating into the ground in both Whites Valley and the surrounding hills ultimately recharges lower elevation aquifers along the southern and eastern margins of the dissected plateau, including aquifers in the Bothwell Pocket area. An intermittent stream flowing from the southern end of Whites Valley to the Bothwell Pocket area is also likely a source of recharge to aquifers in that area. Whites Valley is a seismically active area, and earthquake ground shaking is the principal geologic hazard in the region.

PURPOSE AND SCOPE

This report presents a brief review of the geology, hydrology, and geologic hazards of the Whites Valley area, Box Elder County. Whites Valley is located about 12 miles northwest of Tremonton (attachment 1). This report was requested by Eli H. Anderson, Utah State Representative, House District 1. The scope of work consisted of a literature review. Much of this literature is 20-years old or more and needs to be updated, particularly the ground-water studies. The name(s) and date in parentheses within some sentences identify the source of information presented in the sentence. The sources are listed in the reference section at the end of the report.

TOPOGRAPHY

Whites Valley is a small intermontane valley with a northwest to southeast orientation. The valley floor slopes to the southeast at elevations ranging from about 5,500 feet in the northwest to slightly less than 5,100 feet in the southeast. The valley is bounded by the West Hills to the east and the Blue Spring Hills to the west (attachment 1). Together, these hills form a 5- to 12-mile wide dissected plateau within which Whites Valley is set (Bjorklund and McGreevy, 1974). The crests of these hills generally range from 6,000 to 7,000 feet in elevation.

GEOLOGY

Whites Valley

Whites Valley is filled with unconsolidated (loose, uncemented) Quaternary (1.6 million years or younger in age) deposits. These unconsolidated deposits are probably less than 100 feet thick and overlie the same bedrock unit, the Oquirrh Formation, that forms the surrounding hills (Bjorklund and McGreevy, 1974). Whites Valley was likely a bay of Lake Bonneville during the lake's high stand from about 17,000 to 15,000 years ago. Lake Bonneville covered much of northern Utah and parts of southern Idaho and eastern Nevada from about 30,000 to 12,000 years ago. The unconsolidated deposits below the high stand of the lake (about 5,200 feet in elevation, generally the southeastern portion of the valley) consist of Lake Bonneville deposits and alluvial deposits, which were eroded from the surrounding hills and deposited in Whites Valley by surface water (streams and slope wash) (Beus, 1963). The unconsolidated deposits in areas above the high stand of Lake Bonneville consist primarily of alluvial deposits eroded from the surrounding hills, but colluvial deposits (sediments weathered in place or transported short distances by gravity) also occur. The Lake Bonneville deposits in Whites Valley consist predominantly of well-sorted (sediment containing similar particle sizes) layers of clay, silt, and sand (Beus, 1963). Water-well logs indicate these lake deposits also contain some gravel (Bjorklund and McGreevy, 1973). The alluvial and colluvial deposits consist predominantly of moderately to poorly sorted rock particles of all sizes (Bjorklund and McGreevy, 1974). The characteristics of the bedrock underlying the unconsolidated deposits are the same as those of the bedrock in the surrounding hills (Oquirrh Formation, see below).

West and Blue Springs Hills

West Hills and Blue Springs Hills are composed mostly of bedrock (primarily Oquirrh Formation), but at some locations, particularly along streams, the bedrock is overlain by thin, unconsolidated alluvial and colluvial deposits. The Oquirrh Formation was deposited in an ocean approximately 320 to 250 million years ago (Hintze, 1980), and consists of limestone, sandy limestone, and well cemented sandstone (which some previous investigators have called quartzite) (Beus, 1963; Doelling, 1980). Limestone is a rock type composed predominantly of calcium carbonate. The sandstones are composed primarily of sand grains (mostly quartz) held together by calcareous or siliceous cement (Beus, 1963).

The rocks in the vicinity of Whites Valley are highly fractured (Bjorklund and McGreevy, 1974). Most of these fractures have not been mapped. However, several major fractures along which relative movement has occurred, called faults, have been mapped. The type or direction of relative movement along these faults has not been identified. Beus (1963) mapped an inferred (queried or uncertain) north-south-trending fault along the eastern margin of Whites Valley. Doelling (1980) mapped an east-west-trending inferred fault in the eastern portion of Whites Valley; this fault continues eastward down Johnson Canyon into Malad Valley. Doelling (1980) also mapped two inferred north-south-trending faults at the southern end of the western margin of Whites Valley. For all of these faults, the timing of the most recent movement is unknown, but there is no evidence of movement during the past 10,000 years (Holocene time), and the most recent movement may have occurred prior to 1.6 million years ago (Quaternary time).

HYDROLOGY

Surface Water

A stream channel extends from the southern end of Whites Valley to the Bothwell Pocket, an important area of ground-water development located just north of the community of Bothwell (attachment 1). This stream is intermittent (water flows in the stream for only part of the year). Flow from this stream is likely a source of recharge to ground water in unconsolidated sediments in the Bothwell Pocket area.

Ground Water

Occurrence

Ground water occurs in both unconsolidated sediments and the underlying bedrock in Whites Valley, and in bedrock of the West and Blue Springs Hills (Bjorklund and McGreevy, 1974). Ground water in the unconsolidated deposits in Whites Valley has been encountered at depths as shallow as 11 feet (plate 3 in Bjorklund and McGreevy, 1974). This water is considered to be perched (separated from the main water table by material that is not saturated with water) (Bjorklund and McGreevy, 1974). Below the perched ground water in Whites Valley "the regional water level is probably several hundred feet below the land surface in the underlying Oquirrh Formation" (p. 45, Bjorklund and McGreevy, 1974). Both the unconsolidated sediments and the Oquirrh Formation in the Whites Valley area are aquifers because they are permeable enough (have sufficiently interconnected void spaces) to yield water to wells. The void spaces in the unconsolidated sediments are located between the particles. The void spaces in the Oquirrh Formation are primarily fractures in the rock.

Recharge and Discharge

Recharge to aquifers in the Whites Valley area predominantly comes from precipitation falling on the valley and the surrounding hills. Most precipitation is in the form of snow. Average annual precipitation in the Whites Valley area is likely similar to that at Corinne, about 15 inches (table 1, Bjorklund and McGreevy, 1974).

Water infiltrating into the ground in the Whites Valley area ultimately discharges to lower elevation aquifers to the south and east adjacent to the southern and eastern margins of the West and Blue Springs Hills, including the Bothwell Pocket. Therefore, the Whites Valley area may be a recharge area for aquifers along the margins of these hills. Salt Creek Springs discharge from the Oquirrh Formation along the southern margin of the West Hills; "these springs are a major drain for the West Hills" (Bjorklund and McGreevy, 1974, p. 45). Springs also discharge along the southern end of the Blue Springs Hills. This is because the valley-fill material along the southern end of the hills has a lower permeability (fewer interconnected voids) than the fractured bedrock; this condition retards the movement of ground water from the rock into the valley fill, causing the water to discharge from the bedrock/unconsolidated sediment interface as a spring (Bjorklund and McGreevy, 1974).

The rate of movement of water from the Whites Valley area through bedrock of the West and Blue Springs Hills to the springs at the margins of these hills is unknown. Everett (1987) indicates that flow velocities in fractured bedrock aquifers may range from less than 0.2 miles/year to more than 200 miles/year.

Water Quality

Information on water-quality in the unconsolidated deposits of Whites Valley is reported (Bjorklund and McGreevy, 1973) for one well in which a water sample was collected at a depth of 11 feet. The sample had a total-dissolved-solid content of 661 milligrams per liter (Bjorklund and McGreevy, 1973); according to a classification system developed by the Utah State Department of Environmental Quality (Utah Administrative Code R317-6-3), this water is considered Class II, "drinking water quality ground water." Information regarding water quality in the Oquirrh Formation in the Whites Valley area is not available, but total-dissolved-solid contents are likely to be only slightly higher (because the water has been in contact with rock material for a longer period of time) than those of the unconsolidated sediments. For comparison, the total-dissolved-solid content of water in the Bothwell Pocket area to the southeast of Whites Valley ranges from

600 to 900 milligrams per liter (plate 5, Bjorklund and McGreevy, 1974). Because it is likely that much of the water in the Bothwell Pocket area is recharged by water flowing from the Oquirrh Formation, the total-dissolved-solid content of water in the Bothwell Pocket may be representative of the total-dissolved-solid content of the water in bedrock below Whites Valley.

GEOLOGIC HAZARDS

Potential geologic hazards in the Whites Valley area include shallow ground water, flash floods, debris flows, landslides, surface faulting, and earthquake ground shaking. Ground water has been encountered as shallow as 11 feet below the ground surface in Whites Valley (plate 3 in Bjorklund and McGreevy, 1974), and may be seasonally shallower. Although little is known about the potential for floods in Whites Valley, they are likely to occur during particularly large precipitation events. Landslides and debris flows have not been documented in the Whites Valley area, but may have occurred in the past. Inferred faults have been mapped in Whites Valley, but neither the existence nor the nature and timing of past movement have been studied in sufficient detail to evaluate the potential surface-faulting hazard. Whites Valley is a seismically active area. A number of earthquakes, commonly with magnitudes less than 4.0, have occurred in the Whites Valley area during historical time (Goter, 1990), including five earthquakes with magnitudes ranging from 2.3 to 2.9 which occurred on January 17, 1994. A magnitude 4.8 earthquake occurred in the area on July 3, 1989. It is not known if these historical earthquakes are related to any mapped faults, including those in Whites Valley. However, Whites Valley is located near other, more active faults, including the Wasatch fault zone which is capable of generating earthquakes as strong as magnitude 7-7.5 (Schwartz and Coppersmith, 1984), and strong ground shaking in the valley will likely occur during surface-faulting earthquakes in the northern Utah region.

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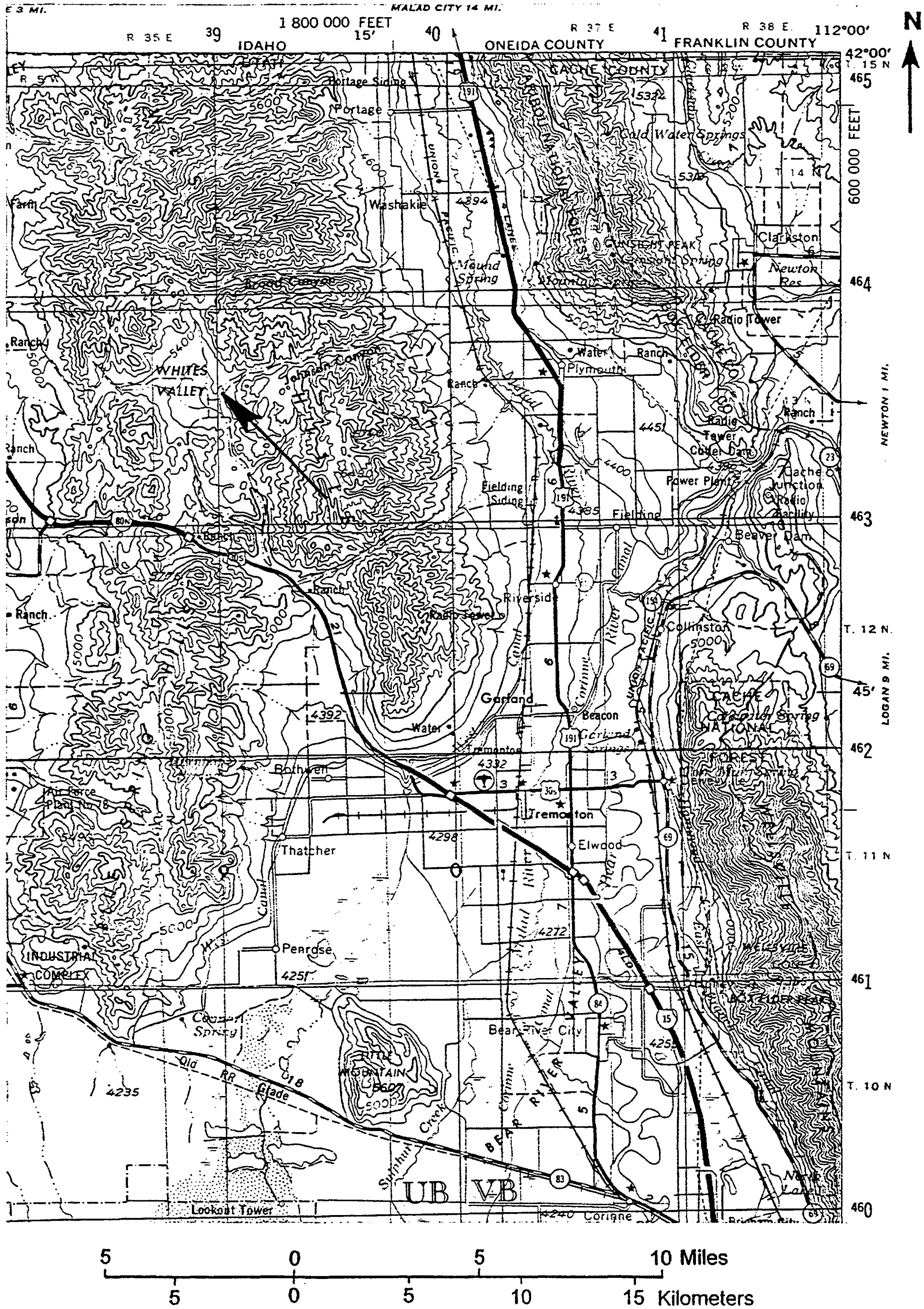
Schwartz, D.P., and Coppersmith, K.J., 1984, Fault behavior and characteristic earthquakes -- examples from the Wasatch and San Andreas fault zones: Journal of Geophysical Research, v. 89, no. B7, p. 5681-5698.

Base Map from BRIGHAM CITY U.S.G.S. 30' X 60' topographic quadrangle



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Attachment 1. Location map for the Whites Valley area.

Project: Investigation of a rock fall in Olympus Cove, Salt Lake County, Utah			Requesting Agency:
By: Bill D. Black	Date: 3-17-94	County: Salt Lake County	Job No: 94-04 (GH-2)
USGS Quadrangle: Sugarhouse (1212)			

PURPOSE AND SCOPE

On March 10, 1994, the Utah Geological Survey (UGS) investigated a rock fall in Olympus Cove, south of Mill Creek Canyon in Salt Lake County. The rock fall damaged a fence, retaining wall, and tennis court at a private residence at 4200 Park Terrace Drive, section 36, T. 1 S., R 1 E., Salt Lake Baseline (attachment 1). The purpose of the investigation was to document the rock-fall occurrence, determine the source and probable cause, and assess the hazard from future rock falls. The investigation consisted of a field reconnaissance, and map and literature review.

DATA AND DISCUSSION

The rock fall consisted of a single large quartzite boulder. Timing of the rock fall is uncertain. The rock fall was not witnessed or heard by the homeowner (Shannon Scott, verbal communication, March 10, 1994). Snowfall from a large storm around the end of February restricted access to the tennis court at the residence. The boulder was reported on March 9, 1994, after the snow melted, and probably came down sometime in early March after the storm (Shannon Scott, verbal communication, March 10, 1994).

The source of the rock-fall boulder was a southwest-facing, ridge-crest outcrop of Pennsylvanian-age Weber Quartzite (Crittenden, 1981) at an elevation of roughly 6,800 feet (2,073 m), 1,360 feet (415 m) above and 2,500 feet (762 m) east of the residence (attachment 1). The boulder measured approximately 5 x 4.5 x 4.5 feet (1.5 x 1.4 x 1.4 m) and had an estimated weight of 13,000 to 14,000 pounds (5,900-6,350 kg). The boulder travelled from the outcrop and took a sinuous path down an intermittent drainage, leaving a trail of sheared oak brush and trees (attachment 1). Slopes in the drainage are very steep, generally greater than 45 percent (Van Horn, 1972a), and are mapped by Van Horn (1972b) as underlain by moderately-stable surficial deposits and bedrock which may be a source of falling rocks. Both the source area and residence lie within the rock-fall hazard-area boundaries mapped by Case (1987).

The rock was probably destabilized by long-term weathering, erosion, and freeze-thaw, and movement may have been triggered by freezing and thawing of moisture from the recent snowstorm. Freezing and thawing of water is particularly important because freezing pressures can break rock and widen discontinuities such as joints and bedding separations. Rock falls caused by freezing and thawing are common during spring and fall months with heavy snow melt or rainfall (Costa and Baker, 1981). Although earthquake ground shaking can also trigger rock falls, there were no earthquakes greater than magnitude 4.0 in northern Utah during February or March (Linda Hall, University of Utah Seismograph Stations, verbal communication, March 15, 1994). The nearest significant earthquakes (main shock magnitude 5.9) occurred in early to mid-February near Afton, Wyoming roughly 160 miles (260 km) northeast of Salt Lake City. This distance from an epicenter would exceed those recorded for historical rock falls in Keefer (1984). The maximum distance for rock falls from a magnitude 5.9 earthquake is about 45 miles (72 km) (Keefer, 1984), so it is unlikely that the rock fall was triggered by the Afton earthquake or its aftershocks.

A hazard from future rock falls in the area remains. The extent of the hazard depends on the presence of loose material of sufficient size in the source area, which was not inspected during the field investigation. A computer rock-fall simulation program developed by Pfeiffer and Higgins (1988) indicates that rocks more than about 60 percent of the actual boulder weight (which remain intact) will generally make it down the slope to the residences. Smaller rocks would remain in the drainage above the residences. Future earthquakes and continuing weathering, erosion, and freezing and thawing may produce additional rock falls, potentially causing significant damage or injury if material of sufficient size is involved.

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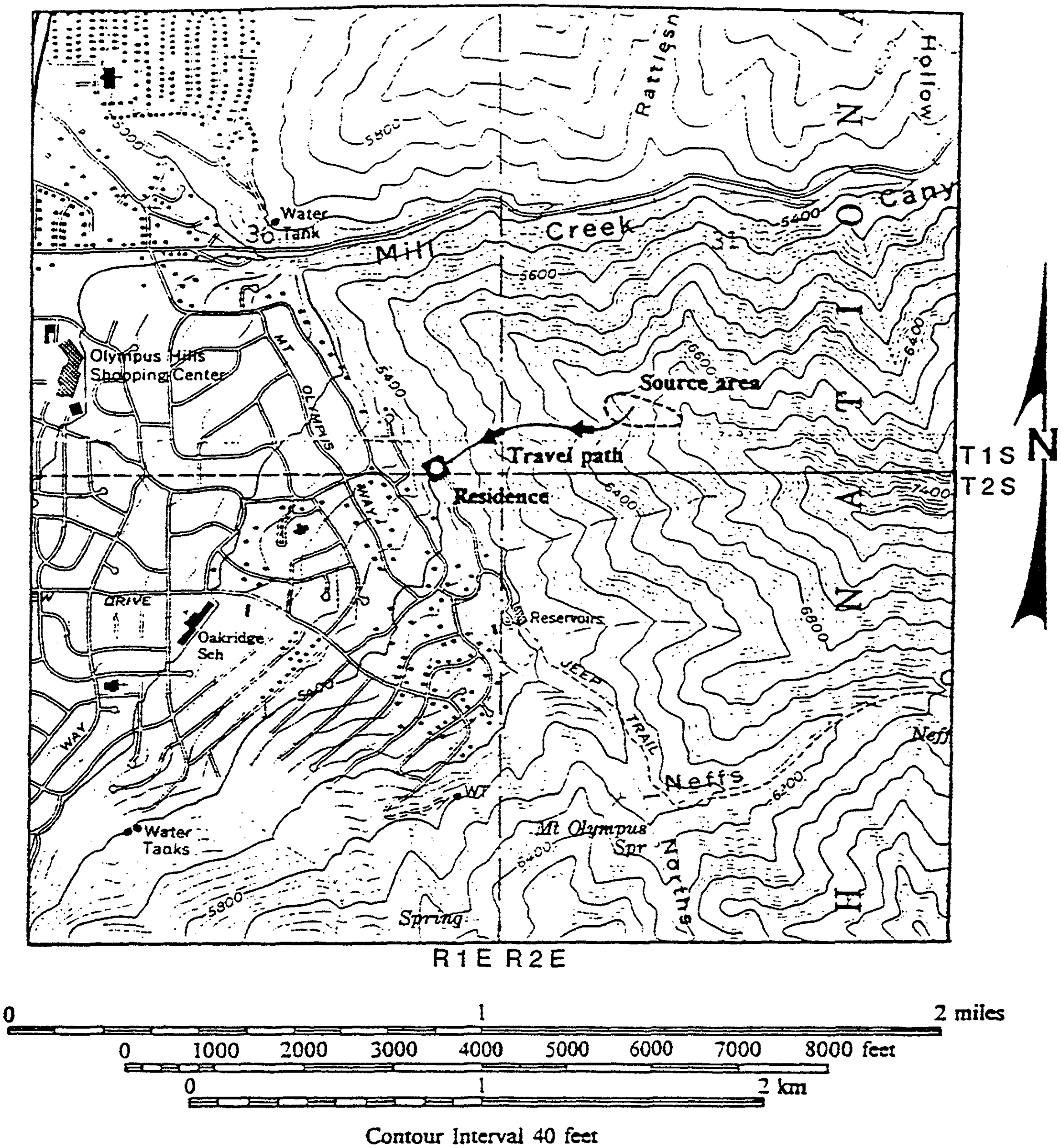
Base map from SUGARHOUSE,
U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location map.

Utah Geological Survey

Project:			Requesting Agency:
Geologic hazards investigation, proposed water-tank site, Provo, Utah.			Provo City Water Resources Department
By: Bill D. Black	Date: 10-20-94	County: Utah	Job No: 94-08 (GH-3)
USGS Quadrangle: Springville (1046)			

PURPOSE AND SCOPE

The Utah Geological Survey (UGS) conducted a geologic-hazards evaluation of a proposed site for a two-million-gallon water tank in the city of Provo, Utah County, Utah (attachment 1). Carl H. Carpenter (Principal Engineer, Provo City Water Resources Department) requested the investigation. The purpose of this investigation was to identify any potential geologic hazards at the site which should be considered prior to construction. The scope of work included a literature and map review, examination of 1:20,000-scale aerial photos (1973), and a field inspection on May 19, 1994. Mike Lowe (UGS) and Bart Simons (Water Sources Division Manager, Provo City Water Resources Department) were present during the field inspection. On September 20, 1994, I also inspected a trench excavated by Rollins, Brown, and Gunnell Inc. for a geotechnical investigation of the site.

SETTING AND GEOLOGY

The proposed water-tank site is in southeastern Provo City, in the SE1/4SE1/4, section 17, T.7 S., R.3 E, Salt Lake Base Line (attachment 1). The site is at approximately 4,790 feet (1,460 m) elevation, on a bench at the base of the Wasatch Range. The water tank will be circular, buried, and made of reinforced concrete (Carl H. Carpenter, Principal Engineer, Provo City Water Resources Department, written communication to Bill Lund, UGS, April 27, 1994).

Surficial deposits at the site consist of sand and gravel deposited by Lake Bonneville, and pre-lake alluvial-fan and landslide deposits (Machette, 1989; attachment 2). Bedrock underlying the surficial deposits is likely the Mississippian-age Humbug Formation, which consists of thickly bedded limestone with some dolomite, and limey quartzitic sandstone (Baker, 1973). The depth to bedrock at the site is unknown, but Baker (1973) maps bedrock outcrops nearby, indicating that surficial deposits may be thin. Depth to ground water at the site is probably greater than

50 feet (15 m) (Anderson and others, 1986). The site is within the Wasatch fault zone (WFZ), an active normal fault at the base of the Wasatch Range. Machette (1989) maps two north-trending, sub-parallel fault scarps bounding the site to the east and west (attachment 2).

The bench on which the site is located was probably formed by Lake Bonneville when it stood at the Provo shoreline (mapped south of the site at roughly 4,800 feet [1,463 m] elevation) (Machette, 1989) from approximately 14,500 to 14,200 years ago. Prior to 14,500 years ago, Lake Bonneville reached its highest stand (5,090 feet [1,551 m]), termed the Bonneville shoreline, but breached its outlet in southern Idaho and abruptly receded to the Provo shoreline (Curry and others, 1984). About 14,200 years ago, subsequent climatic changes caused Lake Bonneville to recede from the Provo shoreline to even lower levels (Scott and others, 1983; Curry and Burr, 1988).

Soils at the site consist of the Pleasant Grove series (PNG2) on terrace escarpments (Provo bench) (Swenson and others, 1972). The soils are gravelly, sandy lake sediments (with rock-fall boulders), which exhibit moderately rapid permeability and low shrink-swell potential (Swenson and others, 1972). In the Unified Soil Classification System, the Pleasant Grove series is a silty sand (SM) overlying silty or clayey gravel (GM or GC), silty or clayey sand (SM or SC), and silt (ML) (Swenson and others, 1972).

GEOLOGIC HAZARDS

Attachment 3 is a summary checklist of potential geologic hazards at the site. All hazards considered are shown and discussed below. A glossary of geologic-hazards terminology is included (attachment 4) to aid in explanation of any unfamiliar terms.

Earthquake Hazards

Utah Valley lies in the Intermountain Seismic Belt, a zone of shallow and diffuse seismicity extending from northwestern Montana to southwestern Utah (Smith and Sbar, 1974; Smith and Arabasz, 1991). In the Provo area, the largest magnitude (estimated) earthquakes during historical time were: (1) a magnitude 5½ earthquake in 1900 near Eureka, 30 miles (48 km) southwest of Provo; (2) a magnitude 5 earthquake in 1915 in Provo; and (3) a magnitude 5 earthquake in 1958, 13 miles (21 km) northeast of Provo (Arabasz and others, 1979). Numerous smaller earthquakes also occurred in Utah County prior to 1989 (Goter, 1990). None of these earthquakes have been attributed to faults mapped at the surface.

The Provo segment of the WFZ, which trends north-south along the base of the Wasatch Range from Alpine to Payson, is the fault of most concern because of its recent movement history, potential for generating large earthquakes, and proximity to the site. Evidence from trenching on the Provo segment of the WFZ suggests that the most recent large earthquake on this segment occurred roughly 600 years ago (Lund and others, 1991). The Provo segment of the WFZ is capable of generating earthquakes up to magnitude 7.5 (Machette and others, 1991). Such an earthquake would produce strong ground shaking at the site, and may produce other geologic effects such as surface fault rupture or slope failures.

Ground Shaking

A major hazard at the site is ground shaking resulting from either a moderate-sized earthquake, which could occur anywhere in the area, or a large earthquake on the WFZ. In an earthquake, seismic waves are generated from the source at depth and travel through the earth, causing ground shaking at the surface. Certain soil conditions can amplify ground shaking. Ground shaking at the water-tank site could damage the tank and/or rupture waterline connections.

Three levels of ground motions may be considered in design of the water tank: (1) probabilistic motions that have a one in 10 chance of being exceeded in a 50-year period, typically used in building design; (2) probabilistic motions that have a one in 10 chance of being exceeded in a 250-year period, approximating those expected in a nearby, large earthquake; and (3) the minimum design motions specified by the 1991 Uniform Building Code (UBC). At the site, a peak ground acceleration in firm soil of about 0.3 g (equivalent to a rock acceleration of 0.36 g) has a 1 in 10 chance of being exceeded in a 50-year period (Youngs and others, 1987). The peak acceleration in firm soil with a 1 in 10 chance of being exceeded in a 250-year period is between 0.7 - 0.8 g (equivalent to a rock acceleration of from 0.84 - 0.96 g) (Youngs and others, 1987). The seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The proposed water-tank site is in UBC seismic zone 3. For zone 3, design calculations require a Z-factor of 0.3, which effectively corresponds to a peak acceleration on rock of 0.3 g. Although the soil profile at the site is not well known, an S-1 soil type is likely. The actual soil type may be determined from the geotechnical investigation. Recent studies by Adan and Rollins (1993) and Wong and Silva (1993) indicate that areas of shallow, stiff soils (such as those at the site) may experience amplified ground motions.

Surface Fault Rupture

Surface fault rupture from a large-magnitude earthquake on the Provo segment of the WFZ could be a hazard at the site. A magnitude 6.5+ earthquake on the WFZ may produce surface offsets of 6 feet (1.8 m) or more, and possibly damage the water tank or sever waterlines and waterline connections. The site is in the surface-fault-rupture-hazard special-study zone mapped by Robison (unpublished Utah County Planning Department map). The purpose of this zone is to delineate areas where site-specific investigations addressing surface-fault-rupture hazards are recommended (Robison, 1993).

To determine if any faults traverse the foundation of the tank, two trenches were excavated by Rollins, Brown, and Gunnell Inc. across the site on September 20, 1994. Logs of these trenches are not included here, but may be found in their report. The trenches exposed bedded nearshore lake deposits with no evidence of faulting or deformation. This evidence suggests surface fault rupture has not occurred at the site during Holocene time. However, because the site is within the WFZ, rupture in a future earthquake cannot be precluded. Also, the fault is mapped 150 feet (46 m) west and 250 feet (76 m) east of the tank location, and surface fault rupture could still damage waterlines and waterline connections.

Other Earthquake Hazards

The liquefaction potential at the site is very low (Anderson and others, 1986). Because the site is in the WFZ, tectonic subsidence is possible. The hazard from earthquake-induced slope failures is discussed below.

Slope Failures

A portion of the bench on which the site is located is mapped by Machette (1989) and Harty (1992) as being underlain by a pre-Lake Bonneville landslide (attachment 2). However, aerial photos and a field inspection of the site suggest that the slide (or portions of it) may have reactivated since Lake Bonneville receded. Although the depth to the slide plane is unknown, the landslide may also involve underlying bedrock of the Humbug Formation. This geologic unit is not generally prone to landsliding, but the Humbug has failed in other slopes in Utah (Kimm M. Harty, UGS, verbal communication, May 25, 1994).

Because the site is located southeast of the landslide, the water tank may not be affected if the slide were to move again. However, the cause of the slide is unclear and similar geologic conditions may exist at the site. A return of the environmental conditions that initiated the slide may reactivate it or cause other slope failures, which could damage waterlines, waterline connections, or the tank. Strong ground shaking may also reactivate the landslide or cause slope failures affecting the water tank. To accurately assess the landslide hazard, detailed geotechnical studies would be required.

The hazard from debris flows and rock falls is low. Debris flows in the mountains to the east would likely be channelled into drainages to the north and south of the site. Although the site is in a rock-fall hazard area mapped by Robison (unpublished Utah County Planning Department map), and rock-fall boulders were observed at the surface during the field inspection, the hazard from rock falls is low because the tank will be buried.

Other Hazards

The hazard from flooding, shallow ground water, and problem soils is low. Geologic mapping by Baker (1973) suggests that excavation for the water tank may encounter shallow bedrock. Radon is generally not a consideration for municipal water systems because sufficient aeration occurs in the system to dissipate radon gas in the water.

CONCLUSIONS AND RECOMMENDATIONS

Geologic hazards are present at the site which could place the tank and its associated workings at risk. These hazards are summarized below and on attachment 3.

The greatest hazard at the site is earthquake ground shaking. Information for three earthquake-resistant design options is presented: (1) a probabilistic peak horizontal ground acceleration in firm soil of about 0.3 g (equivalent to a rock acceleration of 0.36 g) that has a one in 10 chance of being exceeded in 50 years, (2) a probabilistic peak horizontal ground acceleration in firm soil of 0.7 - 0.8 g (equivalent to a rock acceleration of 0.84 - 0.96 g) that has a one in 10 chance of being exceeded in 250 years, and (3) the minimum design ground motions for seismic zone 3 as designated by the UBC. To meet minimum requirements, the water tank must be designed in accordance with seismic zone 3 standards. However, because the rock acceleration exceeds seismic zone 3 design levels and because of likely ground-shaking amplification, I recommend that the water tank be designed in accordance with seismic zone 4 standards. Although the ground-shaking levels in option 2 have a low probability of occurrence, they could occur at any time in a large earthquake.

Trenching suggests that surface fault rupture has not occurred at the site in Holocene time. However, because the site is located within the WFZ, surface fault rupture and tectonic subsidence cannot be precluded. The hazard from liquefaction is low.

The hazard from debris flow and rock falls is low. However, the site is located on a terrace southeast of a landslide. Conditions similar to those which caused this slide could reactivate it or cause additional slope failures, which may damage the tank or its associated workings. Further study would be needed to accurately assess the landslide hazard. The hazard from flooding, shallow ground water, and problem soils is also low. However, excavation for the water tank may encounter shallow bedrock. Radon gas is not an important consideration for a water tank. A standard soil foundation investigation is recommended to provide data required to design the water-tank foundation.

Because of the nearby landslide and location of the water tank within the WFZ, the site is subject to possible hazards which could damage the tank and break connections. If the site is used, I recommend that: (1) provisions be made to protect downstream residents from a tank rupture to reduce danger to life and property, (2) water lines be fitted with valves which shut off automatically if a connection is broken, and (3) a detection system is in place to help ensure that leakage does not affect local ground-water levels and increase the landslide hazard.

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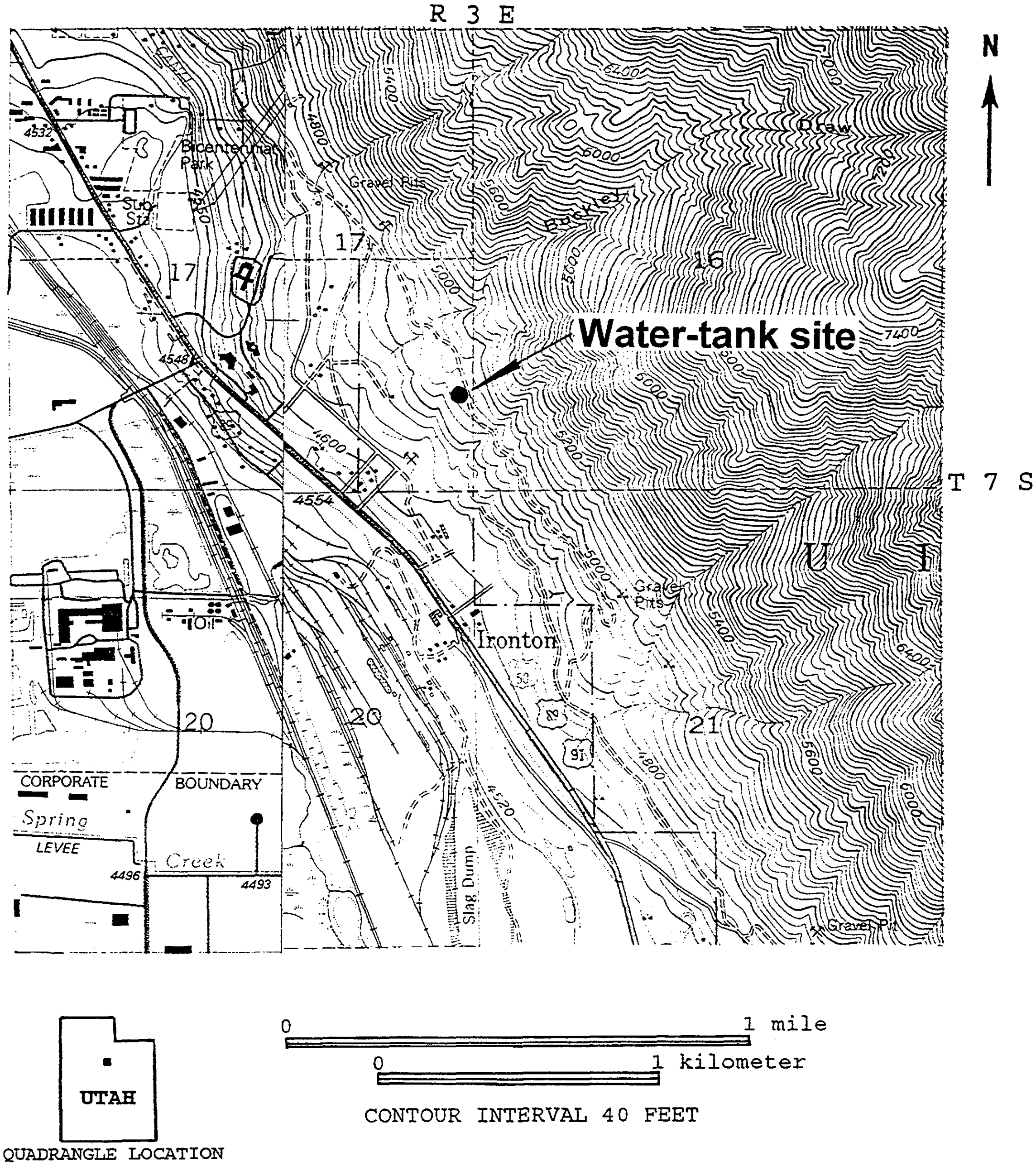
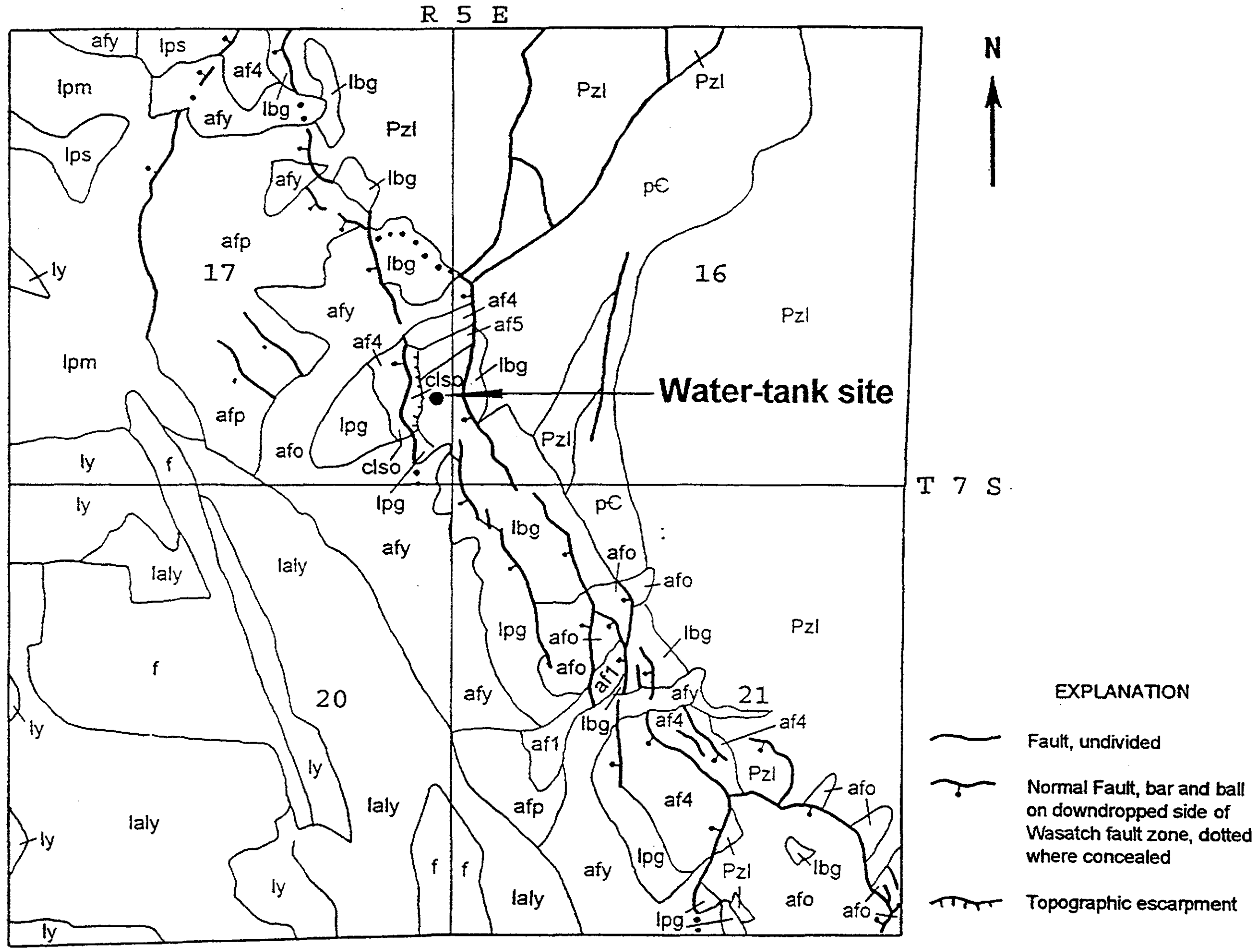
Base map from SPRINGVILLE and PROVO
U.S.G.S. 7-1/2' topographic quadrangles



Attachment 1. Location map.



DEPOSITS YOUNGER THAN THE BONNEVILLE LAKE CYCLE (HOLOCENE TO UPPER PLEISTOCENE)

f	Man-made fill
ly	Younger lacustrine and marsh deposits
laly	Lacustrine, marsh, and alluvial deposits
afl	Fan alluvium, unit 1
afy	Younger fan alluvium, undivided

DEPOSITS OF THE PROVO (REGRESSIVE) PHASE OF THE BONNEVILLE LAKE CYCLE (REGRESSIVE)

afp	Fan alluvium
lpg	Lacustrine gravel
lps	Lacustrine sand
lpm	Lacustrine silt and clay

0 1 mile

0 1 kilometer

DEPOSITS OF THE BONNEVILLE (TRANSGRESSIVE) PHASE OF THE BONNEVILLE LAKE CYCLE (UPPER PLEISTOCENE)

af3	Fan alluvium, unit 3
lbg	Lacustrine gravel

DEPOSITS OLDER THAN THE BONNEVILLE LAKE CYCLE (UPPER PLEISTOCENE TO UPPER TERTIARY)

af4	Fan alluvium, unit 4
af5	Fan alluvium, unit 5
afo	Older fan alluvium
clso	Older landslide deposits

BEDROCK

Pzl	Paleozoic sedimentary rock, lower Pennsylvanian to Cambrian
pЄ	Precambrian rocks

Attachment 2. Surficial geologic map of the water-tank site vicinity (modified from Machette, 1989).

SUMMARY OF GEOLOGIC HAZARDS
Utah Geological Survey
Investigator: Bill D. Black

SITE: Provo water tank

Hazard	Hazard Ratings*			Further Study Recommended**
	Probable	Possible	Unlikely	
Earthquake				S
Ground shaking				
Surface faulting		X		
Tectonic subsidence		X		
Liquefaction	X		X	
Slope failure		X		
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall		X		G
Landslide		X		
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive			X	
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion			X	
Active sand dunes			X	
Mine subsidence			X	
Shallow bedrock		X		
Shallow ground water			X	
Flooding				
Streams			X	
Alluvial fans			X	
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon (not evaluated)				

*Hazard Ratings - Probable, evidence is strong that the hazard exists and mitigation measures should be taken; Possible, hazard possibly exists, but evidence is equivocal, based only on theoretical studies, or was not observed and further study is necessary as noted; Unlikely, no evidence was found to indicate that the hazard is present.

**Further study (S-standard soil/foundation; G-geotechnical/ engineering; H-hydrologic) is recommended to address the hazard.

GLOSSARY OF GEOLOGIC-HAZARDS TERMINOLOGY

Acceleration (ground motion) - The rate of change of velocity of an earth particle caused by passage of a seismic wave.

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by a stream issuing from mountains onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan; stream flooding.

Antithetic fault - Normal fault showing the opposite orientation (dip) and sense of movement as the main fault with which it is associated.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Avalanche - A mass of snow or ice moving rapidly down a mountain slope.

Bearing capacity - The load per unit area which the ground can safely support without excessive yield.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess (wind-blown deposits).

Confined aquifer - An aquifer for which bounding strata exhibit low permeability such that water in the aquifer is under pressure (Also called Artesian aquifer).

Debris flow - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows contain sufficient water to move as a viscous flow. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Debris slide - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Chief mechanism of movement is by sliding. Debris slides generally contain insufficient water to travel long distances from their source areas; may mobilize into debris flows if sufficient water is present.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, and disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Epicenter - The point on the earth's surface directly above the focus of an earthquake.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Exposure time - The period of time being considered when discussing probabilistic evaluations of earthquakes and resulting hazards. Because earthquake occurrence is time dependent, that is, the longer the time period, the higher the probability that an earthquake will occur, the period of time being considered (usually 10, 50, or 250 years) must be specified.

Fault segment - Section of a fault which behaves independently from adjacent sections.

Fault - A break in the earth along which movement occurs.

Focus - The point within the earth that is the center of an earthquake and the origin of its seismic waves.

Graben - A block of earth downdropped between two faults.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Gypsiferous soil - Soil that contains the soluble mineral gypsum. May be susceptible to settlement when wetted due to dissolution of gypsum. See also Soluble soil/rock.

Holocene - An Epoch of the Quaternary Period, beginning 10,000 years ago and extending to the present.

Hydrocompaction - see Collapsible soil.

Intensity - A measure of the severity of earthquake shaking at a particular site as determined from its effect on the earth's surface, man, and man's structures. The most commonly used scale in the U.S. is the Modified Mercalli intensity scale.

Intermountain seismic belt - Zone of pronounced seismicity, up to 60 mi (100 km) wide, extending from Arizona through Utah to northwestern Montana.

Karst - See Soluble soil/rock.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earth flows.

Lateral spread - Lateral downslope displacement of soil layers, generally of several feet or more, resulting from liquefaction in sloping ground.

Liquefaction - Sudden large decrease in shear strength of a saturated, cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Liquefaction severity index - Estimated maximum amount (in inches) of lateral displacement accompanying liquefaction under particularly susceptible conditions (low, gently sloping, saturated flood plains deposits along streams) for a given exposure time.

Magnitude - A quantity characteristic of the total energy released by an earthquake. Several scales to measure earthquake magnitude exist, including local (Richter) magnitude (M_L), body wave magnitude (m_b), and surface wave magnitude (M_s). The local or Richter scale is commonly used in Utah earthquake catalogs. It is a logarithmic scale based on the motion that would be measured by a standard type of seismograph 100 km from the epicenter of an earthquake.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mine tunnels.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence.

Normal fault - Fault caused by crustal extension in which relative movement on opposite sides is vertically downdip.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Perched aquifer - An unconfined aquifer in which the underlying impermeable bed is not continuous over a large area and is situated at some height above the main water table.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Pleistocene - An Epoch of the Quaternary Period, beginning 1.6 million years ago and extending to 10,000 years ago.

Potentiometric surface - The level to which water rises in wells that tap confined aquifers. This level is above the upper surface of the confined aquifer (Also called Piezometric surface).

Quaternary - A period of geologic time extending from 1.6 million years ago to the present, including the Pleistocene and Holocene Epochs.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Recurrence interval - The length of time between occurrences of a particular event such as an earthquake.

Richter magnitude - see Magnitude

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

S factor - Site factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from thickness and type of sediment at a site and attempts to account for the effects of soils on earthquake ground motions.

Sand dunes - See Active sand dunes.

Scarp - A relatively steeper slope separating two more gentle slopes, usually in reference to a faulted surface marked by a steepening where a vertical fault displacement occurred.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche.

Seismicity - Seismic or earthquake activity.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Shear strength - The internal resistance of a body of soil or rock to shear. Shear is the movement of one part of the body relative to another along a plane of contact such as a fault.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Slump - A slope failure in which the slide plane is curved (concave upward) and movement is rotational.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition, or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

Unconsolidated basin fill - Uncemented and nonindurated sediment, chiefly clay, silt, sand, and gravel, deposited in basins.

Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

Z factor - Seismic zone factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from a nationwide seismic zone map which attempts to quantify regional variations of the ground-shaking hazard on rock.

Zone of deformation - The zone in the immediate vicinity of a surface fault rupture in which earth materials have been disturbed by fault displacement, tilting, or downdropping.

Project: Geologic-hazard investigation for a parcel of state-owned land near Logan, Utah			Requesting Agency: State Lands and Forestry
By: M.D. Hylland	Date: 6-13-94	County: Cache	Job No: 94-09 (GH-4)
USGS Quadrangle: Smithfield (1469)			

PURPOSE AND SCOPE

The Utah Geological Survey (UGS) conducted a geologic-hazards investigation of state-owned property northeast of Logan in Cache County, Utah. The Utah Division of State Lands and Forestry is negotiating acquisition of the property from the Utah Division of Wildlife Resources, and is considering residential development of the site. This geologic-hazards investigation was requested by Mr. Kevin S. Carter of the Division of State Lands and Forestry. The purpose of the investigation was to identify potential geologic hazards on the property that should be considered prior to site development. The scope of the investigation included a literature search, aerial-photo interpretation, and a field reconnaissance of the site with Gary Christenson (UGS) on May 11, 1994. Subsurface exploration was not performed as part of this study.

SETTING AND SITE DESCRIPTION

The 119.5-acre site occupies the SW1/4SE1/4 and the SE1/4SW1/4 section 24, and the NE1/4NW1/4 section 25, T. 12 N., R. 1 E., Salt Lake Base Line and Meridian. As shown on attachment 1, the property is at the base of the Bear River Range along the eastern margin of Cache Valley, south of the mouth of Green Canyon and north of the Logan Country Club. Ground-surface elevations at the site range from about 4,840 feet (1,475 m) above sea level along the western boundary to about 5,400 feet (1,646 m) near the northeastern corner. The ground surface slopes down to the west at about 17 percent (10 degrees) across most of the site. However, slopes on the northeastern portion of the site are as steep as 50 to 65 percent (27-33 degrees), with local, near-vertical bedrock exposures up to about 20 feet (6 m) high. Site vegetation generally consists of grasses and sage brush. I observed no surface water on the site.

A fence partially encloses the property, and other fences partition the site interior. Several transmission-line easements cross the site, and an irrigation canal is located along the western property boundary. Residential subdivisions exist west of the site, and a new residential subdivision is being constructed south of the site. Vacant land, including Cache National Forest, borders the site to the north and east.

GEOLOGY AND SOILS

Relatively recent geologic mapping of the site and surrounding area has been completed by Lowe (1987), McCalpin (1989), Lowe and Galloway (1993), and McCalpin (1994). Attachment 2 is a geologic map of the site and vicinity from Lowe and Galloway (1993). A geologic time scale is included as attachment 3.

The geology and topography of the site have primarily been influenced by two factors: (1) normal faulting along the East Cache fault zone, and (2) ancient Lake Bonneville. Normal faulting, which may have begun as early as Eocene time (Galloway, 1970) and continues to the present, is responsible for the steep mountain front of the Bear River Range that rises abruptly above Cache Valley. Numerous studies (for example, Cluff and others, 1974; Lowe, 1987; McCalpin, 1989) indicate that the site straddles the East Cache fault zone (attachment 2). The oldest rocks exposed at the site, consisting of Cambrian limestone and dolomite structurally deformed by folding and thrust faulting prior to normal faulting, are found on the upthrown (east) side of the fault zone. These rocks are discontinuously exposed across the upper portion of the slope and are locally covered with colluvial silty gravel that extends to depths ranging from about 10 to 20 inches (25-50 cm) (U.S. Soil Conservation Service, 1974). On the lower portion of the slope, the bedrock is mantled with a relatively thin layer of sediments deposited during and after occupation of Cache Valley by Lake Bonneville (Lowe and Galloway, 1993). Material exposed on the downthrown (west) side of the fault zone generally consists of unconsolidated Lake Bonneville-aged and younger material hundreds of feet thick (Lowe and Galloway, 1993).

Based on regional studies by Scott and others (1983) and Currey and Oviatt (1985), Lake Bonneville rose to its maximum elevation at the Bonneville shoreline about 16,000 years ago. The lake stabilized at this level due to spillover at a threshold in southeastern Idaho. The Bonneville shoreline is evident as a topographic bench that crosses the northeastern portion of the site at about elevation 5,120 feet (1,560 m). Nearshore sediments (designated Qlc_4 on attachment 2) consisting of bedded, well-sorted sand, gravel, and cobbles were deposited during this highstand and are exposed across the eastern and northern portions of the site (Lowe, 1987). Catastrophic downcutting of the threshold in southeastern Idaho caused the lake level to drop rapidly 360 feet (110 m) to the Provo shoreline about 15,000 years ago. Channels were incised in the lake sediments and other geologic units as streams adjusted to the new Provo-shoreline base level, and the eroded material was deposited in alluvial fans near the mouths of canyons. At the site, these deposits (Qaf_3) consist of poorly sorted, clay- to cobble-sized material and are exposed across the northwestern portion of the site (Lowe, 1987). Post-Lake Bonneville alluvial-fan material (Qaf_1) deposited at the mouths of canyons during Holocene time consists of poorly sorted, clay- to boulder-sized material and comprises the youngest deposits at the site (Lowe, 1987). Holocene alluvial fans from five different drainages have coalesced to form a continuous mantle across most of the western portion of the site.

GEOLOGIC HAZARDS

Attachment 4 is a summary checklist of potential geologic hazards at the site. All of the hazards listed on the checklist are discussed below. A glossary of geologic-hazards terminology is included as attachment 5.

Earthquake Hazards

The site is in the Intermountain seismic belt, a generally north-south-trending zone of seismic activity that bisects the state of Utah. Historical seismicity in the Cache Valley area includes three earthquakes of Richter magnitude 4.0 or greater. The largest recorded earthquake in the area occurred on August 30, 1962. The epicenter of this magnitude 5.7 earthquake was in the Bear River Range approximately 20 miles north of the site (Arabasz and others, 1979). This earthquake was the most damaging in Utah's history because of its magnitude and proximity to populated areas, and caused major structural damage in Logan (Cook, 1972; Christenson, 1986). The epicenters of the two other magnitude 4.0 or greater earthquakes, which occurred in 1923 and 1964, were located within about 4 miles of the site. Numerous earthquakes of magnitude 2.0 to 4.0 have been recorded in the Bear River Range east of Cache Valley, including one with an epicenter located at the mouth of Green Canyon (Arabasz and others, 1979). Based on available information and my field reconnaissance, earthquake hazards that exist at the site include ground shaking, surface faulting, and possibly tectonic subsidence.

Ground Shaking

The most likely and widespread earthquake hazard at the site is strong ground shaking. The strongest ground shaking would likely be associated with a large (surface-faulting) earthquake along the East Cache fault zone, although damaging ground shaking could be associated with a moderate-to-large earthquake anywhere in the area. Geologic evidence indicates that the East Cache fault zone is capable of generating earthquakes much larger than any that have occurred in historical time. Surface-faulting earthquakes with magnitudes ranging from 6.5 to 7.2 appear to have occurred repeatedly in Holocene time along the East Cache fault zone in the vicinity of Logan (Swan and others, 1983). The ground-shaking hazard is generally greatest for sites underlain by relatively thick sequences of unconsolidated, fine-grained soils that amplify ground motion. However, sand and gravel soils less than about 100 feet (30 m) thick can also amplify ground motions, particularly motions with periods less than about 1.0 second (Adan and Rollins, 1993). These periods include those most damaging to one- and two-story structures, such as single-family dwellings.

Three levels of design ground accelerations for the site, expressed as a fraction of gravitational acceleration (g), are summarized below. These are based on: (1) probabilistic peak horizontal accelerations that have a 10 percent chance of being exceeded in a 50-year period, (2) probabilistic peak horizontal accelerations that have a 10 percent chance of being exceeded in a 250-year period, which approximate the largest expected ground motions, and (3) the minimum design accelerations specified in the 1991 Uniform Building Code (UBC). In general, the portion of the property west of the fault trace can be considered a soil site, whereas the portion east of the fault trace can be considered a rock site with shallow, stiff soils. Peak ground accelerations based on contour maps in Youngs and others (1987) for cases (1) and (2) are as follows:

		Peak Ground Acceleration	
10% probability of being exceeded in:		Soil	Rock
	50 years	0.18 g	0.22 g
	250 years	0.40 g	0.48 g

The seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The property is located in UBC seismic zone 3. The seismic zone factor, or Z factor, associated with this seismic zone is 0.30, which effectively corresponds to designing for a peak acceleration on rock of 0.30 g. Soil properties at depth beneath the site west of the fault trace are not known in detail, but are likely dense sand and gravel hundreds of feet thick. The appropriate site coefficient for this portion of the property is S_2, with a corresponding S factor of 1.2. East of the fault trace, the property is underlain by shallow, stiff or dense soils over bedrock. Accordingly, the appropriate site coefficient for the eastern portion of the site is S_1, with a corresponding S factor of 1.0.

Surface Faulting

Another earthquake hazard at the site is surface faulting. In general, the most likely areas of future surface fault rupture are along zones of previous fault rupture, especially zones with evidence of rupture during Holocene time. However, the relative potential for surface faulting at a given time and location varies depending on the recurrence interval of faulting events and the elapsed time since the last event. The site is crossed by a fault scarp associated with the central section of the East Cache fault zone, which shows evidence of two surface-faulting events since formation of the Bonneville shoreline (McCalpin, 1994). The first event occurred between 15,500 and 13,000 years ago and the second event occurred about 4,000 years ago, indicating a recurrence interval of approximately 10,300 years (McCalpin, 1994). However, detailed studies along another normal fault in Utah, the Wasatch fault zone, indicate wide variability in recurrence intervals on individual fault segments (Machette and others, 1991, 1992). This condition makes determination of surface-faulting potential on a given fault segment highly uncertain.

Tectonic Subsidence

Tectonic subsidence on the downdropped (west) side of the fault may occur at the site during a surface-faulting event along the central section of the East Cache fault zone. The amount and extent of possible subsidence or ground tilting is proportional to the amount of vertical displacement at the surface along the fault, as well as the length of fault rupture. The two most recent events along the central section of the East Cache fault zone each involved 1.6 to 6.2 feet (0.5-1.9 m) of vertical displacement (McCalpin, 1994). This range of displacements would be sufficient to produce at least limited subsidence and/or ground tilting west of the fault if surface rupture occurred at the site.

Slope-Failure Hazards

Rock Fall

A rock-fall hazard is present on portions of the site. Rock falls can be a hazard on slopes covered by bouldery colluvium and below exposed bedrock, where rocks can become dislodged and roll downslope. Dislodgement can result from long-term weathering and erosion, or from short-term events such as earthquakes or human activity. Lowe (1987) identified an area of rock-fall hazard on the eastern portion of the site below an outcrop of Cambrian Bloomington Formation (limestone). My reconnaissance confirmed this and other rock-fall hazard areas on the eastern portion of the site, based on bedrock exposures and the presence of boulders (approximately 1 to 2 feet [0.3-0.6 m] in diameter) scattered across the slope below the outcrops. Rock-fall-hazard areas are shown in attachment 6.

Debris Flow

Debris flows could potentially affect drainage channels and the portion of the site underlain by Holocene alluvial-fan deposits (Qaf_1). Lowe (1987) identified a levee constructed by debris-flow events below the mouth of a drainage on the northeastern portion of the site. This levee may have resulted from a debris-flow event evident on the 1937 aerial photographs that I reviewed. I observed no evidence of more-recent debris-flow events at the site, and it appears that the hazard from high-volume debris flows is relatively low. This assessment is based on my observation of bedrock exposed in the bottoms of the drainages east of the site, and only a thin veneer of alluvium in the channel that could be mobilized in a debris-flow event.

Problem Soils

Some localized areas within Holocene alluvial-fan deposits (Qaf_1) at the site may contain collapsible soils. Rogers (1978) noted voids up to about 1/2-inch (1.3 cm) in diameter in similar soils exposed in test pits at an adjacent site south of the property. In general, collapsible soils commonly have a significant fine-grained component and are typically derived from shaly bedrock. Because the source rock for the alluvial-fan material on the site is dominated by limestone, dolomite, and sandstone (Lowe and Galloway, 1993), I expect the extent of the hazard associated with collapsible soils at the site is small.

According to the U.S. Soil Conservation Service (1974), the soil overlying limestone bedrock on the eastern portion of the site has a relatively high erosion potential, and the soils blanketing the remainder of the site have a low to moderate erosion potential. In general, silty soils on slopes disturbed by construction activities will be susceptible to erosion.

Shallow bedrock should be anticipated across the site east of the East Cache fault zone. In addition to bedrock exposures on the upper slope, I observed two transmission-line poles on the eastern portion of the site that were supported by anchored guys, presumably because shallow bedrock hindered sufficient pole embedment in this area. Bedrock was encountered at depths ranging from 1 to 4 feet (0.3-1.2 m) in test pits excavated on the eastern portion of the adjacent site south of the property (Rogers, 1978), which has similar topographic and geologic configurations as the subject property.

Flooding

Alluvial-fan flooding is a hazard at the site. This type of flooding may occur either as clear-water flooding or debris flooding (40 to 70 percent solid material by weight; Costa, 1984) associated with cloudburst rainstorms or rapid snowmelt. The hazard is greatest where drainages are not incised and therefore cannot contain floodwaters and debris, and the water moves across the fan surface as sheet flow or in shallow channels with unpredictable flow paths. At the site, this condition exists west of the East Cache fault zone in Qaf_1 units below about elevation 5,000 feet (1,524 m).

Radon

The radon hazard at the site is unknown, but may range from moderate to high based on the soil permeability and depth to ground water (Black, 1993). Three indoor-radon measurements from homes in Logan near the site range from 4.2 to 7.1 picocuries per liter of air (pCi/L) (Sprinkel and Solomon, 1990). These measurements are greater than the U.S. Environmental Protection Agency (EPA) action level of 4 pCi/L, and probably represent a moderate hazard (B.J. Solomon, Utah Geological Survey, verbal communication, May 13, 1994).

Other Hazards

The liquefaction hazard at the site appears to be low, given the combination of shallow bedrock across at least part of the site, the presence of poorly sorted silty and gravelly soils, and the deep ground-water table (generally greater than 100 feet [30 m] below the ground surface; Bjorklund and McGreevy, 1971). Likewise, the hazard associated with earthquake-induced slope failure (except rock falls) appears to be low because the slopes along the eastern portion of the site show no evidence of past slope failure. Earthquake-related flooding does not appear to be a hazard at the site. Also, the hazard associated with saturated sensitive clay soils that might lose strength during seismic shaking is low because: (1) these types of soils are deep-water deposits, and the soils that underlie the site are generally granular, nearshore deposits, and (2) the soils are relatively dry because of the deep water table beneath the site.

Landsliding could potentially occur on the steep slopes across the northeastern portion of the site, but probably only under extreme conditions. The bedrock units that underlie these slopes do not include those noted by Lowe (1987) as being susceptible to landsliding. I observed no evidence on the aerial photographs or in the field for past deep-seated slumps or slides, or shallow debris slides at the site. I also observed no evidence of avalanche hazard at the site.

I observed no evidence for hazards at the site associated with soluble soil or rock, expansive or organic soils, active sand dunes, or mine subsidence. The hazard associated with soils that are susceptible to piping is low due to the topography and drainage of the site. I also observed no evidence of non-engineered fill at the site.

Aside from alluvial-fan flooding, I observed no evidence of hazards associated with ground or surface water. Ground water is deep at the site and vicinity (Bjorklund and McGreevy, 1971), and there are no streams, lakes, or dams at or near the site that might present a flood hazard. The irrigation canal along the western property boundary is downslope of the site, so does not present a flood hazard.

CONCLUSIONS AND RECOMMENDATIONS

I did not observe evidence of geologic hazards at the site that would preclude residential development. However, geologic hazards such as earthquake ground shaking, surface faulting, tectonic subsidence, rock falls, debris flows, shallow bedrock, and alluvial-fan flooding warrant careful consideration during planning and construction. At a minimum, proposed structures at the property should be designed to meet the seismic provisions of UBC seismic zone 3 as outlined in this report under "Earthquake Hazards," to reduce ground-shaking hazards. Site layout should conform to applicable local-government land-use requirements with regard to surface-fault-rupture and rock-fall hazards. Such requirements typically range from fault setbacks and rock-fall protection structures to disclosure only, and should be determined in consultation with local government officials. Provisions for reducing a tectonic-subsidence hazard are generally not considered for residential subdivisions.

Site-specific studies of the debris-flow and alluvial-fan-flood hazard should be completed to better assess the relative hazard, define affected areas, and recommend hazard-reduction methods, as appropriate. A standard soils/foundation investigation should be performed at the site to provide geotechnical information pertaining to site grading, foundation and pavement design, the presence of collapsible soils, and depth to bedrock. Although the general slope-failure hazard is low, a site-specific slope-stability evaluation should also be performed if any grading or ground modifications are planned for the portion of the site east of the fault.

The indoor-radon measurements from homes located near the site are above the EPA action level of 4 pCi/L, indicating that radon-resistant construction methods should be considered. Homeowners may wish to test for indoor radon after construction to determine the need for further action.

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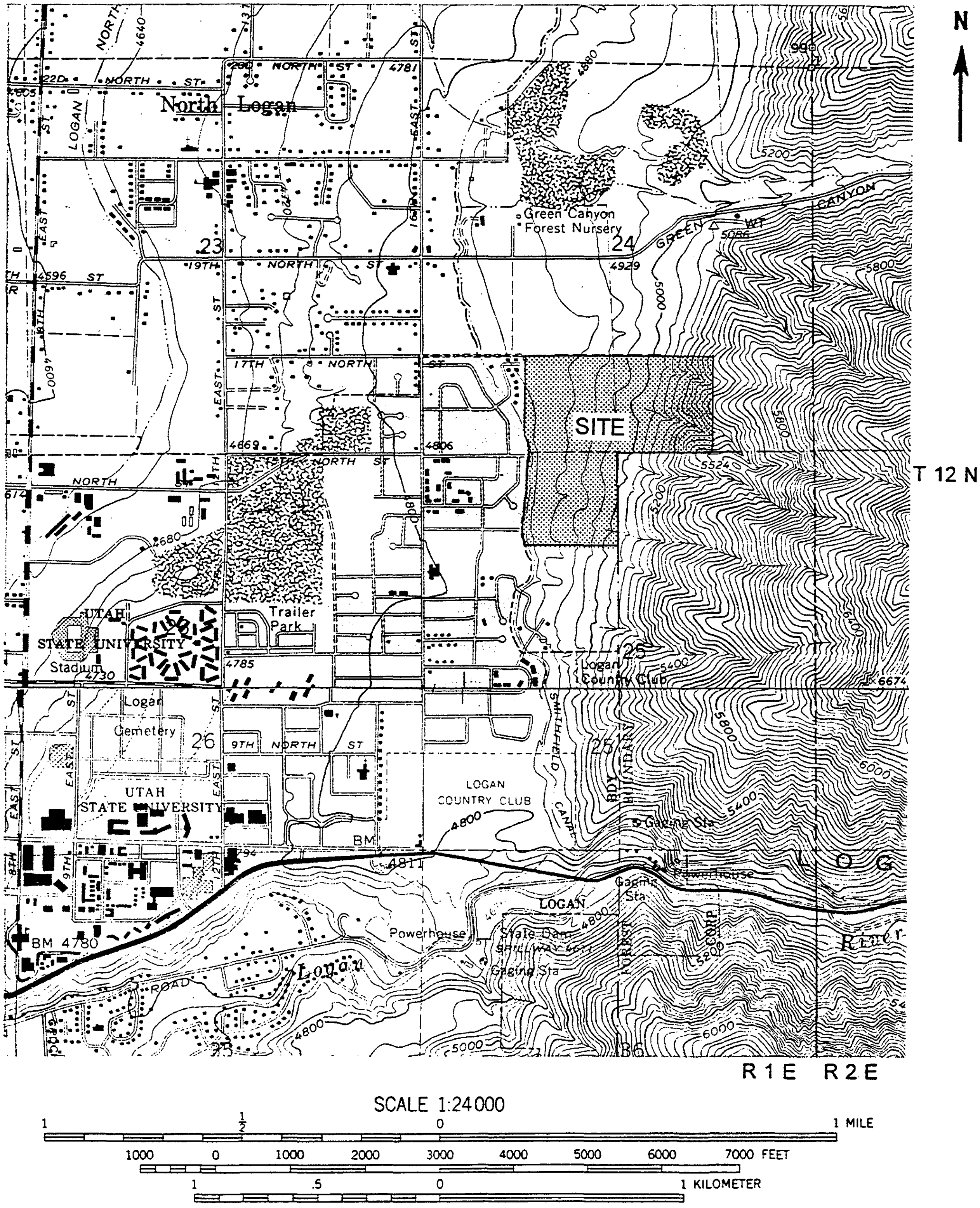
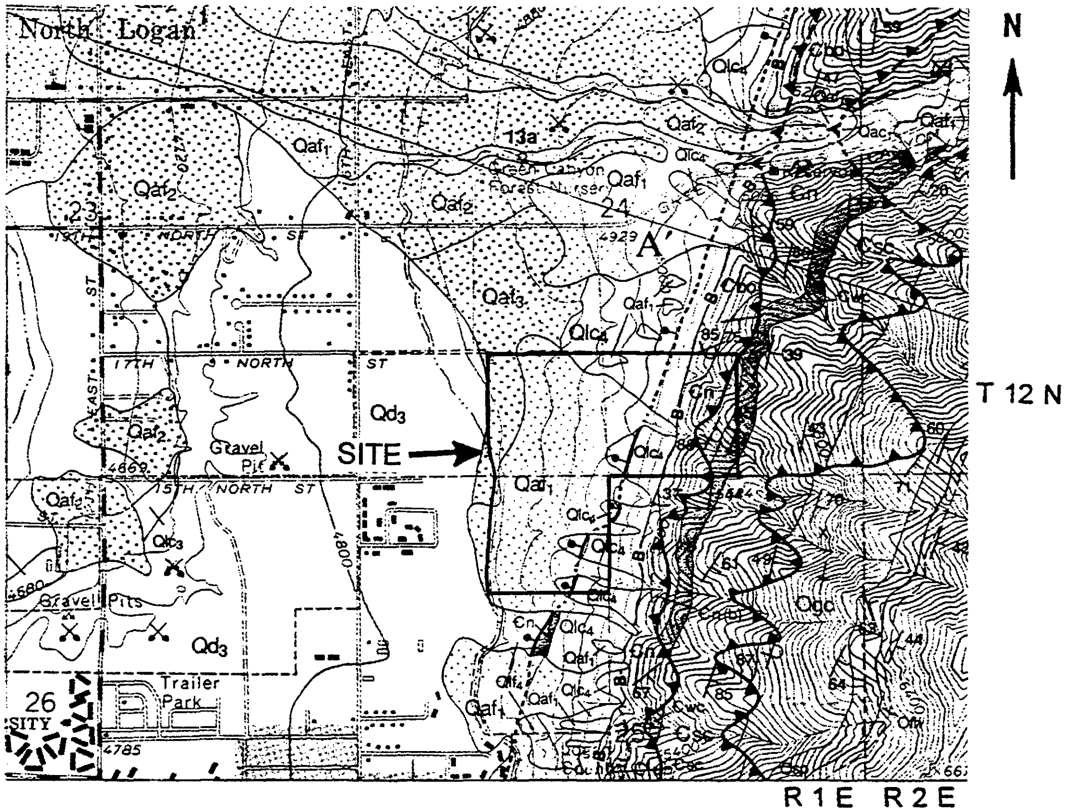
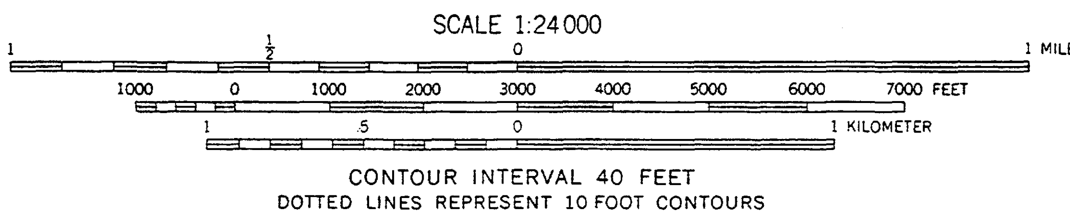
Base Map from SMITHFIELD and LOGAN
U.S.G.S. 7-1/2' topographic quadrangles



Attachment 1. Location map.

Base Map from SMITHFIELD U.S.G.S.
7-1/2' topographic quadrangle





MAP SYMBOLS

CONTACT - dashed where approximate

NORMAL FAULT - dashed where approximate; dotted where concealed; bar and ball on downthrown side; queried where existence uncertain

THRUST FAULT - dashed where approximate; dotted where concealed; sawtheeth on upper plate

TRACE OF SLIDE-BLOCK SURFACE - dashed where approximate

TRACE OF BONNEVILLE SHORELINE

STRIKE AND DIP OF BEDDING

- 64 inclined
- vertical
- 87 overturned

Attachment 2. Geologic map of site and vicinity (modified from Lowe and Galloway, 1993.) See explanation on following page.

DESCRIPTION OF MAP UNITS

* denotes unit exposed on site

QUATERNARY	Holocene	Qac_1	Alluvium and colluvium	
		*Qaf_1	Younger post-Lake Bonneville alluvial-fan deposits	
		Qaf_2	Older post-Lake Bonneville alluvial-fan deposits	
	late Pleistocene	Qlc_3	Lacustrine nearshore deposits	Provo Stage
		Qd_3	Deltaic deposits	
		*Qaf_3	Alluvial-fan deposits	
		Qlf_4	Lacustrine offshore deposits	Bonneville Stage
		*Qlc_4	Lacustrine nearshore deposits	
ORDOVICIAN		Ofh	Fish Haven Dolomite - dolomite	
		Osp	Swan Peak Formation - shale, siltstone, limestone, quartzite	
		Ogc	Garden City Formation - limestone, dolomite, conglomerate	
CAMBRIAN			St. Charles Formation	
		Єsc	Upper Member - limestone, dolomite	
		*Єwc	Worm Creek Quartzite Member - quartzite, limestone, dolomite	
		*Єn	Nounan Formation - dolomite	
		*Єbo	Bloomington Formation - shale, limestone	

Note: Refer to attachment 3 for geologic time scale.

Subdivisions of Geologic Time			Apparent Ages (millions of years before present)
Eras	Periods	Epochs	
CENOZOIC	Quaternary	(Recent) Holocene	.01
		Pleistocene	1.6
	Tertiary	Pliocene	5.3
		Miocene	23.7
		Oligocene	36.6
		Eocene	57.8
		Paleocene	66.4
MESOZOIC	Cretaceous		144
	Jurassic		208
	Triassic		245
PALEOZOIC	Permian		286
	Pennsylvanian (Upper Carboniferous)		320
	Mississippian (Lower Carboniferous)		360
	Devonian		408
	Silurian		438
	Ordovician		505
	Cambrian		570
PRECAMBRIAN			

Attachment 3. Geologic time scale.

SUMMARY OF GEOLOGIC HAZARDS
Utah Geological Survey
Investigator: Michael D. Hylland

SITE: State Lands & Forestry, Cache County

Hazard	Hazard Ratings*			Further Study Recommended**
	Probable	Possible	Unlikely	
Earthquake				
Ground shaking	X			
Surface faulting	X			
Tectonic subsidence		X		
Liquefaction			X	
Slope failure			X	
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall	X			
Landslide			X	
Debris flow		X		G, H
Avalanche			X	
Problem soils/subsidence				
Collapsible		X		S
Soluble (karst)			X	
Expansive			X	
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion		X		
Active sand dunes			X	
Mine subsidence			X	
Shallow bedrock	X			S
Shallow ground water			X	
Flooding				
Streams			X	
Alluvial fans	X			H
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon		X		

*Hazard Ratings - Probable, evidence is strong that the hazard exists and reduction mitigation should be considered; Possible, hazard possibly exists, but evidence is equivocal, based only on theoretical studies, or was not observed and further study is necessary as noted; Unlikely, no evidence was found to indicate that the hazard is present.

**Further study (S-standard soil/foundation; G-geotechnical/ engineering; H-hydrologic) is recommended to address the hazard.

GLOSSARY OF GEOLOGIC-HAZARDS TERMINOLOGY

Acceleration (ground motion) - The rate of change of velocity of an earth particle caused by passage of a seismic wave.

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by a stream issuing from mountains onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan; stream flooding.

Antithetic fault - Normal fault showing the opposite orientation (dip) and sense of movement as the main fault with which it is associated.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Avalanche - A mass of snow or ice moving rapidly down a mountain slope.

Bearing capacity - The load per unit area which the ground can safely support without excessive yield.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess (wind-blown deposits).

Confined aquifer - An aquifer for which bounding strata exhibit low permeability such that water in the aquifer is under pressure (Also called Artesian aquifer).

Debris flow - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows contain sufficient water to move as a viscous flow. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Debris slide - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Chief mechanism of movement is by sliding. Debris slides generally contain insufficient water to travel long distances from their source areas; may mobilize into debris flows if sufficient water is present.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, and disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Epicenter - The point on the earth's surface directly above the focus of an earthquake.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Exposure time - The period of time being considered when discussing probabilistic evaluations of earthquakes and resulting hazards. Because earthquake occurrence is time dependent, that is, the longer the time period, the higher the probability that an earthquake will occur, the period of time being considered (usually 10, 50, or 250 years) must be specified.

Fault segment - Section of a fault which behaves independently from adjacent sections.

Fault - A break in the earth along which movement occurs.

Focus - The point within the earth that is the center of an earthquake and the origin of its seismic waves.

Graben - A block of earth downdropped between two faults.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Gypsiferous soil - Soil that contains the soluble mineral gypsum. May be susceptible to settlement when wetted due to dissolution of gypsum. See also Soluble soil/rock.

Holocene - An Epoch of the Quaternary Period, beginning 10,000 years ago and extending to the present.

Hydrocompaction - see Collapsible soil.

Intensity - A measure of the severity of earthquake shaking at a particular site as determined from its effect on the earth's surface, man, and man's structures. The most commonly used scale in the U.S. is the Modified Mercalli intensity scale.

Intermountain seismic belt - Zone of pronounced seismicity, up to 60 mi (100 km) wide, extending from Arizona through Utah to northwestern Montana.

Karst - See Soluble soil/rock.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earth flows.

Lateral spread - Lateral downslope displacement of soil layers, generally of several feet or more, resulting from liquefaction in sloping ground.

Liquefaction - Sudden large decrease in shear strength of a saturated, cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Liquefaction severity index - Estimated maximum amount (in inches) of lateral displacement accompanying liquefaction under particularly susceptible conditions (low, gently sloping, saturated flood plains deposits along streams) for a given exposure time.

Magnitude - A quantity characteristic of the total energy released by an earthquake. Several scales to measure earthquake magnitude exist, including local (Richter) magnitude (M_L), body wave magnitude (m_b), and surface wave magnitude (M_s). The local or Richter scale is commonly used in Utah earthquake catalogs. It is a logarithmic scale based on the motion that would be measured by a standard type of seismograph 100 km from the epicenter of an earthquake.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mine tunnels.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence.

Normal fault - Fault caused by crustal extension in which relative movement on opposite sides is vertically downdip.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Perched aquifer - An unconfined aquifer in which the underlying impermeable bed is not continuous over a large area and is situated at some height above the main water table.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Pleistocene - An Epoch of the Quaternary Period, beginning 1.6 million years ago and extending to 10,000 years ago.

Potentiometric surface - The level to which water rises in wells that tap confined aquifers. This level is above the upper surface of the confined aquifer (Also called Piezometric surface).

Quaternary - A period of geologic time extending from 1.6 million years ago to the present, including the Pleistocene and Holocene Epochs.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Recurrence interval - The length of time between occurrences of a particular event such as an earthquake.

Richter magnitude - see Magnitude

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

S factor - Site factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from thickness and type of sediment at a site and attempts to account for the effects of soils on earthquake ground motions.

Sand dunes - See Active sand dunes.

Scarp - A relatively steeper slope separating two more gentle slopes, usually in reference to a faulted surface marked by a steepening where a vertical fault displacement occurred.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche.

Seismicity - Seismic or earthquake activity.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Shear strength - The internal resistance of a body of soil or rock to shear. Shear is the movement of one part of the body relative to another along a plane of contact such as a fault.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Slump - A slope failure in which the slide plane is curved (concave upward) and movement is rotational.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition, or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

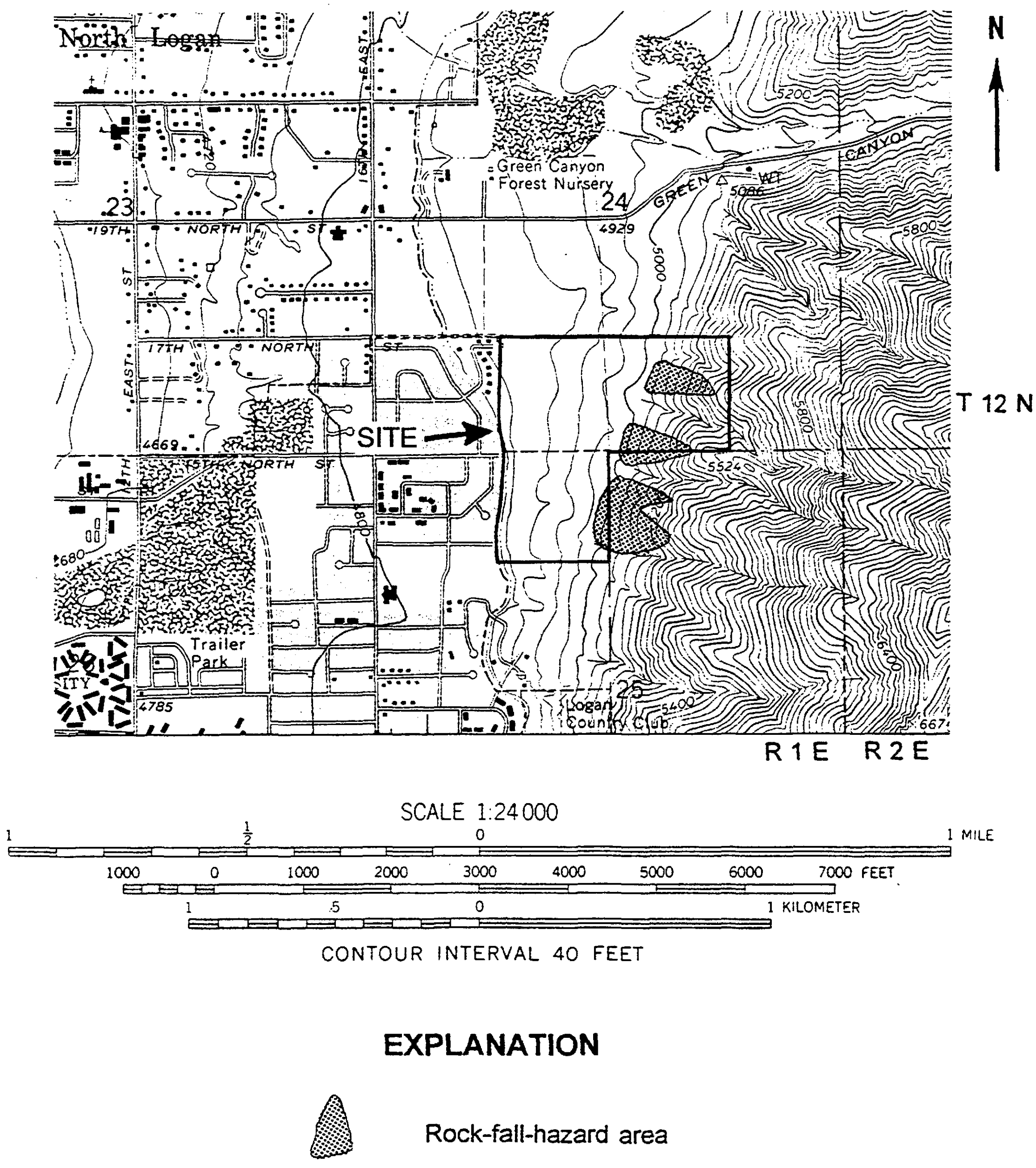
Unconsolidated basin fill - Uncemented and nonindurated sediment, chiefly clay, silt, sand, and gravel, deposited in basins.

Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

Z factor - Seismic zone factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from a nationwide seismic zone map which attempts to quantify regional variations of the ground-shaking hazard on rock.

Zone of deformation - The zone in the immediate vicinity of a surface fault rupture in which earth materials have been disturbed by fault displacement, tilting, or downdropping.

Base Map from SMITHFIELD U.S.G.S.
7-1/2' topographic quadrangle



Attachment 6. Rock-fall-hazard map.

Project: Reconnaissance of landslide southwest of Hoytsville, Utah			Requesting Agency: Emergency Response
By: M.D. Hylland	Date: 9-15-94	County: Summit	Job No: 94-14 (GH-5)
USGS Quadrangle: Wanship (1250)			

PURPOSE AND SCOPE

On August 23, 1994, I completed a reconnaissance investigation of a landslide near Hoytsville, Summit County, Utah. The landslide was brought to my attention by Norma Lee McMichael, a property owner who lives near the landslide. The purpose of the investigation was to evaluate possible risk to life or property. The scope of work for the investigation consisted of a literature review and site visit, including photographic documentation and preparation of a sketch map showing site conditions.

SITE CONDITIONS

The landslide is within an area of pasture along West Hoytsville Road approximately 1.3 miles (2.1 km) southwest of Hoytsville, on the western margin of the Weber River flood plain (attachment 1). The landslide, which is approximately 750 feet (230 m) wide in a north-south direction and 500 feet (150 m) long in an east-west direction, is on an east-facing hillside above and west of West Hoytsville Road. The hillside is underlain by conglomerate, sandstone, siltstone, and mudstone of the Early Tertiary Wasatch Formation (Bryant, 1992). Surficial deposits consist of unconsolidated material derived from those rocks including colluvium and possibly older landslide deposits, based on road-cut and landslide scarp exposures.

The landslide appears to be an earth-block slide or slump (after Varnes, 1978). The main scarp forms an arcuate crack near the top of the hill, which at its highest point is about 140 feet (43 m) above the road. At the main scarp, which is vertical and unvegetated, the head of the landslide has moved approximately 2 to 3 feet (0.6-1 m) vertically (down) and 1 to 1.5 feet (0.3-0.5 m) laterally (east) relative to the crest of the scarp. Numerous ground cracks are present on the landslide, especially across the southern portion. The road crosses the toe of the landslide, and the basal slide plane daylights at or just below the road. A zone of cracks extending across the road to the base of the shoulder fill indicates a lateral shear zone along the northern margin of the landslide.

An irrigation canal traverses the landslide midslope approximately 60 feet (18 m) above the road. I observed a distinct zone of seeps directly below the canal on the northern portion of the landslide. I also observed surface-water flow below the canal on the southern portion of the landslide, although the source areas were obscured by dense vegetation. The water was flowing over the road at four locations, at an estimated rate of 2 gallons per minute (0.1 l/s) at each location. A temporary sign at the base of a cutslope along the west side of the road marked the location of a plugged culvert, presumably plugged by road-maintenance activities, landslide movement, or both. Potholes, extensive pavement cracks, and soft areas that yielded under-foot indicate local saturated subgrade conditions.

Houses and barns in the area are beyond the present northern and southern limits of the landslide. A pump house east of the road is directly across from the middle portion of the landslide.

CONCLUSIONS

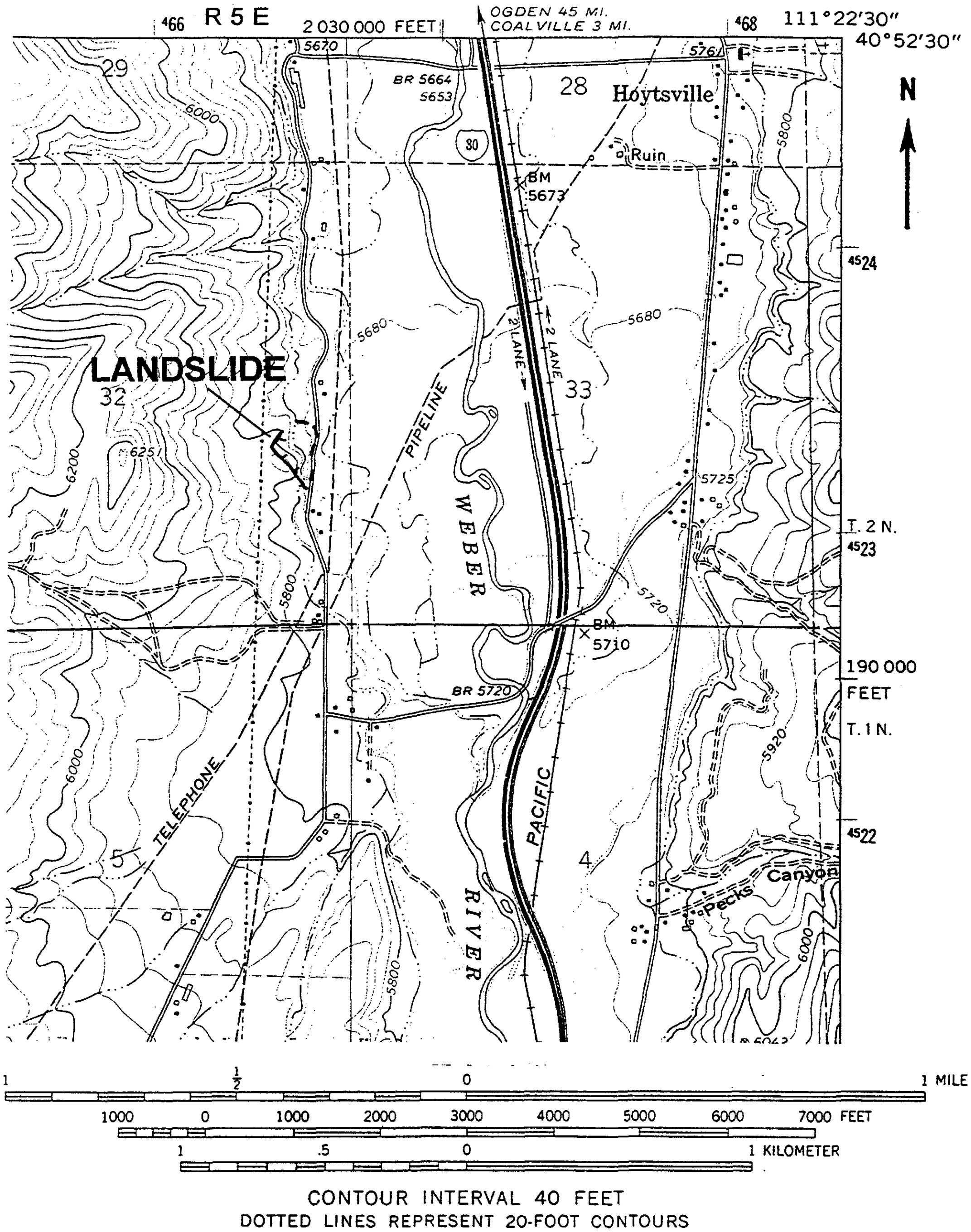
The landslide along West Hoytsville Road appears to be a slow-moving earth-block slide or slump. The primary cause of movement is likely excessive pore-water pressures in the lower portion of the hillside. The source of water may be leakage from the canal, naturally occurring shallow ground water, or both. The landslide does not appear to pose an imminent threat to life or occupied structures. However, continued slope movement should be expected, which may damage the road and canal. Canal damage could result in leakage which in turn may introduce more water into the landslide and promote further movement.

REFERENCES

Bryant, Bruce, 1992, Geologic and structure maps of the Salt Lake City 1° x 2° quadrangle, Utah and Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-1997, scale 1:125,000.

Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L, and Krizek, R.J., editors, Landslides - Analysis and control: Washington, D.C., National Academy of Sciences, Transportation Research Board Special Report 176, Chapter 2, p. 11-33.

Attachment 1. Job No. 94-14 Base Map from WANSHIP U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location map.

Project:			Requesting Agency:
Debris-flow and debris-flood potential in the Trojan #2 burn area near Mapleton, Utah			City of Mapleton
By: M.D. Hylland	Date: 10-24-94	County: Utah	Job No: 94-16 (GH-6)
USGS Quadrangle: Spanish Fork Peak (1005)			

INTRODUCTION

The "Trojan #2" wildfire burned approximately 2,900 acres (1,174 ha) of U.S. Forest Service, State of Utah, and private land on and near the west slope of Spanish Fork Peak, locally known as Maple Mountain, in September 1994. The affected area extends from Middle Slide Canyon, about 1.5 miles (2.4 km) southeast of Mapleton, south to near U.S. Highway 6/50/89 (attachment 1). Middle Slide Canyon was previously burned during a fire in 1989. No houses were involved in either fire and no lives were lost. Removal of vegetal cover, however, results in increased runoff and may significantly increase erosion during periods of rain and/or snowmelt. Flooding and debris flows damaged a house and fence below the mouth of Middle Slide Canyon following the 1989 fire.

In response to a request from C. Wynn Everett, Mapleton City Councilman, I completed a reconnaissance-level investigation of the site. The purpose of the investigation was to evaluate possible risk to life or property associated with the increased potential for erosion and possible resultant debris-flow and debris-flood hazards. The scope of work consisted of a literature review, aerial-photograph review, discussions with U.S. Forest Service and Soil Conservation Service personnel, and a site reconnaissance on September 22, 1994.

SITE CONDITIONS

The Trojan #2 burn area includes six major ephemeral-stream drainages and several subsidiary drainages along the west slope of Maple Mountain, as well as portions of the adjacent valley floor (attachment 1). The mountain front is underlain by the Pennsylvanian-Permian Oquirrh Formation, which generally consists of limestone, sandstone, and quartzite (Baker, 1972). Unconsolidated, middle Pleistocene to Holocene alluvium, Lake Bonneville deposits, and alluvial-fan deposits are present at the base of the mountain front (Machette, 1992). Faulting and associated deformation along the Wasatch fault zone have created a steep escarpment approximately 150 feet (46 m) high in the Lake Bonneville deposits, which generally consist of sand and gravel with local areas of silt. The uplifted Lake Bonneville deposits on the east side of the escarpment form a bench above the valley floor to the west. Surface-water flow and Holocene debris flows from Middle Slide Canyon have eroded a narrow slot in the bench and deposited material at the base of the escarpment, creating a relatively large alluvial fan. Between Middle Slide Canyon and Crowd Canyon, the bench is wide enough to contain most debris flows before they spill over the bench onto the valley floor. A small alluvial fan of Holocene or latest Pleistocene age (Machette, 1992) is present on the valley floor near the mouth of Crowd Canyon, where the bench is again relatively narrow.

Based on extrapolation of U.S. Soil Conservation Service data (Swenson and others, 1972), aerial-photograph review, and soils observed on the hillside just above the bench, the drainage slopes are covered with relatively thin colluvial deposits generally consisting of cobbly silt or clay loam. The colluvium appears to be thicker in the bottoms of the drainages.

Natural vegetal cover in the burn area consists primarily of grass and oak brush, with scattered sage and cactus on the lower slopes and stands of pine trees on the upper slopes. The U.S. Forest Service estimates that a hot burn, resulting in complete loss of large vegetation and 85-90 percent of the ground cover, occurred over 58 percent of the burn area (P. Skabelund, U.S. Forest Service, verbal communication, October 17, 1994). Light to moderate burns, resulting in significant areas of undamaged to lightly damaged vegetation, occurred over the remaining 42 percent of the burn area. Big Slide Canyon had a more extensive hot burn than the other drainages (attachment 1).

A cloudburst rainstorm on September 29, 1994 produced a debris flow that deposited 130 cubic yards (0.08 acre-ft) of material on vacant land on a Holocene alluvial fan at the mouth of Big Slide Canyon (P. Skabelund, verbal communication, October 5, 1994). According to Mr. Skabelund, subsequent rainstorms have resulted in intermittent, hyperconcentrated stream flows from some of the drainages, but no additional debris-flow events. Mr. Skabelund also indicated that none of the flows have approached the Mapleton Lateral Canal closer than about 800 feet (244 m).

Several houses are located on or near the toe of the Holocene alluvial fan at the mouth of Middle Slide Canyon. One of these is the house that was damaged by a debris flow in 1989. The remainder of the valley floor near the base of the escarpment is undeveloped and generally consists of pasture with scattered stock buildings. A deflection berm was constructed in 1989 at the mouth of Middle Slide Canyon to divert debris flows and flood waters away from the houses and onto vacant land. The Mapleton Lateral Canal roughly parallels the mountain front approximately 0.3 to 0.7 mile (0.5-1.1 km) west of the escarpment. Power transmission lines and a service road are on the bench, and the Trojan facilities are at the base of the mountain front near the southern end of the burned area.

CONCLUSIONS AND RECOMMENDATIONS

The potential risk to life and occupied structures from debris-flow or debris-flood damage associated with the Trojan #2 fire is low. The only houses located on Holocene alluvial fans, which are the areas expected to be affected by debris-flow or debris-flood events, are near the mouth of Middle Slide Canyon. The present risk to these houses is low because of the deflection berm and the occurrence of a debris flow five years ago, which reduced the amount of source-area material that could be mobilized in a future debris-flow event. The City of Mapleton may wish to have the deflection berm and burn conditions in Middle Slide Canyon evaluated by the designers of the berm, to assess its adequacy.

Increased runoff carrying considerable ash and mud should be expected until vegetation on the burned slopes has been reestablished. However, significant deposition of this material should be limited to the largely undeveloped Holocene alluvial fans. Near the southern Mapleton City boundary, sheds and other outbuildings located in topographically low areas could be affected by debris floods from Crowd Canyon and the drainage north of Crowd Canyon during an extreme storm event. Aside from a possible increased risk to these unoccupied structures, however, there has not been a significant increase in the debris-flow and debris-flood hazard to local residents resulting from this fire.

For land-use planning considerations, the City of Mapleton should refer to existing geologic-hazards maps (for example, Robison, 1990) to determine the debris-flow hazard areas and where site-specific hazard evaluations are recommended prior to development. The identified hazard zones are valid for both burned and unburned upland conditions. Consideration of geologic hazards in high-risk areas typically results in more cost-effective use of land. The maps, which are available from the Utah County Planning Department, include such hazards as surface fault rupture, landslides, rock fall, and shallow ground water, in addition to debris flows.

REFERENCES

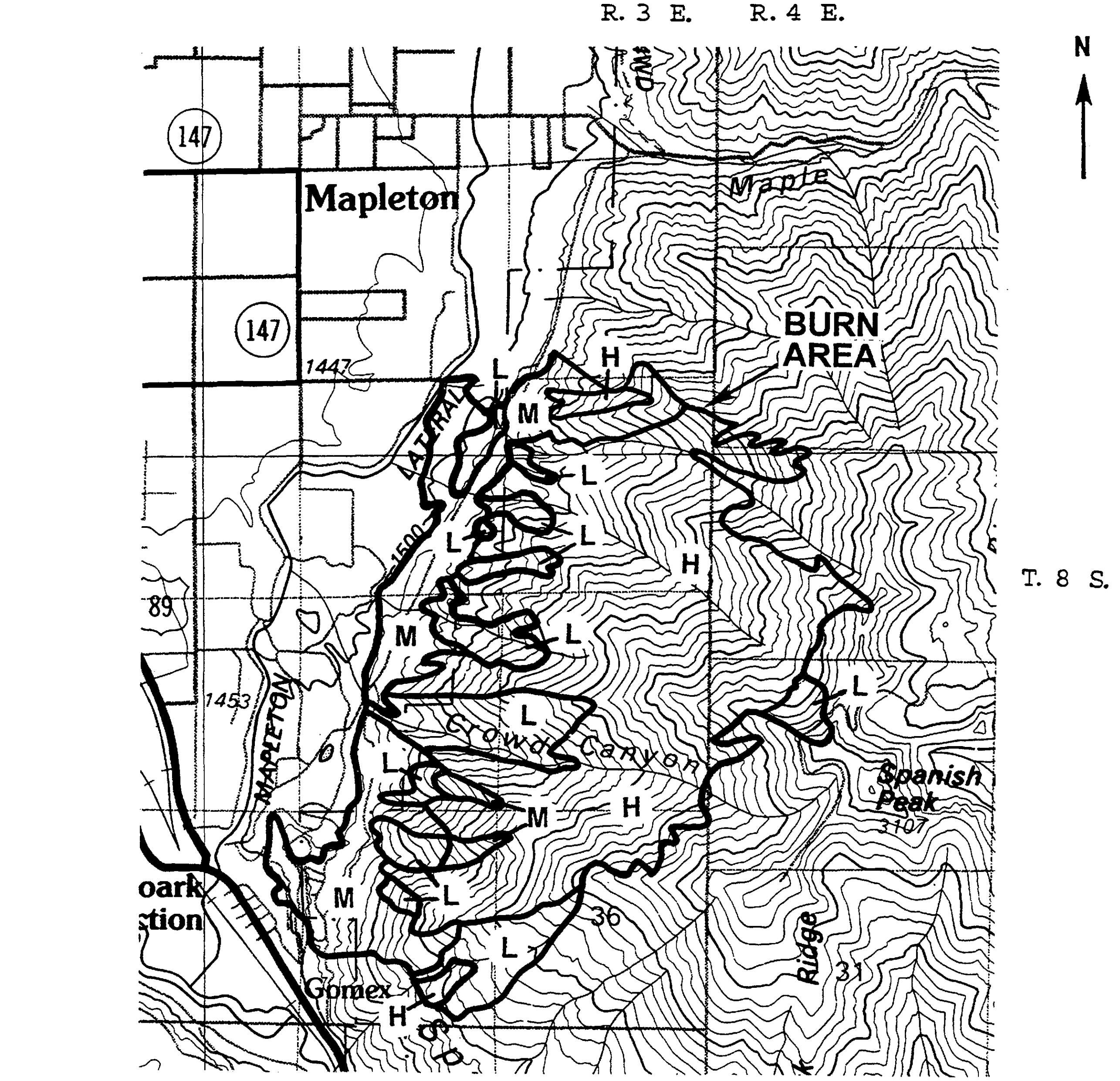
Baker, A.A., 1972, Geologic map of the northeast part of the Spanish Fork Peak quadrangle, Utah County, Utah: U.S. Geological Survey Open-File Report 72-9, scale 1:24,000.

Machette, M.N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-2095, scale 1:50,000.

Robison, R.M., 1990, Utah County natural hazards overlay (NHO) zone - Debris flow: unpublished Utah County Planning Department map, scale 1:24,000.

Swenson, Jr., J.L., Archer, W.M., Donaldson, K.M., Shiozaki, J.J., Broderick, J.H., and Woodward, Lowell, 1972, Soil survey of Utah County, Utah, central part: U.S. Soil Conservation Service in cooperation with Utah Agricultural Experiment Station, 161 p.

Base map from PROVO U.S.G.S. 30 X 60-minute topographic quadrangle



SCALE: 1:50,000
CONTOUR INTERVAL 50 METERS

EXPLANATION:

H	Hot burn
M	Moderate burn
L	Light burn

Reference: Unpublished map provided by the U.S. Forest Service.

Attachment 1. Burn-area location map.

Utah Geological Survey

Project:			**Requesting Agency:**
Geologic reconnaissance of a slope failure near 440 South Scenic Drive, Spanish Fork, Utah County, Utah.			Utah County Public Works Department
By: Bill D. Black	**Date:** 12-19-94	**County:** Utah	**Job No:** 94-18 (GH-7)
USGS Quadrangle: Spanish Fork (1006)			

INTRODUCTION

In response to a request by Paul L. Hawker (Assistant County Engineer, Utah County Public Works Department), I conducted a geologic reconnaissance of a slope failure near 440 South Scenic Drive, Spanish Fork, Utah. The slope failure occurred on the morning of December 6, 1994, and is located in the NE1/4NW1/4 section 30, T. 8 S., R. 3 E., Salt Lake Base Line (attachment 1). The slope failure is in a southwest-facing bluff overlooking the flood plain of the Spanish Fork River, below a subdivision along Scenic Drive at the top of the bluff (attachment 1).

The purpose of this investigation was to preliminarily assess the hazard potential of the slope failure and stability of the remaining slope. The scope of work included a field inspection, review of pertinent literature, and examination of 1:40,000-scale aerial photos (1987). Paul Hawker, Richard Nielson (Design Engineer, Spanish Fork City), Gary Christenson (Utah Geological Survey), and several local homeowners were present during the field inspection.

DESCRIPTION

The slope failure is an earth flow (attachment 2) approximately 60 feet (18.3 m) wide and 50 feet (15.2 m) from the main scarp to the base of the source area. The failure apparently occurred rapidly, as soil in the source area liquefied and flowed to the west onto the flood plain of the Spanish Fork River. The steepness of the slope in the source area is approximately 20 degrees (36 percent); the steepness of the slope (which is fill) above the main scarp is roughly 30 degrees (58 percent). The dip of the main scarp varied from very shallow to nearly vertical, and was 10 to 12 feet (3-4 m) high. Disturbed soil and clumps of uprooted surface vegetation (grasses and weeds) remain in the source area. The source material flowed only a short distance, and did not reach an irrigation canal (Mill Race canal, attachment 1) to the west.

The earth flow is in bluffs bordering the flood plain of the Spanish Fork River. The bluffs are underlain by deltaic sediments and stream alluvium deposited by the Spanish Fork River during the Provo (regressive) phase of Pleistocene Lake Bonneville (Machette, 1989). The bluffs formed when Lake Bonneville receded and the delta was eroded by the Spanish Fork River as it cut down to its present level. The bluffs are now capped by fill emplaced for the subdivision.

The earth flow formed chiefly in interbedded deltaic sand and clay. Water was observed issuing from the scarp. Prior to the earth flow, a spring at the base of the bluffs had formed a shallow pond surrounded by cattails (Lori Bradford, homeowner, verbal communication, December, 1994). Although the discharge of this spring is unknown, it was sufficient to keep the area wet throughout most of the year (Lori Bradford, verbal communication, December, 1994).

The cause of the earth flow was likely a combination of slide-prone geologic materials and excess pore-water pressure from ground water from various sources, including snowmelt and rainfall. Snow accumulations of up to one foot (0.3 m) rapidly melted during rainfall in the week preceding the earth flow (Paul Hawker, verbal communication, December, 1994). The earth flow occurred after the rapid snowmelt and rainfall saturated the hillside and increased flow from the spring, which caused sediments to become unstable and liquefy. Deltaic sediments in the hillside elsewhere show evidence of numerous minor slope failures, and a slope failure similar to this one in the mid-1970s damaged a home along Bottoms Road at the base of the bluffs to the southeast (Paul Hawker, verbal communication, December, 1994).

HAZARD POTENTIAL AND RECOMMENDATIONS

Although the earth flow does not appear to present an immediate hazard, I believe a hazard may exist from future slope failures or erosion. Slopes along the bluff are in a designated landslide-hazard zone on Utah County Planning Department maps (Robison, 1990), and other recent failures and probable older landslide scallops in the bluff indicate slopes in this area have marginal stability. The slope is now steeper than before the failure, because the toe of the slope was removed. Also, fill placed when the homes were built has weighted the top of the slope. These conditions act to decrease slope stability. Additional slope failures may occur, possibly under wet conditions, as the oversteepened main scarp of the failure wears back, undermining the fill and possibly affecting the foundations of homes above the scarp. Erosion of the scarp by the spring or surface runoff could also lead to future instability of the slope. Although unlikely, a sufficiently large slope failure could affect the homes above, as well as block the irrigation canal to the west and cause flooding along the base of the slope.

I recommend that the homeowners monitor the slope above the failure for further evidence of instability, such as new cracks, or erosion of the scarp. I also recommend that the stability of the slope be evaluated by a geotechnical engineer. If slope-stability problems occur, or if the geotechnical evaluation indicates potential instability, measures may be needed to stabilize the slope, such as emplacing a buttress fill at the base of the slope or draining the slope. Any measures taken should be designed by a qualified geotechnical engineer.

REFERENCES

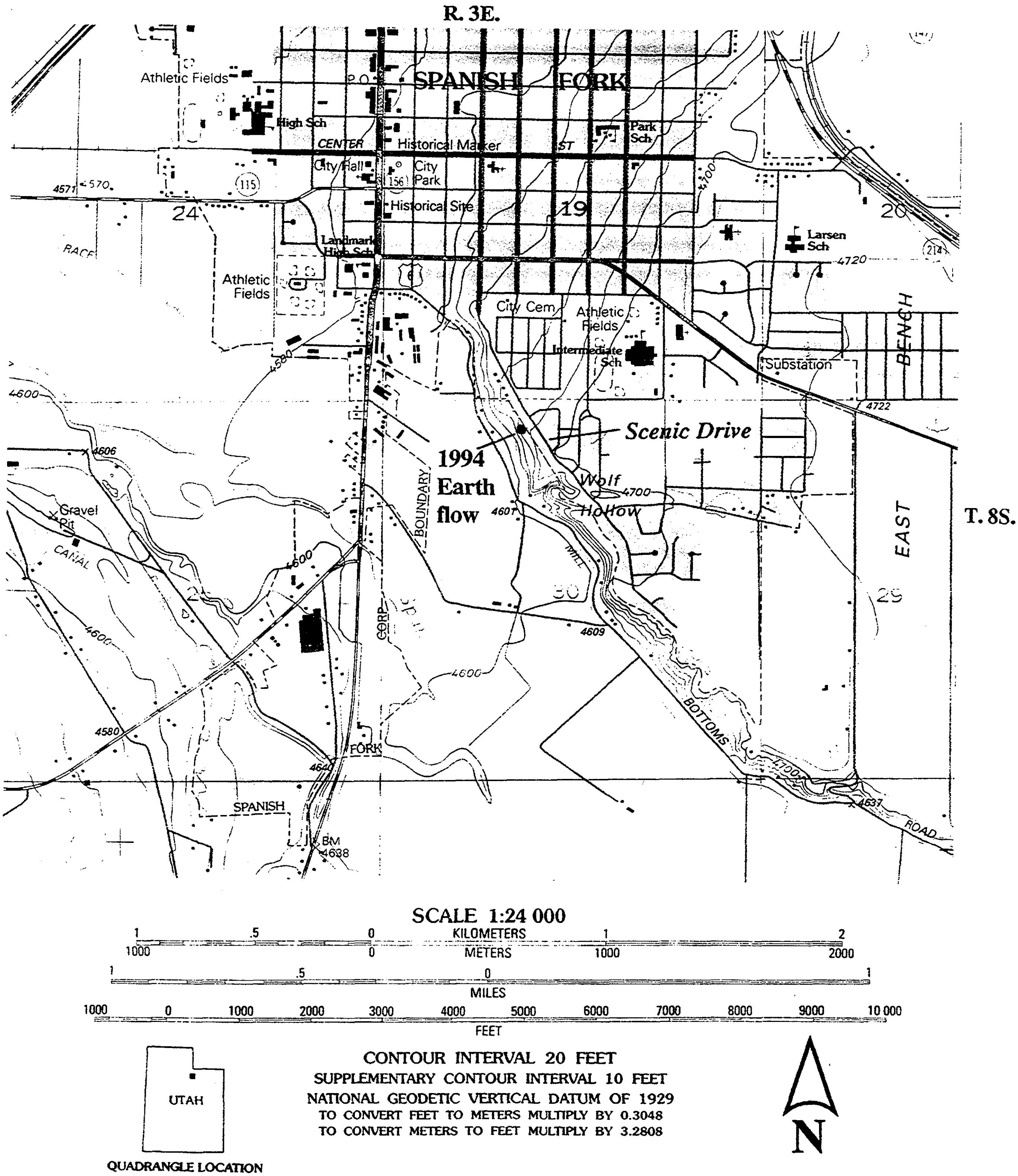
Machette, M.N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2095, 26 p., scale 1:50,000.

Robison, R.W., 1990, Utah County natural hazards overlay zone--landslide, southern Utah County: Utah County Planning Department unpublished maps, scale 1:50,000.

Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L., and Krizek, R.J., editors, Landslides, analysis and control: Washington D.C., National Academy of Sciences, Transportation Research Board, Special Report 176, p. 11-33.

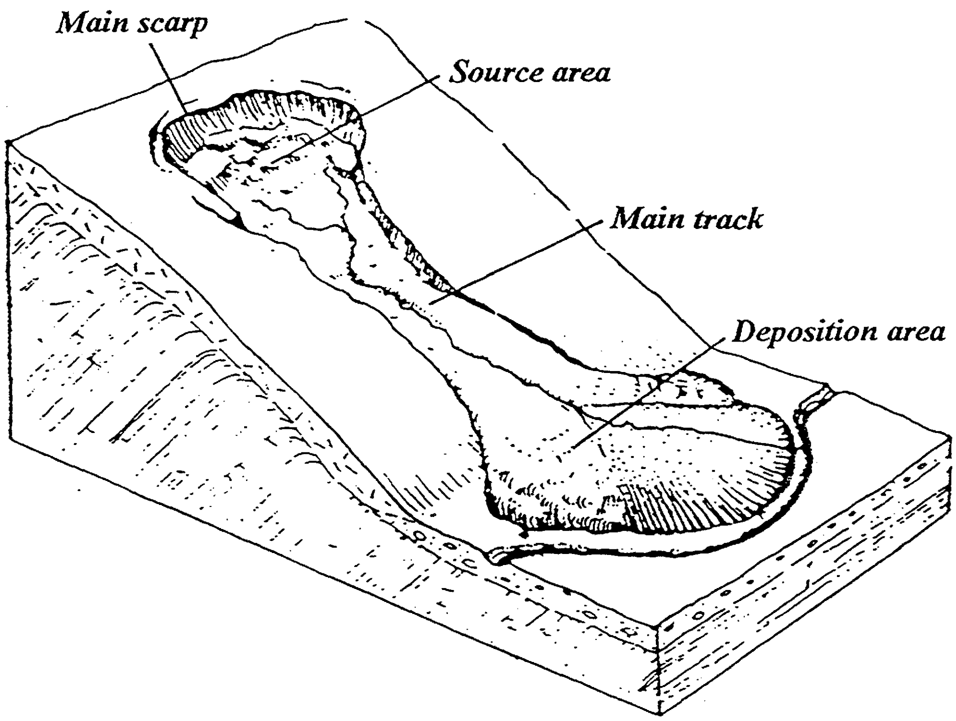
Attachment 1.
Job No. 94-18

Base Map from SPANISH FORK, U.S.G.S.
7-1/2' topographic quadrangle



Attachment 1. Location map.

Attachment 2.
Job No. 94-18



Attachment 2. Block diagram of features commonly associated with an earth flow (modified from Varnes, 1978).

Project: Geologic-hazards investigation for a parcel of proposed School Trust land near Cedar City, Iron County, Utah.			Requesting Agency: School and Institutional Trust Lands Administration
By: Bill D. Black	Date: 1-26-95	County: Iron	Job No: 95-02 (GH-8)
USGS Quadrangle: Cedar City (238)			

PURPOSE AND SCOPE

The Utah Geological Survey (UGS) conducted a geologic-hazards investigation of a parcel of land northeast of Cedar City (NW1/4 section 1, T. 36 S., R. 11 W., Salt Lake Base Line), Iron County, Utah (attachment 1). The School and Institutional Trust Lands Administration (SITLA) is considering acquiring the land from the U.S. Bureau of Land Management for residential development. The investigation was requested by Kevin Carter (Deputy Director, SITLA). The purpose of the investigation was to identify geologic hazards that may constrain development of the site to help the SITLA determine whether or not to acquire the property. The scope of the investigation consisted of a review of available geologic literature and examination of 1:24,000-scale aerial photos. No field inspection was performed.

GEOLOGY AND SOILS

Geologic units at the property consist of bedrock primarily of the Navajo Sandstone and Carmel Formation, alluvial-fan deposits, and landslide deposits (Averitt and Threet, 1973). The Navajo Sandstone is a massive, cliff-forming, cross-bedded sandstone (Averitt and Threet, 1973). The Carmel Formation is massive gypsum, sandstone, mudstone with thin beds of gypsum, and locally fossiliferous shaly limestone (Averitt and Threet, 1973). The southwest part of the property is on an alluvial fan formed by deposition of sediment transported during intermittent flash floods and debris flows. Landslide deposits are found in Stephens Canyon, and east of White Mountain in lot 3 (attachment 1). Slopes in these areas are underlain by the Tropic Shale (Dakota Formation) and the Winsor Member of the Carmel Formation (Averitt and Threet, 1973). These units are slide prone and have produced a number of landslides elsewhere in the Cedar City area (Harty, 1992).

Soils at the property are gravelly and cobbly loam of the Phage series, which exhibits moderate permeability and low shrink-swell potential (U.S. Soil Conservation Service, 1975). In the Unified Soil Classification System, the Phage series is a cobbly silty-clayey gravel (GC or GM-GC).

GEOLOGIC HAZARDS

Attachment 2 is a summary checklist of potential geologic hazards at the property. All hazards considered are shown and discussed below. Attachment 3 is a glossary of geologic-hazards terminology.

Earthquake Hazards

The property is in the Intermountain seismic belt (ISB), a generally north-south zone of seismic activity that bisects the state (Smith and Sbar, 1974; Smith and Arabasz, 1991). A number of earthquakes associated with the ISB have occurred in the Cedar City area. The largest in historical time (1847-present) was the 1902 Pine Valley earthquake (estimated magnitude 6.3) (Pechmann and others, 1992). Two estimated magnitude 5 earthquakes also occurred in Cedar City as part of an earthquake swarm in 1942 (Arabasz and others, 1979). The 1992 M_L 5.8 St. George earthquake was felt in Cedar City (Pechmann and others, 1992), which experienced minor damage from this quake. Earth Science Associates (1982) estimated an average recurrence interval of 200-300 years for earthquakes of magnitude 6 or larger in the Cedar City area.

Four mapped faults with evidence of movement during the Quaternary (last 1.6 million years) are within 10 miles (16 km) of the property (Hecker, 1993): (1) the Hurricane fault, two miles (3 km) to the south (Averitt and Threet, 1973); (2) the Cross Hollow Hills faults, five miles (8 km) to the southwest (Averitt and Threet, 1973); (3) faults bounding the Enoch graben, six miles (10 km) to the north (Anderson and Christenson, 1989); and (4) the Red Hills fault, nine miles (14 km) to the north (Anderson and Christenson, 1989). Although there is no evidence for surface rupture along these faults in the Holocene (last 10,000 years), long-term slip rates suggest that the Hurricane fault may have been active during this period (Hecker, 1993). In addition, Pechmann and others (1992) indicate that the 1992 St. George earthquake probably occurred on the Hurricane fault.

Ground Shaking

A hazard at the property is strong ground shaking from moderate to large earthquakes, which could occur anywhere in the Cedar City area. In an earthquake, seismic waves are generated from the source at depth and travel through the earth, causing ground shaking at the surface which can damage structures.

Engineers may use one of three ground-motion levels in building design to reduce the chances for structural failure during earthquakes: (1) probabilistic motions that have a one in 10 chance of being exceeded in a 50-year period, typically used in building design in the United States; (2) probabilistic motions that have a one in 10 chance of being exceeded in a 250-year period, approximating those expected in a nearby, large earthquake; and (3) the minimum design motions specified by the 1991 Uniform Building Code (UBC). At the property, a peak ground acceleration in rock of about 0.16 g has a 1 in 10 chance of being exceeded in a 50-year period (Algermissen and others, 1990). The peak acceleration in rock with a 1 in 10 chance of being exceeded in a 250-year period is 0.43 g (Algermissen and others, 1990). The seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The property is in UBC seismic zone 2B. For zone 2B, design calculations require a Z-factor of 0.2, which effectively corresponds to a peak acceleration on rock of 0.2 g.

Certain soil conditions can also amplify ground shaking. Although the soil profile at the site is not well known, an S-1 soil type is likely (corresponding to an S-factor of 1.0 for design calculations). The actual soil type may be determined from a geotechnical investigation. Recent studies by Adan and Rollins (1993) and Wong and Silva (1993) indicate that areas of shallow, stiff soils (such as those at the site) may amplify ground motions.

Other Earthquake Hazards

No surficial evidence of active faults exists at the property, so the hazard from surface fault rupture is low. The hazard from tectonic subsidence is also low. The hazard from liquefaction is probably low due to deep ground-water levels (Bjorklund and others, 1978) and nonsusceptible soil conditions. The hazard from slope failures, including those that are earthquake induced, is discussed below.

Slope Failures and Flooding

Landslide deposits are mapped in the northeast corner of the property in lot 3, and in Stephens Canyon to the southeast (attachment 1). The modern state of stability and past conditions which caused these landslides are unknown. Natural or development-induced changes in site conditions (such as site grading, or increased moisture from various sources) could reactivate the landslides or cause other slope failures that could affect the property. Although the Stephens Canyon landslide is unlikely to affect the property, the landslide on lot 3 east of White Mountain (attachment 1) could pose a threat to structures on or near the slide. Landslides typically occur on moderate to steep slopes, and slopes exceeding 30 percent are found along White Mountain and in the east half of the property.

Alluvial fans along the base of the Hurricane Cliffs, including the fan in the southwest part of the property, are commonly subject to debris flows (particularly at canyon mouths). A potential hazard from rock falls also exists at the property. Rocks may dislodge from steep slopes in the east half of the property and from White Mountain.

Ground-water levels at the property are greater than 30 feet (9 m) deep (Bjorklund and others, 1978), so the hazard from flooding due to shallow ground water is low. However, cloudburst storms could cause flash flooding in ephemeral streams and on alluvial fans at the property. One such storm, on July 31, 1989, caused flash flooding which damaged several homes in a new development north of White Mountain, less than one mile (1.6 km) north of the property (Harty, 1989). Because no perennial streams, lakes, reservoirs, or canals exist at or near the property, the hazard from other types of flooding is low.

Problem Soils and Radon

Williams and Rollins (1991) have prepared a map showing areas of potential subsidence due to collapsible soils. This map shows the property to be in an area of low hazard, so it is unlikely to be affected by collapsible soil. However, gypsiferous rock units exist at the property, and dissolution of soluble gypsum in soil or rock could cause subsidence or possibly produce sinkholes. Soils at the property also have a severe limitation for shallow excavations due to very gravelly and cobbly soils (U.S. Soil Conservation Service, 1975). Shallow bedrock likely exists along the base of the hills, and bedrock crops out in many areas of the property, which may cause excavation difficulties (although it provides firm foundation material). Bedrock at or near the surface also severely limits the use of septic-tank drainfields. The hazard from other problem soils, such as expansive soil, is low.

The property is in an area of moderate radon-hazard potential (Black, 1993), primarily due to deep ground-water levels and soils with moderate permeability. Radon is a naturally occurring radioactive gas derived from the decay of uranium, present in nearly all rock and soil. Geologic units with potentially high concentrations of uranium also crop out in the area (Black, 1993). A statewide indoor-radon survey included five measurements in the Cedar City area, which range from 0.6 to 2.1 pCi/L (22.2 to 77.7 Bq/m^3) (Sprinkel and Solomon, 1990). Although these measurements are below the recommended action level of 4 pCi/L (148 Bq/m^3) established by the U.S. Environmental Protection Agency (1992), indoor measurements do not accurately indicate the hazard because indoor-radon levels vary with construction, weather, and occupant lifestyle, as well as geologic conditions.

CONCLUSIONS AND RECOMMENDATIONS

Geologic hazards exist at the property which require additional study and may require hazard-reduction measures. The studies may be performed after the property is acquired, but should precede subdivision layout and planning. Some hazards may be sufficiently severe to preclude development on parts of the property. Ground shaking is a potential hazard, and three earthquake-resistant design options are presented. To meet local government requirements, at a minimum, structures on the property must be designed in accordance with UBC seismic zone 2B provisions. Landslide deposits are mapped in the northeast corner of the property, and slide-prone rock units crop out in the area. The landslide could reactivate and other slope failures may occur, particularly if slope stability is not properly considered during development. Construction on steep slopes exceeding 30 percent requires special techniques, and is commonly restricted by local government ordinances. A potential hazard also exists from debris flows, rock falls in areas near steep slopes along White Mountain and in the east half of the property, and flash floods from cloudburst storms. We recommend that a detailed geotechnical evaluation be performed prior to subdividing the property to further evaluate slope stability and potential debris-flow, rock-fall, and flood hazards.

Although collapsible soils are not likely to affect the property, gypsiferous soil and rock are present which may be susceptible to subsidence and sinkholes. We recommend that a standard soil-foundation investigation be performed prior to construction to provide information on soil properties needed in foundation design, including: (1) an analysis of potential problems caused by gypsum, (2) testing for collapsible soils, (3) evaluation of waste-water disposal options, and (4) determination of the S factor for seismic design. Although nearby indoor-radon measurements are low, the property is in an area of moderate radon-hazard potential. Indoor testing is recommended following construction. Although radon-resistant construction methods are not required, new construction may incorporate these methods to minimize radon hazards.

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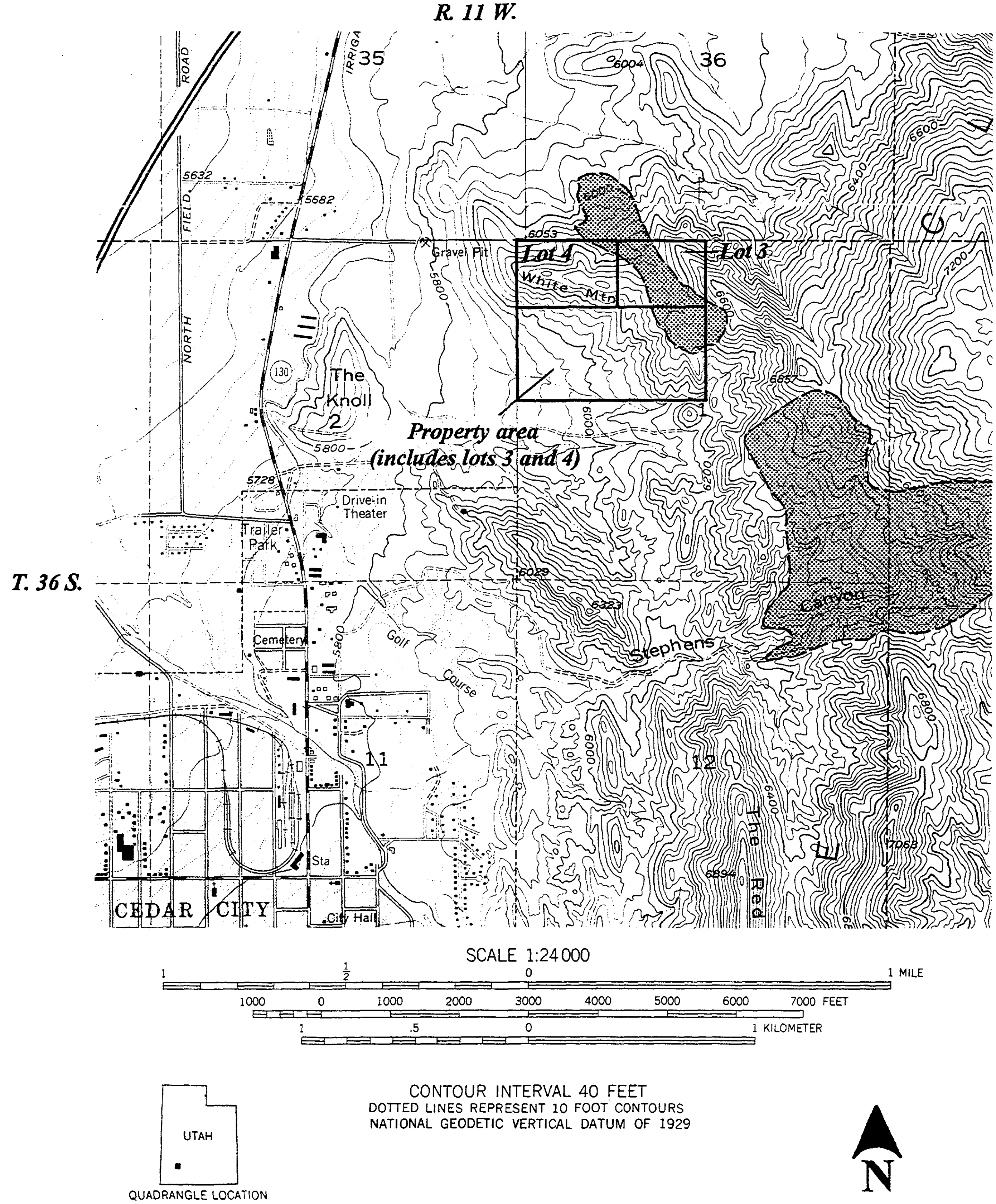
Attachment 1.
Job No. 95-02

Base map from **CEDAR CITY**,
U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location of property and nearby landslide deposits (shaded) mapped by Averitt and Threet (1973).

SUMMARY OF GEOLOGIC HAZARDS
Utah Geological Survey
Investigator: Bill D. Black

SITE: Proposed SITLA property, NW1/4 section 1, T. 36 S., R. 11 W., SLBM

Hazard	Hazard Ratings*			Further Study Recommended**
	Probable	Possible	Unlikely	
Earthquake				
Ground shaking	X			UBC Zone 2B
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction			X	
Slope failure		X		
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall		X		G
Landslide		X		G
Debris flow		X		G
Snow avalanche			X	
Problem soils/subsidence				
Collapsible			X	S
Soluble (karst)		X		S
Expansive			X	
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion			X	
Active sand dunes			X	
Mine subsidence			X	
Shallow bedrock	X			S
Shallow ground water			X	
Flooding				
Streams			X	
Alluvial fans		X		H
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon		X		

*Hazard Ratings - Probable, evidence is strong that the hazard exists and mitigation measures should be taken; Possible, hazard possibly exists, but evidence is equivocal, based only on theoretical studies, or was not observed and further study is necessary as noted; Unlikely, no evidence was found to indicate that the hazard is present.

**Further study (S-standard soil/foundation; G-geotechnical/ engineering; H-hydrologic) is recommended to address the hazard.

GLOSSARY OF GEOLOGIC-HAZARDS TERMINOLOGY

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by deposition from a stream issuing from mountains as it flows onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan.

Avalanche - A large mass of snow or ice moving rapidly down a mountain slope.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess.

Debris flow - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earthflows.

Liquefaction - Sudden large decrease in shear strength of a saturated cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mines.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence, and may have low bearing capacity and stability characteristics.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, such as granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the normal level of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Project: Investigation of a rock fall in Big Cottonwood Canyon, Salt Lake County, Utah			Requesting Agency: Emergency Response
By: M.D. Hylland	Date: 2-6-95	County: Salt Lake	Job No: 95-05 (GH-9)
USGS Quadrangle: Mount Aire (1211)			

PURPOSE AND SCOPE

On January 14, 1995, the Utah Geological Survey investigated a rock fall in Big Cottonwood Canyon at milepost 8 on State Route 152 (SW1/4 section 14, T. 2 S., R. 2 E., Salt Lake Base Line and Meridian; attachment 1). According to media accounts, the rock fall occurred at about 4 p.m. the previous afternoon. The rock fall crushed a car, fatally injured one occupant, seriously injured the other, and resulted in closure of the highway for about three hours. The purpose of the investigation was to determine the source and probable cause of the rock fall and evaluate possible imminent risk to life safety from future rock falls. The scope of the investigation included a field reconnaissance, map and literature review, and discussions with Utah Department of Transportation (UDOT) personnel regarding the history of rock falls in this area.

DATA AND DISCUSSION

The source of the rock fall was a rock outcrop on the north slope of the canyon at an elevation of about 7,000 feet (2,135 m), approximately 200 feet (60 m) above the highway. The rock is Precambrian Mutual Formation quartzite (James, 1979). The outcrop is at the top of a colluvial slope that extends to the highway. The average slope inclination is approximately 100 percent (45°). The lower part of the slope, which appears to be a road cut, is slightly steeper than the upper, natural part of the slope. The break in slope at the top of the road cut is approximately halfway between the outcrop and the road.

The rock fall consisted of numerous cobble- to boulder-sized rocks comprising approximately 50 to 60 cubic yards (38-46 m^3) of material. At the time of our field investigation, UDOT maintenance personnel had moved the material to the south shoulder of the road to clear the highway. The three largest boulders, one of which had landed on the car and caused the fatality, each measured approximately 12 x 8 x 6 feet (3.5 x 2.5 x 2 m) and had an estimated weight of about 45 tons (40,815 kg).

Bedding in the Mutual Formation dips steeply to the northeast in this area, and the rock is extensively fractured. The source outcrop displays an intersecting pattern of planar fractures with one near-vertical set, one set dipping into the slope, and one set dipping downslope. Some of the fractures were open approximately 1 to 2 inches (3-5 cm). The top of the outcrop is vegetated with brush, and roots penetrate many of the fractures. Pieces of root were attached to the side of one of the rock-fall boulders.

The rock fall appears to have originated when part of the outcrop detached along pre-existing fracture planes. The detached rocks probably slid, rolled, and bounced down the upper slope, breaking into additional pieces. Some of these cobble- to boulder-sized fragments came to rest on the upper slope, whereas others continued moving downslope. At the top of the cut slope, the moving rocks stripped the lower branches off of a large evergreen tree to a height of about 15 feet (5 m) above the ground surface. The rocks apparently bounced and rolled down the lower slope, dislodging colluvium and snow that slid to the base of the slope.

CONCLUSIONS AND RECOMMENDATIONS

The rock fall was likely the result of long-term physical and chemical weathering along fractures in the rock. Pressure from root and ice growth in bedding planes, joints, and other fractures can widen existing discontinuities and eventually break the rock apart. Rock falls caused by weathering and erosion are common during spring and fall months with heavy snowmelt or rainfall (Costa and Baker, 1981). This is demonstrated annually in Big Cottonwood Canyon, where rock falls require cleanup on a regular basis in spring and fall months at several locations (William Hale, UDOT, verbal communication, January 24, 1995).

Ground shaking associated with earthquakes of magnitude 4.0 or greater can trigger rock falls (Keefer, 1984). However, the largest earthquake that occurred in the region on January 13 was a magnitude 2.6 event in central Utah (Sue Nava, University of Utah Seismograph Stations, verbal communication, January 26, 1995). This earthquake was too small to be felt even in central Utah near the epicenter, and thus is extremely unlikely to have triggered the rock fall in Big Cottonwood Canyon.

The conditions at the site did not indicate that additional rock falls present an immediate threat to life safety. However, snowmelt and/or spring rains could dislodge the rocks that came to rest on the upper slope, and additional rock will likely detach from the outcrop in the future. Previous rock falls involving large boulders have occurred twice in the past nine years at this highway location (William Hale, UDOT, verbal communication, January 24, 1995), and the fracture spacing indicates that large boulders can be expected in future rock falls. A significant long-term hazard therefore remains from future rock falls.

The extent of exposed, fractured rock and the steepness and height of the canyon walls puts severe practical limitations on reducing the overall rock-fall hazard in Big Cottonwood Canyon. However, it may be prudent to perform a detailed hazard evaluation of the milepost-8 site and other areas in the canyon where rock falls occur on a regular basis. The objectives of such an evaluation would be to locate and characterize source areas, determine the size of material that could be produced, and consider possible rock-fall-hazard reduction measures in the areas of highest hazard.

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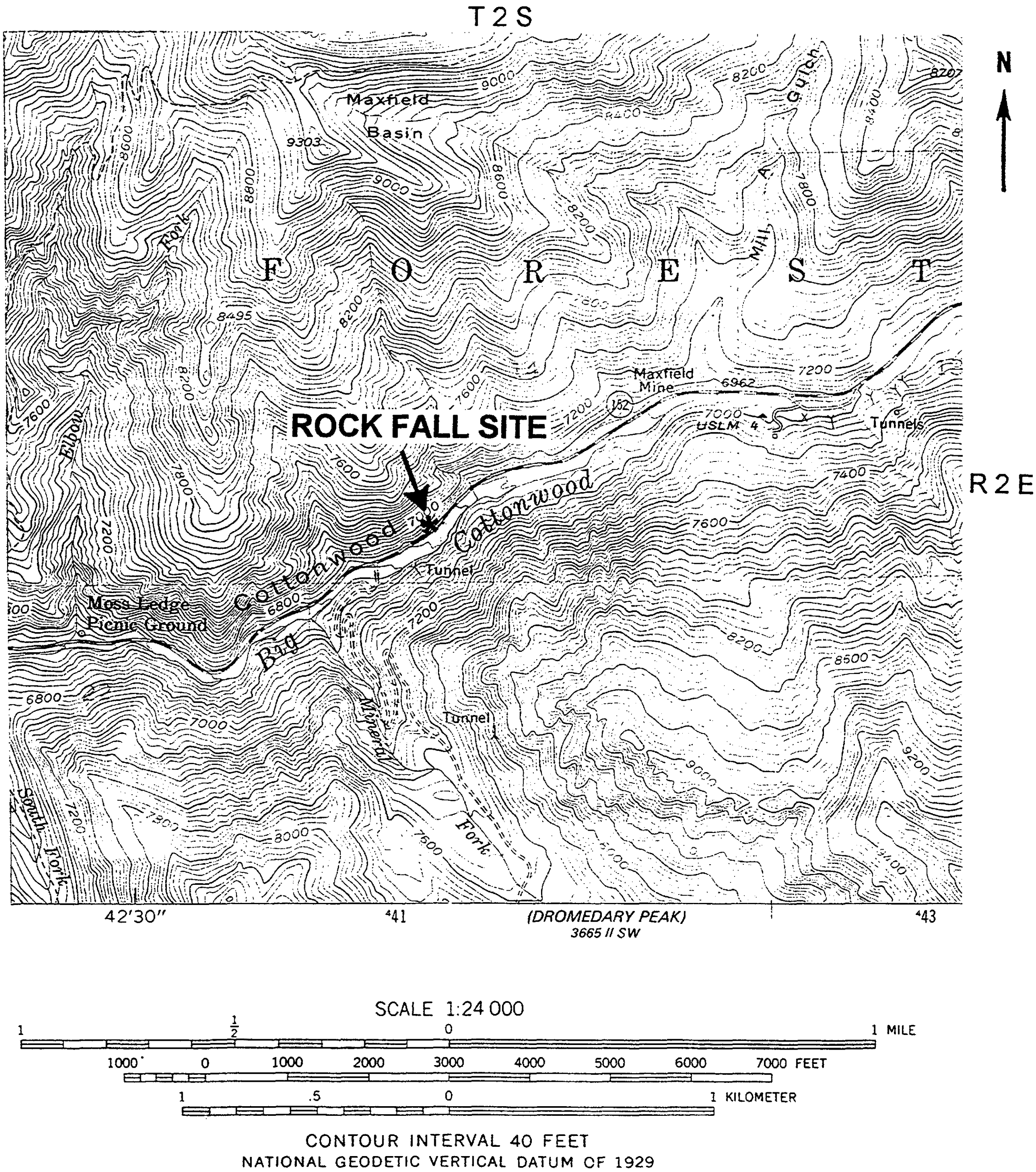
Attachment 1. Job No. 95-05 Base Map from MOUNT AIRE U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location of rock fall that occurred January 13, 1995 in Big Cottonwood Canyon, Salt Lake County, Utah.

Project: Reconnaissance of two landslides at the mouth of Centerville Canyon, Davis County, Utah			Requesting Agency: Centerville City
By: M.D. Hylland	Date: 4-21-95	County: Davis	Job No: 95-07 (GH-10)
USGS Quadrangle: Bountiful Peak (1294)			

INTRODUCTION

On April 12, 1995, the Utah Geological Survey (UGS) conducted a reconnaissance of two landslides at the mouth of Centerville Canyon east of Centerville City, Utah. Mike Hylland and Noah Snyder (UGS) were accompanied by Randy Randall, Centerville Public Works Director. The site visit was requested by Fred Campbell, Centerville City Engineer. The purpose of the visit was to evaluate the cause and hazard potential of the landslides.

SITE CONDITION

The landslides are in the SW1/4SE1/4 section 8, T. 2 N., R. 1 E., Salt Lake Base Line and Meridian (attachment 1), about 1 mile (1.6 km) east of Main Street in Centerville City. Evidence of landsliding consists of two shallow debris-slide tracks on the steep south slope of Centerville Canyon, which is vegetated with oak brush and sparse grass. The slide tracks are surrounded by vacant land, but a residential area is approximately 1/4 mile (0.4 km) to the west, between the site and a small debris basin along the stream that flows out of the canyon.

Metamorphic bedrock exposed in and around the slide tracks on the lower one-third of the slope, as well as on the north slope of the canyon, indicates generally shallow bedrock in the area. The debris slides involved unconsolidated Pleistocene Lake Bonneville nearshore deposits, consisting of sand and gravel with cobbles and boulders, which overlie the bedrock. The slide tracks extend approximately 200 to 250 feet (60-75 m) up the slope from the stream at the base of the slope, and are each about 15 to 20 feet (5-6 m) wide. Debris sliding that created the larger, western track occurred recently, probably this spring, as indicated by an unvegetated, fresh slide track. We observed cobbles and boulders in the stream channel at the base of the western slide track, probably remaining from the recent landsliding. Debris sliding that created the smaller, eastern track occurred less recently, as indicated by grass growing in that slide track.

We observed ground-water seepage from rock near the base of the south slope at several locations outside of the slide tracks; there was no ground-water seepage within the slide tracks at the time of our visit. A clay water pipe approximately 14 inches (36 cm) in diameter traverses the slope near the top of the slides, and was broken by the western slide. Randy Randall indicated that the water pipe has not been used for about 30 years.

The western slide is visible on 1989 aerial photographs. Sliding was initiated at this site in 1983 (Mike Lowe, UGS [former Davis County geologist], verbal communication, April 12, 1995), probably as a result of elevated ground-water levels and increased seepage associated with rapid melting of an unusually heavy snowpack.

CONCLUSIONS AND RECOMMENDATIONS

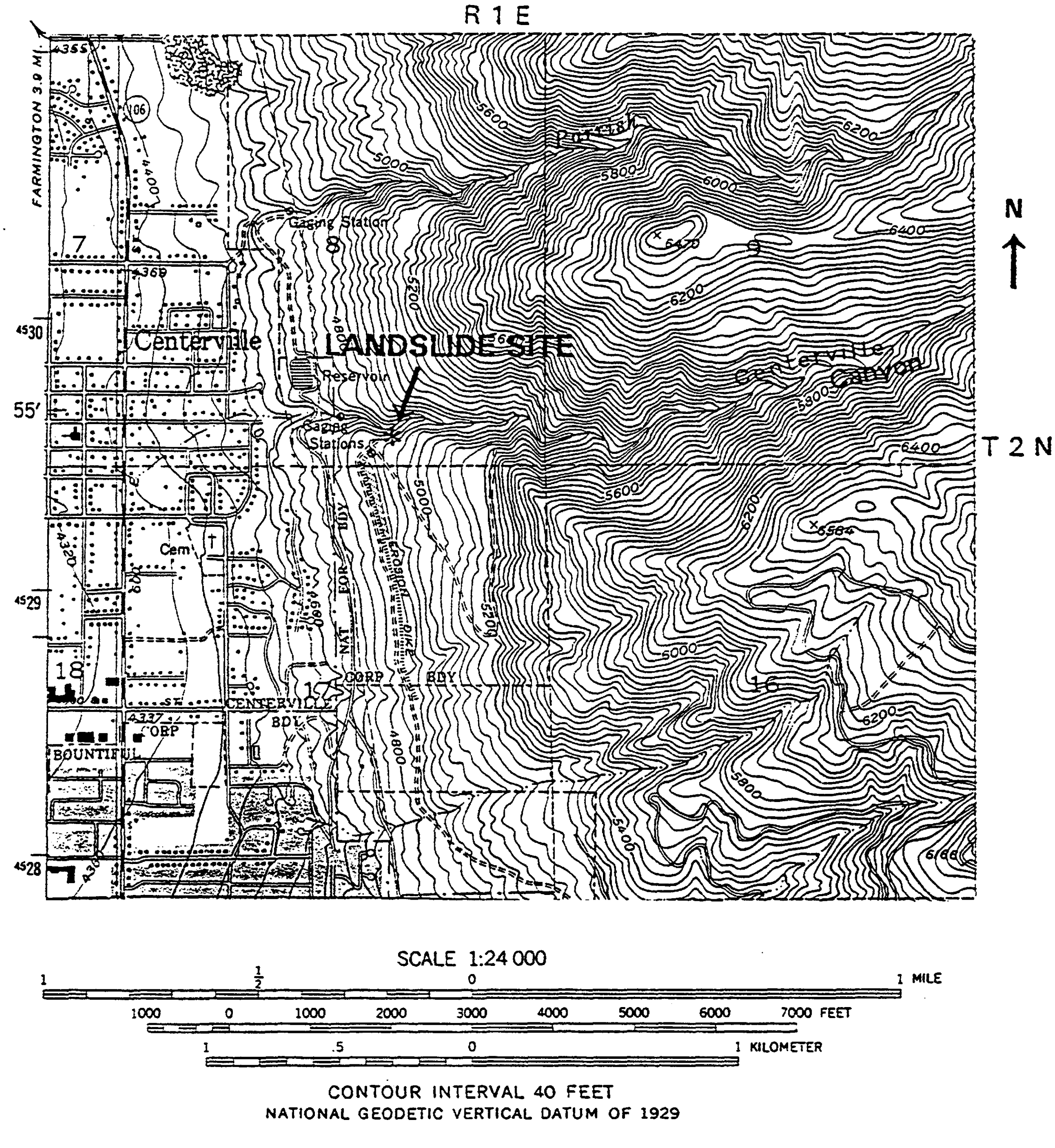
The recent landsliding at the site was probably triggered by elevated ground-water levels and increased seepage this spring. Intermittent, shallow debris sliding should be expected to continue at the site, with headward (upslope) and minor lateral expansion of the slide tracks. Landsliding will likely be accelerated during periods of heavy precipitation and/or rapid snowmelt, when increased pore-water pressures and seepage along the contact zone between the bedrock and surficial deposits may occur. Slide material could possibly dam the stream temporarily, creating a potential flood hazard downstream. However, the type of landsliding and the nature and likely amount of slide material are such that landslide dams should wash out quickly, and any landslide-associated flooding should be restricted to stream-bank areas upstream from the debris basin.

Centerville City should monitor conditions at the site periodically, especially during periods of heavy precipitation and/or rapid snowmelt. The abandoned water pipeline should also be checked to ensure that water does not flow through it at any time, since water introduced near the top of the slides may promote further landsliding. If water is observed discharging from the broken pipeline, it should be plugged or removed. The UGS should be notified immediately of any major changes in landslide activity at the site.

Because Centerville Canyon is a "pristine" canyon with much debris accumulated along its channel, it may have the potential to generate large debris flows unrelated to the slides discussed above. The adequacy of the existing debris basin and risk to homes along the creek both above and below the basin should be evaluated in light of the debris-flow potential of the canyon. One measure to consider is locating a flood-/debris-flow-hazard-reduction structure near the mouth of the canyon upstream from existing development.

Attachment 1. Job No. 95-07

Base Map from BOUNTIFUL PEAK U.S.G.S. 7-1/2' topographic quadgrangle



Attachment 1. Location of landslides near Centerville, Utah.

Project:			Requesting Agency:
Geologic reconnaissance of the Zion Canyon landslide of April 12, 1995, Zion National Park, Washington County, Utah			Emergency Response
By: Barry J. Solomon	Date: 4-28-95	County: Washington	Job No: 95-08 (GH-11)
USGS Quadrangle: Springdale East (73)			

INTRODUCTION

At about 9:00 p.m. on April 12, 1995, a landslide occurred on the west bank of the north fork of the Virgin River in Zion Canyon, Zion National Park (attachment 1). The landslide dammed the river and formed a pond about 20 feet (6 m) deep. About 1,000 campers were evacuated from the Watchman and South campgrounds downstream in case sudden dam failure initiated flooding. Drinking-water supplies were temporarily disrupted in the campgrounds and in the town of Springdale, 3 miles (5 km) south of the landslide. The river gradually cut around the toe of the slide and drained the pond, but caused no downstream flooding. As the river flowed around the slide it eroded the east river bank and washed out a 600-foot (180-m) section of the adjacent Zion Canyon Scenic Drive. The road was the only access for vehicular traffic to Zion Lodge, where more than 300 guests and lodge employees were stranded without water, sewer, electricity, or phone service. A one-lane, temporary road was cut into the slope on the east side of the river by park personnel for evacuation of the lodge, which was completed on the morning of April 14.

On April 13, 1995, the Utah Geological Survey (UGS) and Utah Division of Comprehensive Emergency Management (CEM) responded to this event. Fred May (CEM) and I arrived at the landslide at about 4:00 p.m. I was concerned with the geologic characteristics of the slide and its potential for renewed movement, as well as the condition of adjacent slopes and potential for new slides. Dr. May was concerned with damage assessment and coordination of emergency-response activities of the state of Utah. Upon arrival we inspected the landslide, attended a meeting of personnel from Zion National Park, and then met with Dave Keough, Regional Geotechnical Engineer for the Rocky Mountain Region of the National Park Service. After the meetings I participated in a helicopter reconnaissance of the landslide. On the morning of April 14, Dr. May and I continued our inspection of the landslide and checked to see if any additional movement had occurred overnight, and then walked about one mile (1.6 km) up the canyon to look for evidence of other slope failures. Prior to leaving the park, I discussed our observations of the landslide and recommendations for hazard reduction with Mr. Keough. His plan for remediation included: (1) excavation of the toe of the landslide and return of the river to its pre-slide position on the west side of the flood plain, (2) reconstruction of the road on a rebuilt embankment on the east side of the flood plain, and (3) construction of a ditch between the road and the cut face on the east canyon wall for collection of rock-fall debris. This report summarizes my observations and recommendations.

LANDSLIDE GEOLOGY

The landslide moved southeast from the face of Sand Bench, a 600-foot- (180-m-) high bluff at the base of a prominent sandstone cliff (attachment 1). The cliff rises another 2,200 feet (670 m) to an elevation of 7,043 feet (2,147 m) at the peak of The Sentinel. Prehistoric landslide deposits form the bulk of the bluff (Grater, 1945). A terrace on the upper surface of the bluff, part of the "high terrace remnants" identified by Coney (1959), developed in the late Pleistocene when the Virgin River was from 600 to 900 feet (180-270 m) above its present level.

The prehistoric landslide (attachment 1) detached from the face of The Sentinel and slumped beneath the terrace (Eardley, 1965), blocking Zion Canyon and creating an extensive lake (Grater, 1945). The canyon was first blocked about 4,000 years ago, an age determined by radiocarbon dating, measurement of varves in lake clays, and estimation of the rate of sediment transport in the river (Hamilton, 1979). The lake behind the prehistoric landslide dam was about 0.7 square miles (1.8 km^2) in area and at least 350 feet (115 m) deep during its early years (Hamilton, 1979). A radiocarbon date of 3,600 $\pm$ 400 years B.P. on plant carbon from non-lacustrine silt above the lake beds indicates when the dam was finally breached by the lake waters.

The prehistoric landslide is in the Lower Jurassic Kayenta Formation. The Kayenta consists of about 600 feet (180 m) of reddish-brown mudstone that is the source of numerous slope failures in the Zion Park region (Hamilton, 1978). The Kayenta overlies the Springdale Sandstone Member of the Lower Jurassic Moenave Formation. The Springdale Sandstone, about 150 feet (45 m) thick, forms a prominent ledge near the base of the bluff. The ledge is about at river level near the 1995 landslide. The Kayenta is overlain by the Lower Jurassic Navajo Sandstone, a uniform quartzose sandstone that reaches a maximum thickness of about 2,000 feet (600 m) in Zion Park. The Sentinel face is composed of Navajo Sandstone, which is capped by the Middle Jurassic Temple Cap Sandstone.

The 1995 landslide is the latest in a series of historical slope failures occuring in the prehistoric landslide. Grater (1945) noted two "major slides" in the complex, one in 1923 and the other in 1941, and another landslide reportedly happened during the Richter magnitude (M_L) 5.9 earthquake of September 2, 1992. That earthquake, with an epicenter 5 miles (8 km) southeast of St.

George, Utah and 28 miles (45 km) southwest of Springdale, also triggered a large landslide with its basal slide plane in the Petrified Forest Member of the Upper Triassic Chinle Formation (Black and others, 1994).

The 1995 landslide is a complex slide with an earth slump at its head and an earth flow at its toe. The slide mass measures roughly 500 feet (150 m) from the main scarp to the toe, with a width of about 150 feet (45 m). Using a calculated surface area of 75,000 square feet (7,000 m^2) and an estimated average depth to the basal slide plane of 40 feet (12 m), the total volume of material involved is about 110,000 cubic yards (84,000 m^3). This is comparable to the volume of the 1941 landslide, estimated at 150,000 cubic yards (115,000 m^3) (Grater, 1945). The average gradient of the slope prior to the 1995 slide was 80 percent. The landslide has a clearly defined main scarp as high as 75 feet (23 m), and a sharp secondary scarp about 30 feet high (9 m), indicating that the upper part of the landslide moved in two coherent pieces. Several ground cracks are present on the southwest margin of the slide.

Cracks are also found in ancient slide debris on the steep west bank of the river about 2,000 feet (600 m) upstream. The lower part of the cracks are nearly vertical, in a zone about 2 feet (o.6 m) wide and 20 feet (6 m) tall, but curve northward in a gentle arc at the top of the zone. The cracks do not appear to penetrate deeply into the river bank.

Previous studies in the Springdale area (Harty, 1990; Hamilton, 1992; Black and others, 1994) noted a correlation between increased precipitation and landsliding, and this is apparently the cause of the 1995 landslide. Precipitation was 189 percent of average for the water year through April 14, 1995 in the Dixie region (verbal communication, Utah Climate Center). Weather records from Zion National Park show no precipitation in early April, immediately prior to the landslide, but precipitation was much higher than average during March. Average precipitation in March is 2.80 inches (7.11 cm), but 5.73 inches (14.55 cm) fell during March, 1995. Much of this, 3.40 inches (8.64 cm), fell during a six-day period early in the month, culminating in 1.06 inches (2.69 cm) of precipitation on March 6, 1995. This moisture rapidly infiltrates the porous and permeable prehistoric landslide debris. Seeps visible at the upper surface of the underlying Springdale Sandstone suggest that the sandstone-landslide interface is relatively impermeable. Accumulating moisture at the interface reduced cohesion and increased pore pressure in overlying fine-grained deposits, and slope failure followed.

HAZARD POTENTIAL AND RECOMMENDATIONS

Although landslide movement ceased by 4:00 p.m. on April 13, slope-stability hazards persist. Additional sliding is possible on the wedge of debris between the main and secondary landslide scarps, and near ground cracks on the landslide margin and upstream. Other potential hazards are related to the construction of the temporary road which cuts into prehistoric landslide debris on the east bank of the river, planned excavation of the 1995 landslide toe to return the river to its original course on the west margin of the flood plain, and reconstruction of the permanent road to Zion Lodge.

Failure of the cracked landslide margin and debris wedge may occur, but the volume of additional material subject to sliding is small compared to the original slide volume. The main scarp may also retreat farther upslope, contributing additional material. However, upslope retreat does not pose a threat to structures because there are none on top of the bluff. The slide mass should be closely monitored during the reconstruction phase to minimize the hazard of renewed slope instability.

Although the upstream cracks on the west margin of the river do not appear to penetrate deeply, they are also of concern. The cracks are on the near-vertical lower part of the hillside. Should portions of the hillside fail near the cracks, the upper slopes may be undermined and a larger landslide may occur. This area should be monitored after the reconstruction phase, particularly during periods of heavy precipitation.

The prehistoric landslide debris exposed during construction of the temporary road consists of an intact block of weathered and fractured Kayenta mudstone and siltstone that dips about 10 degrees southeast into the adjacent hillside. This dip increases the slope stability, but the cut slope should be reinforced once the permanent road bed is reconstructed and the temporary road abandoned to reduce the potential hazard of slope failure.

Hazard potential would normally be increased by excavation of the landslide toe, but a slope break in the landslide profile suggests that the toe has actually overridden the intact Springdale Sandstone ledge near the slope base. Thus, the bulk of the landslide may be reinforced by the ledge itself rather than by the toe of debris below the ledge. A buttress of granular material on the ledge would provide further reinforcement.

Care must be exercised during channel and road reconstruction to minimize disturbance because additional sliding might again impact the flow of the river and threaten workers and tourists. Additional investigation of the hazard potential is warranted before channel and road reconstruction begins, and design features should be incorporated to reduce the post-construction landslide hazard.

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Grater, R.K., 1945, Landslide in Zion Canyon, Zion National Park, Utah: Journal of Geology, v. 53, no. 2, p. 116-124.

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Hamilton, W.L., 1979, Holocene and Pleistocene lakes in Zion National Park, Utah, *in* Linn, R.M., editor, Proceedings of the first conference on scientific research in the National Parks: New Orleans, 1977 Conference, U.S. National Park Service and American Institute of Biological Science, p. 835-844.

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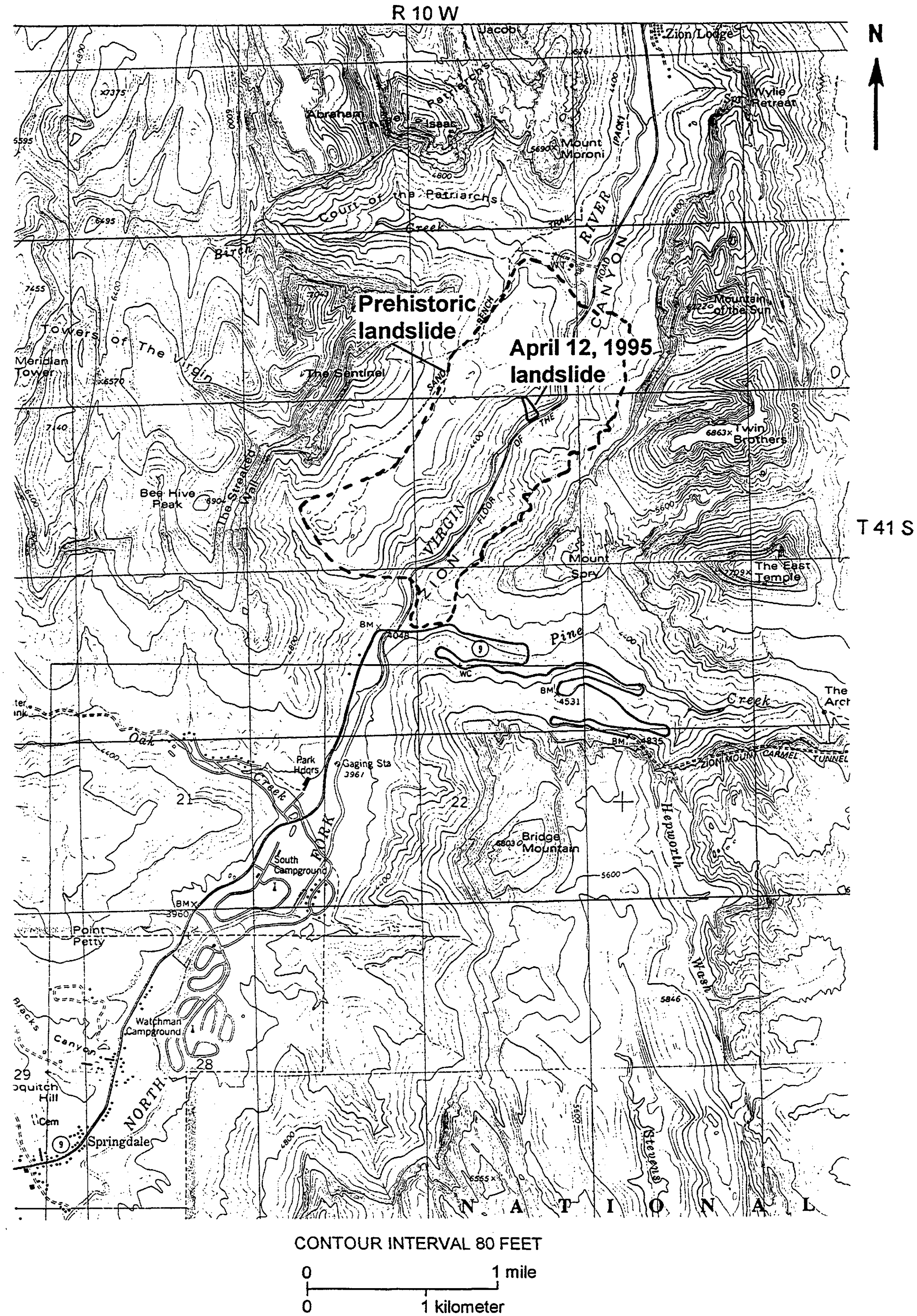
Attachment 1. Job No. 95-08 Base Map from SPRINGDALE EAST, U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. The landslide of April 12, 1995 and a generalized outline of the prehistoric landslide (modified from Hamilton, 1978) in Zion Canyon.

Project: Geologic reconnaissance of a slope failure in Spanish Fork Canyon, Utah County, Utah.			Requesting Agency: Emergency Response
By: Bill D. Black, Barry J. Solomon	Date: 11-16-95	County: Utah	Job No: 95-16 (GH-12)
USGS Quadrangle: Mill Fork (962)			

INTRODUCTION

On November 3, 1995, a slope failure in Spanish Fork Canyon temporarily blocked U.S. Route 6 and the Denver and Rio Grande Western rail line. The slope failure occurred in a south-facing hillslope in the SW1/4NE1/4 section 33, T. 9 S., R. 5 E., Salt Lake Base Line, north of Soldier Creek (attachment 1).

The purpose of these investigations was to document the slope failure, assess whether or not the failure or remaining slope poses a safety hazard, and advise Utah Department of Transportation (UDOT) officials of our findings. The scope of work included a literature review, and field inspections on November 4 (Barry J. Solomon) and 6 (Bill D. Black). Alan Mecham, Merrill Jolley, and Ed Beck (UDOT Region Three) were present during the field inspection on November 6. Material deposited by the slope failure had been removed from the road and rail lines prior to the field inspections.

DESCRIPTION

The slope failure is an earth flow (attachment 2) approximately 80 feet (24 m) wide and 115 feet (35 m) long from the main scarp to the base of the source area. The steepness of the slope in the source area prior to failure was roughly 22 degrees (40 percent). The main scarp is nearly vertical and about 10 to 12 feet (3-4 m) high; an open crack extends east 16 feet (5 m) from the main scarp across the adjacent unfailed slope. The failure occurred as surficial material in the source area flowed south onto the flood plain of Soldier Creek. The source material flowed about 200 feet (61 m) across U.S. Route 6 and the Denver and Rio Grande Western rail lines, and was quickly cleared by UDOT and railroad crews. Assuming an average depth to the failure plane of 5 feet (1.5 m), total volume of the earth flow was approximately 1,700 cubic yards (1,300 m^3).

The earth flow occurred in a south-facing slope bordering the flood plain of Soldier Creek. The slope is underlain by alluvium and colluvium. Bedrock in the area is coarse conglomerate and sandstone of the Red Narrows facies of the Cretaceous North Horn Formation (Merrill, 1972). Several springs are in and around the source area. Merrill (1972) believes the springs are due to fracturing associated with the nearby Martin Mountain fault, about 0.4 miles (0.6 km) to the east. A tufa deposit was mapped by Merrill (1972) around the springs. Water was flowing from the source area following the earth flow.

The earth flow is composed of alluvium and colluvium, and blocks of tufa from around the springs. Springs in the source area and above the main scarp saturated the hillslope, and the earth flow likely occurred when high pore-water pressure caused the slope to become unstable. The tufa deposit may also have contributed to the failure by restricting ground-water flow and weighting the soil in the source area. Although no landslides are mapped in the area to suggest previous slope instability, the North Horn Formation is considered a landslide-prone geologic unit (Harty, 1991, 1992). However, undisturbed bedrock outcrops were observed above the main scarp and no in-place bedrock was involved in the failure.

SLOPE-FAILURE HAZARD AND RECOMMENDATIONS

A slope-failure hazard exists for portions of the unfailed slope on the eastern edge of the earth flow. The open crack extending from the main scarp through this section of the slope indicates the slope is unstable. Failure of this slope section could bring down an additional estimated 450 cubic yards (350 m^3) of material, which may again temporarily block the highway and rail lines and pose a hazard. A hazard also exists for smaller slope failures and erosion from the oversteepened main scarp. However, bedrock upslope from the main scarp should restrict the extent of erosion or generation of additional slope failures, and improved drainage from the springs as a result of the failure may increase slope stability.

We recommend reducing the hazard from additional slope failures or falling debris. Further study may be needed to determine the best hazard-reduction techniques, which may include placing concrete barricades along the toe of the source area and warning signs along the highway, removing the unstable material on the eastern edge of the source area (in imminent danger of failing), and improving slope drainage. Barricades alone at the base of the unfailed slope section would be unlikely to stop material from a large failure. Even after hazard-reduction techniques are implemented, the slope should be monitored for evidence of instability.

REFERENCES

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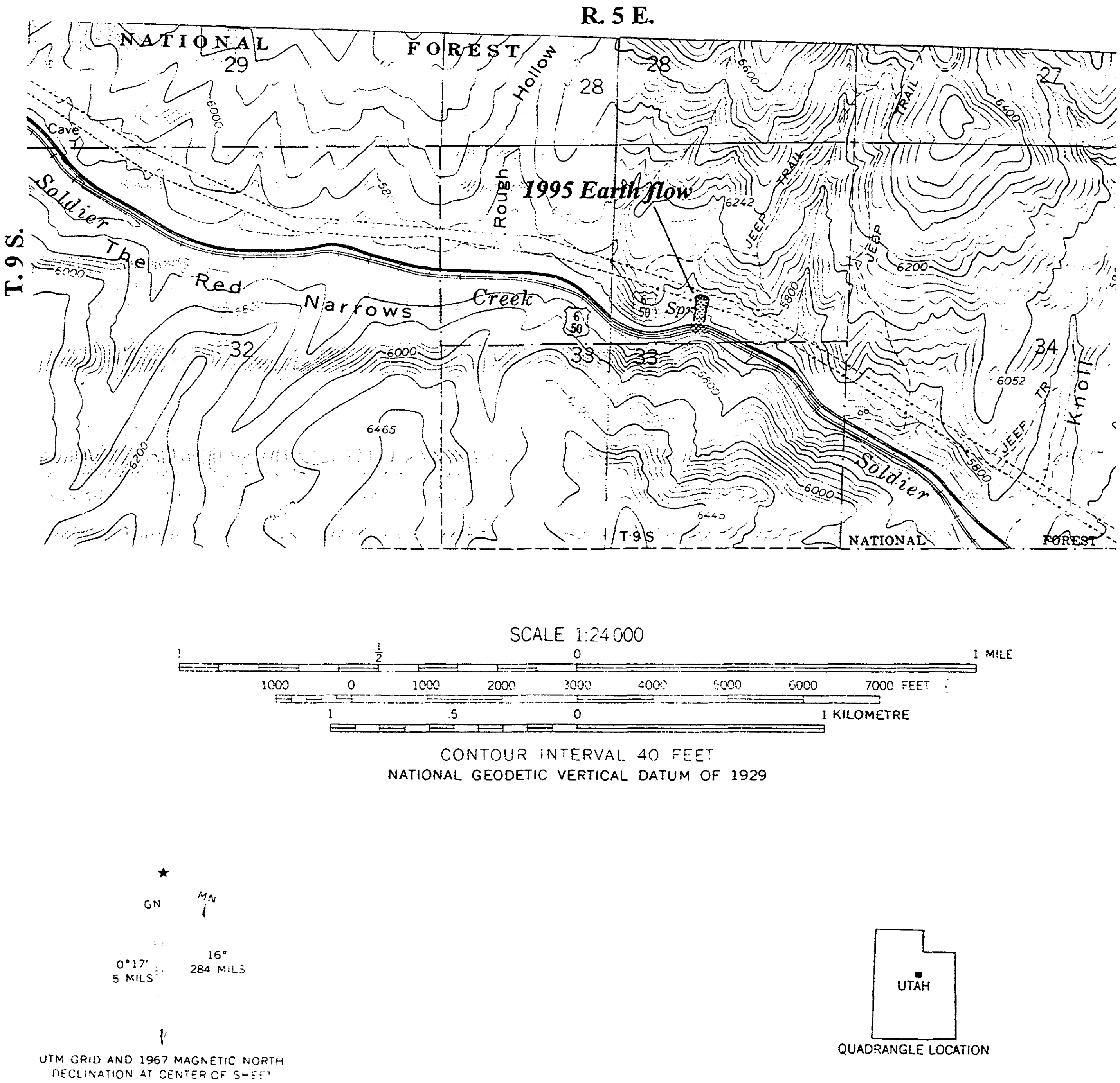
Merrill, R.C., 1972, Geology of the Mill Fork area, Utah: Brigham Young University Geology Studies, v. 19, pt. 1, p. 65-88.

Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L., and Krizek, R.J., editors, Landslides, analysis and control: Washington D.C., National Academy of Sciences, Transportation Research Board Special Report 176, p. 11-33.

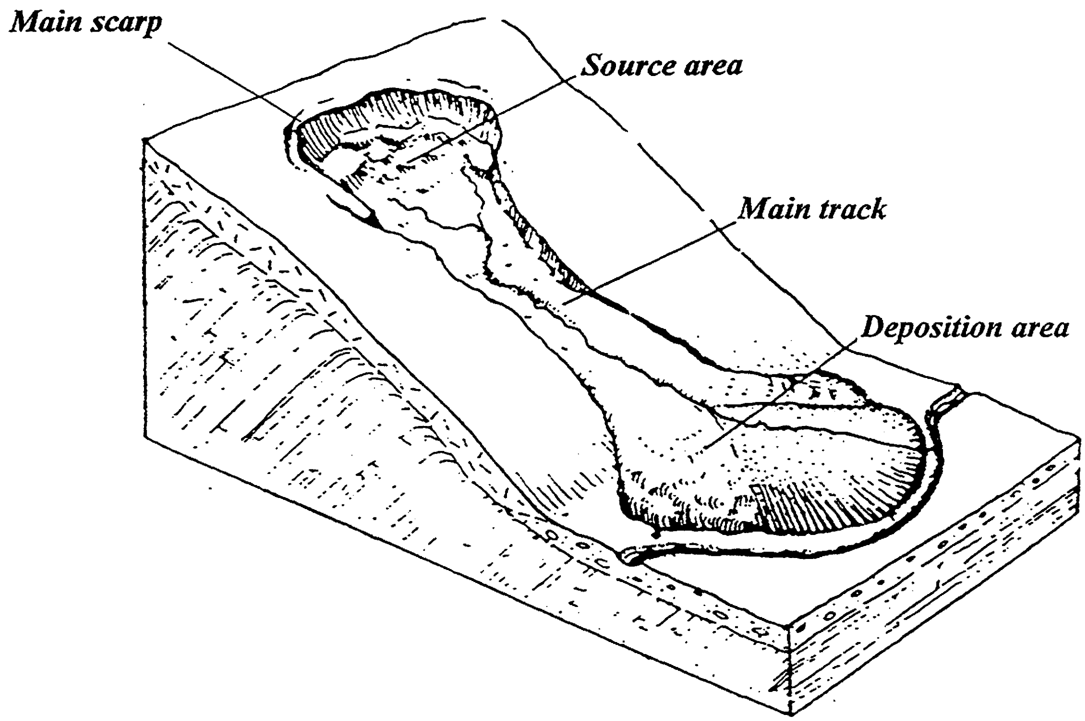
Attachment 1.
Job No. 95-16

Base map from **THISTLE** and **MILL FORK**,
U.S.G.S. 7-1/2' topographic quadrangles.



Attachment 1. Location map.

Attachment 2.
Job No. 95-16



Attachment 2. Block diagram of features commonly associated with an earth flow (modified from Varnes, 1978).

REVIEWS

Project:			Requesting Agency:
Review of "Site reconnaissance geotechnical study, Lot 701, Fir Run Drive, Timber Lake Development, Wasatch County, Utah."			Wasatch County
By: Barry J. Solomon	Date: 1-14-94	County: Wasatch	Job No: 94-01 (R-1)
USGS Quadrangle: Heber Mountain (1125)			

PURPOSE AND SCOPE

This report is a review of the engineering-geologic portions of the geotechnical report (SHB AGRA, Inc., 1993) for a residential lot in the Timber Lake development, about 9 miles (14 km) southeast of Heber City, Utah. A single-family cabin with an on-site septic-tank/leach-field system is proposed at the site. The review was requested by Robert A. Mathis, Wasatch County Planner. The scope of work included a review of geologic literature and past correspondence related to the property, but did not include a site inspection. Geotechnical-engineering aspects of the report regarding earthwork (design of cut and fill slopes) and foundations should be reviewed by a qualified geotechnical engineer.

Landslide potential in the vicinity of the property was noted by Utah Geological Survey geologist Mike Lowe, in a letter to Mr. Mathis dated November 10, 1993. Mr. Lowe stated that "Lot 701 is near, if not on, a queried landslide" based on his air-photo mapping (Lowe, in preparation). The geotechnical report concurs with Mr. Lowe and locates the landslide on the central and northern portion of the site (SHB AGRA, Inc., 1993, p. 3). The report states that slope movement was to the north toward the Lake Creek drainage, but that the movement was "very old" and "no evidence of recent or imminent slope instability was noted." The report further states that movement was "prehistoric, and possibly, much older than 500 to 600 years ago." Rationale given for age of the movement is the vertical orientation of trees on the north part of the lot, which provides "no evidence of any extensive downward soil creep."

The SHB AGRA, Inc. report (1993, p.4) recommends a setback of at least 20 feet (6 m), and preferably 30 feet (9 m), from the crest of steeper slopes on the northern portion of the lot, and proposes restrictions for the amount of fill to be used in this area to reduce the potential for overloading the crest of steeper slopes. The recommended location of the septic-tank/leach-field system is "west and northwest of the site, as far away and sidegradient of the proposed structure, as possible" (SHB AGRA, Inc., 1993, p. 5). "Extremely dense vegetation growth" indicates a "significant sustained source of near surface groundwater" on the property (SHB AGRA, Inc., 1993, p. 4).

Mr. Lowe, in his previously referenced letter, listed two slope-stability issues to be addressed in any geotechnical report to be prepared for Lot 701: (1) the existence and, if present, stability of a landslide on the lot, and (2) the stability of the slope along the north edge of the lot with respect to both landsliding and erosional slope retreat. Neither issue is adequately addressed in the report. As noted above, the report confirms the presence of a landslide associated with steep slopes in the central and northern portion of the lot. However, no data on slope grades or heights are included to define "steep," and the location of the landslide is unknown because the geotechnical report did not include location or site geologic maps, or a site plan. Such maps and plans (preferably on a suitable topographic base) are essential elements of geotechnical reports in which site design recommendations are made. Whereas the report proposes a prehistoric age for last slope movement, this age is not defensible solely on the basis of tree orientation, particularly when no subsurface data were collected and observation of the surface was hindered because "the ground was covered by approximately six inches of snow" at the time of the site visit (SHB AGRA, Inc., 1993, p. 2). The report suggests a setback and fill restriction to reduce potential hazards due to this slope failure, but presents no analyses to indicate how these restrictions were determined. Also, slope steepness and stability of the remainder of the site is not addressed. The apparent presence of shallow ground water at the site is a particular concern with respect to slope stability. The report recommends a general location for the septic-tank/leach-field system, but the description is vague and the report does not include sufficient data to demonstrate that disposal of sewage effluent at that location will not contribute to slope instability.

Because the SHB AGRA, Inc. geotechnical report does not adequately address the potential for slope instability or provide sufficient information for site design, the following actions would be prudent prior to issuance of a zoning-compliance certificate:

1. Construct a site plan on a suitable topographic base and show geographic features, lot lines, and proposed design features.

2. Construct a geologic map to indicate the distribution of surficial geologic units in the site vicinity and the location of features relevant to the discussion of potential slope instability.

3. Perform quantitative analyses of factors of safety (under static and dynamic conditions) or provide other defensible criteria to evaluate slope stability and justify setback recommendations, such as projected stable slope angles, the orientation of potential slope-failure planes, and/or the rate of erosional slope retreat; this may necessitate excavating one or more trenches, or drilling one or more boreholes, to

evaluate soil and ground-water conditions and look for evidence which might indicate instability, the nature and extent of disturbance, and the presence of a possible slide plane.

4. Demonstrate the stability of onsite slopes not underlain by the mapped landslide but underlain by geologic material similar to that beneath the landslide.

5. Clearly define areas where the house, septic-tank/leach-field system, and fill may be located without adverse effects on slope stability; consideration should be given to the potential influence of sewage effluent on both the slide plane of the existing landslide and activation of a new or deeper slope failure; the vague description, "as far away and sidegradient...as possible," is not sufficiently specific.

Completion of these tasks will provide more conclusive data for assessing the potential for slope instability, and will provide justification for recommending specific design features to reduce the potential hazard. I have discussed the necessity for additional documentation of evidence for slope stability with Mr. William J. Gordon, SHB AGRA, Inc., engineer for the study of Lot 701 (verbal communication, January 14, 1994), and he indicated that further studies were planned to supplement the reconnaissance geotechnical report (SHB AGRA, Inc., 1993). At some point, site suitability for a septic-tank\leach-field system must also be addressed; information in the geotechnical report on slope steepness, shallow ground water, and proximity to surface water raises concerns regarding site suitability for waste-water disposal.

REFERENCES CITED

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SHB AGRA, Inc., 1993, Site reconnaissance geotechnical study, lot 701, Fir Run Drive, Timber Lake Development, Wasatch County, Utah: Salt Lake City, Utah, SHB AGRA, Inc., Job No. E93-2833, unpublished report, 12 p.

Project:			Requesting Agency:
Review of "Report, fault rupture, landslide, and groundwater hazards evaluation, Uintah Highland homesites, approximately 6100 South 2850 East and 6100 South Osmond Lane, Weber County, Utah."			Weber County Planning Commission
By: W.E. Mulvey	Date: 2-14-94	County: Weber County	Job No: 94-03 (R-2)
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

In response to a request from Edward Reed, Weber County Planner, I reviewed a 1993 geologic hazards report by SHB AGRA, Inc. for two proposed residential lots at 6100 South 2850 East and 6100 Osmond Lane, Weber County, Utah (SHB AGRA, Inc., 1993). The scope of work included a literature review, but not a field inspection of the site.

DISCUSSION

The SHB AGRA, Inc. (1994) report identifies fault rupture, ground shaking, landsliding, and shallow ground water as geologic hazards which may exist at the site. This is a complete listing of possible hazards present with the exception of the potential for liquefaction and liquefaction-induced landslides. SHB AGRA concludes, based on trenches excavated at the site, that surface faulting is not a hazard and, therefore, risk-reduction measures are not necessary. The Wasatch fault is located approximately 400 feet east of the site (Nelson and Personius, 1993). With respect to earthquake ground shaking, SHB AGRA recommends that, as a minimum, buildings be designed and constructed in accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. This is in accordance with requirements for earthquake-resistant design of buildings under the 1991 UBC.

In the trenches excavated at the site, SHB AGRA observed recent landslide deposits and delineated a zone of landsliding. SHB AGRA states that structures are located outside of this zone and the potential for future landslide movement at the proposed structure locations can be mitigated by control of ground water. Evidence is lacking in the report to support the lack of potential for future landsliding. No drains are shown on or above the landslide or between the proposed structure and the landslide on the lower lot. Also, SHB AGRA did not adequately characterize the landslide (thickness, type of failure, slope steepness, geologic unit that failed, amount of movement) or evaluate its stability or the stability of the surrounding slopes. No geotechnical information concerning the extent of grading or design of cuts and fills was provided.

Shallow ground water was observed in trench 3, and in excavations on adjacent lots to the north and south (Greg C. Schlenker, SHB AGRA, verbal communication, February 7, 1994; Lowe, 1992, 1993). Although shallow ground water was not encountered on the lower lot at the time of the investigation, the mottled soils observed in trenches 1 and 2 indicate the past presence of shallow ground water. The SHB AGRA report concludes that ground water around the foundation and perimeter of the structure on the upper lot can be controlled by a below-slab dewatering system and an area subdrain upslope from the structure (SHB AGRA, Inc., 1993). These drainage systems are to lower the local water table to: (1) reduce ground-water damage to the structures, and (2) reduce landslide hazards. The dewatering systems should reduce the risk to the structure on the upper lot from shallow ground water, but they do not drain the landslide on the structure location on the lower lot and do not eliminate the potential for slope failures on either lot.

Trench logs show the site to be underlain by clean sands from Lake Bonneville to a depth of at least 8 feet (2.4 m). Shallow ground water in these clean sands indicates a localized perched ground-water table and a potential for liquefaction from ground shaking during an earthquake. This hazard is not addressed in the report.

CONCLUSIONS

In conclusion, SHB AGRA identified ground shaking, landsliding, and shallow ground water as potential hazards at the site, but determined that surface faulting is likely not a hazard. Based on the information provided in the report, this appears to be accurate. However, the report does not adequately address the stability of existing slopes, the potential for further movement of the landslide on the lower lot, or the potential for earthquake-induced liquefaction. The effect of shallow ground water on basement flooding and shallow landsliding is addressed on the upper lot with perimeter drains, but is not addressed on the lower lot.

If significant grading is planned, cuts and fills should conform to specifications in chapters 29 and 70 of the UBC. Grading plans and design of dewatering-systems and cuts and fills should be reviewed by a geotechnical engineer. I recommend that the existence of the consultant's report and my review be disclosed to future lot or home buyers.

REFERENCES CITED

Lowe, Mike, 1992, Review of "Report, debris flow and fault hazard assessment, 0.51-acre lot, NW 1/4 NW 1/4 SW 1/4 sec. 24, T. 5 N., R. 1 W. Uintah, Weber County, Utah, for Mr. Charles W.

Richards": Unpublished Utah Geological Survey Technical Memorandum 92-13, 3 p.

Lowe, Mike, 1993, Review of "Report, fault rupture, groundwater, and debris flow hazards evaluation, proposed home site, approximately 2850 East 6025 South, Weber County, Utah," by SHB AGRA, Inc.: Unpublished Utah Geological Survey Technical Memorandum 93-14, 2 p.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2199, scale 1:50,000.

SHB AGRA, Inc., 1993, Report, fault rupture, landslide, and groundwater hazards evaluation Uintah Highland Homesites approximately 6100 south 2850 East and 6100 South Osmond Lane, Weber County, Utah: Unpublished consultant's report, 9 p.

Project:			Requesting Agency:
Review of "Report for fault rupture hazard study, proposed Rock Loft residential development, Fruit Heights, Utah."			Davis County
By: Bill D. Black	Date: 4-5-94	County: Davis County	Job No: 94-05 (R-3)
USGS Quadrangle: Kaysville (1320)			

PURPOSE AND SCOPE

This report presents the results of a review of an engineering-geologic report (SHB AGRA, 1993) for lots in the proposed Rock Loft residential development (SW1/4SE1/4 section 36, T. 4 N., R. 1 W., and NW1/4NE1/4 section 1, T. 3 N., R 1 W., Salt Lake Base Line), Fruit Heights, Davis County, Utah. The review was requested by Jeff Oyler, Davis County Community Development. The scope of work included a literature review and examination of aerial photographs (1985, 1:20,000 scale). Mike Lowe (Utah Geological Survey) visited the site on May 28, 1993, and examined trenches excavated by SHB AGRA that exposed the Wasatch fault. Also present during that field visit was Greg Schlenker (SHB AGRA).

DISCUSSION

The SHB AGRA (1993) report identifies earthquake ground shaking and surface-fault rupture as potential geologic hazards at the site. Concerning ground shaking, the report recommends that all structures be designed and constructed in accordance with Uniform Building Code seismic zone 3. This recommendation meets state- and local-government requirements for earthquake-resistant design for reducing ground-shaking hazards. The SHB AGRA (1993) report identifies two faults which cross the proposed site. Both faults were exposed in a generally NW-SE-trending trench; a second trench to the northeast of the first trench exposed no evidence of faulting. SHB AGRA (1993) believes that the westernmost (primary) fault, at the base of a 60- to 80-foot (18- to 24-m) high scarp, is the main trace of the Wasatch fault. The easternmost (secondary) fault is thought to be associated with the main trace. No deformation was encountered in the trenches between the two faults.

Although the SHB AGRA (1993) trench exposed the main fault, it did not extend far enough west to permit evaluation of additional faulting and deformation. West of the main-fault trace, Nelson and Personius (1993) show an antithetic fault which projects through the site and may be concealed by alluvial-fan deposits. In addition, artificial fill exposed in the trench indicates that the surface west of the main fault has been disturbed. Surficial evidence of faulting and deformation west of the main fault would thus be difficult to detect.

CONCLUSIONS

Recommendations in the SHB AGRA (1993) report meet UBC requirements to reduce ground-shaking hazards at the proposed site. However, the potential surface-fault rupture hazard has not been adequately evaluated west of the main-fault trace. Thus, the UGS recommends additional trenching prior to development west of the main fault. The SHB AGRA (1993) report recommends a 10-foot (3-m) setback from the two faults in their trenches. Guidelines developed by Robison (1993) recommend a minimum 50-foot (15-m) setback, but variances can be made from these guidelines based on trench data. Since no deformation was encountered in the SHB AGRA (1993) trench between the faults, a 10-foot (3-m) setback may be adequate.

REFERENCES

Nelson, A.R., Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Map I-2199, 22 p., scale 1:50,000.

Robison, R.M., 1993, Surface fault rupture - a guide for land-use planning, Utah and Juab Counties, Utah, *in* Gori, P.L., editor, Applications of research from the U.S. Geological Survey program, assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1519, p. 121-128.

SHB AGRA, 1993, Report for fault rupture hazard study, proposed Rock Loft residential development, Fruit Heights, Utah, for Mr. Dale Jost: Unpublished consultant's report, 5 p.

Project:			Requesting Agency:
Review of "Geoseismic study, lot 17, Mountain Terrace Estates, 1400 East Terrace Drive, Fruit Heights, Utah, for Dr. and Mrs. Gary Cutler" by Sergent, Hauskins, and Beckwith.			Fruit Heights City
By: Gary E. Christenson	Date: 4-22-94	County: Davis	Job No: 94-06 (R-4)
USGS Quadrangle: Kaysville (1320)			

PURPOSE AND SCOPE

At the request of Dallas C. Monsen, Public Works Director, Fruit Heights City, I reviewed a geotechnical report by Sergent, Hauskins, and Beckwith (1992) for lot 17, Mountain Terrace Estates, in Fruit Heights (SW1/4NW1/4 section 36, T. 4 N., R. 1 W., Salt Lake Base Line). The scope of work for this review included interpretation of aerial photographs (1985, 1:24,000 scale), but no field inspection was performed.

The Sergent, Hauskins, and Beckwith (1992) report addresses earthquake ground shaking and surface fault-rupture hazards. With regard to ground shaking, the report recommends construction in compliance with Uniform Building Code (UBC) seismic zone 3. Regarding surface fault rupture, the trenching investigation identified four faults crossing the property, including the main trace of the Wasatch fault. Displacements on faults range from 2 inches to more than 4 feet, and Sergent, Hauskins, and Beckwith (1992) recommends a 10-foot setback from all faults with 4 inches or more of displacement. These setbacks define a buildable area in the center of the lot, bounded by faults with displacements of 6 inches, 11 inches, and greater than 4 feet and underlain by a fault with 2 inches of displacement.

The recommendation in the report to construct buildings to UBC seismic zone 3 standards satisfies minimum state requirements for earthquake-resistant design to reduce ground-shaking hazards. Faults appear to be adequately identified on the lot. The lot is clearly within the zone of deformation of the main trace of the Wasatch fault. The possibility of ground deformation anywhere on the lot accompanying surface fault rupture on the Wasatch fault cannot be precluded, although it is most likely within the recommended setbacks.

The report does not show the buildable area resulting from the recommend setbacks or the proposed location of the house, and it is not clear whether or not sufficient area remains to place a house. If space is available and construction is permitted, close inspection of the foundation excavation by a qualified engineering geologist should be required to verify that fault setbacks are followed, identify any additional faults encountered, and revise recommendations as necessary. A letter documenting the inspections and certifying that setbacks were followed should be submitted to the city. The existence of the Sergent, Hauskins, and Beckwith (1992) report, this review, and the inspection-documentation letter should be disclosed to all potential owners of the property prior to purchase.

REFERENCE

Sergent, Hauskins, and Beckwith, 1992, Geoseismic study, lot 17, Mountain Terrace Estates, 1400 East Terrace Drive, Fruit Heights, Utah, for Dr. and Mrs. Gary Cutler: Unpublished consultant's report, 6 p.

Project: Review of "Environmental Impact Report, Scenic Hills No. 3 PUD, North Salt Lake City, Utah"			Requesting Agency: North Salt Lake City Planning Commission
By: Barry J. Solomon	Date: 5-24-94	County: Davis	Job No: 94-07 (R-5)
USGS Quadrangle: Salt Lake City North (1254)			

INTRODUCTION

This report is a review of the engineering-geologic portions of the environmental impact report (Applied Geotechnical Engineering Consultants, Inc. [AGEC], 1994) for the 47-lot Scenic Hills No. 3 planned unit development (PUD) on the southeastern margin of North Salt Lake City. The review was requested in a motion made and passed by the North Salt Lake City Planning Commission at their meeting on the evening of Tuesday, May 10, 1994. The scope of work included a review of geologic literature and aerial photographs, but did not include a site inspection. Geotechnical-engineering aspects of the report regarding earthwork (design of cut-and-fill slopes) and foundations should be reviewed by a qualified geotechnical engineer.

GEOLOGY AND GEOLOGIC HAZARDS

The property is predominantly underlain by mixtures of sand and gravel deposited by Pleistocene Lake Bonneville (Nelson and Personius, 1990). The westernmost corner of the property is underlain by Holocene to uppermost Pleistocene fan alluvium. The main trace of the Warm Springs fault, the northernmost portion of the Salt Lake City segment of the Wasatch fault zone, extends through the western portion of the property; a fault trace of lesser lateral extent bounds the property to the west. There are four potential geologic hazards associated with development of the property: 1) earthquake ground shaking, 2) surface fault rupture, 3) flooding and debris flows, and 4) landslides.

The project is in an area which has a moderately high risk of experiencing strong ground shaking related to potential earthquake activity. This is reflected by the location of the property in Uniform Building Code (UBC) seismic zone 3. AGEC (1994, p. 19) recommends conformance to UBC seismic zone 3 construction standards, and this is a satisfactory response to the potential ground-shaking hazard.

The presence of the Warm Springs fault across part of the property indicates a potential for damage to structures built within the zone of deformation associated with the fault due to surface rupture during future large earthquakes on the Salt Lake City segment of the Wasatch fault zone. AGEC (1994, p. 18-19) constrained the location of the zone of deformation along the main fault trace by excavating two trenches across the trace and mapping offset and related deformation exposed on trench walls. They then defined a setback zone within which surface rupture may occur and construction is not recommended. The setback distance is narrower in the vicinity of the trenches, where confidence in the specific location of the zone of deformation is high, and widens away from the trenches where such confidence is lower. This is a reasonable approach and adequately addresses the potential for surface fault rupture along the main trace of the Warm Springs fault. The smaller, westernmost fault trace, which apparently runs along the base of the scarp along the western edge of the property, was not trenched. However, adherence to the property-line setbacks for structures required by local ordinance should sufficiently reduce the likelihood of construction in the zone of deformation associated with the westernmost fault trace.

A potential flooding and debris-flow hazard may exist where drainages traverse the property, at the mouths of such drainages, or in areas of existing alluvial-fan and debris-flow deposits. Several small, dry drainages extend northwest through the proposed subdivision, but according to AGEC (1994, p. 20), the "...drainages have been cut off by the developments to the east." This will presumably divert any flood waters and debris upslope of the proposed subdivision or reduce flow velocity and debris volume to a non-hazardous level. A larger drainage is present along the southwestern property boundary. Nelson and Personius (1990) mapped fan alluvium at the mouth of this drainage in the westernmost corner of the property, and Davis County Planning Commission (1989a) mapped a debris flow emanating from the drainage mouth. AGEC (1994, figure 2) proposes to maintain this area as an undeveloped scenic easement and, if implemented, floods and debris flows will not pose hazards to the proposed development. If development is proposed in or at the mouth of this drainage, further study of possible flood and debris-flow hazards is needed.

The northwestern and southwestern parts of the property lie in an area recommended for landslide-hazard special studies (Davis County Planning Commission, 1989b). This recommendation was based upon the presence of natural slopes in excess of 30 percent. AGEC (1994, figure 2) identifies additional areas, principally along small drainages which traverse the length of the site, with slopes in excess of 35 percent. No existing landslides were identified by Nelson and Personius (1990), nor could I identify any on aerial photographs. AGEC (1994) did not identify any landslides either, but they did not specifically state that an attempt at landslide identification or assessment of slope stability was made. AGEC (1994, p. 12) recommends a building setback from cut or natural slopes greater than 2:1 (horizontal to vertical), but this may be insufficient protection in areas of prior slope instability or potentially unstable slopes. Thus, further evaluation of the potential landslide hazard, or a written statement from AGEC indicating that slopes have been evaluated and providing reasons for why they are considered stable, is warranted.

CONCLUSIONS

AGEC (1994) provides sufficient evidence for the absence of hazards due to surface fault rupture, floods, and debris flows, if setbacks and the scenic easement recommended by AGEC are adhered to. The potential ground-shaking hazard will be minimized if construction conforms to standards outlined for seismic zone 3 in the UBC, as recommended by AGEC. However, AGEC (1994) has not provided sufficient evidence for the absence of a potential landslide hazard and further information on the potential landslide hazard is needed. The AGEC (1994) report, future geologic reports related to the site, and this review should be disclosed to all potential buyers.

REFERENCES

Applied Geotechnical Engineering Consultants, Inc., 1994, Environmental impact report, Scenic Hills No. 3 PUD, North Salt Lake City, Utah: Applied Geotechnical Engineering Consultants, Inc., unpublished consultant's report prepared for Hill, Jamison and Associates, Inc., Bountiful, Utah, 30 p.

Davis County Planning Commission, 1989a, Debris-flow hazard special study zone map, Salt Lake City North quadrangle, Utah: Unpublished Davis County Planning Commission map, scale 1:24,000.

---1989b, Landslide hazard map, Salt Lake City North quadrangle, Utah: Unpublished Davis County Planning Commission map, scale 1:24,000.

Nelson, A.R., and Personius S.F., 1990, Preliminary surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2132, scale 1:50,000.

Project: Review of "Oak View Hollow Subdivision, North Salt Lake, Utah -- Environmental Reconnaissance and Geologic Faulting"			Requesting Agency: North Salt Lake City Planning Commission
By: Barry J. Solomon	Date: 7-1-94	County: Davis	Job No: 94-10 (R-6)
USGS Quadrangle: Salt Lake City North (1254)			

INTRODUCTION

This report is a review of the engineering-geologic portions of the environmental reconnaissance and geologic faulting report (Kaliser, 1994) for the 29-lot Oak View Hollow subdivision on the southeastern margin of North Salt Lake City. The review was requested by Ken Millard, consultant for the North Salt Lake City Planning Commission. The scope of work included a review of geologic literature and aerial photographs, and a site inspection. Geotechnical-engineering aspects of the report regarding earthwork and foundations should be reviewed by a qualified geotechnical engineer.

DATA SUMMARY

The property is underlain by mixtures of sand and gravel deposited by Pleistocene Lake Bonneville (Nelson and Personius, 1991). The Davis County geologic-hazards maps indicate no significant potential for debris flows, landslides, or rock falls, and the property is located in Zone C (an area of minimal flooding) on the Flood Insurance Rate Map of the area (Federal Emergency Management Agency and Federal Insurance Administration, 1981). Kaliser (1994) did not report any evidence of significant slope instability or earth movement, nor did I find such evidence during air-photo interpretation or site inspection. Kaliser (1994) considers potential geologic hazards at the property to include earthquake ground shaking and surface fault rupture.

The property may experience strong earthquake ground shaking. It is in Uniform Building Code (UBC) seismic zone 3, and Kaliser (1994, p. 11) recommends conformance to UBC seismic zone 3 construction standards.

The property may lie within the zone of deformation of the seismically active Wasatch fault zone (Nelson and Personius, 1991), which indicates a potential for damage to structures from surface rupture during future large earthquakes. The property is in a 1-mile-wide gap between the southern end of the Weber segment and the northern end of the Warm Springs fault on the Salt Lake City segment of the Wasatch fault zone. Several short north-trending fault scarps are preserved in this gap, which may be part of a network of subsidiary faults like those seen in gaps between other segments of the Wasatch fault zone (Personius, 1990). Kaliser (1994) indicates that one of these short scarps is mapped on the property, subparallel to the eastern property boundary (Nelson and Personius, 1991), and this short scarp is in the approximate location of two similar, short scarps mapped by Cluff (1970).

Kaliser (1994, p.9) conducted a surface reconnaissance of the property and found three "slight breaks-in-slope," across which he excavated three exploratory trenches to determine the relation between these slope breaks and potential surface fault rupture. He did not relate these slope breaks to scarps identified by either Cluff (1970) or Nelson and Personius (1991), but I presume that these were the only scarps found on the property. I confirmed the slope breaks of Kaliser (1994) during my site inspection and also did not see any other more prominent scarps. Although trench logs are not included, Kaliser (1994, p. 9) reports that he found no evidence in the trenches for offset or deformed strata related to faulting. The slope breaks are thus not related to surface fault rupture, but Kaliser did not propose an alternate explanation.

CONCLUSIONS

Kaliser (1994) finds no significant potential for any geologic hazard other than earthquake ground shaking at the proposed Oak View Hollow subdivision, and I believe the report adequately supports this finding. The potential ground-shaking hazard will be minimized if construction conforms to standards outlined for seismic zone 3 in the UBC, as recommended by Kaliser (1994). Although the property is near the Wasatch fault zone, Kaliser (1994) did not find evidence to suggest surface fault rupture. I recommend the Kaliser (1994) report and this review be disclosed to all potential buyers.

REFERENCES

Cluff, L.S., Brogan, G.S., and Glass, C.E., 1970, Wasatch fault, northern portion, earthquake fault investigation and evaluation, prepared for the Utah Geological and Mineral Survey: Oakland, California, Woodward-Clyde and Associates, 27 p., scale 1:24,000.

Federal Emergency Management Agency and Federal Insurance Administration, 1981, Flood insurance rate map, City of North Salt Lake, Davis County, Utah: Federal Emergency Management Agency and Federal Insurance Administration, Community-Panel No. 490048 005 C.

Kaliser, B.N., 1994, Oak View Hollow subdivision, North Salt Lake, Utah -- environmental reconnaissance and geologic faulting:

Salt Lake City, Utah, unpublished consultant's report prepared for Kent Hoggan, 15 p.

Nelson, A.R., and Personius, S.F., 1991, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2199, scale 1:50,000.

Personius, S.F., 1990, Surficial geologic map of the Brigham City segment and adjacent parts of the Weber and Collinston segments, Wasatch fault zone, Box Elder and Weber Counties, Utah: U.S. Geological Miscellaneous Investigations Series Map I-1979, scale 1:50,000.

Project: Review of "Report, Engineering Geology Reconnaissance, Lot 263, Timber Lakes Development, East of Heber City, Utah."			Requesting Agency: Wasatch County
By: M.D. Hylland	Date: 6-27-94	County: Wasatch	Job No: 94-11 (R-7)
USGS Quadrangle: Center Creek (1126)			

PURPOSE AND SCOPE

This report is a review of the engineering-geologic portions of a geotechnical report (SHB AGRA, Inc., 1994) for lot 263 in the Timber Lakes residential development, about seven miles east of Heber City, Utah. This review was requested by Mr. Robert A. Mathis, Wasatch County Planner, on June 15, 1994. The scope of this review included a literature review and aerial-photograph interpretation, but did not include a site inspection. Additionally, the Utah Geological Survey is performing ongoing geologic-hazards studies in the Timber Lakes area. Recommendations pertaining to foundation design in the SHB report should be reviewed by a qualified geotechnical engineer.

SUMMARY OF REPORT

According to the SHB report, a two- to three-story, single-family residence is proposed for the site. Site grading is expected to include cuts and fills not exceeding four to five feet. A septic tank and associated leach field will also be constructed at the site.

The stated objective of the SHB study was to determine if the site "...has experienced, or in our opinion could experience, any engineering geology factors which could preclude construction of a single-family residential home" (p. 1, sec. 1.2). The scope of the SHB study included a site reconnaissance and aerial-photograph review, but did not include any subsurface exploration.

The SHB report qualitatively describes the site topography as including a "...higher east portion..." and a "...relatively steep sustained downward slope to the lower flatter far western portion..." (p. 3, sec. 3.1). The eastern portion of the site is variously described as "...moderately downward sloping..." to sloping "...gently downward..." (p. 3, sec. 3.1). No quantitative data on slope heights or inclinations were presented. The western portion of the site "...is associated with the flood plain..." of a small creek (p. 3, sec. 3.1). However, the report does not discuss stream flow or channel characteristics, or the potential for a flood hazard. The report states that "no signs of past or imminent mass instability were noted. However, near the crest of the transitional slope between the higher and lower portions of the site, some minor 6- to 12-inch-high 'offsets' in the natural terrain were observed" (p. 3, sec. 3.1). These offsets were characterized as "...descriptive of small headscarps of slumps, but could also be animal trails." SHB further evaluated the nature of the linear offsets observed at the site through aerial-photograph review. According to the report, "the detailed review showed no patterns which would indicate past or imminent slope instability" (p. 4, sec. 4).

The SHB report describes the geologic materials at the site, based on "...our knowledge and experience...," as surficial soils "...basically of glacial origin" underlain by "...volcanic rocks associated with the Keetley Formation" (p. 4, sec. 3.2). These materials are described in the report as "...extremely variable...." However, the report documents no test holes or observations of exposed geologic units, and presents no data pertaining to the physical properties (for example, grain-size distribution, consistency, moisture content) of the materials at the site.

The SHB study identified no evidence of ground-water seepage "...in the higher portions of the site" (p. 4, sec. 3.2). The report states that "ground water could be present down at the base of the steep transitional slope" (p. 4, sec. 3.2), but presents no basis for this conclusion.

The SHB report concludes that the proposed single-family residence can be constructed on the eastern portion of the site, but a strong recommendation is given "...that the home be constructed no closer than 50 feet of the crest of the steep transitional slope in the center of the site" (p. 4, sec. 5.1). The report also strongly recommends that "...the leach field system associated with the septic tank be established downgradient and laterally from the home," and that the leach field "...be at least 40 to 50 feet downgradient and laterally from the home" (p. 6, sec. 5.4). The report states that "waters emanating from the leach field will reduce the shear strength of the soils" (p. 6, sec. 5.4).

CONCLUSIONS AND RECOMMENDATIONS

The SHB report appears to conclude that there are no engineering-geology factors that would preclude construction of a single-family residence at the site. However, a potential landslide hazard is implied by the recommended 50-foot building setback. Although this may be adequate to sufficiently reduce the risk, I cannot determine this with certainty because the report presents no specific data on slope height, slope inclination, or the physical properties of the geologic materials at the site. The following information must be presented before I can determine the adequacy of the proposed setback and possible need for other hazard-reduction measures:

1. Measured slope heights and inclinations. Preferably, these should be indicated on a site plan along with lot lines, other existing site features, and proposed design features.

2. Classification and distribution of geologic materials at the site. If this information cannot be obtained from surficial exposures or shallow hand-tool explorations, backhoe test pits or boreholes may be necessary. Soils should be classified in accordance with a standardized engineering classification system, such as the Unified Soil Classification System. These data, along with slope height and inclination data, will provide criteria with which to evaluate slope stability and justify setback recommendations.

3. Description of stream flow (ephemeral, perennial) and channel characteristics (aggraded, incised), and evaluation of potential impacts on slope stability at the site associated with stream migration and/or erosion.

4. Characterization of ground-water conditions near the base of the steep slope. The presence or absence of shallow ground water beneath the slope will have a significant affect on slope stability.

5. Characterization of the linear offsets at the top of the steep slope based on other field observations. The apparent absence of certain patterns on aerial photographs is not definitive evidence for the lack of small-scale, landslide-related features, given the limitations of site vegetative cover and photograph scale and resolution.

6. Clear definition of areas where the leach field may be located without adverse effects on slope stability. Consideration should be given to the potential influence of sewage effluent on slope stability, as well as the possibility of effluent seepage from the slope face.

From this supplemental information, SHB can provide its assessment of the hazard and the rationale for its building-setback recommendation and other recommended mitigation measures. The supplemental information should also include detailed recommendations pertaining to site grading if there is any possibility of slope-stability impacts associated with proposed cuts and fills. This supplemental information should be reviewed prior to issuance of a building permit.

At some point, general site-suitability aspects for a septic-tank/leach-field system will need to be evaluated. Information in the SHB report on slope steepness, potential instability, and the possibility of shallow ground water at the base of the steep slope raises concerns regarding site suitability for waste-water disposal. Also, a detailed geotechnical assessment of the drainage ditch that crosses the upper portion of the site, including recommendations for maintaining adequate runoff conveyance through this area, should be included in the final site-design information.

REFERENCE

SHB AGRA, Inc., 1994, Report, engineering geology reconnaissance, lot 263, Timber Lakes development, east of Heber City, Utah: Salt Lake City, Utah, unpublished consultant's report prepared for Coldwell Banker Premier, 7 p.

Project: Review of "Report, Geological Reconnaissance, Timber Lakes Development, Lots 355 & 356."			Requesting Agency: Wasatch County
By: M.D. Hylland	Date: 8-2-94	County: Wasatch	Job No: 94-12 (R-8)
USGS Quadrangle: Center Creek (1126)			

PURPOSE AND SCOPE

This report is a review of engineering-geology documents pertaining to lots 355 and 356 in the Timber Lakes residential development, about seven miles east of Heber City, Utah. These documents consist of an engineering-geology report (Dames & Moore, 1994), and a Dames & Moore letter dated July 18, 1994 which addresses their review of 1993 aerial photographs that became available after the report was prepared. This review was requested by Robert A. Mathis, Wasatch County Planner, on July 20, 1994. The scope of this review included a literature review, aerial-photograph interpretation, and a telephone conversation with Russell L. Owens, P.E., a Dames & Moore geotechnical engineer who is familiar with the project. This review did not include a site inspection. However, I am familiar with the site conditions at these lots as the result of my field work in this area in May, 1994.

SUMMARY OF REPORT

According to the Dames & Moore report, a house, septic tank, drain field, and access road are planned for the property. The scope of the Dames & Moore study included a review of 1975 aerial photographs and a site visit. Their site visit did not include subsurface exploration, but shallow soils were observed in landslide scarps and were field-classified.

Based on the site conditions described in the Dames & Moore report and shown on a sketch map in the report, the property is within an area of relatively recent landsliding (slumping). The report indicates that a near-vertical scarp ranging between 3 and 6 feet (1-2 m) high crosses the upper (southern) portion of the property. The report also indicates that a steep slope approximately 140 feet (43 m) north of the planned house location "...is a result of a landslide that probably occurred perhaps as much as 100 years ago" (p. 3). The proposed location of the house and septic tank is on the landslide block between these two scarps. Utility service lines extending from the road (Tree Top Lane) to the house will need to cross the southern scarp, because the scarp extends across the full width of the property.

The Dames & Moore report concludes that "...the soil conditions and topography on and adjacent to the building lots are the result of alpine glacial deposition, erosion, landslides, and large slumps," and that "slumping has occurred and soil creep and more slumping can be expected to occur in the future at undetermined periods" (p. 3). The Dames & Moore letter concludes that "...recent movement is not apparent" based on comparison between conditions observed on 1993 and 1975 aerial photographs, although the report acknowledges that the 1975 photographs "...do not provide the detail that is desirable" (p. 2) due to their small scale.

The Dames & Moore report presents several general recommendations regarding monitoring slump scarp and surface-water conditions, controlling surface drainage, performing laboratory testing on soil samples for foundation design and site grading recommendations, and drain-field sizing. The report also recommends a floating foundation for the house, to consist of a reinforced concrete mat placed directly on the soil or supported on concrete piles. The report recommends a provision for jacking to maintain a level foundation, presumably in the event of landslide movement.

CONCLUSIONS AND RECOMMENDATIONS

The Dames & Moore report documents a landslide hazard at lots 355 and 356, and I concur with this assessment. The landslide conditions described in the report are in general agreement with those I observed in this area in May. Based on aerial-photograph review and discussions with the owner of the cabin on lot 823, which is adjacent to lot 355 to the east, the scarp that crosses lots 355 and 356 and extends eastward across lot 823 formed during a slump event in the mid-1980s, a period of abnormally high precipitation in Utah. It is possible that similar slumping may occur in this area under similar ground-moisture conditions during the design life of the proposed house. Future movement on the existing scarp or new scarps presents a concern related to damage to proposed utility lines that must cross the scarp. A ruptured water line could introduce a significant amount of water into the landslide area and promote further sliding.

The information in the Dames & Moore report is of a qualitative, reconnaissance-level nature, and the recommendations imply that slope movement during the design life of the structure should not be discounted. To show that the landslide is stable, or to substantiate the effectiveness of proposed stabilization measures, the property owner would need to provide the results of a detailed, quantitative analysis that clearly demonstrates an acceptable factor of safety for the site. General recommendations for such a study are summarized in our draft "Guidelines for Site-Specific Geotechnical Studies to Evaluate Landslide Hazards in Wasatch County, Utah," copies of which are available from the Utah Geological Survey office in Salt Lake City. A detailed study of this property should specifically include: drilling to determine the depth of the existing slip surface; obtaining soil samples for geotechnical laboratory testing; slope profiling and surficial geologic mapping to construct a cross section extending between Tree Top Lane and the base of the steep scarp north of the site, and; a quantitative factor-of-safety analysis. A copy of our "Guidelines" should be provided to the owner if he chooses to proceed with a detailed study. The detailed study should also address the possible impacts to slope stability associated with the location and use of the proposed septic system, and recommend provisions for utility lines to accommodate slope movement.

The Dames & Moore report includes general recommendations for foundation design. Detailed foundation-design recommendations, when available, should be reviewed by a qualified geotechnical engineer. If the project is permitted, a requirement should be made for disclosure of the Dames & Moore documents, this review, and any subsequent reports to any future buyers.

REFERENCE

Dames & Moore, 1994, Report, geological reconnaissance, Timber Lakes Development, Lots 355 & 356: Salt Lake City, Utah, unpublished consultant's report prepared for Louis A. Trujillo, 5 p.

Project:			Requesting Agency:
Review of geologic-hazards studies for lots 18 and 31, Pole Patch Subdivision Phase II, Pleasant View, Utah.			Weber County Planning Commission
By: Barry J. Solomon	Date: 9-2-94	County: Weber County	Job No: 94-13 (R-9)
USGS Quadrangle: North Ogden (1370)			

INTRODUCTION

At the request of Troy Herold, Weber County Planning Commission, I reviewed reports on geologic hazards for each of two lots in the Pole Patch Subdivision Phase II (Delta Geotechnical Consultants, Inc., 1994b, 1994c). Lot 18 is in the NW¼ NW¼, and lot 31 is in the NE¼ NW¼, section 17, T. 7 N., R. 1 W., Salt Lake Base Line and Meridian, on the Pleasant View salient. The scope of work for this review included inspection of Weber County Planning Commission geologic-hazards maps and aerial photographs (1985, 1:24,000 scale). No field inspection was performed.

GEOLOGIC HAZARDS

Delta Geotechnical Consultants, Inc. (1994b, 1994c) identifies earthquake ground shaking, surface fault rupture, landslides, rock falls, debris flows, and floods as potential hazards at both lots. This appears to be a complete and accurate listing of the potential hazards present.

Their assessments indicate that both lots will likely be subject to strong earthquake ground shaking during moderate to large earthquakes in the area. They recommend that buildings be constructed to the standards for Uniform Building Code seismic zone 3, at a minimum, to reduce earthquake ground-shaking hazards. This will satisfy state requirements and, if the recommendation is followed, should reduce losses from this hazard in future earthquakes.

Delta Geotechnical Consultants, Inc. (1994b) indicates that: (1) lot 18 does not lie within the "potential surface fault rupture sensitive area overlay zone" as defined by the Weber County Planning Commission, (2) active faults are mapped about 600 feet northeast of the lot, and (3) a dwelling may be constructed on the lot without undo risk from this hazard. The northeast part of lot 31 does lie within this "sensitive area overlay zone." However, Delta Geotechnical Consultants, Inc. (1994c) indicates that active faults are no closer than 150 feet northeast of this lot and do not pose a significant hazard for surface fault rupture. I agree with these conclusions, and with their recommendation that it would be prudent to conduct an inspection of the home-foundation excavation on lot 31 to ensure that faults are not present.

Their assessments indicate that the potential for landslide and rock-fall hazards is low. They found no evidence on or near the lots of either past landsliding, rock-fall clasts, or bedrock outcrops capable of generating rock falls. They recommend no special considerations for mitigation or avoidance of landslides or rock falls, and I concur.

Delta Geotechnical Consultants, Inc. (1994b, 1994c) found no evidence for recent debris-flow and flood deposits on either lot. They conclude that the active channel of the alluvial fan beneath the lots, several hundred feet to the east on lot 27, is adequate to contain typical annual snowmelt and rainfall. However, they state that because the sites are located on an active alluvial fan, some degree of inherent risk from debris flows and floods during very large storms and runoff events will always exist. They further recommend that the building pad on lot 31 be located on the southeastern part of the lot to avoid steeper slopes and an abandoned drainage channel which could concentrate storm-water runoff. I agree with their conclusion of the inherent risk from debris flows and floods on an active alluvial fan. The potential for this hazard may be reduced by use of hazard-reduction techniques on and near the active drainage channel which traverses lot 27 of this subdivision, and will be further reduced through the use of location restrictions for building on lot 31 recommended by Delta. However, it is my understanding that the techniques recommended for use on lot 27 only assumed a design storm with a 10-year return period, as required by Pleasant View City ordinance (Terri Cragun, Pleasant View City Treasurer, verbal communication, September 1, 1994). I believe that the use of a 100-year return period is more prudent and is consistent with federal requirements under the National Flood Insurance Program. Channel dimensions for the 10- and 100-year storms are given in Delta Geotechnical Consultants, Inc. (1994a).

CONCLUSIONS

Most conclusions and recommendations in the geologic-hazards reports by Delta Geotechnical Consultants, Inc. (1994b, 1994c) are prudent and reasonably address the potential for, and reduction of, geologic hazards on lots 18 and 31 of Pole Patch Subdivision Phase II. However, their recommendations regarding the potential debris-flow/flood hazard are reasonable only if risk is to be reduced below that posed by a design storm with a 10-year recurrence interval, as required by Pleasant View City ordinance. Standard practice in flood-hazard reduction suggests that a more prudent recurrence interval would be 100 years. I therefore recommend that measures be taken to protect the properties and their structures from a design storm with a recurrence interval of 100 years. If adequate measures are incorporated into the design of the active channel on lot 27, they will also help protect lots 18 and 31.

However, even these measures do not eliminate the debris-flow/flood hazard, and an inherent risk remains. If the city wishes to eliminate the hazard, further study would be required, and construction of a debris-basin or substantial deflection/containment berms at the canyon mouth may be necessary.

Delta Geotechnical Consultants, Inc. (1994b, 1994c) also recommend that the final plans and site specifications be reviewed by Delta Geotechnical Consultants, Inc., to determine whether the consultant's recommendations were properly understood and implemented. I concur with this recommendation, and further advise that the existence of the reports and this review be disclosed to future lot or home buyers.

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Delta Geotechnical Consultants, Inc., 1994b, Geologic hazards study, lot 18, Pole Patch Subdivision Phase II, Pleasant View, Utah: Salt Lake City, Utah, unpublished consultant's report, May 27, 1994, 9 p.

Delta Geotechnical Consultants, Inc., 1994c, Geologic hazards study, lot 31, Pole Patch Subdivision Phase II, Pleasant View, Utah: Salt Lake City, Utah, unpublished consultant's report, June 20, 1994, 11 p.

Project:			Requesting Agency:
Review of report "Geotechnical investigation, proposed Natural Resources Office Building, 1596 West North Temple, Salt Lake City, Utah".			Utah Department of Natural Resources
By: Bill D. Black, Gary E. Christenson	Date: 9-13-94	County: Salt Lake	Job No: 94-15 (R-10)
USGS Quadrangle: Salt Lake City North (1254)			

PURPOSE AND SCOPE

This report is a review of the geologic-hazards sections of the geotechnical report (Kleinfelder, 1994) for the proposed Natural Resources office building at 1596 West North Temple (SE1/4 section 34, T. 1 N., R. 1 W., Salt Lake Base Line), Salt Lake City, Utah. The review was requested by Kathleen Clarke and Greg Sheehan, Utah Department of Natural Resources (DNR). The scope of work consisted of a review of available literature, including reports on previous investigations at the site by the Utah Geological Survey (UGS) and discussions with David Marble, a geotechnical engineer with the Utah Division of Water Rights.

DISCUSSION

Earthquake ground shaking

The Kleinfelder (1994) report only briefly addresses the hazard from earthquake ground shaking at the site. The report notes that the site is in Uniform Building Code (UBC) seismic zone 3, requiring design for a peak rock acceleration of 0.3 g. The UBC design accelerations are based on levels of ground shaking on rock with a 10 percent probability of exceedance in 50 years. At the DNR building site, the appropriate rock acceleration is about 0.36 g (Youngs and others, 1987), indicating that seismic zone 3 minimum standards may not be adequate.

Although the peak ground acceleration with a 10 percent probability of exceedance in 50 years is typically used in building design, this acceleration is less than half of that expected in a nearby magnitude 7.0-7.5 earthquake. Although the Kleinfelder (1994) report correctly states that the site is in UBC seismic zone 3, the report incorrectly states that seismic zone 3 is "...defined as a region where peak ground accelerations produced by a magnitude 7.0 earthquake would be on the order of 0.3 g." The peak acceleration in a magnitude 7 earthquake could be much higher and could well exceed the building design level.

Although the Kleinfelder (1994) report addresses the UBC seismic zone requirement, the report makes no reference to the "site coefficient" also required by the UBC for seismic design to account for amplified ground shaking in soft soils such as those at the site. Based on boring data in the Kleinfelder (1994) report, an S_3 or S_4 site coefficient is likely. For proper seismic design, the appropriate site coefficient should be determined.

To meet state- and local-government requirements for earthquake-resistant design for reducing ground-shaking hazards, the structure must (at a minimum) be designed and constructed in accordance with UBC seismic zone 3 standards using the appropriate site coefficient. However, recent studies along the Wasatch Front indicate higher expected levels of earthquake ground shaking than were used in preparing the UBC seismic zone map. Technically, this places much of the Wasatch Front, including the DNR building site, in UBC seismic zone 4.

Liquefaction

The Kleinfelder (1994) report states that liquefaction resulting from strong ground shaking is a potential hazard at the site, and that a ground acceleration of 0.3 g would be required to cause liquefaction. Although calculations to support this conclusion are not provided in the report, the probability of occurrance of 0.3 g ground accelerations is sufficiently high to merit further consideration of liquefaction. To adequately evaluate the liquefaction hazard and provide the information needed for foundation design, further study is needed to: (1) identify potentially liquefiable beds, (2) determine minimum ground motions needed to induce liquefaction and the probability that these ground motions will be exceeded, and (3) determine the potential types of resulting ground failure and possible effects on the building. From this information, the likelihood and severity of liquefaction can be assessed and a decision made regarding foundation design.

Kleinfelder (1994) believes that the interbedded clay, silt, and silty sand would limit the effects of liquefaction and thereby reduce the potential for damage. Although this may be true, Case (1988) reports evidence for liquefaction in a trench excavated for the foundation investigation for the nearby existing DNR building (Puri, 1978a). Puri (1978a) noted that trench walls collapsed soon after opening because the fine to medium sand liquefied. Puri (1978b) suggested that if ground accelerations reached 0.2 g "...there is a strong possibility that some of the substrata would liquefy...". Thus, liquefaction appears to be a significant hazard at the site and options for reducing the hazard should be evaluated and incorporated into the building and foundation design.

Other hazards

The Kleinfelder (1994) report states that clay soils at the site were soft, with low strength and high compressibility when subjected to the expected foundation load, and uses this information to calculate settlement. However, no tests were apparently made on the clay soils to determine if they are sensitive and could liquefy or lose bearing strength during strong ground shaking. Although sensitive clays are not common in Utah, they have been found in the vicinity of Great Salt Lake.

Shallow ground water is also a potential hazard at the site, but is minimized by the building design (slab-on-grade with no basement). Ground-water tables fluctuate seasonally and over longer periods in response to climatic conditions, and the water table at the time of this investigation is probably not representative of the shallowest water tables likely to occur at the site. Kleinfelder (1994) reports no other geologic hazards at the site which would preclude its proposed use, and we concur. Because of the site's elevation and proximity to Great Salt Lake, the possibility of flooding under certain climatic or earthquake-induced conditions cannot be precluded but is considered remote during the design life of the building.

RECOMMENDATIONS

We recommend that the UBC site coefficient be determined and used in the seismic design of the building to address soft soils at the site, and that the building be designed at a minimum to UBC seismic zone 3 but preferably to seismic zone 4 standards.

More quantitative information is needed to determine the appropriate foundation design with respect to liquefaction, including identification of liquefiable layers (depth, thickness, and areal extent beneath the building), analysis of the likelihood and possible effects of liquefaction, and analysis of the cost vs. hazard-reduction effectiveness of various foundation alternatives. We also recommend that the sensitivity of clays be determined and, if sensitive clays are found, their possible effects on foundation design be analyzed.

It is possible that all of these analyses can be done with existing information and samples (if available), and may not require additional drilling. We also recommend that the earthwork and foundation-design sections of the report be reviewed by a qualified geotechnical engineer.

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Project: Review of report "Geotechnical study - Promontory PUD, 2850 East, 6200 South, Uintah, Utah"			Requesting Agency: Weber County Planning Commission
By: Bill D. Black	Date: 12-9-94	County: Weber	Job No: 94-17 (R-11)
USGS Quadrangle: Ogden (1345)			

PURPOSE AND SCOPE

This report presents the results of a review of an engineering-geologic report (Earthtec Testing and Engineering, 1994) for the proposed Promontory Planned Unit Development (PUD) at 6200 South and 2900 East (SE1/4SE1/4 section 23, T. 5 N., R. 1 W., Salt Lake Base Line), Uintah, Weber County, Utah. The review was requested by Jim Gentry, Weber County Planning Commission. The scope of work included a literature review. I have reviewed only sections of the report dealing with geologic hazards. Sections discussing foundations, retaining walls, and pavement design should be reviewed by a geotechnical engineer.

DISCUSSION

The Earthtec Testing and Engineering (1994) report identifies ground shaking as a potential geologic hazard at the site, and recommends that all structures be designed and constructed in accordance with Uniform Building Code (UBC) seismic zone 3 with a S=1.2 site coefficient. This recommendation meets state- and local-government requirements for earthquake-resistant design for reducing ground-shaking hazards. The development is roughly 600 feet (183 m) west of the main trace of the Wasatch fault, outside the zone where surface-fault-rupture studies are required (Lowe, 1988a), and is in an area of very low liquefaction potential (Anderson and others, 1994).

Erosion and slope stability are also identified as potential geologic hazards at the site (Earthtec Testing and Engineering, 1994). Regarding erosion, the report recommends maintaining disturbed slopes until they are revegetated, and concentrating runoff in lined or armored channels. Because the site is not in designated debris-flow or landslide hazard areas (Lowe, 1988b, 1988c), the hazard from debris flows and landslides is not discussed in the report. The hazard from rock fall is also low (Utah Geological Survey unpublished map).

Cut slopes at the site may have marginal stability, and standard vertical-wall retaining systems or steepened rock-retained slopes are recommended in the report (Earthtec Testing and Engineering, 1994). An estimated angle of internal friction of 43 degrees was used in slope-stability calculations (Earthtec Testing and Engineering, 1994). The typical range of angles of internal friction for granular soils is 33 to 39 degrees (Hammond and others, 1992), and the estimated value of 43 degrees is high without supporting soil-test data. A lower angle of internal friction may reduce the factor of safety (resistance) below the minimum of 1.5 calculated for cut slopes at the site and specified by the UBC. Although the report includes slope-stability analyses for static conditions, no analyses were reported for dynamic conditions such as those produced by earthquake ground shaking.

Design specifications are given in the report for rock-retained slopes. However, rocks placed to retain slopes elsewhere along the Wasatch Front have become dislodged. The rocks may break or be dislodged (possibly damaging downslope structures) if slopes are subjected to ground shaking in earthquakes, or if underlying soils are wetted during rainstorms (Brian Bryant, Salt Lake County Geologist, verbal communication, December, 1994). Earthtec Testing and Engineering plans to perform soil tests and further slope-stability analyses before finalizing the slope design (Robert Barton, Professional Engineer, Earthtec Testing and Engineering, verbal communication, December, 1994).

Although the Earthtec Testing and Engineering (1994) report does not consider radon, the development is in an area of high radon-hazard potential (Black and Solomon, in preparation). Radon is a radioactive gas of geologic origin that is a suspected cause of lung cancer. Nearby test results show indoor-radon levels as high as 15.0 picocuries per liter (pCi/L) (5.6 x 10^{-3} Becquerels per cubic meter [Bq/m^3]) (Utah Department of Environmental Quality unpublished data). The Environmental Protection Agency (1992) recommends that action be taken to reduce indoor levels when they exceed 4 pCi/L (148 Bq/m^3). Because techniques for reducing indoor-radon levels can be incorporated into new construction at a cost cheaper than the cost of fixing the building later, the developer may wish to consider radon-resistant building design.

CONCLUSIONS AND RECOMMENDATIONS

Recommendations in the Earthtec Testing and Engineering (1994) report meet UBC requirements to reduce ground-shaking hazards at the proposed site. Erosion hazards are adequately addressed, as long as channelled runoff is directed away from nearby homes. Dynamic slope-stability analyses need to be performed in addition to static analyses to fully address slope-failure hazards, and more work is needed before finalizing design of rock-retained cut slopes. The angle of internal friction used in slope stability calculations is high and should be determined from a soil test. The factor of safety should be recalculated using soil-test data and the design revised as necessary. Steepened rock-retained slopes have failed elsewhere and boulders emplaced in the slopes could dislodge and pose a hazard to downslope structures, unless adequate design provisions are incorporated to accomodate ground shaking and wetting of slopes.

Although not addressed in the report, the site is in a high radon-hazard potential area and indoor testing should be conducted following construction. Techniques may be incorporated into the building design prior to construction to reduce (anticipated) high indoor-radon levels. Foundation, retaining wall, and pavement-design recommendations should be reviewed by a geotechnical engineer.

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Project:			Requesting Agency:
Review of "Investigation of surface fault rupture hazard at the proposed Eagles subdivision, Ogden, Utah"			Ogden City Community Development Department
By: Barry J. Solomon	Date: 1-11-95	County: Weber County	Job No: 95-01 (R-12)
USGS Quadrangle: North Ogden (1370)			

INTRODUCTION

In response to a request from Richard Frye, Ogden City Planner, I reviewed the engineering-geology aspects of a geotechnical report (EarthFax Engineering, 1994) for the Eagles residential subdivision located in the NW1/4SW1/4 section 10, T. 6 N., R. 1 W., Salt Lake Base and Meridian, in Ogden, Utah. The scope of work included a literature review and examination of aerial photographs (1937, 1,20:000 scale; 1985, 1:24,000 scale), but not a field inspection of the site. Mike Lowe and M.D. Hylland, Utah Geological Survey (UGS), visited the site on October 20, 1994, when trenches excavated by EarthFax to study surface faulting were open.

GEOLOGIC HAZARDS

The EarthFax Engineering (1994) report identifies surface faulting, earthquake ground shaking, ground tilting, rock fall, and debris flows as the principal geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. The report also addresses liquefaction potential and slope-failure hazards. The EarthFax report concludes that the liquefaction potential is very low and, with the exception of debris flows, no evidence of active landsliding or other slope failures was present.

EarthFax excavated six trenches to investigate surface traces of the Wasatch fault zone mapped by Nelson and Personius (1993) and Delta Geotechnical Consultants (1985). Earthfax found that the locations of main fault traces identified by trenching generally agrees with those of the earlier studies, although the number of faults and complexity of faulting is greater. EarthFax proposes a fault setback zone of 30 feet on either side of the surface projection of known faults, and recommends that construction be prohibited within this zone. I believe that the Earthfax trench investigation was reasonable and adequately delineated potentially active faults within the Eagles subdivision, and that their proposed fault-setback zone is a prudent hazard-reduction technique.

EarthFax considered the potential for other earthquake-related hazards, including earthquake ground shaking, ground tilting, and liquefaction. They recognize the potential severity of earthquake ground shaking in the region and recommend that, at a minimum, all buildings be designed and constructed in full accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. This satisfies state and local government minimum requirements. They observed tilted beds in faulted portions of their trenches, and recognize that tilting is likely to occur during future earthquakes. They found no evidence of saturated, granular sediments in the trenches, and conclude that the potential for liquefaction is very low. This is consistent with the very low liquefaction potential of the site vicinity determined by Anderson and others (1994), and I concur.

EarthFax also considered slope-failure hazards. Although these hazards are included in their discussion of "Other Earthquake-Related Hazards," slope failures may occur in the absence of earthquakes. Their conclusions regarding slope-failure hazards are, for the most part, valid and based on adequate observations of site conditions. EarthFax observed the presence of loose boulders and fractured bedrock across the mountain front above the site, and determined that a rock-fall hazard exists. However, they conclude that no practical design, engineering, or construction methods exist to mitigate the rock-fall hazard. EarthFax confirmed the presence of Holocene debris-flow deposits on site, as mapped by Nelson and Personius (1993), by observation of the deposits both on the ground surface and in trench exposures. Because of these deposits, EarthFax concludes that future debris flows on the site are possible, but provides no assessment of the severity of the hazard or need for hazard-reduction measures. EarthFax noted hummocky topography on the south portion of the site which suggested to them a possible rock slide or lateral-spread landslide. Pashley and Wiggins (1972) also infer a rock-slide mass in this area, extending westward from the west portion of the Eagles subdivision. However, one of the EarthFax trenches transected this feature, and trench exposures indicated to EarthFax that the surficial materials were of debris-flow origin, confirming an alternate hypothesis of Pashley and Wiggins (1972) for the origin of the feature. The absence of a lateral-spread landslide on the site is consistent with recent mapping by Harty and others (1993), who place the eastern boundary of the liquefaction-induced North Ogden landslide complex west and north of the Eagles subdivision.

EarthFax provides a reasonable interpretation of the potential for slope failure, with one exception. During the trench visit, UGS geologist Mike Lowe (verbal communication, 1995) noted a relatively fresh scarp which parallels a portion of Harrison Boulevard along the west property boundary. He interpreted this to be a result of slumping of the road cut which may affect nearby lots in the subdivision. EarthFax did not specifically address this feature, although it may be included in a fault setback zone.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, EarthFax adequately investigated most geologic hazards. EarthFax identified areas of potential surface fault rupture, and their recommended setback zones are adequate estimates of potential zones of deformation. EarthFax makes a prudent recommendation that design and construction standards, at minimum, be consistent with those required for UBC seismic zone 3 to address the potential for earthquake ground shaking. EarthFax satisfactorily identified the potential for ground tilting, liquefaction, and rock falls. To address these hazards, I recommend disclosure of the EarthFax (1994) report and this review to potential buyers.

Further studies should be conducted to investigate the potential of debris-flow/flood hazards and landslides. Because parts of the subdivision are located on active alluvial fans, an inherent risk exists from debris flows and floods during very large storms or rapid-snowmelt floods. This hazard may be reduced by use of hazard-reduction techniques on and near active drainage channels which traverse and bound the subdivision. Regarding debris flows, further study is required to determine the severity of the hazard. Depending on the hazard severity, construction of a debris basin or substantial deflection/containment berms at the Jumpoff Canyon mouth may be prudent. Measures to reduce flood hazards should be designed using a 100-year return period consistent with federal requirements under the National Flood Insurance Program. Additional investigations are also needed to characterize the possible landslide scarp observed by UGS geologist Mike Lowe, map the location of the feature, and provide recommendations for hazard reduction if a potentially active landslide is present.

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Project: Review of report, "Timber Lakes Lot #1115, Wasatch County, Utah."			Requesting Agency: Wasatch County
By: M.D. Hylland	Date: 1-17-95	County: Wasatch	Job No: 95-03 (R-13)
USGS Quadrangle: Center Creek (1126)			

PURPOSE AND SCOPE

This report is a review of a letter report (Kaliser, 1994) for lot 1115 in the Timber Lakes residential development, about seven miles east of Heber City, Utah. This review was requested by Robert A. Mathis, Wasatch County Planner. The purpose of this review is to evaluate whether geologic hazards were adequately addressed to support the recommendations for cabin and drain-field siting given in the report. The scope of this review included a literature review, aerial-photograph interpretation, and discussions with the Wasatch City-County Health Department and Bruce N. Kaliser, the author of the report. This review did not include a site inspection, but the Utah Geological Survey is performing ongoing geologic-hazards studies in the Timber Lakes area.

SUMMARY OF REPORT

According to the Kaliser report, a 22- by 30-foot cabin and 1,000-gallon septic tank and associated drain field are proposed for the lot. The report states that the lot is on a generally north-facing slope above Lake Creek. Kaliser describes the topography as sloping downward "...gently to very gently to the northeast..." on the upper, southern portion of the lot, then sloping downward steeply to the north between a "...well-defined break-in-slope..." and Lake Creek (p. 2). Kaliser also describes a steep, east-facing slope in a dissected drainage from Witts Lake along the eastern boundary of the lot (p. 2). The report does not include a site plan showing the location of the slope breaks. Slope inclinations given for the steep north slope are 35 degrees just below the crest and 45 degrees for the "...overall slope down to Lake Creek" (p. 2). The 35-degree inclination was measured using a Brunton compass, whereas the 45-degree inclination was estimated from topographic contour lines on the Center Creek, Utah, 7.5-minute U.S. Geological Survey quadrangle (B. Kaliser, verbal communication, January 11, 1995). No slope inclination was given for the steep east slope.

The report describes exposures of pyroclastic rocks at the toe of the slope on the lot west of the site, in the Witts Lake drainage on the eastern part of the site, and on the north side of Lake Creek across from the site (p. 3). Kaliser also observed a rock exposure on the south side of Ridge Pine Drive, an undetermined distance west of the site (B. Kaliser, verbal communication, January 11, 1995). Although soils overlying the rock are not specifically described, Kaliser refers to regolith "...about one foot in thickness..." in the Witts Lake drainage, and a 2- to 3-foot thickness involved in a small slide near the toe of the slope west of the site (p. 3). The report describes a stream terrace on both sides of Lake Creek "...at about an elevation of 4 feet above the channel" (p. 3).

The report states that "the lot sits on terrain which has been involved in large-scale landslide activity in the geologic past" (p. 2). Kaliser describes historic, shallow sliding of surficial materials that occurred at the toe of the slope west of the site (p. 2 and 3), and on both sides of the Witts Lake drainage (p. 3 and 4). Kaliser also describes a shallow slide on lot 1115 on the west slope of the Witts Lake drainage with an associated "moisture zone" (p. 4), and surficial movement at the toe of the steep north slope "...to an elevation of about 15 feet above the [Lake Creek] terrace" (p. 3). This latter area notwithstanding, the report states that "there are not suspicious characteristics to this [the steep north] slope on the subject property" (p. 4), and mature evergreen trees on the north slope show no deformation other than that associated with soil creep and the effects of snowpack on the steep slope (B. Kaliser, verbal communication, January 4, 1995).

The Kaliser report concludes that "...the profile and history of the high north slope appears to indicate a relatively high degree of stability over the period of at least recent hundreds of years if not for a considerably longer period," and that "the east slope does demonstrate a different character although all indications are that only shallow movement has occurred and will likely occur in the future" (p. 4). In consideration of a worst-case slope-stability scenario, the report recommends that the cabin be located "...as far from the east break-in-slope as possible" (p. 5). The location recommended in the report would place the cabin 48 feet west of the east slope break and 25 feet south of the north slope break, with the drain field in the extreme southwest corner of the lot.

CONCLUSIONS AND RECOMMENDATIONS

The Kaliser report implies that the proposed development of lot 1115 is feasible, but that building setbacks should be made to reduce the hazard associated with possible landslides on the steep north and east slopes. I agree with Mr. Kaliser's observations and conclusions that the area of lot 1115 has been involved in large-scale landsliding in the past, and that shallow sliding of surficial materials has characterized slope movements in the recent past and should be typical of slope movements in the near future. I also agree with the recommendation to place the drain field as far away from the steep slopes as possible to reduce the risk of effluent seepage from the slope face and possible slope destabilization due to increased pore-water pressure.

The building setback distances given in the report seem to be adequate for the expected shallow slope movement during the design life of the structure, assuming slope conditions do not change and movement continues at the present rate. The setback distances, however, may not be adequate for slope retreat associated with a deep-seated landslide event. A previous engineering-geology study in Timber Lakes (Earth Store, 1988) concluded that the typical stable-slope inclination on terrain adjacent to Lake Creek is approximately 3:1 (19 degrees). Projecting a 3:1 slope upward from Lake Creek and from the Witts Lake drainage may leave very little, if any, buildable area on the lot. Determining where a projected 3:1 slope would intersect the ground surface is very difficult in the absence of a site topographic map or slope profile.

If the site is underlain at a shallow depth by competent bedrock, stable slopes much steeper than 3:1 may be possible, with a low probability of deep-seated landsliding. Although rock exposures on and near lot 1115 suggest that shallow bedrock may underlie the lot, the data presented in the report are inconclusive regarding the extent and competency of rock beneath the lot. The steep bedding dip (45 degrees; Kaliser report, p. 3) in these geologically young (Tertiary) rocks indicates that they have been displaced by previous landsliding or other means. Also, I understand that a seepage trench was excavated on the lot in July, 1994 to a depth of approximately nine feet below the ground surface. The trench extended into clayey soils, and bedrock was not encountered (Loren Allred, Wasatch City-County Health Department, verbal communication, January 12, 1995).

Field-measured profiles of the north and east slopes would help in evaluating the setback recommendations. If the profiles show that insufficient buildable lot area would remain behind projected 3:1 slopes, and should the owners wish to challenge the applicability of the 3:1-slope-setback criterion, additional investigation would be necessary to adequately characterize the nature of the subsurface materials at the lot. Depth to bedrock could be verified by any of several techniques, including backhoe excavations, hand- or power-auger holes, or geophysical investigations. If bedrock is deep, an engineering factor-of-safety analysis of the soil slopes would be required to better evaluate the adequacy of proposed setbacks, or to provide design information for alternative foundations that would extend into stable material below the depth of potential failure planes.

Given the steepness and geologic conditions of the north and east slopes, shallow slope movement such as soil creep and debris slides should be expected. If construction of the cabin is permitted, I recommend that the building-setback areas be treated as buffer zones, with no brush clearing, grading, addition of water, or dumping of material, to reduce the chances for accelerated slope movement. Also, the property owners should monitor slope conditions for such features as leaning evergreen trees, ground cracks or downsets, or the appearance of ground-water seepage. A qualified engineering geologist should be consulted if any of these features are observed, to evaluate the landslide hazard and, if necessary, recommend hazard-reduction measures.

No geologic hazards other than landsliding were addressed in the Kaliser report. Whether Kaliser evaluated other hazards in his study is not clear, although I am unaware of any in this general area that would preclude development of the site as proposed.

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Project:			Requesting Agency:
Review of "Report, Geologic Hazards and Groundwater Imposed Limitations Evaluation, Proposed Moses Mountain Subdivision, 2527 East Bonneville Terrace Drive, and 5548 South Karen Drive, Weber County, Utah."			Weber County
By: M.D. Hylland	Date: 1-24-95	County: Weber	Job No: 95-04 (R-14)
USGS Quadrangle: Ogden (1345)			

PURPOSE AND SCOPE

This review is of a geologic-hazards report (AGRA Earth & Environmental, Inc., 1995) for the proposed Moses Mountain subdivision 1-1/4 miles northeast of Uintah, Utah. The review was requested by Jim Gentry, Weber County Planner. The purpose of this review is to evaluate whether AGRA Earth & Environmental, Inc. (AGRA E&E) adequately addressed geologic hazards to support the site-development recommendations given in their report. The scope of this review included a literature review, aerial-photograph interpretation, and discussion with Greg Schlenker of AGRA E&E, one of the authors of the report. The review did not include a site inspection.

SUMMARY OF REPORT

The AGRA E&E report addresses surface-fault-rupture, flood, debris-flow, and landslide hazards as well as ground-water-imposed limitations to proposed development of the site. According to the report, the site consists of an approximately two-acre parcel on a west-facing slope. The parcel is proposed to be subdivided into two residential lots, with plans for construction of a house on the lower lot. The report states that "near the west side of the site, a northwest-trending escarpment rises abruptly to the east several feet. This escarpment is believed to be the result of displacement along the Wasatch fault" (p. 3). Also, "an unnamed drainage channel crosses the northwest portion of the site" (p. 3).

AGRA E&E evaluated the surface-fault-rupture hazard at the site by interpreting aerial photographs and excavating two trenches. The report indicates that the trench on the upper lot encountered unfaulted, late Pleistocene lacustrine deposits, whereas the trench on the lower lot encountered unfaulted colluvial and alluvial deposits of uncertain age. Neither trench extended across the fault scarp. AGRA E&E interprets the colluvium in the lower trench as being related to surface faulting upslope of the trench (that is, material eroded from the fault scarp). Based on the trench log included in the report (AGRA E&E, figure 3), the alluvial deposits extended to the bottom of the trench approximately 5-1/2 to 6-1/2 feet below the ground surface. The report states that "...the minimum age of the unfaulted deposits exposed in Trench 1 [the lower trench] cannot be demonstrated" (p. 4). AGRA E&E believes the alluvial deposits "...are relatively ancient, and substantially older than 1,000 years old," based on overlying "...substantially thick surficial colluvial deposits..." and "...relatively deep topsoil development..." (p. 5).

AGRA E&E cites an estimate by Machette and others (1991) of 1,000-years-before-present for the time of the most recent surface-faulting event on the Weber segment of the Wasatch fault zone. Based on the interpretation that the trenched deposits are older than 1,000 years and the absence of rupture or deformation of the deposits, AGRA E&E concludes that "...faulting has not occurred where the trenches are located" (p. 5). The report states that "...if the structures proposed for the site are placed within a general southeast to northwest projection of the trenches...hazards related to fault rupture will be minimal" (p. 5).

To address the potential flood hazard at the site, AGRA E&E referred to the results of a previous study (SHB AGRA, Inc., 1994) that evaluated the potential flood hazard of the same drainage that crosses the site. That study determined the peak discharge from the 100-year, 24-hour precipitation event to be approximately 20 cubic feet per second, based on the U.S. Soil Conservation Service Curve Number Unit Hydrograph method (AGRA E&E, 1995, p. 5). AGRA E&E recommends that this discharge be considered in the design of site improvements and culverts.

AGRA E&E evaluated the potential debris-flow hazard at the site by noting that no debris-flow deposits were observed in the lower trench. Based on this observation and the assumed age of over 1,000 years for the deposits, AGRA E&E believes that "...debris flow deposition has probably not occurred on the site within at least the past 1,000 years," and therefore "...the occurrence of debris flows to the site is unlikely" (p. 6). However, AGRA E&E recommends that construction of windows or openings lower than one foot above existing grade be avoided on the north and northwest sides of proposed structures.

AGRA E&E observed no evidence for past slope movement on or in the vicinity of the site. The report does not present any slope-inclination data. However, topographic contour lines on the site plan included in the report (AGRA E&E, figure 2) indicate slopes range from about 15 percent (9°) to 56 percent (29°), with the majority of slopes 44 percent (24°) or greater. The report states that "the earth materials at the site are older than the most recent earthquake producing surface fault rupture on the local trace of the Wasatch fault. Therefore, the site has experienced strong earthquake shaking and the absence of landslide deposits demonstrates the stability of the natural slopes..." (p. 6). AGRA E&E recommends "...that any significant modifications to the steeper natural slopes should be coordinated with AGRA Earth & Environmental" (p. 6).

The report states that "...no indications of shallow groundwater were observed..." at the site (p. 6). AGRA E&E "...project[s] the static groundwater table to be greater than 10 feet below the site surface" (p. 6). AGRA E&E recommends installation of a foundation chimney subdrain system to accommodate seasonal, shallow "perched" ground-water conditions.

CONCLUSIONS AND RECOMMENDATIONS

The data presented in the AGRA E&E report are adequate to support the conclusions and recommendations given regarding the potential flood and landslide hazards and ground-water-imposed limitations at the site. I agree with AGRA E&E's conclusions regarding these hazards and limitations, although in some cases, for different reasons than those given by AGRA E&E. However, the data addressing the surface-fault-rupture hazard on the western part of the site are inconclusive, and I do not believe that the debris-flow hazard has been adequately addressed. My concerns and recommendations are outlined in the following paragraphs.

AGRA E&E has demonstrated that Holocene surface fault rupture has not occurred within the area of their upper trench, based on their documentation of unfaulted pre-Holocene deposits. AGRA E&E has not demonstrated, however, the absence of Holocene surface fault rupture within the area of their lower trench. Given the uncertainty of the age of the deposits exposed in their lower trench, these deposits may be relatively young and overlie Holocene deposits that have been disrupted or deformed by faulting prior to the most recent surface-faulting event. A paleoseismic study (Forman and others, 1991) of the Weber segment of the Wasatch fault zone, which included trenching at East Ogden, determined deposition rates of fault-scarp-derived colluvium. The study found that fault-scarp-derived colluvium 50 to 90 centimeters (20-36 in) thick was deposited in time periods of less than 400 to 600 years, respectively, at a probable rate of 10-13 centimeters (4-5 in) per 100 years. The colluvium exposed in the AGRA E&E trench is up to about 24 inches thick, based on the trench log (AGRA E&E, figure 3). Applying Forman and others' deposition rate, the colluvium at the subject site could have been deposited in less than about 450 years. Also, the rate of topsoil development varies widely depending on such factors as clay content in parent materials, local climatic conditions, vegetation, and hillslope processes. Therefore, invoking "...substantially thick surficial colluvial deposits..." and "...relatively deep topsoil development..." as evidence for the age of the underlying alluvium does not provide a conclusive basis for determining the age of these deposits.

AGRA E&E believes "...that the faulting and fault rupture hazards are concentrated at the main trace of the Wasatch fault" (p. 5). Mapping by Nelson and Personius (1993), however, indicates the presence of an antithethic (east-dipping) normal fault west of the main trace of the Wasatch fault in the vicinity of the site. The average width of the graben (downdropped zone between the faults) is about 300 feet, based on Nelson and Personius' mapping and my review of 1:24,000-scale stereoscopic aerial photographs. Surface disruption or deformation could occur anywhere within the graben area during a future surface-faulting earthquake on the Weber segment of the Wasatch fault zone. Therefore, the part of the lower lot west of the Wasatch fault trace shown on AGRA E&E's figure 2 may be vulnerable to surface-fault rupture.

Lowe (1990, p. B-8) and Robison (1993, p. 127) present general guidelines to address surface-fault-rupture hazards in areas where surficial deposits are less than 10,000 years old and thick enough to conceal older Holocene deposits that may be faulted. These reports also present general guidelines for addressing zones of deformation, including graben-bounding antithetic faults. These guidelines should be followed to the extent feasible to better evaluate the surface-fault-rupture hazard at the site.

Additional information is necessary to adequately evaluate the debris-flow hazard at the site. The absence of debris-flow material in the deposits exposed in the AGRA E&E trenches does not preclude the possibility of a potential hazard at the site. Several issues must be addressed to adequately evaluate the debris-flow hazard, including the potential for the drainage basin to produce debris flows, the possible volume of material that could be produced in a debris flow, and the channel's ability to contain debris flows in the vicinity of the site. I recommend that these issues be addressed relative to the guidelines for debris-flow-hazard studies in Weber County (Lowe, 1990, p. G-6).

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Project: Review of "Geotechnical investigation, Kinesava Ranch lot 28 near Springdale, Utah."			Requesting Agency: Town of Springdale
By: Barry J. Solomon	Date: 4-28-95	County: Washington	Job No: 95-06 (R-15)
USGS Quadrangle: Springdale West (74)			

INTRODUCTION

At the request of Sally Fox, Springdale Director of Community Development, I reviewed the engineering-geology aspects of a geotechnical report (RB & G Engineering, Inc., 1994) for lot 28 in the Kinesava Ranch Subdivision. The lot is located in the SW1/4 section 32, T. 41 S., R. 10 W., Salt Lake Base and Meridian, in Springdale, Utah. The scope of work for this review included a literature review and examination of aerial photographs (1960, 1:24,000 scale, black and white; 1992, 1:12,000 scale, color). Although no field inspection was performed of this specific site, I conducted field mapping of this area in November, 1994, as part of an ongoing project to evaluate geologic hazards in Springdale.

GEOLOGIC HAZARDS

The RB & G report identifies earthquake ground shaking and slope instability as the principal geologic hazards at the site. RB & G encountered no ground water in a test hole drilled at the site to a depth of 36 feet (11 m), so the report did not consider shallow ground water to be a potential hazard. The RB & G report also did not consider the potential for other earthquake-related hazards, expansive soil, rock fall, flooding, or debris flows.

The RB & G report recognizes the potential severity of earthquake ground shaking in the region and recommends that buildings on lot 28 be designed and constructed in compliance with the provisions for Uniform Building Code (UBC) seismic zone 2B. However, UBC seismic provisions apply only to ground shaking and not to other earthquake hazards. The RB & G report does not address the potential for other earthquake hazards such as liquefaction, surface fault rupture, and ground tilting. The depth to water in the onsite test hole and the appreciable amount of fines in shallow soil suggest that the potential for liquefaction is very low. The absence of surface faulting on or near the site, and the presence of generally flat bedding (Marshall, 1956; Hamilton, 1978; Solomon, in preparation), suggest that the potential for surface fault rupture and associated ground tilting is negligible.

Numerous landslides have occurred in the Springdale area. These include large slope failures involving thousands of acres, such as the Late Pleistocene Johnson Mountain landslide in southeast Springdale (Shroder, 1967), the Late Pleistocene Eagle Crags landslide just south of Springdale (Shroder, 1967), and the landslide in northern Springdale caused by the 1992 St. George earthquake (Black and others, 1994). However, smaller landslides are also common in the vicinity (Harty, 1990). Slope instability of both large and small slides is generally initiated by failure of clay-rich beds in the Petrified Forest Member of the Triassic Chinle Formation. The RB & G report recognizes potential regional slope instability, but its description of onsite conditions is contradictory. The report states on p. 2 that "the proposed development is located...on ancient slide material," but in the next sentence adds that "there is no evidence of any local slide areas throughout the site." The report correctly identifies subsurface material as the Petrified Forest Member and states that the unit consists of shale and sandstone. I have found that the Petrified Forest Member at Springdale consists mostly of varicolored, bentonitic claystone, with rare interbeds of sandstone. Outcrops of this member are uncommon on the Kinesava Ranch development, and where visible display fractured and distorted bedding, gypsum crusts, and ground-water seeps. The land surface is commonly covered by colluvium similar to that found to a depth of 36 feet (11 m) in the RB & G test hole, but the colluvium is considerably thinner on slopes. Regional characteristics of the Petrified Forest Member and its presence at Kinesava Ranch suggest that onsite slopes may be prone to failure, particularly if altered by development. The RB & G report addresses the potential for failure of the colluvium on steep slopes (p. 3-4), but does not address the potential for failure of claystone in the Petrified Forest Member beneath the colluvium.

The Petrified Forest Member may also be the source of expansive soil. Clay minerals in these deposits expand and contract with changes in moisture content. Such changes may result from precipitation or water introduced by development, such as landscaping, wastewater, or leaking household water lines. Pressures exerted by expansive soil may exceed foundation loads and crack foundations, heave road surfaces, and disrupt wastewater disposal systems. Materials encountered by RB & G in the onsite borehole are principally mixtures of sand and gravel, with no reported expansive clay. However, the borehole is on a ridgetop where coarse-grained colluvium is likely thicker than elsewhere on the site. Expansive clay may be at shallow depths on slopes with thinner colluvium. The potential for expansive soil varies across the site and is not addressed in the RB & G report.

Coarse, angular rock fragments are common in onsite colluvium. These fragments may be rock-fall debris derived from sandstone in the hillsides above the site. The potential for this hazard is not addressed in the RB & G report.

The potential for flooding and debris flows is also not addressed in the RB & G report. Lot 28 is bounded on the north and south by ephemeral stream channels. Cloudburst storms can cause torrential floods in the channels and on downstream low areas. The flood plain near the confluence of the two channels downstream of lot 28 is evidence of past flooding, an alluvial fan at the channel mouth is evidence of debris-laden floods or debris flows, and colluvium on slopes upstream of lot 28 provides ample debris for future events. Although the onsite hazard is restricted to the channels, the hazard is not evaluated in the RB & G report, and it provides no site design to restrict development within these areas.

CONCLUSIONS AND RECOMMENDATIONS

The RB & G report adequately addresses the potential for earthquake ground shaking and shallow ground water. The report makes a prudent recommendation that design and construction standards, at a minimum, be consistent with those required for UBC seismic zone 2B to address the potential for earthquake ground shaking. This satisfies state and local government minimum requirements. The depth of ground water reported by RB & G is apparently sufficient to avoid potential hazards associated with shallow ground water.

Although the RB & G report does not specifically address the potential for other earthquake hazards, its data on ground-water depth and grain size from the onsite test hole, and my own mapping, indicate that the potential for these hazards is very low. Other earthquake hazards include liquefaction, surface fault rupture, and ground tilting.

The RB & G report also does not address the rock-fall hazard. Coarse, angular rock fragments in onsite colluvium may be rock-fall debris derived from sandstone in the hillsides above the site. Rock falls are common on Springdale slopes, but engineering methods to reduce the hazard may be difficult and expensive. To address the rock-fall hazard, I recommend at least disclosure of the RB & G report and this review to potential buyers.

The association between landslides and the rock unit beneath the site, and my observations elsewhere on the Kinesava Ranch Subdivision, suggest that further study is required to determine the landslide potential. Expansive soil is also common in Springdale and avoidance is often not possible. Because both slope stability and expansive soils are site-specific hazards, both should be addressed for the final proposed construction site. If potential landslide or expansive-soil hazards are present, recommendations should be provided for hazard reduction.

Because parts of the lot are located on channels which feed a downstream flood plain and active alluvial fan, a risk exists from debris flows and floods during storms. These hazards may be reduced by use of hazard-reduction techniques in and near active drainage channels, or by land-use restrictions. If construction is planned in or near channels, further study is required to determine the severity of the hazard and recommend hazard-reduction measures. Measures to reduce flood hazards should be designed using a 100-year return period consistent with federal requirements under the National Flood Insurance Program.

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Project: Review of "Report, geologic hazards and ground-water-imposed limitations evaluation, proposed Carey Estates subdivision, 6080 South, 2850 East, Weber County, Utah"			Requesting Agency: Weber County Planning Commission
By: Bill D. Black	Date: 5-10-95	County: Weber	Job No: 95-09 (R-16)
USGS Quadrangle: Ogden (1345)			

PURPOSE AND SCOPE

This report presents the results of a review of a geologic-hazards report (AGRA Earth and Environmental, 1995) for the proposed Carey Estates subdivision at 6080 South and 2850 East (NW1/4SW1/4 section 24, T. 5 N., R. 1 W., Salt Lake Base Line), Weber County, Utah. Jim Gentry, Weber County Planning Commission, requested the review. The scope of work included a literature review.

DISCUSSION

The AGRA Earth and Environmental (1995) report identifies surface fault rupture as a potential hazard at the property. The property is roughly 500 feet (122 m) west of the main trace of the Wasatch fault (Nelson and Personius, 1993) and is in the area where surface-fault-rupture studies are required (Lowe, 1988a). A 110-foot (34-m) trench excavated across the property exposed no evidence of deformation associated with surface fault rupture, so AGRA Earth and Environmental (1995) concluded that surface fault rupture is not a hazard.

Landslide deposits exposed in the trench suggest that slope failures are a potential hazard at the property (AGRA Earth and Environmental, 1995). Previous investigations (Sergent Hauskins, and Beckwith, 1992; SHB AGRA, Inc., 1993a, 1993b) also identified landslide problems on adjacent lots to the west; reports of their findings and recommendations are reviewed in Harty (1992a, 1992b), Lowe (1993), and Mulvey (1994). The landslide is thought to be geologically recent and probably active, and water is likely a major factor in its stability (AGRA Earth and Environmental, 1995). However, the landslide was not characterized and little is known about its thickness, failure type, amount of movement, or failure plane. A previous investigation (SHB AGRA, Inc., 1993a), cited in the AGRA Earth and Environmental (1995) report, also failed to adequately characterize the landslide (Mulvey, 1994).

The AGRA Earth and Environmental (1995) report recommends that structures be set back a minimum of 10 feet (3 m) from the landslide deposits (station 70 in the trench exposure). They also recommend that footings be placed into higher-strength lacustrine deposits, below an imaginary 2:1 slope projection from the base of the cut slope along 2850 East (figure 5; AGRA Earth and Environmental, 1995), and that no site improvements be made that would adversely affect surface drainage or slope stability. I concur with the latter recommendations, but believe a 10-foot (3-m) setback from the landslide may be insufficient. The landslide is apparently active and has been loaded by fill at its head (AGRA Earth and Environmental, 1995). Renewed movement may occur if water is introduced into the subsurface by landscaping, poor site drainage, or adverse environmental conditions, and could produce a steep main scarp that removes support of slopes on this lot. To reduce this hazard, the 2:1 slope projection for minimum footing depth could also be projected from the landslide failure plane. This would probably require a setback of more than 10 feet (3 m).

The AGRA Earth and Environmental (1995) report also identifies shallow ground water and ground shaking as potential hazards at the property. Perched water tables less than 10 feet (3 m) deep may occur in the western portion of the property, and AGRA Earth and Environmental recommends that a subdrain system be installed on the perimeter of below-grade portions of the proposed structure. This recommendation should reduce ground-water levels and may also improve stability of the hillside downslope from the structure. They also recommend that all structures be designed and constructed according to Uniform Building Code (UBC) seismic zone 3, which meets state- and local-government requirements for earthquake-resistant design for reducing ground-shaking hazards.

The potential for liquefaction was not evaluated in the AGRA Earth and Environmental (1995) report. Although the property is in a mapped area of very low liquefaction potential (Anderson and others, 1994), perched shallow ground water and near-surface sediments at the site suggest there is a potential for liquefaction during strong ground shaking. The potential for liquefaction-induced slope failures was also not evaluated, and ground shaking could reactivate the landslide or cause additional slope failures. The hazard from debris flows and rock falls at the site is low (Case, 1988; Lowe, 1988b).

CONCLUSIONS AND RECOMMENDATIONS

The AGRA Earth and Environmental (1995) report lists surface fault rupture and landslides as two potential hazards at the property. No evidence of surface fault rupture was exposed in their trench, so the likelihood of this hazard is low. However, AGRA Earth and Environmental identified an active landslide at the property, which suggests slopes may have marginal stability. Recommendations in their report regarding footing depth and site improvements will help reduce the hazard from landsliding, but I believe the 10-foot (3-m) setback is probably insufficient. Placing the footings below a 2:1 slope projection from the basal slide plane of the landslide provides additional safety, and probably requires a larger setback. More work is needed to adequately characterize the landslide and determine the failure plane. A qualified geotechnical engineer should also review site-grading and landscaping plans to ensure that site improvements do not affect stability of the landslide and surrounding slopes.

Ground shaking and shallow ground water are also listed as potential hazards at the property (AGRA Earth and Environmental, 1995). Recommendations in the AGRA Earth and Environmental (1995) report meet minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. Their recommendations also adequately address the hazard from shallow ground water, and I recommend that the consultant inspect the foundation excavation and subdrain system to ensure that the plans are followed. However, conditions at the property suggest there is a potential for liquefaction, which was not addressed in their report. Liquefaction evaluations are usually not required for single-family dwellings. However, I recommend that existence of this hazard be disclosed to future buyers. I also recommend that potential buyers be made aware of the existence of the AGRA Earth and Environmental (1995) report and my review.

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Sergent, Hauskins, and Beckwith, 1992, Report "Slope stability reconnaissance, lots 7, 8, 9, 10, and 11, Eastwood subdivision no. 8, Uintah, Weber County, Utah": Unpublished consultant's report, 5 p.

SHB AGRA, Inc., 1993a, Report "Fault rupture, landslide, and ground-water hazards evaluation, Uintah Highland homesites, approximately 6100 South 2850 East, and 6100 South Osmond Lane, Weber County, Utah": Unpublished consultant's report, 9 p.

----1993b, Report "Fault rupture, ground water, and debris-flow hazards evaluation, proposed home site, approximately 2850 East 6025 South, Weber County, Utah": Unpublished consultant's report, 9 p.

Project: Review of "Engineering geology of the Malan property, Ogden, Utah"			Requesting Agency: Ogden City Planning Division
By: Bill D. Black	Date: 6-15-95	County: Weber	Job No: 95-10 (R-17)
USGS Quadrangle: Ogden (1345)			

PURPOSE AND SCOPE

This report is a review of a geologic-hazards report (Kaliser, 1995) for the Malan property at roughly 1850 East and 2850 South (SE1/4NE1/4 section 34,T.5N., R.1W., Salt Lake Base Line) in Ogden City, Weber County, Utah. Richard Frye, Ogden City Planning Division, requested the review. The scope of work consisted of a literature review.

DISCUSSION

Surface fault rupture is a potential hazard at the property (Kaliser, 1995), and the southeast corner of the area is in the surface-fault-rupture special-study zone (SFRZ) on Weber County Planning Commission maps (Lowe, 1988). Kaliser (1995) excavated two trenches in the SFRZ. One trench (exposure no. 1) is near the southeast corner of the property, and the other (exposure no. 2) is approximately 240 feet (73 m) to the west near the edge of the SFRZ. Exposure no. 1 showed backtilted lacustrine sediments that indicate deformation associated with surface faulting. Exposure no. 2 showed no evidence of deformation. Based on this, Kaliser (1995) recommends that no occupied structure be built within 37 feet (11 m) of the southern border of the property, and within 44 feet (13 m) of an unmapped topographic scarp near exposure no. 1 in the southeast corner of the property.

Debris flows and flooding are also potential hazards. Kaliser (1995) believes the hazard from debris flows is low because the property has experienced no historical debris-flow events and is 1,700 feet (518 m) from the mountain front. He does not recommend any hazard-reduction measures for debris flows. Kaliser (1995) indicates that alluvial-fan flooding from Taylor Canyon could occur at the property, and recommends constructing a berm along the north property line to deflect possible floodwaters. He also states that discharge from the Malan Spring pipeline and runoff from the Wasatch Range front could cause localized flooding, and recommends eliminating the pipeline discharge and making provisions to accommodate the runoff.

Although a large rock slide is mapped east of the property, Kaliser (1995) believes there is "zero" risk of future movement. However, he identified a potential hazard from rock falls and steep unstable cut slopes. He believes the rock-fall hazard is low, but observed possible rock-fall boulders at the property and recommends informing future homeowners that rock falls could occur in the future. Areas with steep cut slopes are mapped as "nonbuildable areas" in his report. He recommends that no construction take place in the "nonbuildable areas" areas without first consulting a qualified geotechnical engineer.

CONCLUSIONS AND RECOMMENDATIONS

Kaliser (1995) believes the western limit of the zone of deformation of the Wasatch fault is at exposure no. 1 and does not extend to exposure no. 2. However, because the trenches did not extend the entire width of the SFRZ (perpendicular to the trend of the fault), the portion of the SFRZ between the trenches was not investigated. Smaller faults could occur in the untrenched areas that are obscured at the surface. In addition, his recommendations are unclear and he needs to show the SFRZ and his recommended setback distances on a site map. If the property owner wants to build occupied structures in the SFRZ in untrenched areas, additional trenching of at least the proposed building sites will be needed to demonstrate a lack of faulting.

I concur with Kaliser (1995) that the hazard from debris flows is probably low. However, the property is located on an active alluvial fan formed by repeated debris-flow events. Although the property is 1,700 feet (518 m) from the mountain front, sediment-laden flood waters from numerous debris flows/floods (including the 1991 Cameron Cove debris flow in North Ogden) have travelled much farther (Mike Lowe, Utah Geological Survey, verbal communication, June, 1995). Regarding flooding, I also concur with Kaliser's (1995) recommendations to eliminate discharge from the Malan Spring pipeline, construct a berm to deflect flood waters from Taylor Canyon away from the property, and improve drainage to accommodate runoff from the east. Improving drainage may also reduce flooding from a future debris flow. A qualified geotechnical engineer is needed for proper design of the berm for both debris flows and flooding, and should review any site-drainage plans prior to development. Care must be taken to ensure that any actions taken to protect this property do not negatively impact adjacent properties.

I believe the potential for movement of the rock slide is probably low, but not "zero" as Kaliser (1995) states. Regarding rock-fall and slope-stability hazards, I concur with his recommendations that the potential for future rock falls should be disclosed to prospective buyers, and that no construction should take place in "nonbuildable areas" on steep cut slopes without first consulting a qualified geotechnical engineer.

The hazard from ground shaking is not addressed in Kaliser (1995). Ground shaking is typically the most widespread and damaging earthquake hazard. The property is located in Uniform Building Code seismic zone 3, and all structures should be designed and constructed in accordance with seismic zone 3 requirements for earthquake-resistant design.

REFERENCES

Kaliser, B.N., 1995, Engineering geology of the Malan property, Ogden, Utah: Unpublished consultant's report, 9 p.

Lowe, Mike, 1988, Potential surface-fault rupture sensitive area overlay zone--Ogden quadrangle: Weber County Planning Commission unpublished map, scale 1:24,000.

Project: Review of geologic-hazards report for Barnett subdivision near Spring Lake, Utah			Requesting Agency: Utah County
By: M.D. Hylland	Date: 9-18-95	County: Utah	Job No: 95-11 (R-18)
USGS Quadrangle: Spanish Fork (1006) and Payson Lakes (965)			

PURPOSE AND SCOPE

This report is a review of a geologic-hazards report (Moore, 1995) for the proposed two-lot Barnett subdivision 1/2-mile east of the community of Spring Lake, Utah. The review was requested by Jeff Mendenhall, Utah County Planning and Zoning Department. The purpose of this review is to evaluate whether the report adequately addressed geologic hazards at the site. The scope of this review included a literature review and stereoscopic aerial-photograph interpretation (1958, scale 1:10,000), but did not include a site inspection.

GEOLOGIC HAZARDS

The Moore report addresses rock-fall, landslide, debris-flow, and surface-fault-rupture hazards based on the site's location within the Utah County Natural Hazards Overlay (NHO) Zone (Robison, 1990). The Moore report does not address other potential geologic hazards, such as earthquake ground shaking, liquefaction, shallow ground water, or problem soils. Except for ground-water depth, which Robison (1990) indicates is greater than 50 feet in the vicinity of the site, these other potential hazards are also not included in Utah County's NHO Zone.

The Moore report indicates that structures will be placed within 150 feet of the northern boundary of the lots. This area is characterized by gentle slopes ranging from about 10 to 19 degrees underlain by well-sorted alluvial deposits with minor colluvium (Moore, 1995). The Moore report indicates no rock-fall hazard in the building area; no evidence of previous landslides, slumps, or debris flows; and no surface expression of any faults on or near the building sites. Accordingly, the report presents no hazard-reduction or site-development recommendations pertaining to geologic hazards.

CONCLUSIONS AND RECOMMENDATIONS

The validity of the conclusions presented in the Moore report is difficult to evaluate because the report contains little supporting data. However, the proposed building area on the northern part of the lots is outside of the rock-fall and landslide NHO zones, and, as indicated in the Moore report, is 300 to 500 feet north of surface traces of the Wasatch fault as mapped by Machette (1992). Therefore, I agree with the report's implied conclusion that the potential rock-fall, landslide, and surface-fault-rupture hazards are low within the proposed building area.

The debris-flow (and associated alluvial-fan-flood) hazard at the site has not been adequately addressed in the Moore report. The debris-flow NHO zone covers a large part of the proposed building area on both lots, and corresponds to coalesced alluvial fans mapped by Machette (1992) as Holocene to latest Pleistocene in age. The Moore report indicates a lack of surficial evidence for previous debris flows, but this does not preclude a potential hazard at the site. Several issues must be addressed to adequately evaluate the debris-flow hazard, including the potential for the drainage basins to produce debris flows, the possible volume of material that could be mobilized and affect the site during a debris flow, and the effect of any existing structures or topography on the possible travel path of a debris flow. Furthermore, debris flows represent an extreme, debris-laden type of alluvial-fan flooding. Floods with less sediment than a debris flow, such as debris floods and clear-water floods, can also potentially damage structures on an alluvial fan and threaten life-safety. I recommend that the potential for debris flows and alluvial-fan flooding in general be determined, to provide a basis for structure siting and any warranted hazard-reduction measures.

I also recommend that a standard soil-foundation study be performed at the site. This study can assess the potential for geologic hazards not addressed by the Utah County NHO, such as liquefaction and problem soils, and can confirm shallow-ground-water conditions at the site. Earthquake ground shaking can be addressed by adhering to the seismic provisions for construction in Uniform Building Code (UBC) seismic zone 3.

REFERENCES

Machette, M.N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2095, scale 1:50,000.

Moore, R.L., 1995, Utah County, Re: Barnett subdivision, SW¼ SE¼ Sec. 29, T. 9 S., R. 2 E., lots 1 & 2: unpublished consultant's report, 1 p.

Robison, R.M., 1990, Utah County natural hazards overlay (NHO) zone, southern Utah County: unpublished Utah County Planning Department maps, scale 1:50,000.

Project:			Requesting Agency:
Review of "Geotechnical investigation, Canyon View Estates, 2800 North 2200 East, Layton, Utah"			Layton City Community Development Department
By: Barry J. Solomon	Date: 9-18-95	County: Davis	Job No: 95-12 (R-19)
USGS Quadrangle: Kaysville (1320)			

INTRODUCTION

In response to a request from Doug Smith, Layton City planner, I reviewed the engineering-geology aspects of a geotechnical report (Applied Geotechnical Engineering Consultants, Inc. [AGEC], 1994) for the Canyon View Estates residential subdivision located in the NW1/4 section 11, T. 4 N., R. 1 W., Salt Lake Base and Meridian, in Layton, Utah. The scope of work included a literature review and examination of aerial photographs (1985, 1:24,000 scale), but not a field inspection of the site.

GEOLOGIC HAZARDS

The AGEC (1994) report identifies landsliding and earthquake ground shaking as the principal geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. The report also addresses liquefaction potential and concludes that the liquefaction potential is very low.

AGEC conducted a field investigation to examine surficial geology, collect information on subsurface conditions, and obtain samples for laboratory testing. During its field investigation, AGEC found evidence of a landslide complex on steep slopes along the south and east portions of the property, but does not map the location of the landslides. The AGEC (1994) report states that these slopes are "hummocky and irregular" (p. 2), and "some active landsliding has occurred in the recent past" (p. 9). AGEC proposes that buildings constructed near the crest of the slope be set back from the crest at least to areas underlain by slopes of less than 30 percent, or to a setback line shown on figure 1 of its report, whichever is farthest from the crest of the slope. AGEC based the setback line of figure 1 on topography and an "evaluation of the slope" (AGEC, 1994, p. 9), but the evaluation criteria are not specified. My review of the literature (Nelson and Personius, 1993) and air photos of the area confirms that existing landslides, presumably including those discussed but not mapped by AGEC (1994), are outside the setback line, on slopes greater than 30 percent.

Because the setback line of figure 1 excludes areas underlain by slopes of 30 percent or more, and locally excludes additional small areas underlain by slopes less than 30 percent, I believe that the AGEC recommendation for building setbacks is reasonable and adequately delineates areas susceptible to landsliding. The building setback proposed by AGEC is a prudent hazard-reduction technique.

AGEC also considered the potential for the earthquake-related hazards of ground shaking and liquefaction. AGEC recognizes the potential severity of earthquake ground shaking in the region and recommends that buildings be designed and constructed in full accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3 (AGEC, 1994, p. 14). This satisfies state and local government minimum requirements. AGEC's site-specific investigation indicated a "very low" liquefaction potential (AGEC, 1994, p. 13), however, the AGEC report did not describe specific evidence for this assessment. AGEC's logs of two borings on the southeastern property margin just above the crest of the steep slope show the presence of shallow, medium dense to very dense, granular soils, but ground water was not encountered until depths of 31 and 32 feet (9.4 and 9.8 meters). I assume that this density and lack of saturation in shallow soils is a primary reason for AGEC's assessment of the liquefaction potential, and I concur.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, AGEC adequately investigated geologic hazards at Canyon View Estates. AGEC identified areas of potential landsliding, and setback lines recommended by AGEC are adequate estimates of potential areas of slope instability. AGEC makes a prudent recommendation that design and construction standards be consistent with those required for UBC seismic zone 3 to address the potential for earthquake ground shaking. AGEC satisfactorily identifies the potential for liquefaction. Both the slope stability and liquefaction evaluations are based on present conditions. If slopes are significantly modified or if ground-water levels increase as a result of development, slope stability and liquefaction potential may change and should be re-evaluated. I advise that the existence of the AGEC (1994) report and this review be disclosed to future lot or home buyers.

REFERENCES

Applied Geotechnical Engineering Consultants, Inc. (AGEC), 1994, Geotechnical investigation, Canyon View Estates, 2800 North 2200 East, Layton, Utah: Midvale, Utah, unpublished consultant's report prepared for Hill, Jamison and Associates, Inc., 16 p.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2199, scale 1:50,000.

Project:			Requesting Agency:
Review of "Report, Slope Stability Evaluation, Proposed Tyler Ridge Condominium Development, Approximately 1910 South 1275 East Street, Ogden, Utah."			Ogden City
By: M.D. Hylland	Date: 10-3-95	County: Weber	Job No: 95-13 (R-20)
USGS Quadrangle: Ogden (1345)			

PURPOSE AND SCOPE

This report is a review of a slope-stability evaluation (AGRA Earth & Environmental [AGRA], 1995) for the proposed Tyler Ridge condominium development in Ogden, Utah. The review was requested by Kirk Smith, Ogden City Planner. The purpose of this review is to evaluate whether AGRA adequately characterized slope stability at the site to support its recommendation for a reduction of the 100-foot building setback required by Ogden City. The scope of this review included a literature review and stereoscopic interpretation of aerial photographs (1937, scale 1:20,000; 1985, scale 1:24,000), but did not include a site visit.

GEOLOGIC CONDITIONS

As summarized in AGRA (1995), the 0.8-acre site is adjacent to the southwestern margin of the Ogden River landslide complex's western amphitheater. A "moderately steep" landslide scarp 35 to 55 feet high bounds the site to the northeast (AGRA, 1995, p. 4). Tabulated slope data from the site vicinity indicate scarp gradients range from 5.2H:1V (horizontal:vertical) to 0.8H:1V, and "general grade" ranges from 6.3H:1V to 4.7H:1V (AGRA, 1995, p. 6). AGRA (1995) observed no indications of active landsliding on the slope northeast of the site.

AGRA's scope of work did not include subsurface exploration. Subsurface materials were described as "...laminated lacustrine clays and fine silty sands, with some silty gravels on or near the surface," based on observations in the vicinity of the site (AGRA, 1995, p. 4). AGRA (1995) projects the depth of static ground water beneath the site at greater than 50 feet, based on the results of previous geotechnical studies in the vicinity of the site summarized in Vandre and Lowe (1995).

AGRA (1995) concludes that the site is stable under present conditions, but notes that "...future activity on the Western Amphitheater landslide complex, and/or future seismic activity, may reduce the stability of the moderately steep slope to the northeast of the site" (p. 6). AGRA (1995) does not expect deep-seated landsliding to occur on the slope northeast of the site, based on projected deep ground water. Accordingly, AGRA (1995, p. 7) recommends a building setback line based on projection of a 2H:1V slope upward from the toe of the steepest slope segment. This results in a setback from the top of the landslide scarp of approximately 15 feet, as measured on figure 2 in AGRA (1995).

PREVIOUS SETBACK RECOMMENDATION

The 100-foot building setback required by Ogden City is based on a slope-stability evaluation for a site southeast of the proposed Tyler Ridge development, at about 20th Street and Tyler Avenue (Dames & Moore, 1979). The site location with respect to the western amphitheater is similar to that of the proposed Tyler Ridge development. However, the landslide scarp at the site studied by Dames & Moore is higher (60-80 feet) and the average slope is steeper (1.6H:1V) (Dames & Moore, 1979) than at the Tyler Ridge site (35-55 feet and 2H:1V; AGRA, 1995). Dames & Moore's (1979) study included drilling a 45-foot-deep boring and calculating a factor of safety for the existing slope based on "...projected strength parameters and the measured slope geometry..." (Dames & Moore, 1979, p. 6). Moist lacustrine deposits consisting of silty clay and clayey silt were encountered below a depth of 8.5 feet in the boring (Dames & Moore, 1979). The 100-foot setback recommendation was based on "...analytical projections of the failure surface...and by evaluating the average slopes of those portions of the slide complex to the east, where it appears that significant liquefaction-induced failures have occurred" (Dames & Moore, 1979, p. 7).

CONCLUSIONS AND RECOMMENDATIONS

The 100-foot setback recommendation in Dames & Moore (1979) was derived in part from on-site, subsurface soil and ground-water data and applies to conditions at that site. I agree with AGRA (1995) that a lesser degree of potential landslide hazard probably exists at the Tyler Ridge site than at other locations within the Ogden River landslide complex, including the site evaluated by Dames & Moore. Because the scarp at the proposed Tyler Ridge development is not as steep or high as that at the site of the Dames & Moore study, the 100-foot setback might be reduced at the Tyler Ridge site without posing an unacceptable increased risk to life safety. However, recommendations for a significant reduction of the setback distance, such as that proposed by AGRA (1995), should be supported by a quantitative analysis based on site-specific data.

In general, I consider a setback based on a projected 2H:1V slope in unconsolidated, non-cohesive, granular material to be the minimum allowable because the projected slope is generally near the angle of repose of the material when dry. Such a slope would still be susceptible to retreat by weathering, sloughing, and erosion, and could be destabilized by a rise in ground-water level. Elsewhere in the Ogden River landslide complex, gradients of inactive landslide slopes and slopes in the fine-grained, clayey lacustrine material are typically gentler than about 4H:1V (SHB AGRA, Inc., 1993; Vandre and Lowe, 1995), which represents a more stable slope for these materials. Similarly, the natural "general grade" of the slope bounding the Tyler Ridge site is about 5H:1V (AGRA, 1995, p. 6). In view of the lack of site-specific data at this site and the relatively high likelihood that shallow subsurface soils are clayey, I believe a more conservative setback is prudent unless site-specific geologic data and analyses are submitted to support AGRA's recommendation. The potential for changed conditions accompanying development, specifically increases in ground-water levels, also must be considered.

REFERENCES

AGRA Earth & Environmental, Inc., 1995, Report, slope stability evaluation, proposed Tyler Ridge condominium development, approximately 1910 South 1275 East Street, Ogden, Utah: Salt Lake City, unpublished consultant's report, 8 p.

Dames & Moore, 1979, Slope stability study, proposed northern portion of the Eastgrove condominium development, approximately 20th Street and Tyler Avenue, Ogden, Utah, for A & B Investment: Salt Lake City, unpublished consultant's report, 8 p.

SHB AGRA, Inc., 1993, Report, geotechnical/geoseismic feasibility study, proposed Burnham Woods residential development, irregular-shaped parcel north of 20th Street in the area between Pierce Avenue and Fillmore Avenue, Ogden, Utah: Salt Lake City, unpublished consultant's report, 12 p.

Vandre, B.C., and Lowe, Mike, 1995, The Rainbow Imports landslide - a window for looking at landslide mechanisms within the Ogden River landslide complex, Weber County, Utah, *in* Lund, W.R., editor, Environmental and engineering geology of the Wasatch Front region: Utah Geological Association Publication 24, p. 137-156.

Project: Review of "Geotechnical Engineering Report, Jean Eyre Residence at lot 986, Acorn Way, Timber Lakes Subdivision, Heber City, Ut			Requesting Agency: Wasatch County
By: M.D. Hylland	Date: 10-25-95	County: Wasatch	Job No: 95-14 (R-21)
USGS Quadrangle: Center Creek (1126)			

PURPOSE AND SCOPE

This report is a review of the engineering-geologic portions of a geotechnical-engineering report (Crawford Environmental Specialists, Inc. [Crawford], 1995) for lot 986 in Timber Lakes Estates, about seven miles east of Heber City, Utah. The review was requested by Robert Mathis, Wasatch County Planner. The purpose of this review is to evaluate whether geologic hazards were adequately addressed to support site-development recommendations given in the report. The scope of this review included a literature review and stereoscopic interpretation of aerial photographs (1962, 1:20,000 scale; 1987, 1:40,000 scale), but did not include a site visit. Recommendations pertaining to foundation design is the Crawford report should be reviewed by a qualified geotechnical engineer.

SUMMARY OF REPORT

The Crawford report generally addresses active faults, liquefaction, ground shaking, landslides, floods, radon, and problem soils, as well as suitability for wastewater disposal in septic-tank soil-absorption (STSA) systems. Conclusions and recommendations given in the report are based on a site reconnaissance and excavation of a 9-foot-deep trench. The report concludes that "no engineering-geology issues are present which would preclude construction of the proposed house" (Crawford, 1995, p. 6). However, the report recommends house construction only on the part of the lot within 50 feet of Acorn Way, with a minimum 30-foot setback from the top of a steep slope that descends to a stream channel at the back of the lot.

CONCLUSIONS AND RECOMMENDATIONS

Although the Crawford report does not provide a clear basis for its structure-siting recommendations, I believe that the recommendations are adequate to reduce the risk associated with landslide hazards to an acceptable level. This conclusion is based on my projections of stable slopes determined by previous studies at Timber Lakes (Earthstore, 1988; Hylland and Lowe, 1995). Using the lot dimensions i the report and assuming the steep slope is approximately 50 feet high (based on the U.S. Geological Survey topographic map [40-foot contour interval] and a reference to the stream elevation in the Crawford report), an imaginary plane projected up from the stream channel at a stable-slope angle of 4H:1V (horizontal:vertical, or 25 percent) intersects the upper part of the lot south (outside) of the recommended building area.

The Crawford report does not address the potential for expansive soils, nor does it recommend a location for the STSA-system drain field on the lot. However, Dan Crawford (written communication, 1995) indicates that the site soils do not display any evidence of shrink-swell potential, and recommends locating the STSA-system drain field at least 30 feet away from the top of the steep slope. With this supplemental information, I believe the conclusions and recommendations in the Crawford report adequately address geologic hazards at the site.

REFERENCES

Crawford Environmental Specialists, Inc., 1995, Geotechnical engineering report, Jean Eyre residence at lot 986, Acorn Way, Timber Lakes Subdivision, Heber City, Utah: Salt Lake City, unpublished consultant's report, 10 p.

Earthstore, 1988, Report, geotechnical/engineering geology study, plats 19A, 19B 20A, and 20B, Timber lakes development, located approximately seven miles east of Heber, Utah, in Wasatch County, for Wasatch County: Salt Lake City, unpublished consultant's report, 14 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazards of western Wasatch County, Utah, in Lund, W.R., editor, Environmental and engineering geology of the Wasatch Front region: Utah Geological Association Publication 24, p. 121-136.

Project:			Requesting Agency:
Review of "Report, Engineering Geology/Geotechnical Study, Canyon Meadows Residential Devevelopment, Upper Provo Canyon North of Highway 189 Near Deer Creek Dam, Wasatch County, Utah."			Wasatch County
By: M. D Hylland	Date: 11-6-95	County: Wasatch	Job No: 95-15 (R-22)
USGS Quadrangle: Aspen Grove (1128)			

PURPOSE AND SCOPE

This report is a review of the engineering-geologic portions of an engineering-geology/geotechnical report (AGRA Earth & Environmental, Inc. [AGRA], 1995, including Report Addendum No. 1 dated August 16, 1995) for the Canyon Meadows residential development in Wasatch County, Utah. The review was requested by Robert Mathis, Wasatch County Planner. The purpose of this review is to evaluate whether landslide hazards and other engineering-geologic considerations were adequately addressed such that additional site-specific studies would not be needed for individual lots. The scope of this review included a literature review and stereoscopic interpretation of aerial photographs (1962, 1:20,000 scale; 1987, 1:40,000 scale), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA report should be reviewed by a qualified geotechnical engineer.

SUMMARY OF REPORT

The AGRA report addresses landsliding and slope stability, shallow bedrock, shallow ground water, and moisture sensitivity (expansive characteristics) of the site soils. Conclusions and recommendations given in the AGRA report are based on literature review, engineering-geologic mapping of the site, subsurface exploration consisting of 15 test pits and five borings, and limited geotechnical laboratory testing.

AGRA (1995) concludes that the existing landslide underlying Canyon Meadows is inactive, but that the toe of the landslide southeast of the site is subject to movement along U.S. Highway 189. AGRA (1995) recommends "changes to the site should be evaluated carefully to promote continued stability..." (p. 9), and requests supplemental review of site-grading plans prior to construction "because of the concern regarding landslides, and the effect that the proposed grading and development plan may have..." (p. 16). AGRA (1995) also provides recommendations for permanent cut and fill slopes, as well as monitoring of the landslide surface.

AGRA (1995) reports no shallow bedrock at the site, but includes consideration of shallow bedrock in their development recommendations. AGRA (1995) encountered shallow ground water at the site, and provides recommendations to reduce this hazard. AGRA (1995) concludes that the site soils generally are not moisture sensitive, but that isolated pockets of sensitive (expansive) or collapsible soils could exist. The report does not provide specific recommendations pertaining to these types of soils.

CONCLUSIONS AND RECOMMENDATIONS

The AGRA report presents generally adequate recommendations for overall site development, and I agree with AGRA's assessment of the present level of landslide activity at the site. I also agree with AGRA's concerns regarding possible slope destabilization if care is not taken during future development, both within Canyon Meadows and that associated with the Utah Department of Transportation's (UDOT) planned realignment of Highway 189. Because AGRA's conclusions regarding landslide movement are based on present conditions, and because future development and highway construction could significantly change those conditions, I support AGRA's recommendations for supplemental review of Canyon Meadows grading plans prior to construction, and close communication between Canyon Meadows and UDOT regarding UDOT's assessment of pre- and post-highway-construction stability of the landslide. I also recommend that, at a minimum, the following be disclosed to all potential lot owners on the landslide: the existence of the landslide; the potential for future movement of the landslide; and the existence of the AGRA, UDOT, and any other pertinent engineering-geologic reports.

I believe that the AGRA report provides sufficiently detailed recommendations for individual lot development of some, but not necessarily all, of the lots in the Canyon Meadows development. AGRA's recommendation for a maximum 2.5H:1V (horizontal:vertical) permanent slope in clayey soils is appropriate for peak-strength conditions in material not weakened by landsliding, but may not assure stability for residual-strength conditions in weakened landslide material. Also, AGRA does not address the effects on slope stability associated with the orientation of planar features, such as bedding, in subgrade material. To address variability of soil strength and orientation of planar features, as well as other pertinent slope-stability considerations, I recommend that a site-specific slope-stability evaluation be completed prior to construction on any lot with a significant slope (10-feet high or greater) steeper than 3.5H:1V in clayey soils having shale parent material. As indicated on figure 2 in AGRA (1995), this includes areas mapped as C(sw)c-b,SH, R(wp)c-m,SH, S(fl)c-m,SH, and S(sf)c-b,SH-SS. The slope-gradient criterion is based on the average residual-strength friction angle for the Manning Canyon Shale as determined from direct-shear laboratory tests on samples obtained near Canyon Meadows (Parsons Brinckerhoff Quade & Douglas, Inc., 1994). The site-specific evaluation should confirm the presence or absence of clayey soils and/or shale, determine appropriate shear-strength parameters (peak strength versus residual strength) for the subgrade materials, evaluate evidence for shallow ground water, evaluate the dip of bedding or other planar features that could affect slope stability, and provide appropriate site-specific recommendations.

Because AGRA (1995) provides no basis for its conclusion regarding expansive soils and does not provide specific recommendations pertaining to expansive soils, I recommend further clarification of this hazard. Shrink-swell potential is an important design consideration both for lightly loaded structures (roads, sidewalks, houses) and septic-tank soil-absorption systems. The Manning Canyon Shale is known to exhibit expansive characteristics (Mulvey, 1992), and x-ray diffraction analysis determined that soil samples derived from the Manning Canyon Shale in the vicinity of Canyon Meadows contained expansive smectite clay minerals (Parsons Brinckerhoff Quade & Douglas, Inc., 1994). Therefore, I recommend that AGRA substantiate its conclusion regarding expansive soils through documentation of field observations and/or laboratory-test results, or provide specific recommendations if a hazard is found.

AGRA (1995) requests notification "...if additional information is found at the site during the construction phase of the project..." so that it can make any necessary modifications to its recommendations (p. 3). I believe that only a qualified engineering geologist or geotechnical engineer has the expertise to assess and recognize engineering-geologic conditions that may require modifications to recommendations. Given the known landslide susceptibility (Harty, 1991) and expansive characteristics (Mulvey, 1992) of the Manning Canyon Shale, and the sensitivity of this site to development acknowledged by AGRA (1995), I recommend a construction-monitoring program be established to evaluate individual lot conditions. To be effective, such a program requires the geotechnical consultant to observe and evaluate any significant excavations, cuts, and fills, and submit a report either: (1) confirming that conditions were as expected and their recommendations were followed, or (2) assessing new conditions, revising recommendations, and documenting that the revised recommendations were followed.

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APPENDIX

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