TECHNICAL REPORTS FOR 1996
APPLIED GEOLOGY PROGRAM

compiled by
Bea H. Mayes

REPORT OF INVESTIGATION 231 1997
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

Mayes
TECHNICAL REPORTS FOR 1996 APPLIED GEOLOGY PROGRAM
UGS Report of Investigation 231

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Cover photo: Piping-induced slope failure
in Spanish Fork Canyon
photo credit: F.X. Ashland

PREFACE

The Applied Geology Program of the Utah Geological Survey (UGS) maps and defines geologic hazards, helps assess and protect ground-water resources, 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 facilities, water tanks, and schools. We define drinking-water source-protection zones for public water-supply wells and springs. 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, soil problems in developing areas, and 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 47 technical reports completed in 1996 (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, some of which were produced on a copy machine. This is the tenth compilation of the Applied Program's technical reports.

Bea H. Mayes
February 4, 1997

Applied Geology Program

TECHNICAL REPORT SITES
1996

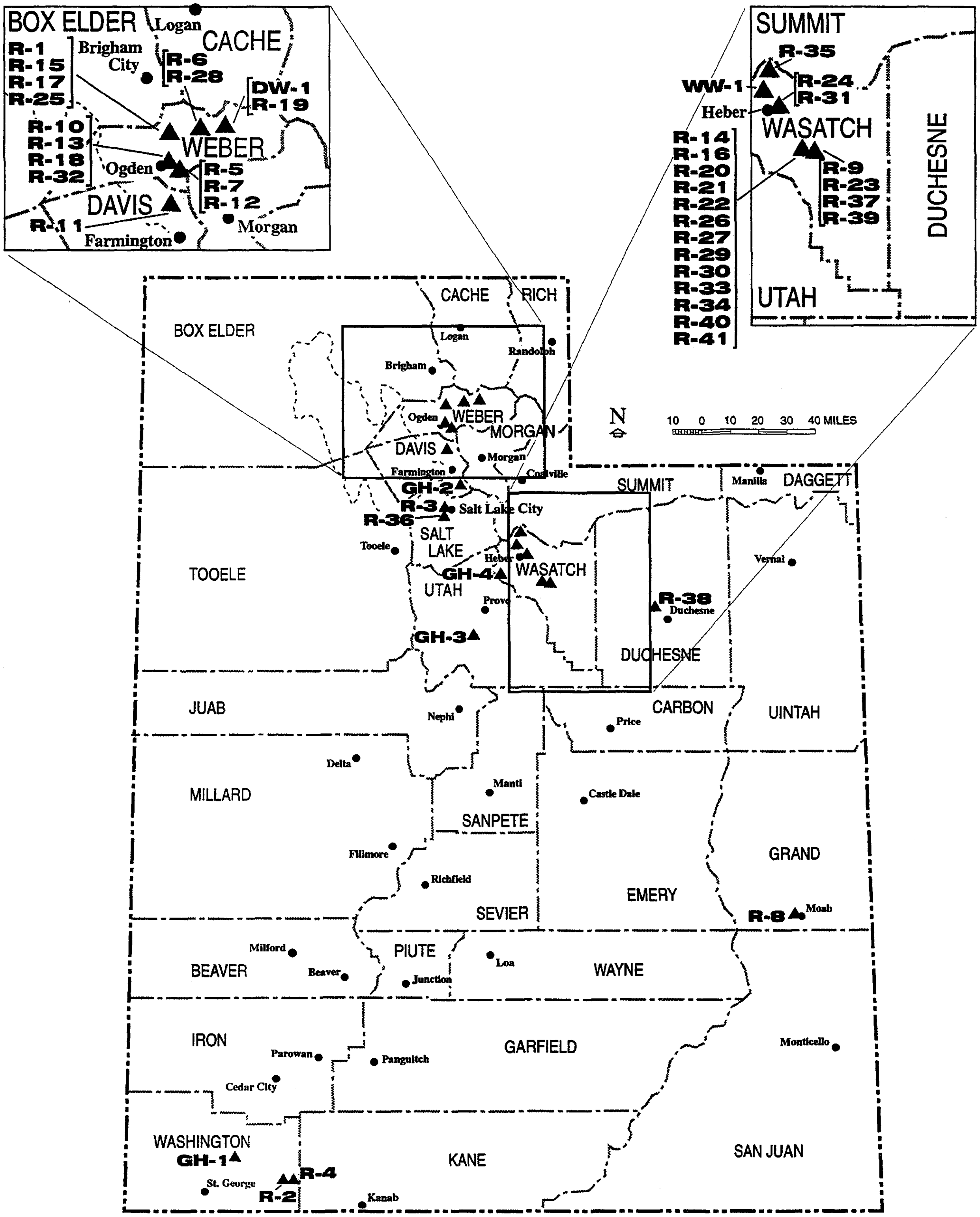

Figure 1. Location map.

CONTENTS

Illustration

DRINKING WATER SOURCE PROTECTION

Project: Delineation of drinking water source protection zones for Green Hills Country Estates well 01, Weber County, Utah			Requesting Agency: Green Hills Country Estates Water Company
By: Mike Lowe and Charles E. Bishop	Date: July 2, 1996	County: Weber	Job No: 96-23 (DW-1)
USGS Quadrangle: Browns Hole (1368)		Number of attachments: 6 and Appendices A and B	

INTRODUCTION

This report describes our delineation of drinking-water-source-protection (DWSP) zones for a public-supply well (Utah Division of Drinking Water system number 29053, source number 01) in the SW¼NE¼SW¼ section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian, in eastern Ogden Valley, Weber County (attachment 1). The Green Hills Country Estates Water Company (GHCEWC) owns the well and requested the delineation. The scope of work included a literature search, review of water-well logs, field reconnaissance, and an unsuccessful aquifer test.

Public-water suppliers in Utah are required by Utah's Drinking Water Source Protection Rule (R309-113, Utah Administrative Code; administered by the Utah Division of Drinking Water) to develop a DWSP plan for each well or spring used as a public drinking-water source. A part of this plan involves delineating DWSP zones. Utah's DWSP Rule (R309-113-9 [1]) defines four DWSP zones:

Zone 1 - the area within a 100-foot (30-m) radius from the wellhead;

Zone 2 - the area within a 250-day ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the well, or the ground-water divide, whichever is closer to the well;

Zone 3 (waiver zone) - the area within a three-year ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the well, or the ground-water divide, whichever is closer to the well; and

Zone 4 - the area within a 15-year ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the well, or the ground-water divide, whichever is closer to the well.

Delineation of DWSP zones 1, 2, and 4 are required by the DWSP Rule. A waiver zone, zone 3, is included to assist the water supplier with future monitoring waivers (see R309-1104).

One of two procedures may be used to delineate the DWSP zones: (1) a "Preferred Delineation Procedure," which is based on ground-water times of travel and local hydrogeology; or (2) an "Optional Two-Mile Radius Delineation Procedure" which is based on identifying all upgradient areas supplying water to a well or spring within a fixed 2-mile (3.2-km) radius of the drinking-water source. We delineated the DWSP zones for GHCEWC well 01 using the "Preferred Delineation Procedure" because it closely reflects the hydrogeologic system and we believe it is more accurate.

DWSP zones 2, 3, and 4 were delineated in this study. Zone 1, a 100-foot fixed radius around the well, is not shown on the map or discussed further in this report.

GEOLOGY

GHCEWC well 01 is in eastern Ogden Valley near the southern end of the Bear River Range. Ogden Valley is a segment of the Wasatch Hinterlands section of the Middle Rocky Mountains physiographic province (Stokes, 1977).

The GHCEWC well is near the mouths of Maple and Kelley Canyons, which drain the southern end of the Bear River Range, and is just east of the inferred location of the East Ogden Valley fault zone (attachment 2). Surficial sediments at the well are locally derived clay- to boulder-size alluvium. The driller's log for the well (appendix A) indicates unconsolidated deposits are 81 feet (25 m) thick. At depth, some of the alluvial sediments may have been deposited by the South Fork of the Ogden River.

The Precambrian Maple Canyon Formation, which crops out north and east of the well (Crittenden, 1972), is a 1,000- to 1,500-foot-thick (300 to 450 m) sequence of clastic rocks that are divided into three informal members based on lithology (Crittenden and others, 1971). The lowest unit (the argillite member) is about 500 feet (150 m) of olive drab to gray, thin-bedded, silty argillite or siltstone containing one or more beds of greenish-gray arkosic sandstone (Crittenden and others, 1971). The middle unit (the green arkose member) is 500 to 1,000 feet (150 to 300 m) of relatively thick-bedded, massive, dark-gray to brown weathering, very fine-grained arkosic sandstone. The uppermost unit (the conglomerate member) is 60 to 500 feet (18 to 150 m) thick and consists of two white to light gray, pebble to small cobble conglomerates (locally quartzites) and an intervening olive drab laminated argillite (Crittenden and others, 1971). A subsurface projection (attachment 3) based on Crittenden's (1972) map indicates the fractured rock unit penetrated by the GHCEWC well from 81 to 260 feet (25 to 79 m) and described by the driller (appendix A) as "green and brown shell (sic)" should be the green arkose member of the Maple Canyon Formation (Frank Ashland, Utah Geological Survey, verbal communication, January 31, 1996).

Other rock units crop out in the Bear River Range east of the well, including: the Precambrian Kelley Canyon Formation (argillite, dolomite, limestone, and quartzite), Caddy Canyon(?) Quartzite, Inkom(?) Formation (argillite), Mutual Formation (quartzite), and the volcanic (mostly basalt) and terra cotta quartzite members of the Browns Hole Formation; the upper and lower members of the Precambrian to Cambrian Geertsen Canyon Quartzite (mostly quartzite, but some arkose at the base of the lower member); the Cambrian Maxfield Limestone; and the Upper Cretaceous to Tertiary conglomerates of the Wasatch and Evanston Formations (Crittenden and others, 1971; Crittenden, 1972).

The Precambrian and Cambrian rock units are extensively fractured and are offset by normal and reverse faults (attachment 2), including the Maple Canyon thrust north and east of the well (Crittenden, 1972). Although outcrops are not common in slopes underlain by the Maple Canyon Formation, we did measure fracture trends at one small outcrop in Maple Canyon (NE¼NW¼NE¼ section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian). Two fracture sets were identified. One set strikes N. 16° E., dips 20° W., and has a fracture spacing of about two inches (5 cm). The other set strikes N. 90° E., dips 15° E., and has a fracture spacing ranging from 8 inches to 1.5 feet (20 to 46 cm). Beds north and west of the Maple Canyon thrust dip primarily to the northwest, away from Kelley and Maple Canyons and away from the well (attachments 3 and 4) (Crittenden, 1972). Attachment 3 was prepared assuming Crittenden's (1972) dip near the borrow pit northwest of the well was not representative of the regional dip. Beds north and east of the Maple Canyon thrust dip primarily to the northeast, also away from Kelley and Maple Canyons and the well (attachment 2) (Crittenden, 1972). The Maple Canyon thrust fault also dips away from the well in all directions (attachments 3 and 4).

THE WELL

The following information regarding the GHCEWC well is taken from the driller's log (appendix A). The well (surface elevation approximately 5,030 feet [1,533 m]) was drilled to a total depth of 260 feet (79.3 m) in 1979 using rotary drilling methods. The well-casing diameter is 10 inches (25 cm) from 0 to 100 feet (0 to 30.5 m) and 8 inches (20 cm) from 100 to 240 feet (30 to 73 m). The gage and construction type for the casing is unknown. The casing was perforated 130 times from 120 to 240 feet (37 to 73 m) using both a cutting torch and knife (mills?). Perforation size is 8¼ inches by 2¼ inches (21 cm by 5.7 cm). All perforations are below the valley-fill/bedrock contact, so the well draws water from fractured rock.

AQUIFER DATA

We attempted an aquifer test on January 31, 1996, but failed because we were unable to get a water-level indicator deeper than 140 feet (43 m) due to an obstruction in the well. When originally drilled in April 1979, the reported static water level was 35 feet (10.7 m). Avery (1994) reports a water level of 25.3 feet (7.7 m) in July 1984. Although the well was not pumped for more than 24 hours prior to our attempted aquifer test, the water level was below 140 feet (43 m).

The well yielded 90 gallons/minute (340 L/min) during a pump test immediately after construction. No time or drawdown information from the 1979 pump test was provided on the driller's log, so the well-yield information cannot be used to estimate aquifer properties. However, the yield of 90 gal/min (340 L/min) qualitatively indicates that the aquifer has a high transmissivity. The drawdown of more than 115 feet (35 m) over the 12-year period since the 1984 measurement indicates that the storativity and rate of recharge of the Maple Canyon Formation aquifer are low.

The well is dewatered when pumped for extended lengths of time (Lou Cooper, Green Hills Country Estates resident, verbal communication, December 11, 1995), also indicating storativity and rate of recharge of the aquifer are low.

Previous hydrologic studies in Ogden Valley include Leggette and Taylor (1937), Thomas (1945), Lofgren (1955), Doyuran (1972), and Avery (1994). These studies primarily address ground-water conditions in the unconsolidated valley-fill aquifer and provide little information relevant to bedrock aquifers such as the Maple Canyon Formation. The 1994 potentiometric surface of the valley-fill aquifer in the vicinity of the GHCEWC well is between 30 and 50 feet (9 and 15 m) below the ground surface (Avery, 1994). The fact that the water level in the GHCEWC well was greater than 140 feet (43 m) on January 31 1996, indicates little hydraulic communication between the Maple Canyon Formation aquifer and the valley-fill aquifer and that the well's casing is preventing leakage from the valley-fill aquifer into the well.

HYDROGEOLOGY

Ground-water flow to GHCEWC well 01 is in bedrock in closely spaced, likely interconnected fractures, and probably also along bedding planes. There are no bedrock units stratigraphically above the Maple Canyon Formation of significantly lower permeability to as aquitards (attachments 3 and 4). We believe these rock units therefore form a single heterogeneous, probably anisotropic aquifer, and that the recharge area for the Maple Canyon Formation aquifer at the GHCEWC well is within the combined approximately 2 square-mile (5 km^2) drainage basin of Maple and Kelley Canyons. Because the bedding of geologic units within the drainage basin generally dips away from the drainage basin (attachments 2, 3 and 4), we believe that the drainage-basin divide is actually a conservative estimate of the ground-water divide and defines a maximum limit of the recharge area. The Maple Canyon thrust fault may be a ground-water-flow boundary, carrying some ground-water away from the well. During spring runoff, however, surface water from the drainage basin above the fault likely crosses it and recharges the well.

Where possible, Utah's DWSP zones are based, in part, on ground-water times of travel which can be estimated using Darcy's Law if aquifer properties and hydraulic gradient are known. Because little information is available on the hydrologic properties of the Maple Canyon Formation, and the only water-level information for the aquifer is from the GHCEWC well, data are insufficient to estimate ground-water times of travel or draw conclusions about the Maple Canyon Formation's performance as a fractured-rock aquifer. However, to check whether our proposed drainage-basin recharge area could be reduced, we used information regarding the range of ground-water-flow velocities in various types of geologic material, including fractured rocks, summarized by Everett (1987). Fractured rock may have flow velocities of 0.1 cm/sec (283 feet/day) or greater (attachment 5). At a velocity of 0.1 cm/sec, ground water could travel more than 70,000 feet (21,300 m) in 250 days (calculation 1, appendix B). Because the most distal point within the surface-drainage basin is about 12,300 feet (3,750 m) from the well, these generalized ground-water velocities from the literature do not help to delineate DWSP zone boundaries within the surface-drainage basin. However, they do confirm that the entire drainage basin may recharge the well.

DWSP ZONES

DWSP zones 2, 3, and 4 for the GHCEWC well are shown on attachment 6. Because of the potentially rapid flow velocities and small recharge area, the boundaries of all three DWSP zones extend to the ground-water divide, which we believe corresponds with the drainage-basin divide. The maximum upgradient distance from the well to the DWSP-zone boundary, orientation N. 42° E., is about 12,300 feet (3,750 m). The maximum downgradient distance is about 200 feet (61 m). The maximum width of the combined DWSP zones is about 6,900 feet (2,100 m).

SUMMARY AND RECOMMENDATIONS

We were unable to measure water levels in or conduct an aquifer test to determine aquifer properties for the GHCEWC well. Our conclusion that the drainage basin for Maple and Kelley Canyons is the recharge area for the GHCEWC well in the Maple Canyon Formation aquifer is therefore based on: (1) ground-water velocities reported in the literature, (2) our belief that none of the stratigraphic units above the Maple Canyon Formation act as ground-water-flow barriers and that the rock units can therefore be treated as a single heterogeneous, anisotropic aquifer, and (3) evidence that leakage between the Maple Canyon Formation aquifer and the overlying valley-fill aquifer is insignificant. Because this DWSP-zone delineation is based on few data, we consider it preliminary and recommend the DWSP zones be redelineated should a mechanism for measuring water levels in the well be found and an aquifer test run.

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Avery, Charles, 1994, Ground-water hydrology of Ogden Valley and surrounding area, eastern Weber County, Utah, and simulation of ground-water flow in the valley-fill aquifer system: Utah Department of Natural Resources Technical Publication 99, 84 p.

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Leggette, R.M., and Taylor, G.H., 1937, Geology and ground water resources of Ogden valley, Utah: U.S. Geological Survey Water Supply Paper 796-D, 161 p.

Lofgren, B.E., 1955, Resume of the Tertiary and Quaternary stratigraphy of Ogden Valley, Utah *in* Eardley, A.J., editor, Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geological Society Guidebook no. 10, p. 70-84.

Stokes, W.L., 1977, Subdivisions of the major physiographic provinces in Utah: Utah Geology, v. 4, no. 1, p. 1-17.

Thomas, H.E., 1945, The Ogden Valley artesian reservoir, Weber County, Utah: Utah State Engineer Technical Publication No. 2, 37 p.

APPENDIX A

WELL LOG

Form 115—5M—12-60

Examined xm
Recorded: B. C. ______ T. S. ______
Inspection Sheet ______
Copied ______

REPORT OF WELL DRILLER

STATE OF UTAH

Application No. Ex 1296 (35 ac)
Claim No. ______
Coordinate No. ______

GENERAL STATEMENT: Report of well driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of the well. Failure to file such reports constitutes a misdemeanor.)

Greenhill Dev Co.

(1) WELL OWNER:

Name Elm Spotten
Address ______

(2) LOCATION OF WELL:

County ______ Ground Water Basin ______ (leave blank)

North 1500 feet, East 1750 feet from SW Corner (South / West)

of Section 9, T. 6 N, R. 2 E SLBM (strike out words not needed)

(3) NATURE OF WORK (check): New Well ☒ Replacement Well ☐ Deepening ☐ Repair ☐ Abandon ☐

If abandonment, describe material and procedure: ______

(4) NATURE OF USE (check): Domestic ☒ Industrial ☐ Municipal ☒ Stockwater ☐ Irrigation ☐ Mining ☐ Other ☒ Test Well ☐

(5) TYPE OF CONSTRUCTION (check): Rotary ☒ Dug ☐ Jetted ☐ Cable ☐ Driven ☐ Bored ☐

(6) CASING SCHEDULE: Threaded ☐ Welded ☐

10" Diam. from 0 feet to 100 feet Gage ______
8" Diam. from 0 feet to 240 feet Gage ______
______" Diam. from ______ feet to ______ feet Gage ______

New ☒ Reject ☐ Used ☐

(7) PERFORATIONS: Perforated? Yes ☒ No ☐

Type of perforator used Torch 40' + 80' Knife
Size of perforations 8"x1/4" inches by 2"x1/4" inches
130 perforations from 120 feet to 240 feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet

(8) SCREENS: Well screen installed? Yes ☐ No ☒

Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ Set from ______ ft. to ______
Diam. ______ Slot size ______ Set from ______ ft. to ______

(9) CONSTRUCTION:

Was well gravel packed? Yes ☐ No ☒ Size of gravel: ______
Gravel placed from ______ feet to ______ feet
Was a surface seal provided? Yes ☒ No ☐
To what depth? 100 feet
Material used in seal: Gravel + cement
Did any strata contain unusable water? Yes ☐ No ☒
Type of water: ______ Depth of strata ______
Method of sealing strata off: ______

Was surface casing used? Yes ☒ No ☐
Was it cemented in place? Yes ☒ No ☐

(10) WATER LEVELS:

Static level 35 feet below land surface Date 4-20-79
Artesian pressure ______ feet above land surface Date ______

LOG RECEIVED:
MAR 20 1980
WATER RIGHTS

(11) FLOWING WELL:

Controlled by (check) Valve ☐ Cap ☐ Plug ☐ No Control ☐
Does well leak around casing? Yes ☐ No ☐

(12) WELL TESTS: Drawdown is the distance in feet the water level is lowered below static level.

Was a pump test made? Yes ☒ No ☐ If so, by whom? Scott Stephenson
Yield: 90 gal./min. with ______ feet drawdown after ______ hours
Bailer test ______ gal./min. with ______ feet drawdown after ______ hours
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? No ☐ Yes ☐

(13) WELL LOG: Diameter of well 8 inches

Depth drilled 260 feet. Depth of completed well 240 feet.

NOTE: Place an "X" in the space or combination of spaces needed to designate the material or combination of materials encountered in each depth interval. Under REMARKS make any desirable notes as to occurrence of water and the color, size, nature, etc., of material encountered in each depth interval. Use additional sheet if needed.

From	To	Clay	Silt	Sand	Gravel	Cobbles	Boulders	Hardpan	Conglomerate	Bedrock	Other	REMARKS
0	7	X										
7	10	X			X							
10	37	X					X					
37	43	X			X							
43	66	X					X					
66	70				X							
70	81	X					X					
81	260										X	Green + Brown shale

Work started April 1979 Completed April 1979

(14) PUMP:

Manufacturer's Name ______
Type: ______ H. P. ______
Depth to pump or bowles ______ feet

Well Driller's Statement:

This well was drilled under my supervision, and this report is true to the best of my knowledge and belief.

Name Northwest Well Drlg Dev (Person, firm, or corporation) (Type or print)
Address 1436 Marilyn Dr Ogden Ut
(Signed) Jerry Mitchell (Well Driller)
License No. 366 Date April 20, 1979

USE OTHER SIDE FOR ADDITIONAL REMARKS

APPENDIX B

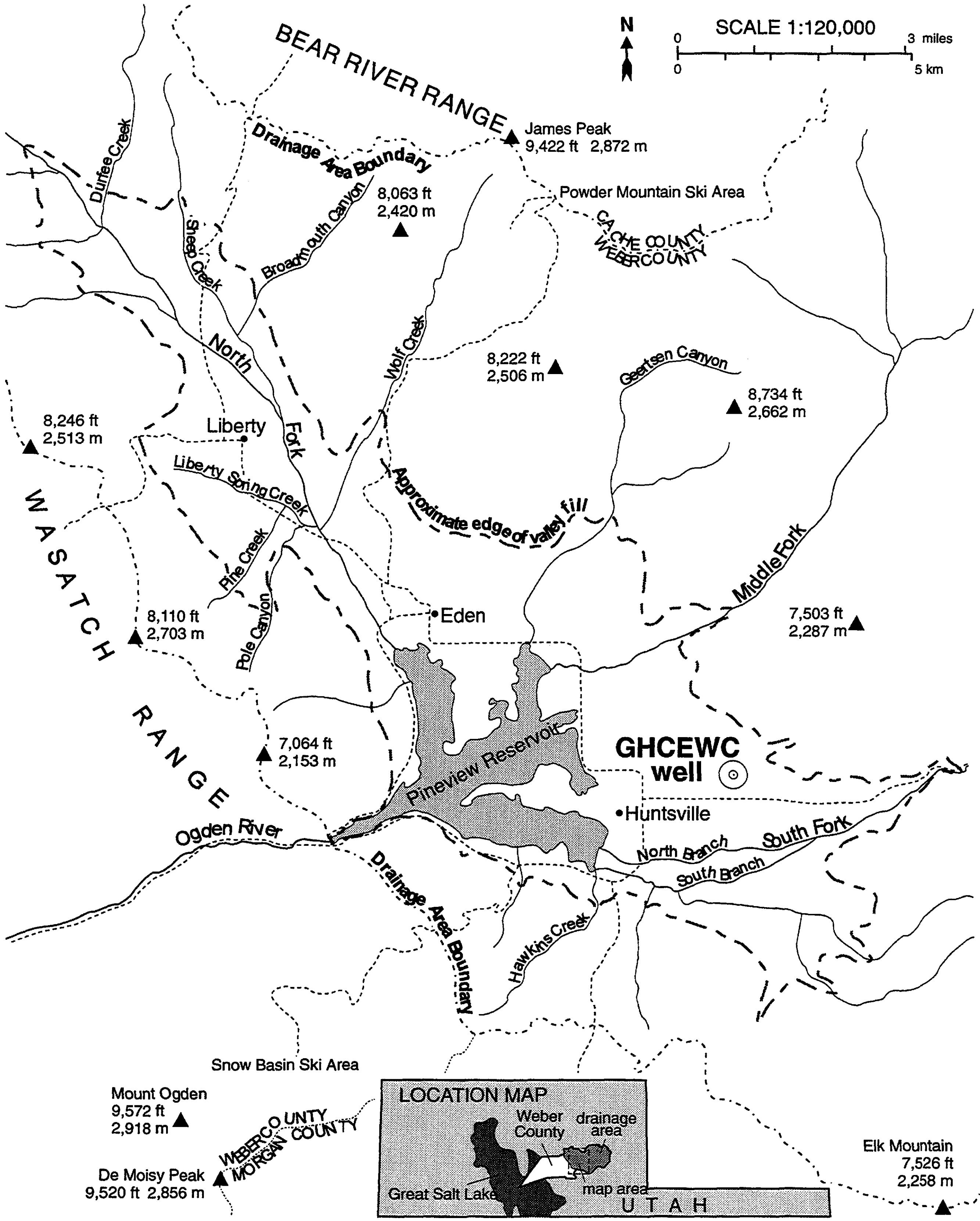
CALCULATION 1

0.1 cm/sec X 1.9685039 ft/min/cm/sec = 0.19685 ft/min

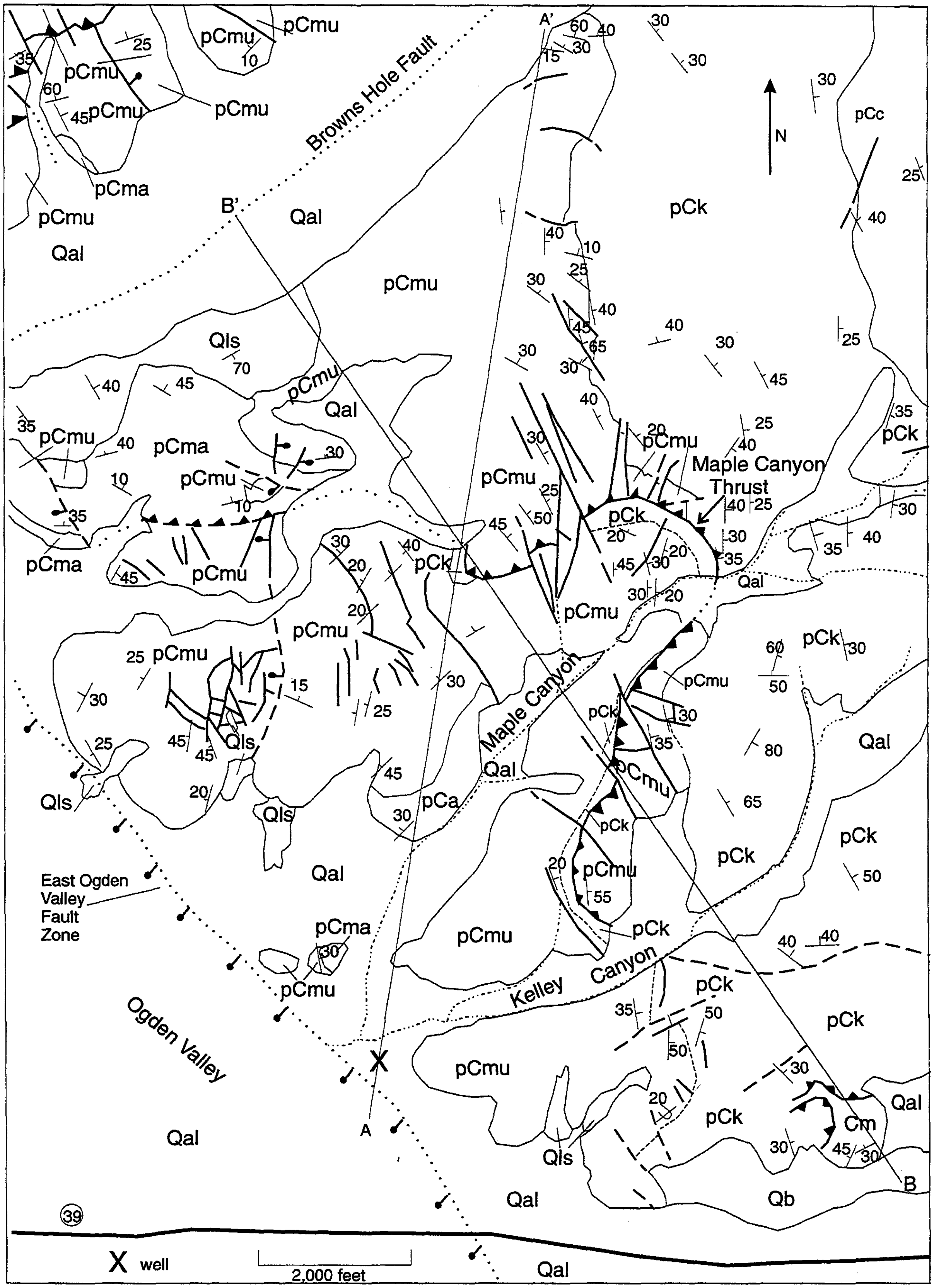
0.19685 ft/min X 60 min/hr = 11.811 ft/hr

11.811 ft/hr X 24 hr/day = 283.464 ft/day

283.464 ft/day X 250 days = 70,866 feet traveled in 250 days



Attachment 1. Location map.



Attachment 2. Geology (modified from Crittenden, 1972). Explanation on following page.

Explanation

Qal - recent alluvial deposits

Qls - landslide deposits

Qb - lacustrine deposits

Cm - Maxfield Limestone

pCc - Caddy Canyon(?) Quartzite

pCk - Kelley Canyon Formation

pCmu - Maple Canyon Formation, upper members (includes green arkose and conglomerate members)

pCma - Maple Canyon Formation, lower argillite member

pCp - Perry Canyon Formation (cross section only)

contact - Dashed where approximately located.

normal fault - Bar and ball on down-dropped side. Dashed where inferred; dotted where concealed.

high angle fault - Dashed where inferred; dotted where concealed.

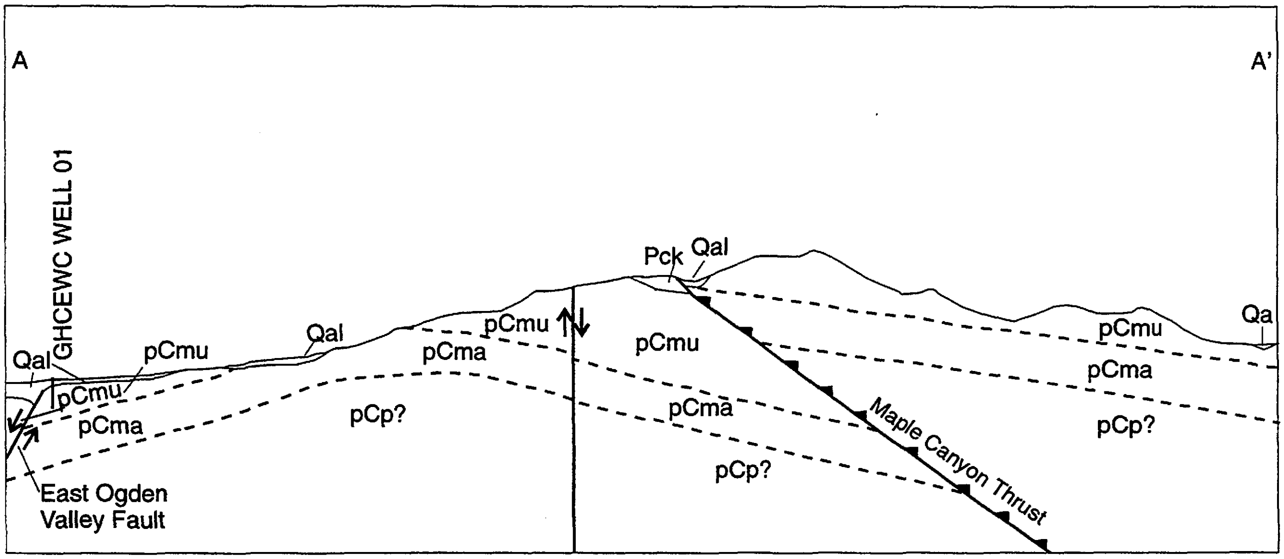
thrust fault - Sawteeth on upper plate. Dashed where inferred; dotted where concealed.

X GHCEWC well

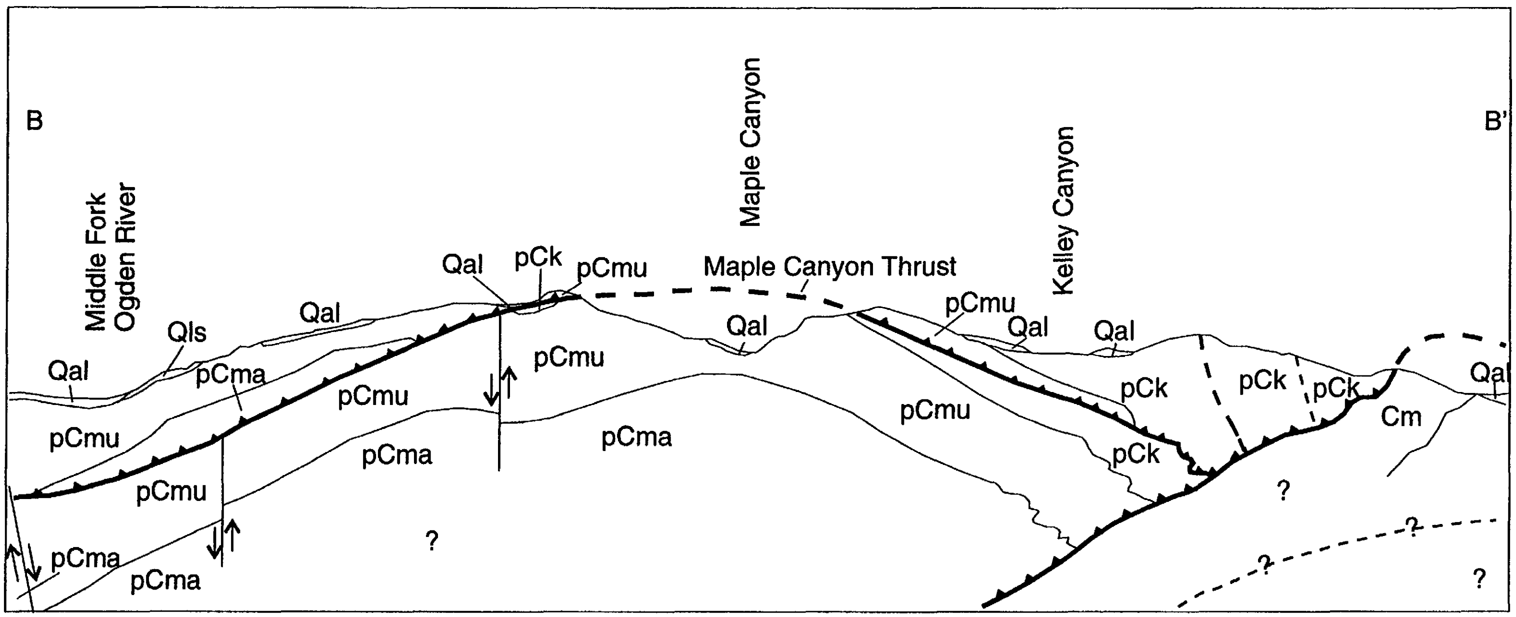
A —— A' cross-section lines

15 strike and dip of beds

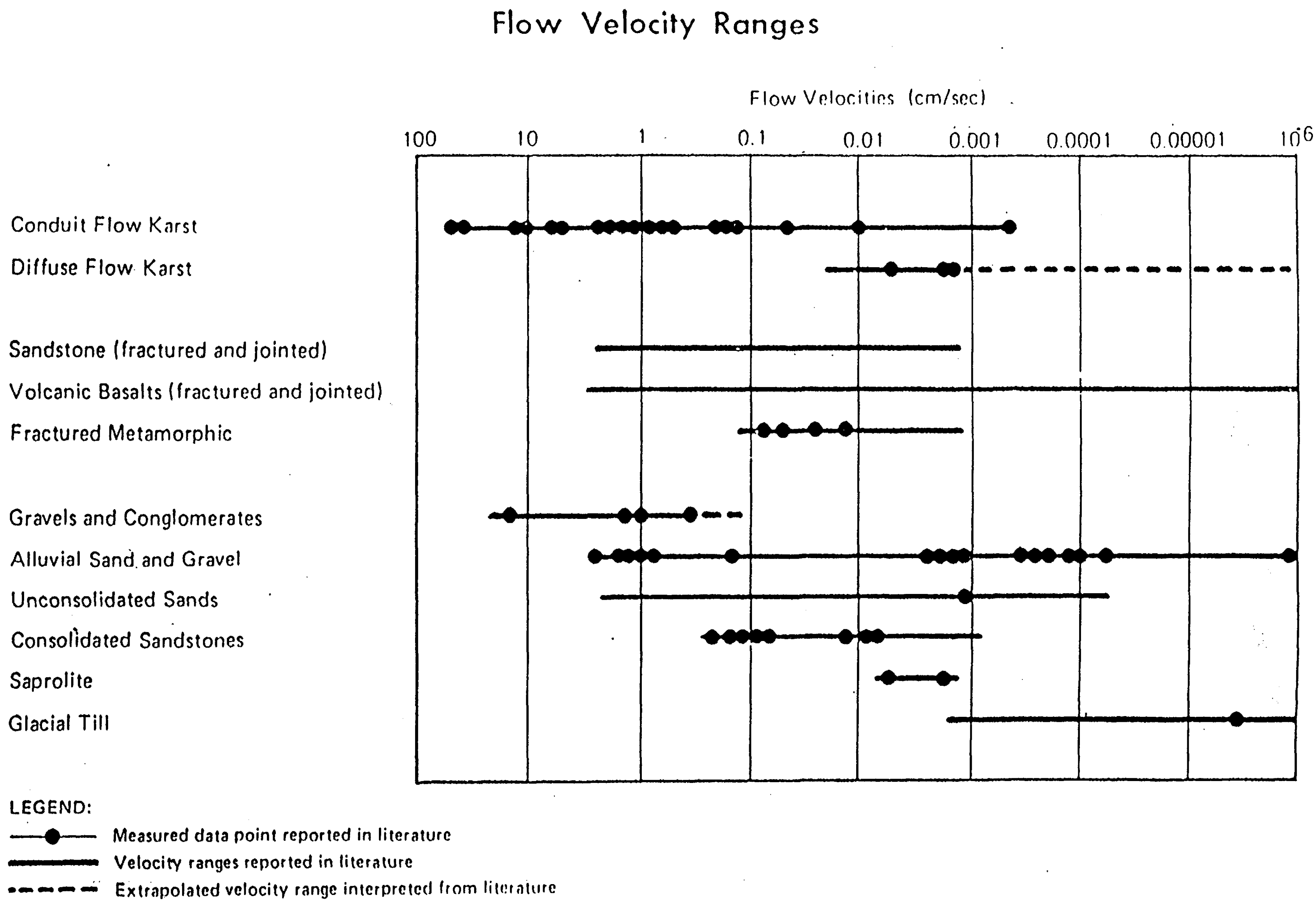
Attachment 2 (continued). Explanation for geologic map of Maple and Kelley Canyons area (modified from Crittenden, 1972).



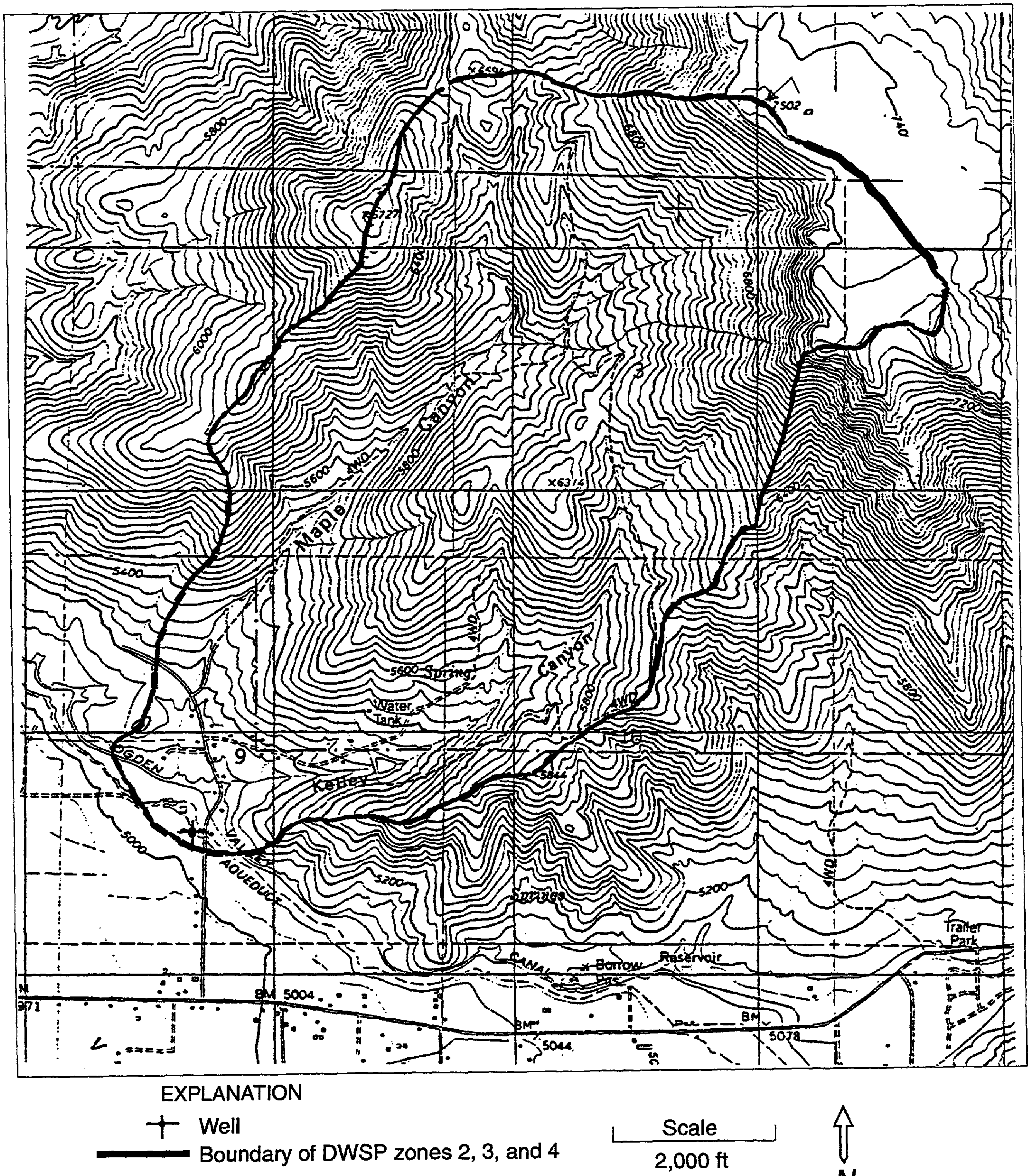
Attachment 3. Geologic cross section trending north-south through GHCEWC well. Based on geology modified from Crittenden (1972). See attachment 2 for location and explanation.



Attachment 4. Geologic cross section trending NW-SE in the Maple and Kelley Canyon areas (from Crittenden, 1972). See attachment 2 for location.



Attachment 5. Diagram showing ground-water-flow velocity ranges for various geologic materials (from Everett, 1987).



Attachment 6. Map showing boundary of drinking-water-source-protection (DWSP) zones 2, 3, and 4.

WASTEWATER DISPOSAL

Project:			Requesting Agency:
Summary of test-pit observations to evaluate soil and rock suitability for wastewater disposal, Wasatch View Acres, Wasatch County, Utah			Wasatch City-County Health Department
By: M.D. Hylland	Date: 9-20-96	County: Wasatch	Job No: 96-34 (WW-1)
USGS Quadrangle: Heber City (1168)		Number of attachments: none	

At the request of Phil Wright, Wasatch City-County Health Department, I visited the Randy Clute property in Wasatch View Acres on September 12, 1996. The site encompasses five acres in the NW1/4 section 28, T. 3 S., R. 5 E., Salt Lake Base Line and Meridian. I was accompanied by Mr. Wright and Tracy Richardson, also of the Wasatch City-County Health Department. The purpose of this site visit was to observe test-pit exposures of soil and rock to evaluate the suitability of these materials for on-site wastewater treatment in a proposed conventional septic-tank soil-absorption (STSA) system. In addition to the test-pit observations, my conclusions are based on observations of a 200-foot-long cut slope and natural exposures of soil and rock on the site, as well as a literature review.

The test pits and cut slope exposed consistent soil and rock conditions to depths of about 6 to 12 feet below the ground surface. Modern residual soil consisting of a dark-gray A horizon and a dark-brown, slightly clayey B horizon extends to a depth of about 15 to 20 inches. The soil is developed on a rock unit mapped by Bromfield and others (1970) as the Coyote Canyon volcanic breccia member of the Tertiary Keetley Volcanics. The rock consists of scattered gravel- to cobble-sized andesitic clasts within a gray, fine- to medium-grained sandy matrix. The upper approximately 1 foot of the rock is weathered to a reddish-brown color (Cr horizon) and contains closely spaced, oxidized fractures parallel to the ground surface. The degree of induration, or hardness, of the rock below the Cr horizon ranges from poor to moderate.

The site is on a south-facing slope composed of alternating slope and bench segments; the test pits and cut slope were excavated in a slope segment. Relatively well-indurated volcanic breccia is exposed at the ground surface within the bench segments. In general, I expect that relatively thicker soil and poorly indurated rock underlie the slope segments throughout the site, whereas the benches are underlain by harder rock that is less susceptible to weathering and soil formation.

The presence of volcanic breccia at depths of less than five feet supports previous mapping that indicates generally unsuitable conditions for conventional STSA systems in this area due to shallow rock (Hylland, 1995). The volcanic breccia should be considered bedrock where it is moderately to well indurated, such as at the west end of the cut slope and in the bench areas, and therefore unsuitable for a STSA-system drain field. Where poorly indurated, however, I expect the physical characteristics and engineering properties (such as permeability) of the rock are similar to those of a very dense, non-stratified sandy soil. Therefore, areas on the site underlain by poorly indurated rock to depths greater than five feet may be suitable for a STS. system drain field contingent on acceptable percolation rates and subject to Wasatch County requirements. A topographic survey and additional test-pit explorations with percolation test would be needed to identify such areas.

REFERENCES

Bromfield, C.S., Baker, A.A., and Crittenden, Jr., M.D., 1970, Geologic map of the Heber quadrangle, Wasatch and Summit Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-864, scale 1:24,000.

Hylland, M.D., 1995, Suitability for wastewater disposal in septic-tank soil-absorption system western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map i western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plate 3A-3D, scale 1:24,000.

GEOLOGIC HAZARDS

Project:			Requesting Agency:
La Verkin Creek sinkhole geologic investigation, Washington County, Utah			Division of Comprehensive Emergency Mgmt.
By: William R. Lund	Date: August 7, 1996	County: Washington	Job No: 96-30 (GH-1)
USGS Quadrangle: Pintura (117)		Number of attachments: Schuster GPR report, 13 p.	

INTRODUCTION

On Monday, July 15, 1996, I was contacted by Fred May, Hazards Mitigation Officer for the Utah Department of Public Safety Division of Comprehensive Emergency Management (CEM), and asked to participate in an investigation of the disappearance of all water from the lower reaches of La Verkin Creek in Washington County, Utah. The purpose of my participation was to provide geologic expertise and support on a team formed by CEM to investigate the cause of the disappearance and to formulate a mitigation plan for returning water to La Verkin Creek. Besides the Utah Geological Survey, other agencies participating on the team include the Bureau of Land Management (BLM); U.S. Geological Survey (USGS) Water Resources Division; National Resource Conservation Service (NRCS); Utah Division of Wildlife Resources; Utah Division of Water Rights; Washington County Water Conservancy District; Washington County Emergency Management Office (Sheriff's Department); La Verkin City; and several water right holders.

The scope of my investigation included a review of pertinent geologic and hydrologic literature, examination of 1:24,000 scale aerial photographs of the area, review of the lithologic and geophysical logs of a nearby oil well, a field reconnaissance, and participation in a ground penetrating radar (GPR) survey of the site. In addition, I attended a team meeting where various mitigation strategies and options were discussed and I have consulted with other team members, in particular geologists from the BLM (Larry Gore) and NRCS (Bob Rasely). This report presents the results of the geologic investigation into the disappearance of water from La Verkin Creek. Issues related to mitigation have not yet been resolved by the team.

BACKGROUND

La Verkin Creek is tributary to the Virgin River. It is a source of irrigation water for agriculture, and helps maintain minimum flows in the Virgin River to provide habitat for several endangered fish species. In addition, access to upper La Verkin Creek canyon has been restricted for many years, as a result, the riparian habitat along that portion of the stream is considered one of the best in southwestern Utah.

At about 9:00 p.m. on Thursday July 11, 1996, residents along lower La Verkin Creek noticed that the creek, which had been flowing between 3 and 5 cubic feet per second (cfs), was dry. They reported the incident to the Washington County Sheriff's Department. Suspecting that a landslide may have dammed the creek in the narrow, remote, upper reaches of the canyon, the Sheriff prepared to evacuate individuals living along the creek in anticipation of a possible dam-burst flood. With daylight on Friday morning (7/12/96), Washington County Search and Rescue Team members (and a separate group from the Washington County Water Conservancy District and La Verkin City) made their way into the canyon and discovered that rather than being dammed behind a landslide, the water in the creek was simply flowing to a point in the stream channel where it ponded and disappeared into the stream bed. The pond was reported to be about the size of a "pickup truck bed" and was capturing the entire flow of the stream (Richard Leavitt, Washington County Search and Rescue, verbal communication, 7/12/96).

SETTING AND GEOLOGY

The sink area is located in the main channel of La Verkin Creek in section 31, T. 40 S., R. 12 W., Salt Lake Base Line and Meridian (SLBM). At the sink, La Verkin Creek canyon is narrow (about 600 feet wide) and steep walled. The Kaibab Limestone crops out in the west wall of the canyon (Cook, 1960). A yellowish interbedded limestone and shale unit crops out in the lower part of the east canyon wall and is overlain by the Lower Red Member of the Moenkopi Formation about 60 feet above the stream channel. Although generally similar in appearance to the Kaibab, the limestone in the east canyon wall may be the Timpoweap Member of the Moenkopi Formation (Hintze, 1988), which also consists of limestone. Regardless of whether the unit in the east canyon wall is uppermost Kaibab or the Timpoweap Member, the flood plain of La Verkin Creek is underlain by limestone dipping about 15 degrees to the east-southeast. Examination of the canyon walls showed that the limestone on both sides of the canyon contains numerous open joints and fractures, likely due to the site's proximity to the Hurricane fault (Schramm, 1994), and many small solution cavities.

Two side drainages, one from the west and the other from the east, enter La Verkin Creek canyon at the sinkhole site. The west drainage is the larger of the two and has deposited a large alluvial fan that forces the creek against the east side of the canyon. Although smaller, the east drainage is very steep, and has contributed large boulders (some greater than 4 feet in diameter) to the alluvium in the creek. Thickness of the alluvium in the stream channel is more than 15 feet, which is the depth to which backhoes have excavated at the site without encountering bedrock.

Examination of 1;24,000-scale aerial photos of the site taken in 1982 showed no evidence of previous sinkhole development. Review of the lithologic and geophysical logs of the Buttes Gas and Oil Company Federal 30-B3X well drilled in section 30, T. 40 S., 12 W. SLBM about a mile from the sinkhole site provided no additional insight regarding the characteristics of the rock units underlying the site. Although drilling began in the Kaibab Limestone, the logs all start at a depth of 185 feet, well below the Kaibab - Timpoweap contact. The lithologic log indicates no open joints or cavities.

SITE RECONNAISSANCE

Fred May, Jim Howells, USGS Water Resources Division, and I arrived at the site on Monday afternoon (7/15/96). Mr. Kevin Hyde, a local water user, was already present with a construction crew and was building a small dam across La Verkin Creek and installing approximately 40 feet of 24-inch diameter plastic pipe from the dam around the sink area and back into the stream channel.

Construction activity had largely obscured natural conditions at the site; however, it was possible to observe an undisturbed section of the stream bottom near the east stream bank immediately downstream from the new dam. Two roughly circular depressions, each about 4 feet in diameter and 1 to 2 feet deep, were exposed in the stream bottom. Cobbles and boulders had slumped into the depressions and there was no material in the depressions smaller than about coarse-gravel size. When construction activity caused a release of water from the dam, approximately 2 to 3 cfs of water was observed disappearing into the depressions (flow estimated by J. Howells). In addition to our observations, Mr. Hyde provided the following account of his observations since arriving at the site on Saturday morning (7/13/96).

Mr. Hyde stated that by Saturday morning the original pond, which was close to the west stream bank, had grown considerably larger, a second pond had formed a short distance upstream and east of the first, and that water was rapidly disappearing into the stream bottom as evidenced by the presence of a strong vortex in each pond. He reported that the swirling water was causing the stream banks to erode, further enlarging both ponds, and that a set of concentric cracks roughly 40 feet in diameter had formed in the stream alluvium and flood-plain deposits around the sink area. Mr. Hyde first attempted to plug the sinkholes by pushing alluvium from the stream banks into the sink area. This effort proved unsuccessful and in fact exposed a third sink further upstream and east of the first two. The new sink also began to take water. According to Mr. Hyde, the three sinks formed a distinctive linear pattern trending at an oblique angle across the stream channel. Based on Mr. Hyde's description of the location of the sinkholes, the linear pattern trends about N. 15-20° E., and is roughly parallel to the canyon floor. With the appearance of the third sink, Mr. Hyde decided to construct the dam and pipe the water around the sinks as a temporary measure to restore flow in La Verkin Creek. During construction Mr. Hyde noted an almost complete absence of silt- and sand-size material in the stream alluvium over the sink area. The result was an open, box-work deposit in the stream channel that became coarser grained with depth.

GROUND PENETRATING RADAR SURVEY

On July 29, 1996, Dr. Jerry Schuster of the University of Utah ran three ground penetrating radar (GPR) survey lines across the site. Dr. Schuster summarized the survey results in his report (attached) as follows:

> *The key objective was to detect the presence and delineate the extent of a postulated "sinkhole." The GPR data were of excellent quality, with good reflection signals emanating from depths of more than 140 feet. The GPR data did not show the*

characteristic radar signature of an open, unfilled cavern larger than 5 feet in diameter. Instead, the data showed the clear presence of slumps, joints, and/or fault-like features at shallow depths under and around the "sinkhole" area. These features are consistent with a sinkhole filled with rubble.

The GPR survey shows (see attached report survey lines COP2 and COP3) that the area underlain by the collapsed sinkhole extends westward beyond the channel of La Verkin Creek and underlies part of the west stream bank.

CONCLUSIONS AND RECOMMENDATIONS

The sinkholes that appeared in La Verkin Creek on July 11, 1996, developed where the stream crosses limestone terrain (either the Kaibab Limestone or the Timpoweap Member of the Moenkopi Formation). The highly jointed and fractured nature of the limestone exposed in the canyon walls at the sinkhole site, the linear pattern formed by the three sinkholes, the vortices that formed in the sinks as they drained water to the subsurface (implying relatively large open conduits in the subsurface), and the results of the GPR survey conducted at the site lead me to conclude that the water disappearing into the sinks is flowing through the coarse alluvium in the stream bottom and into the underlying limestone. The lack of silt and sand in the stream alluvium above the sinkholes implies that this finer material is being piped into the sinks. The GPR survey showed no evidence of large open voids in the subsurface, but rather a system of joints and fractures or a small, linear collapsed sinkhole filled with rubble. Therefore, no apparent safety hazard is created by operating heavy equipment over the sinkhole area. However, the sinkhole feature identified by the GPR survey continues westward from the stream channel to a point beneath the west stream bank. To achieve an effective seal of the sinkhole area, it will be necessary to extend mitigation measures over that area. I recommend that the mitigation method selected either be designed by or reviewed by an engineer familiar with sinkhole-related problems.

REFERENCES

Cook, E.F., 1960, Geologic map of Washington County; supplement to geologic atlas as Utah - Washington County: Utah Geological and Mineralogical Survey Bulletin 70, scale approximately 1:196,400.

Hintze, L.F., 1988, Geologic history of Utah: Brigham Young University Geology Studies Special Publication 7, 202p.

Schramm, M.E., 1994, Structural analysis of the Hurricane fault in the transition zone between the Basin and Range Province and the Colorado Plateau, Washington County, Utah: Las Vegas, University of Nevada at Las Vegas M.S. thesis, 90 p., 6 plates.

Sinkhole Hunting By A GPR Survey In Virgin River Area

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August 3, 1996

Executive Summary

A Ground Penetrating Radar (GPR) recon survey was carried out July 29, 1996 over a "sinkhole" that recently drained the water flow from a small river (part of the Virgin River system). The key objective was to detect the presence and delineate the extent of the postulated "sinkhole". The GPR data were of excellent quality, with good reflection signals emanating from depths of more than 140 feet. The GPR data did not show the characteristic radar signature of an open unfilled cavern larger than 5 feet in diameter. Instead the data showed the clear presence of slumps, joints and/or fault-like features at shallow depths under and around the "sinkhole " area. These features are consistent with a sinkhole filled in with rubble.

GPR Survey

The purpose of the GPR survey was to detect the presence and delineate the extent of a postulated "sinkhole" that drained a part of the Virgin River. A recon GPR survey was carried out July 29, 1996 by Jerry Schuster with assistance from UGS and BLM personnel.

The approximate locations of the three GPR survey lines are depicted in Figure 1. A common offset profile (COP) configuration was employed where the offset between the Systems and Software EKKO IV source and transmitter was 2 m, 50 MHz antennae were used, and the step size was 0.5 m. Surveying equipment was not employed because the objective was to perform a quick GPR hunt for sinkholes; consequently elevation values along the GPR lines were roughly determined by line-of-sight estimates.

The GPR data for the three COP lines are depicted in Figure 2, where elevation corrections are used to adjust the recording surface to a level datum. This procedure is known as an elevation statics correction. The actual surface of the ground is denoted by an arrow at the RHS of the COP sections. The depth sections were created from the recorded time sections by using a soil velocity of .15 m/ns; this velocity value was measured from the direct wave velocity in a Common Midpoint Profile taken along the COP1 line.

GPR Data Interpretation

According to Peter Anon at Systems and Software, the classic radar signature of a buried unfilled sinkhole in Florida limestone is an intense brightening of the reflections from the roof of the cavern. In addition, a chimney of reverberations or scattered energy should be present in the data collected directly over the sinkhole. Such signatures are seen over limestone sinkholes in Florida. The GPR data in Figure 2 show no such signatures of an unfilled sinkhole. Instead, the GPR features around the sinkhole areas in the COP2 and COP3 lines show lateral discontinuities in the reflectors as indicated by the sub-vertical line drawings in Figure 3. I interpret these discontinuities to represent joints and/or faults. The frowns in these figures represent radar diffractions that emanate from chunks of rock such as boulders larger than two feet or so.

Note the dipping reflectors along the RHS of the COP2 line in Figure 3. The continuity of these reflectors become interrupted over the sinkhole area, with some possible slumping of the reflectors. It is important to discover the geologic reason for these jointing+slumping observations. These features are consistent with a sinkhole filled in with competent rubble.

Figure 4 depicts the COP1 line shown in Figure 3, except a longer time window of data is displayed. These data show good reflections to depths greater than 40 m.

Caveats On GPR Data Interpretation

Some caveats on the above interpretation include:

1). The GPR data do not show the classic radar signature of an unfilled cavern that is larger than 5 feet in height and diameter. However, this classic signature is defined for the Florida limestone environment and so the S. Utah environment may be different. However, I would be surprised if it was much different.

2). Elevation data were only estimated by eyesight with a Brunton compass; the greatest elevation change along a line was estimated to be no more than 12 feet. Therefore I estimate that the elevation corrections have an error no greater than about 3-4 feet. Dip angles of beds will also have some errors.

3). Only 3 GPR lines were acquired, and so sinkholes could be lurking in areas not intersected by these lines.

4). The COP lines were not migrated, so that interference effects are not corrected. This can lead to misleading (but probably not serious) interpretations.

5). Not enough time was given to me to perform migration and an extensive interpretation of the data.

6). The velocity of .15 m/ns was used to estimate depths to the reflectors, but this velocity estimate is probably accurate to about 20 percent. Hence depths are inaccurate to about 20 percent. Also use Figure 5 to correct the apparent depths in Figure 3 to actual depths.

Summary

The GPR method works well in this S. Utah environment in mapping out reflectors and joints down to a depth of greater than 100 feet. The GPR data do not show the classic radar signature of an unfilled cavern that is larger than 5-6 feet in height and diameter. Instead the data show evidence of jointing/faulting and some slumping over the sinkhole site. A more precise interpretation can be made by performing a 2-3 day survey over the area with both 100 MHz and 50 MHz GPR equipment. Care should be taken to carefully measure elevation values along the lines, all data should be migrated prior to interpretation, step sizes of no more than a foot should be used over the sinkhole sites, and isopach+fault maps should be constructed from the migrated data. Perhaps another geophysical method (such as resistivity) could also be used to narrow the range of possible interpretations.

FIGURES

Figure 1. Map showing approximate locations of 3 GPR survey lines in the Virgin River area.

Figure 2. COP data for lines COP1, COP2, and COP3. Offset and depth units are in meters, and the data are corrected to a flat datum plane about 2 meters above the bridge elevation. The ground surface is along the arrow depicted on the RHS, and units are in meters. Figure 5 should be used to convert the apparent depths here to actual depths.

Figure 3. Same as Figure 2 except lines are drawn to indicate faults/joints, and frowns are drawn to indicate diffraction events.

Figure 4. COP1 line for a longer recording time and a different gain. Note the high quality reflections from deep depths.

Figure 5. Conversion chart to estimate the actual depths from the apparent depths in Figures 2-4.

FIGURE 1.

APPROXIMATE MAP OF GPR SURVEY

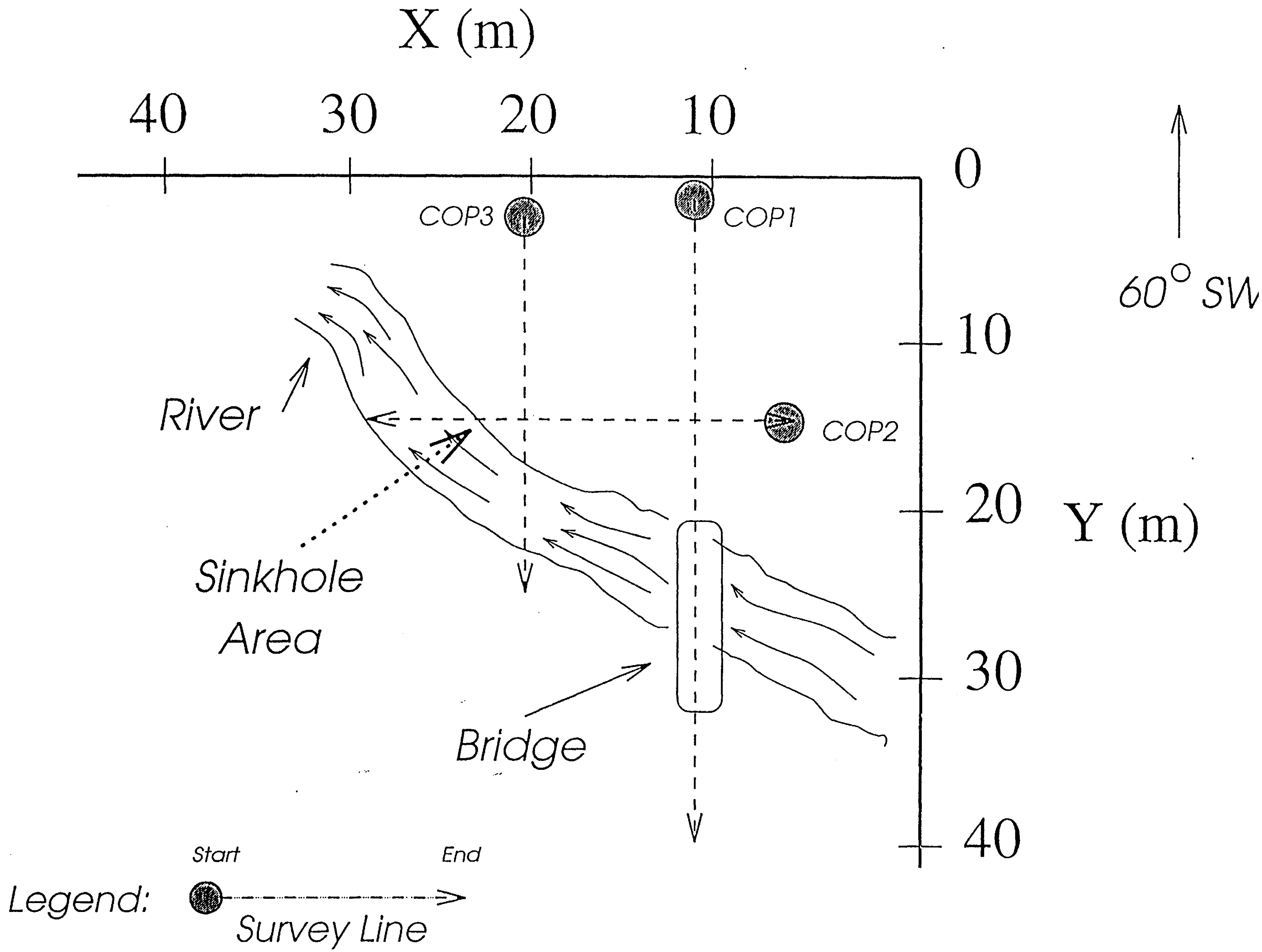
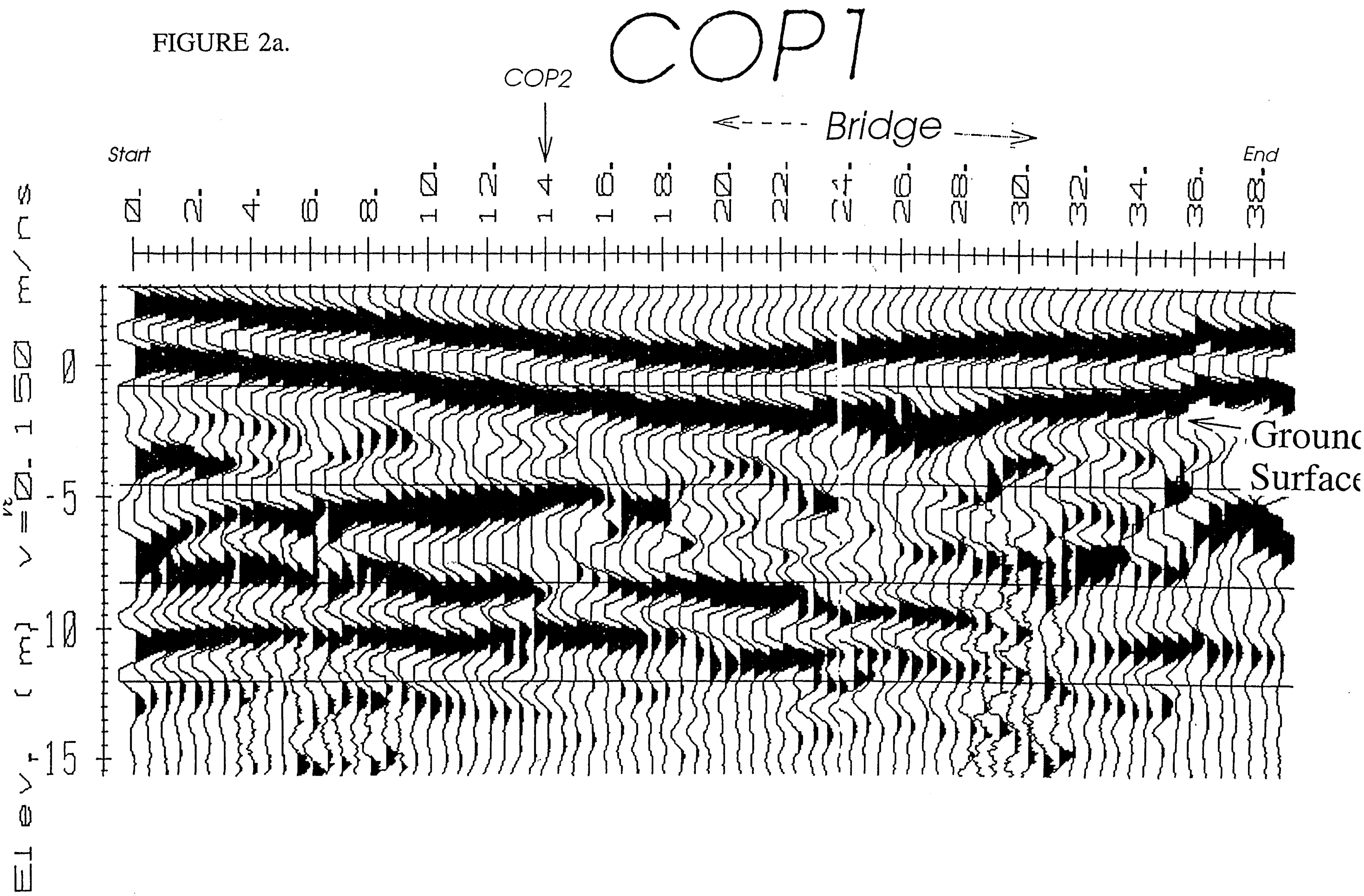


FIGURE 2a.



COP1
COP2
Bridge
Start
End
0. 2. 4. 6. 8. 10. 12. 14. 16. 18. 20. 22. 24. 26. 28. 30. 32. 34. 36. 38.
0
-5
-10
-15
Elev. (m) v=0.150 m/ns
Ground Surface

FIGURE 2b.

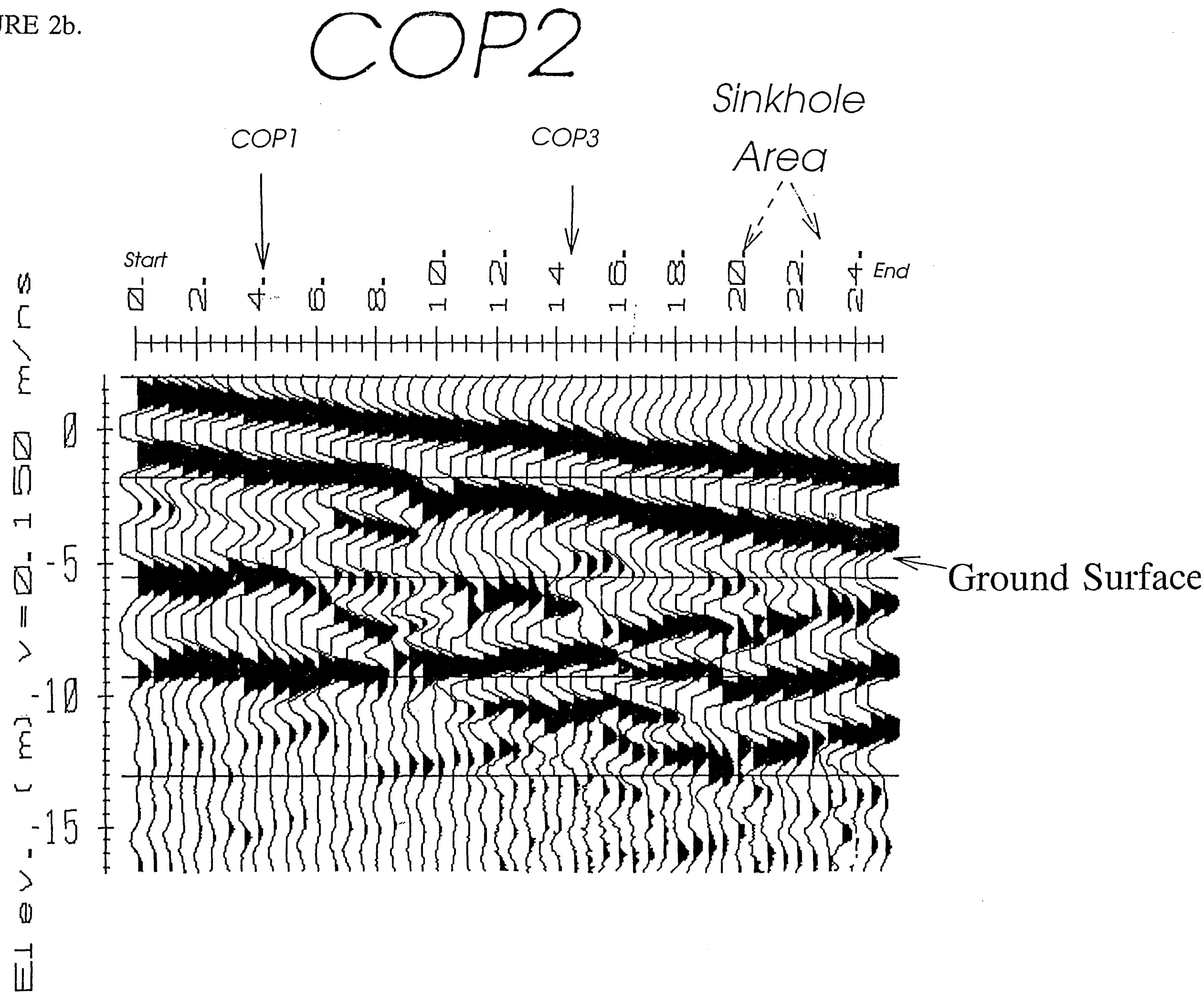
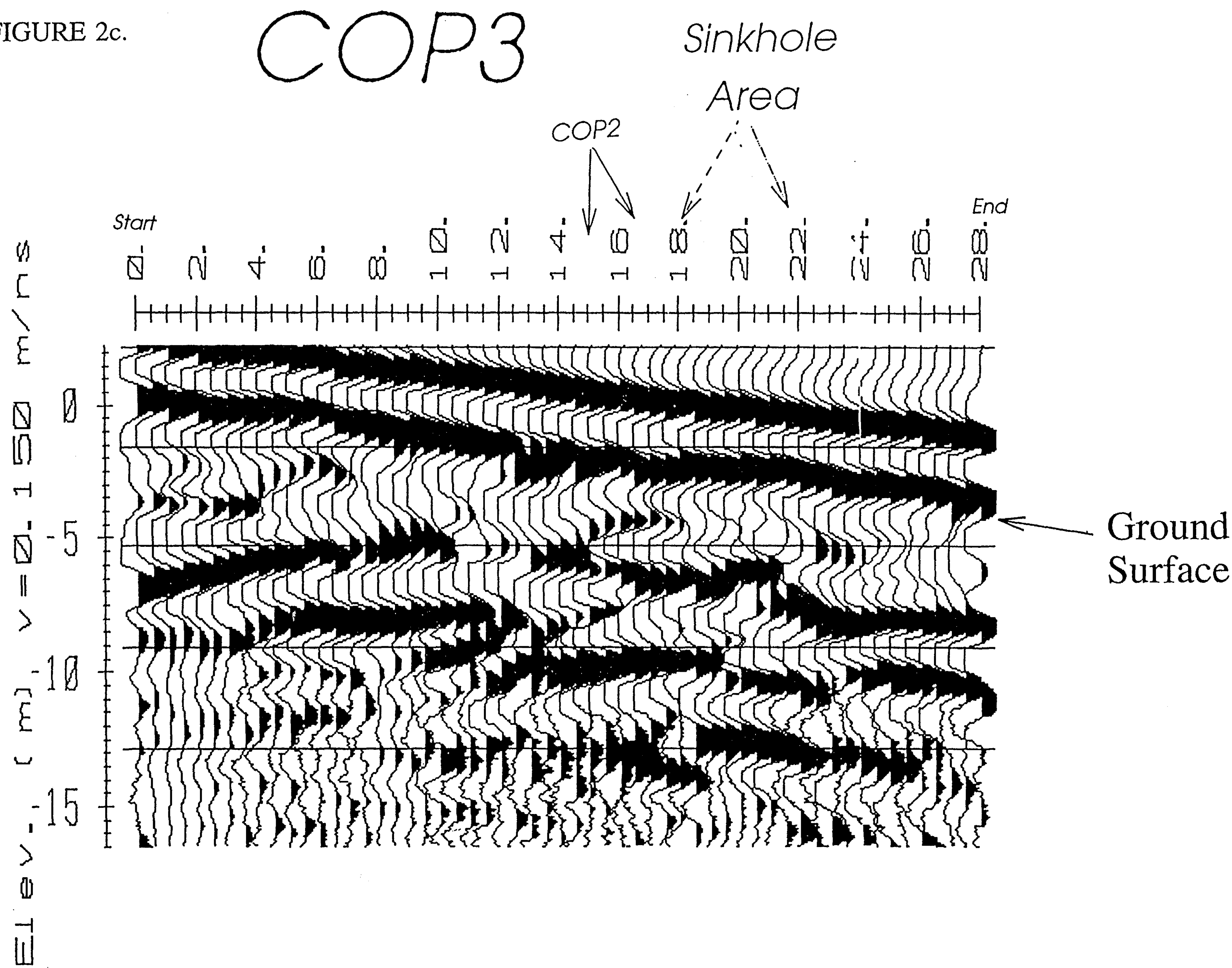
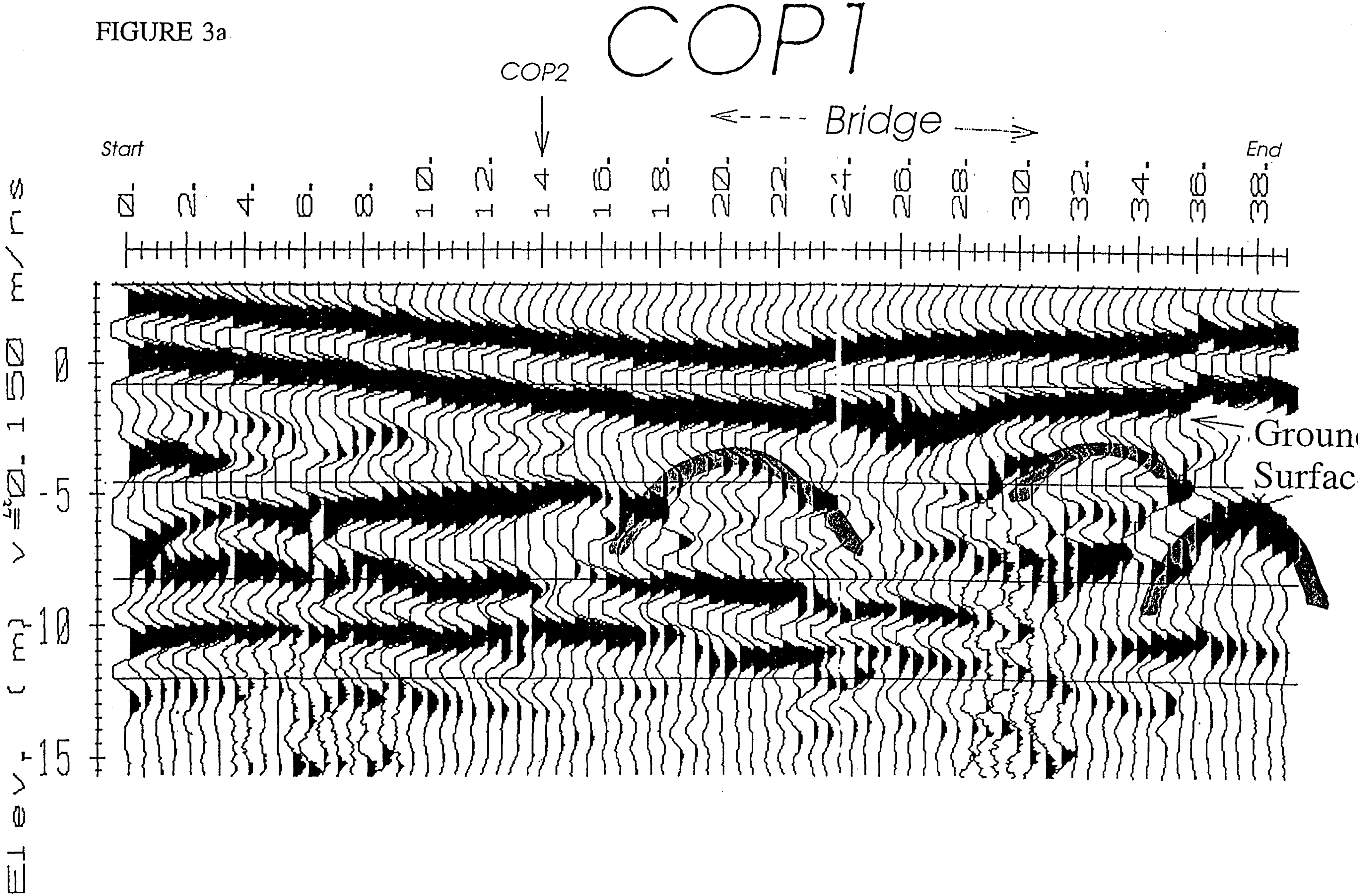

COP2
Sinkhole
Area
COP1
COP3
Start
End
Ground Surface
0. 2. 4. 6. 8. 10. 12. 14. 16. 18. 20. 22. 24.
0
-5
-10
-15
Elev. (m) v=0.150 m/ns

FIGURE 2c.



COP3
Sinkhole
Area
COP2
Start
End
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
22.
24.
26.
28.
Elev. (m), v=0.150 m/ns
0
-5
-10
-15
Ground
Surface

FIGURE 3a



COP1
COP2
Bridge
Start
End
0. 2. 4. 6. 8. 10. 12. 14. 16. 18. 20. 22. 24. 26. 28. 30. 32. 34. 36. 38.
0
-5
-10
-15
Elev. (m) v=0.150 m/ns
Ground Surface

FIGURE 3b.

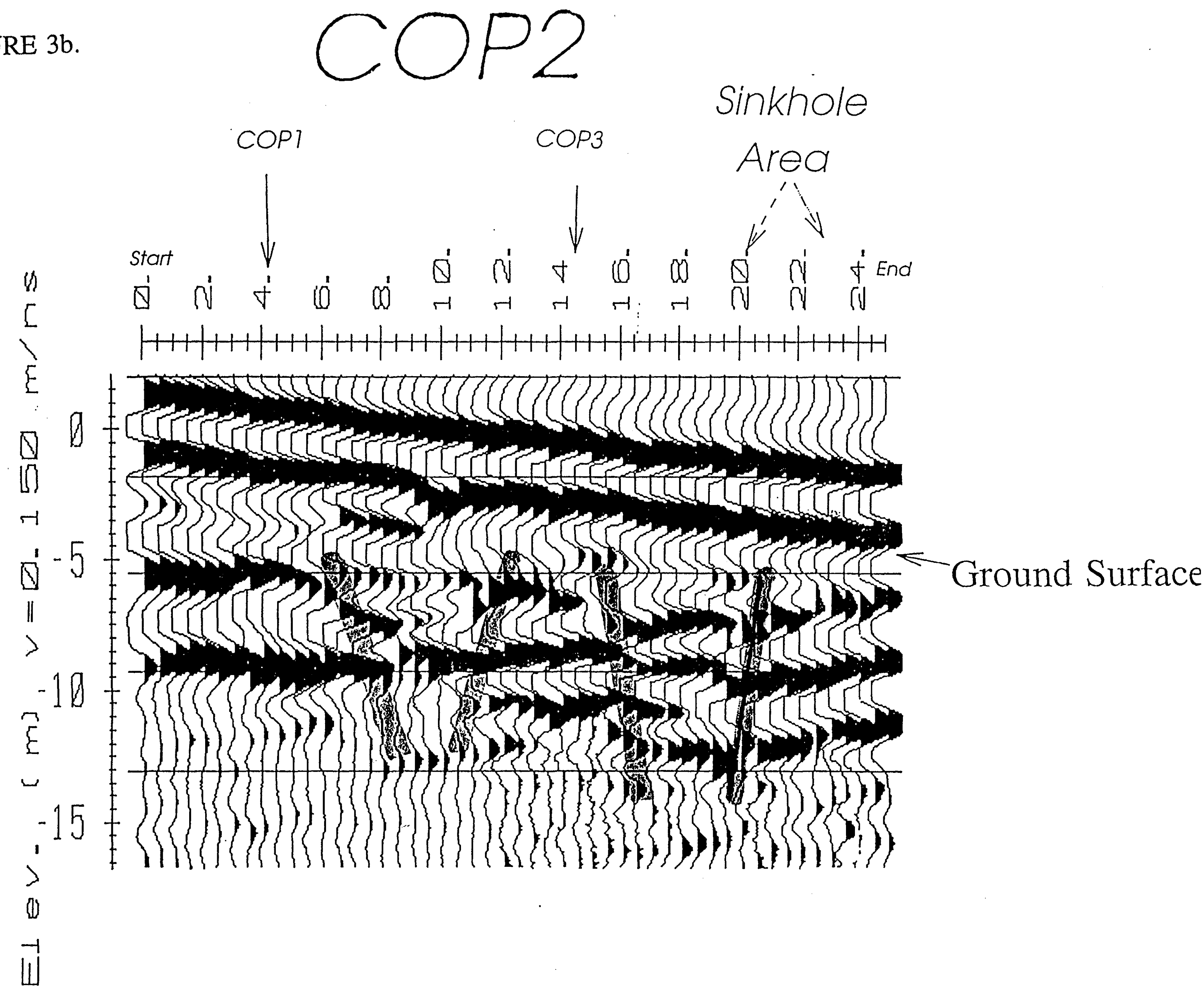
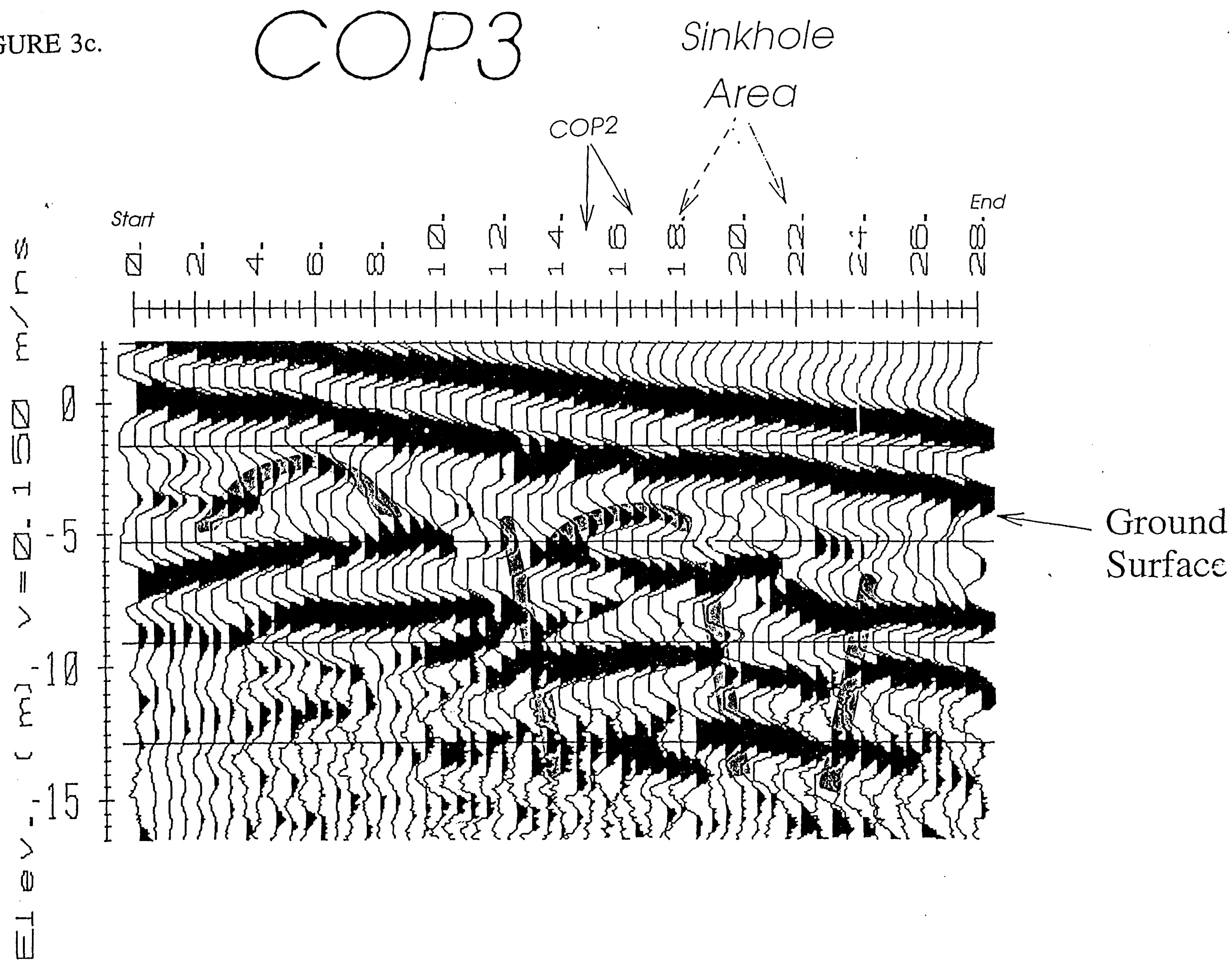
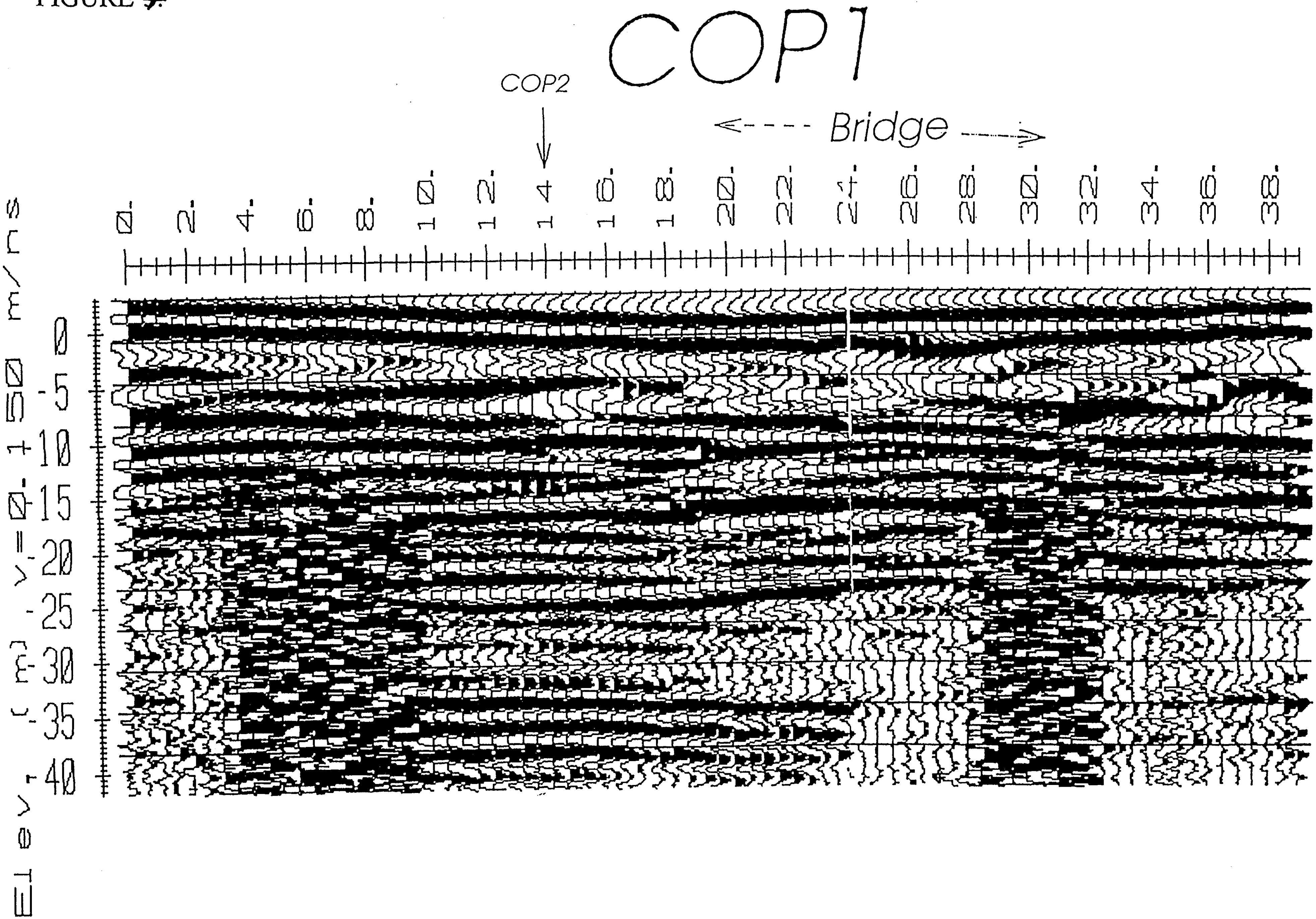

COP2
Sinkhole Area
COP1
COP3
Start
End
0. 2. 4. 6. 8. 10. 12. 14. 16. 18. 20. 22. 24.
Elev. (m) v=0.150 m/ns
0
-5
-10
-15
Ground Surface

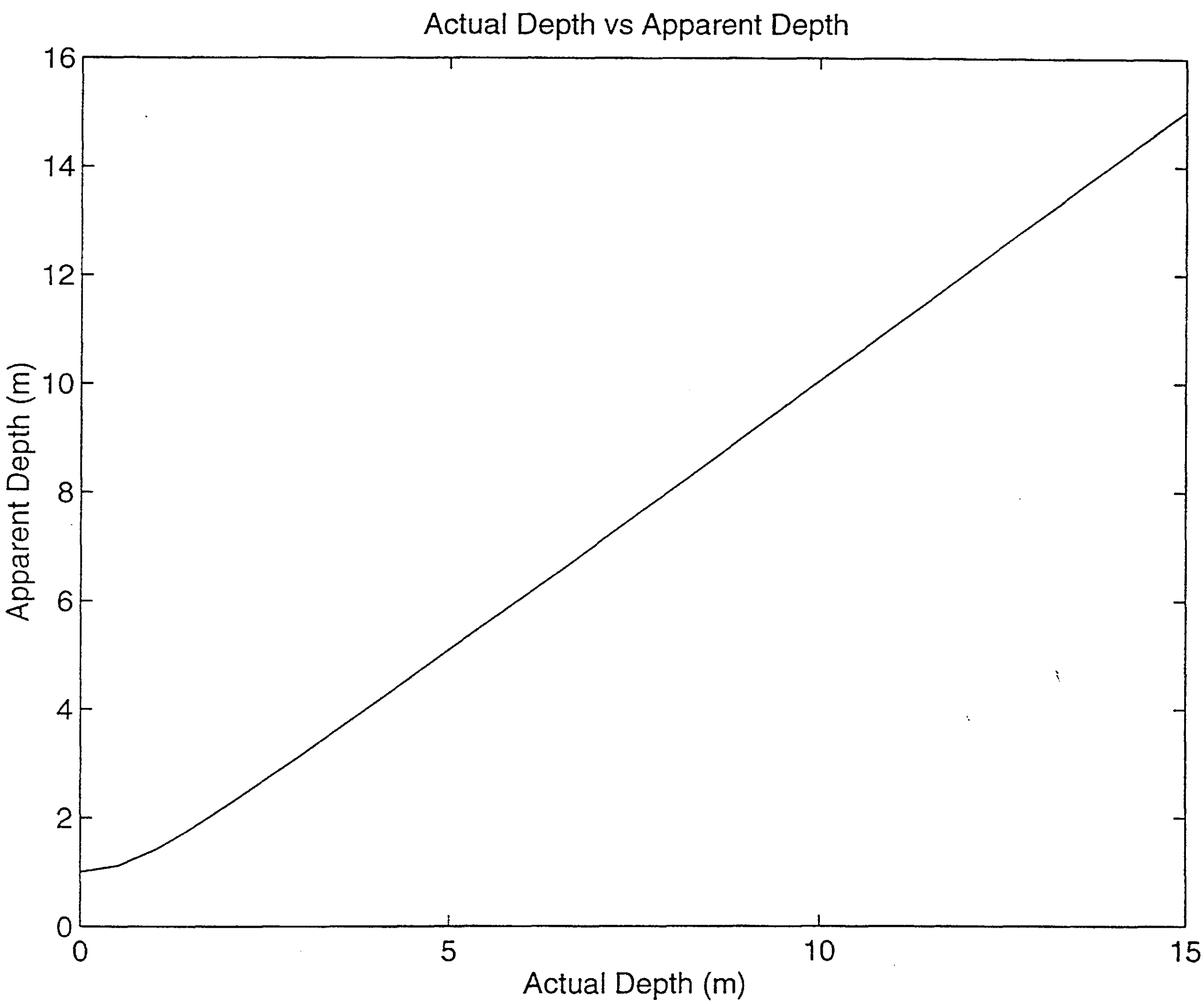
FIGURE 3c.



COP3
Sinkhole
Area
COP2
Start
End
0. 2. 4. 6. 8. 10. 12. 14. 16. 18. 20. 22. 24. 26. 28.
0
-5
-10
-15
Elev. (m) v=0.150 m/ns
Ground Surface

FIGURE 4





Actual Depth vs Apparent Depth
Apparent Depth (m)
Actual Depth (m)
0
2
4
6
8
10
12
14
16
0
5
10
15

FIGURE 4.5

Project:			Requesting Agency:
Reconnaissance geologic evaluation of the relative debris-flow hazard in the Centerville area, Davis County.			Centerville City
By: Francis Ashland	Date: 9-30-96	County: Davis	Job No: 96-32 (GH-2)
USGS Quadrangle: Bountiful Peak (1294)		Number of attachments: 1	

In response to a request by Fred Campbell, Centerville City Engineer, I evaluated the relative debris-flow hazard of Centerville Canyon and other canyons affecting the Centerville area in Davis County (attachment 1). The scope of the evaluation included review of aerial photographs (1989, scale 1:12,000) and a reconnaissance by Gary Christenson (Utah Geological Survey) and myself on August 27, 1996 of historical landslides in Centerville Canyon and of several other historical landslides visible from Skyline Drive. Although the latter are not in drainages that flow toward Centerville, they provide insight into the overall landslide activity and relative debris-flow hazard in the area.

The majority of historical landslides that were active in 1983-85 in the upper part of Centerville Canyon and are visible on 1989 aerial photographs showed little evidence of continued movement at that time. Only the smaller of these remained unvegetated, possibly suggesting that they may still have been active in 1989. Because thick vegetation obscures other landslides, no determination could be made regarding their condition although the vegetation indicates a lack of major activity.

The field visit to upper Centerville Canyon confirmed that the majority of landslides active in 1983-85 show little evidence of current activity. This, however, does not preclude the potential for one of these landslides to generate a debris flow in the future, especially if the drainages experience a rapid snowmelt or cloudburst-storm event.

I also visited a landslide in the mouth of Centerville Canyon (attachment 1) that was active as recently as 1995 (Hylland, 1995). With the exception of minor erosion and raveling of cobbles and boulders from its steep sides, I observed no evidence of significant changes in the landslide since 1995. Upslope of the main scarp I observed no tension cracks or direct evidence of headward (upslope) expansion of the landslide. I observed a small sliver of vegetated soil that had detached from the scarp in the uppermost part of the slide. Although I believe it is likely that this material will eventually slide downslope, its volume is too small to dam the stream or generate a debris flow.

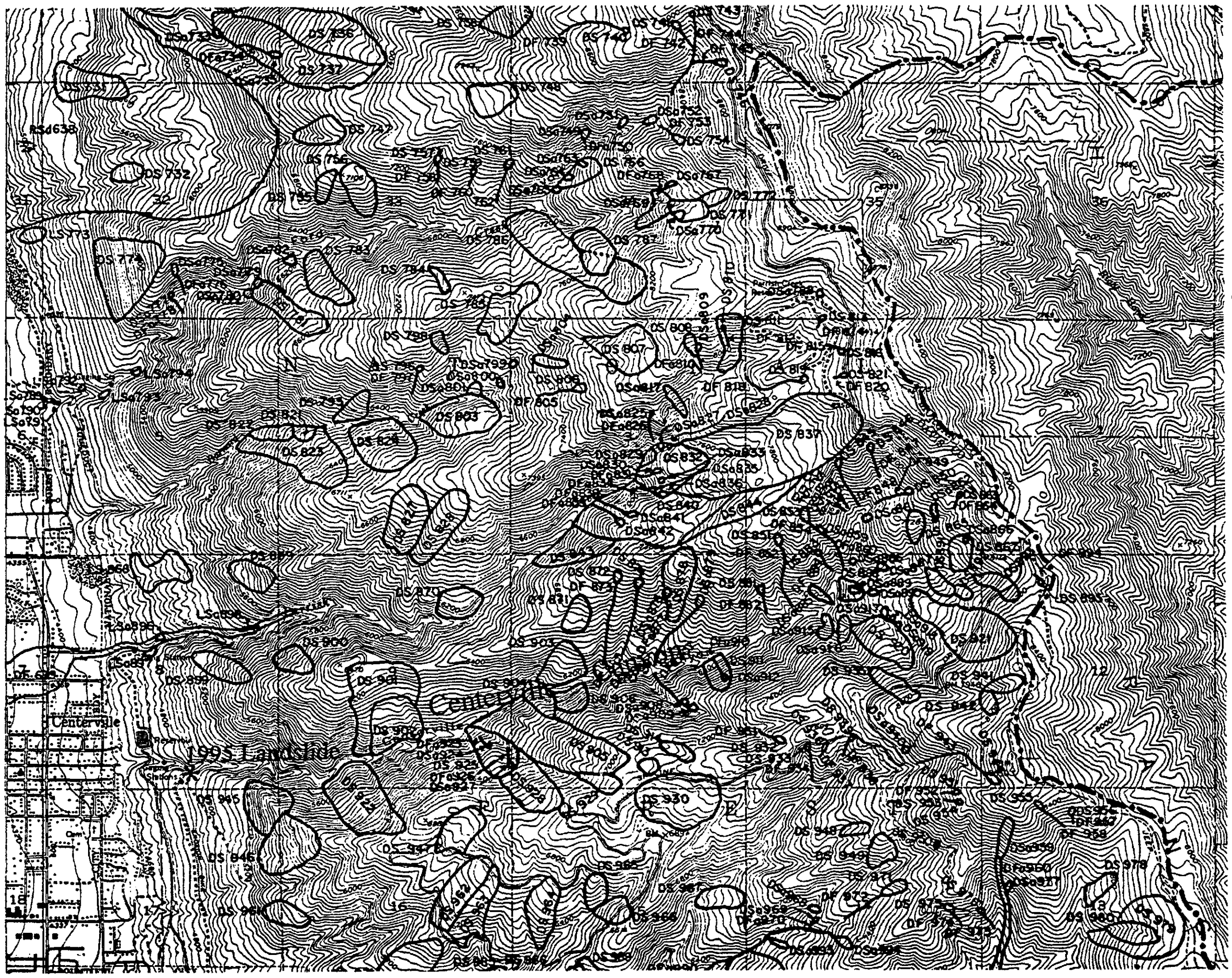
In conclusion, my investigation suggests that the debris-flow hazard in Centerville Canyon or other canyons affecting Centerville has not significantly changed in recent years. Because Centerville Canyon is a "pristine" canyon with much debris accumulated along its channel, it retains the potential to generate large debris flows. The relatively low gradient of the canyon's channel, as compared to other nearby drainages, may partly explain the accumulation of debris in the channel and the lack of historical debris flows which have reached the mouth of the canyon. The adequacy and location of the existing debris basin and risk to homes both above and below the basin should be evaluated because 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 of existing development.

REFERENCE

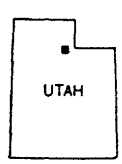
Hylland, M.D., 1995, Reconnaissance of two landslides at the mouth of Centerville Canyon, Davis County, Utah in Mayes, B.H., (compiler), Utah Geological Survey Report of Investigation, 228, p. 71-73.

Modified from Slope-Failure Inventory Map-
Bountiful Peak 7 ½' topographic quadrangle,
Mike Lowe, unpublished geologic-hazard map



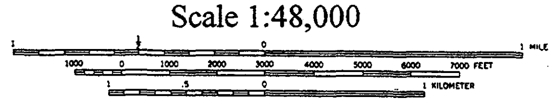
T. 3 N.
T. 2 N.

R. 1 E.

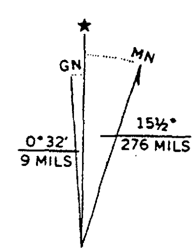


QUADRANGLE LOCATION

Scale 1:48,000



CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



UTM GRID AND 1975 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Attachment 1. Map showing landslides in the Centerville area, Davis County, Utah.

Project: Geologic reconnaissance of a piping-induced slope failure near 830 South Scenic Drive, Spanish Fork, Utah.			Requesting Agency: Spanish Fork City
By: Francis Ashland	Date: 10-15-96	County: Utah	Job No: 96-33 (GH-3)
USGS Quadrangle: Spanish Fork (1006)		Number of attachments: 1	

INTRODUCTION

On the morning of September 8, 1996, a slope failure initiated in the lower part of an 80-foot-high bluff near 830 South Scenic Drive, Spanish Fork, Utah. The slope failure is in the SE1/4NW1/4SE1/4 section 30, T. 8 S., R. 3 E., Salt Lake Base Line and Meridian (attachment 1). The southwest-facing bluff borders the flood plain of the Spanish Fork River and is below a subdivision along Scenic Drive at the top of the bluff. The slope failure progressed across a terrace that is about 100 feet wide at the base of the steeper sloping upper section of the bluff. On the morning of September 19, 1996, the upper section of the bluff above the terrace began to fail following moderate to heavy rain earlier in the week. Spanish Fork officials and work crews responded to the failure in an effort to protect a home at the top of the bluff. They were successful in temporarily stopping the slope failure from progressing to the upslope property.

On September 9, 1996, in response to a request by Richard Nielson (Assistant Public Works Director, Spanish Fork), I conducted a geologic reconnaissance of the initial slope failure. The purpose of this initial investigation was to preliminarily assess the possible causes of the failure, the stability of the remaining (upper) slope, and the hazard potential of the slope failure. The scope of the investigation included a field reconnaissance and review of published geologic and geologic-hazard maps. On September 19, 1996, Richard Nielson indicated that a failure of the upper part of the bluff had initiated and was progressing upslope. UGS senior geologist Barry Solomon and I visited the site to assess the hazard to the upslope properties and to provide technical assistance to Spanish Fork responders at the site.

SEPTEMBER 8, 1996 SLOPE FAILURE

The slope failure that initiated on September 8 occurred in a terrace in the lower part of the bluff. The toe of the terrace is approximately 6 to 10 feet high and has been modified and cut to allow construction of a hay barn. The terrace slopes gently southwest but is locally flat. The terrace ranges from about 70 to 100 feet wide and rises about 15 feet from southwest to northeast where it intersects the base of the steeply sloping upper part of the bluff. The entire bluff is about 80 feet high. The slope failure is approximately 25 feet wide and 100 feet long and cuts the entire width of the terrace.

The bluff is underlain by deltaic sediments that are capped by stream alluvium deposited by the Spanish Fork River (Machette, 1992). The deltaic deposits at the failure consist of gently tilted foreset beds of fine- to medium-grained sand and sandy silt with minor pebble gravel lenses. The overlying stream alluvium consists of a cobble-rich gravel. On the terrace, the alluvium is only a thin veneer and therefore the failure is in the deltaic deposits. A wide variety of landslide features are visible in the bluff. Landslide deposits likely overlie stream alluvium and deltaic deposits locally on the terrace. Circular depressions and seeps (springs) were observed in the terrace surface adjacent to the failure area, indicating piping has been active.

Discussions with the owner of the farm property below where the slope failure occurred and another eyewitness who worked on the farm indicate the failure initiated when discharge increased from a spring in the toe of the lower terrace. Spring discharge reportedly begins in July and lasts the remainder of the year, suggesting it is related to irrigation upgradient of the bluff. According to the eyewitness, progressive sloughing and erosion at the discharge point formed a tunnel-like subsurface void that eventually collapsed. Following the collapse, discharge continued from upslope, was temporarily ponded and likely saturated the lower part of the collapsed soils. Continued discharge upslope eventually resulted in overtopping of the dam created by the collapsed soil. This material was then eroded or liquefied and flowed, and was redeposited against the upslope side of a hay barn and adjacent hay bales, forming a truncated fan and burying the foundation wall near the east corner of the barn under about 3 feet of soil. Deposition extended about 200 feet to the northwest between the barn and the toe of the terrace and 150 feet southeast of the barn.

On the following day, September 9, I observed discharge continuing from a 3-foot-diameter soil pipe at the upslope scarp of the failure and from other smaller soil pipes in the walls of the failure zone and near the toe of the terrace. These smaller soil pipes that now intersect the wall of the failure zone likely acted as feeders to the main soil pipe which had collapsed. The smaller soil pipes range from 4 to 12 inches in diameter. In addition to the secondary piping, surficial sloughing and minor slumping were observed near the lower part of the failure zone and along the walls of the main failure zone. Some sloughing was observed at the base of the upper steeply sloping part of the bluff.

Based on the description given by the eyewitness and my observations made in the field on September 9, I believe the main slope failure resulted from rapid enlargement and collapse of a pre-existing soil pipe which "daylighted" at the toe of the terrace. Enlargement was induced by high rates of ground-water flow in the pipe caused by a shallow, probably rising water table in the terrace. Rapid erosion, sloughing, and possibly undercutting formed a void in the face of the terrace at the point of discharge. The overlying dry terrace soils formed a bridge with sufficient strength to allow continued enlargement and upslope progression of the void beneath the terrace surface. This void then collapsed, initiating sloughing in the walls of the collapse. This process may have repeated several times.

STABILITY OF THE REMAINING SLOPE ON SEPTEMBER 9, 1996

Collapse of the piping-induced void had progressed to the base of the steeper upper slope and caused local failure of a small area of the upper slope. The collapse resulted in the removal of lateral support at the base of the upper slope across an area about 25 feet wide. I observed no evidence of cracking or other deformation in the lawns of the properties upslope of the failure that would indicate instability of the upper part of the bluff. However, on-going discharge from the 3-foot-diameter soil pipe at the base of the upper slope could result in enlargement and collapse of the pipe and potential initiation of slope failure, causing damage to the homes above.

SEPTEMBER 19, 1996 FAILURE OF THE UPPER SLOPE

On the morning of September 19, the upper slope began to fail (Richard Nielson, verbal communication, September 19, 1996). The failure initiated about 30 hours after moderate to heavy precipitation associated with a two-day storm event on September 16 and 17. By about 1:00 p.m. the failure had progressed about midway up the upper section of the bluff, forming a vertical wall in the delta deposits about 40 feet high. Slope failure was occurring due to a process of undercutting and falling of material from a nearly vertical face as ground water discharged from four soil pipes and eroded soil near the base. Earth-fall material would temporarily block flow of water to the channel in the floor of the collapsed area which had formed on September 8. Saturation of the lower part of the earth-fall material would cause it to liquefy and flow downslope toward the hay barn. Discharge from the soil pipes would immediately increase following this downslope surge and the process of undercutting and falling would continue.

Spanish Fork officials and work crews responded to the failure of the upper slope by placing large boulder-size riprap in the failure zone in an attempt to buttress the failing slope and reduce the rate of slope retreat. By September 20, they had filled the upper part of the terrace that had failed on September 8 with riprap and were working on buttressing the upper slope (Richard Nielson, verbal communication, September 20, 1996). Mr. Nielson indicated that a filter fabric was emplaced beneath the riprap to reduce piping and erosion. Walt Jones, a contracted consulting geotechnical engineer with Terracon, indicated he believed the efforts by Spanish Fork had eliminated the "imminent danger" to the home upslope of the failure (verbal communication, September 20, 1996). He also indicated Terracon would be discussing a proposal to conduct a study of ground-water conditions near the failure with Spanish Fork officials in the upcoming week.

RECOMMENDATIONS AND CONCLUSIONS

Although measures taken by Spanish Fork may have reduced the immediate risk of damage to the home upslope of the failure, these actions do not preclude the potential for additional failure of the bluff. I recommend that the upper slope be monitored for evidence of instability including cracks, sagging, or tilting. I also recommend that a geotechnical engineer evaluate the long-term effectiveness of the buttress in restoring the lateral support removed by the failure of the terrace and lower half of the upper part of the bluff.

In addition, further evaluation of the piping hazard in the bluff is needed. Piping and spring discharge appear to have been major contributors to this most recent slope failure and were likely contributing factors to past slope failures elsewhere on the bluff. In my opinion, the potential for ongoing piping, collapse, and associated slope failure will remain until ground-water conditions that result in the springs near the base of the bluff are changed. I believe a ground-water study is an essential first step in finding a long-term solution to this problem. In the interim, I recommend that the bluff be monitored, especially following heavy rains or rapid snowmelt, for evidence of piping and above-average discharge from springs that might indicate imminent instability. Homeowners above the bluff should consider drainage improvements to avoid collection and infiltration of runoff and a reduction in landscape irrigation.

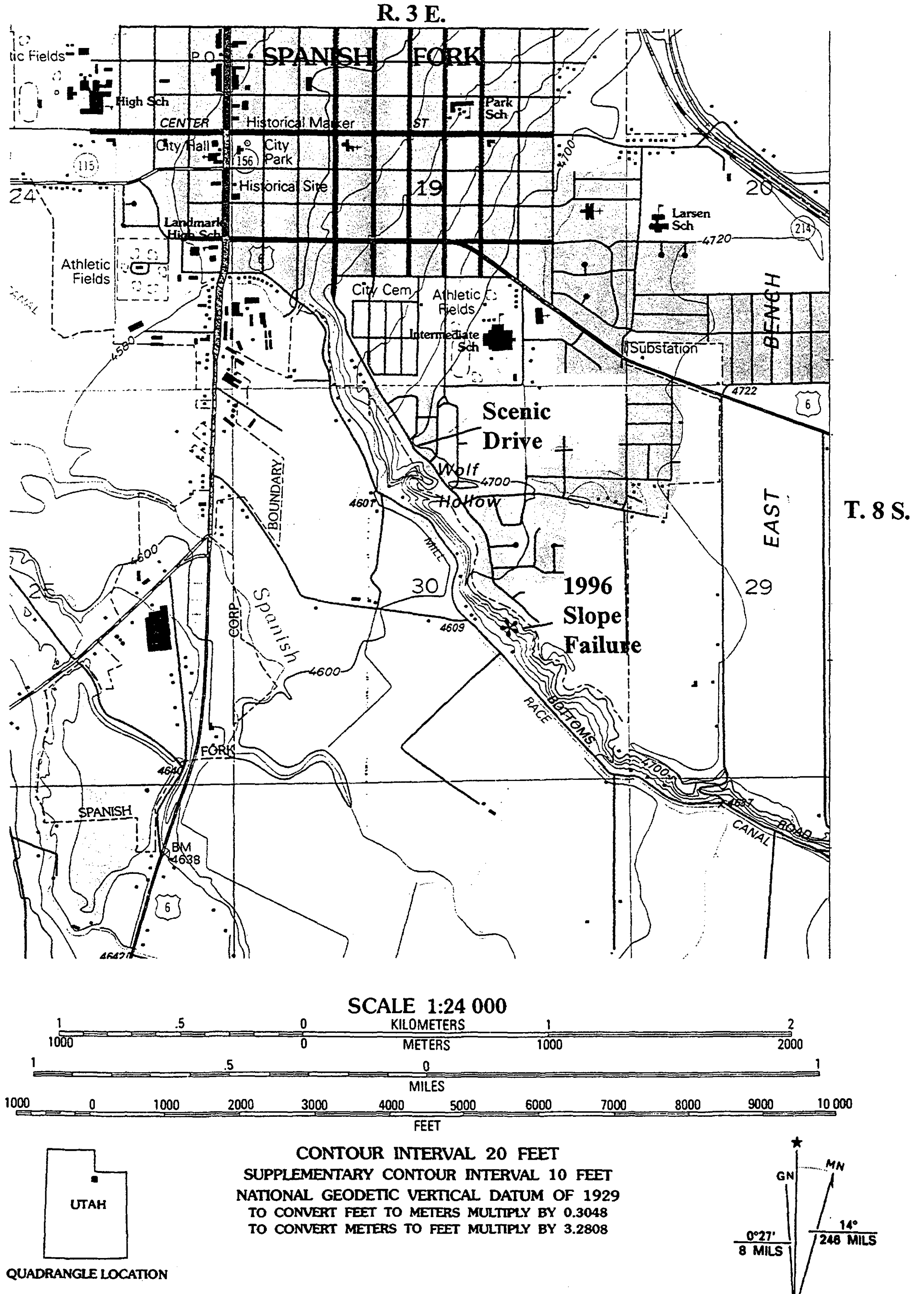
Spanish Fork may wish to consider greater setbacks from the crest of the bluff for future construction. Slopes along the bluff are in a designated landslide-hazard zone (Robison, 1990), and the abundance of landslide features indicates slopes in this area have marginal stability. Efforts to prevent irrigation-induced raising of the ground-water table in the delta deposits will help avoid slope failures but will not preclude failures triggered by natural conditions such as rapid snowmelt, rainstorms, or earthquakes.

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, 26 p., scale 1:50,000.

Robison, R.W., 1990, Utah County natural hazards overlay zone - landslide, Spanish Fork quadrangle: Utah County Planning Department unpublished maps, scale 1:24,000.

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



Attachment 1. Location map.

UTM GRID AND 1994 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

<table>
<tr><td colspan="3">Project:
Investigation of a rock fall on State Route 189, Wasatch County, Utah</td><td>Requesting Agency:
Utah Department of Transportation</td></tr>
<tr><td>By:
Francis X. Ashland</td><td>Date:
12-31-96</td><td>County:
Wasatch</td><td rowspan="2">Job No:
96-47
(GH-4)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Aspen Grove (1128)</td><td>Number of attachments:
1</td></tr>
</table>

On December 11, 1996, I investigated a rock fall near milepost 18.8 on State Route 189 in Wasatch County (attachment 1), at the request of Jon Bischoff, Utah Department of Transportation (UDOT). The rock fall occurred that same morning on the southeast side of the highway in the NW1/4SW1/4SE1/4 section 5, T. 5 S., R. 4 E. Rock-fall debris appeared to have blocked the northeast-bound lane and part of the southwest-bound lane of the highway, but had been removed and placed in nearby pull-outs northeast and northwest of the rock-fall site by UDOT maintenance personnel. Additional rock-fall debris remained in-place between the edge of the highway and the rock-cut slope. The purpose of the investigation was to document the rock fall, assess the overall rock-cut stability, and determine whether additional failure in the rock-fall area was imminent. The scope of the investigation included a field reconnaissance and a review of geologic maps and literature. Heavy snow was falling during most of the field reconnaissance.

The source of the rock fall was the lower part of a northwest-facing rock-cut slope on the southeast side of the highway. The rock fall occurred along the northeastern end of a continuous cut slope that extends southwest about 1,500 feet. The rock types where the slope failure occurred include yellow- to rust-stained, olive-gray cherty limestone and tan sandstone of the Permian-Pennsylvanian Oquirrh Formation (Baker, 1964). Bedding dips moderately east at the rock-fall site. The rock mass is faulted and intensely sheared, and fracture surfaces are covered by calcite and manganese (pyrolusite) mineralization. The source area for the rock fall was the lower part of the cut slope where the rock mass is intensely brecciated beneath a low-angle west-dipping fault. The rock is so intensely brecciated, altered, and weathered in this area that it can be easily excavated by hand. Rock-fall debris consisted of numerous cobble- to boulder-sized fragments of limestone and sandstone. The largest boulders measured between 5 and 6 feet in maximum dimension, but the majority of the debris measured less than 18 inches in size.

The rock fall was likely the result of long-term physical weathering along the numerous fractures in the rock mass and poor rock-mass quality in the near-vertical rock cut. Because the rock fall was preceded by at least one cycle of warm and cold weather that included sub-freezing temperatures at night and precipitation, the failure was likely triggered by cycles of ice growth and melting that loosened the rock mass. One open tension crack was observed behind a thin column-like panel of rock on the southwest side of the rock-fall zone. The crack was open approximately 1 inch on the southwest side but closed on the northeast side of the approximately 3-foot-wide panel. The hinge-like opening of the fracture may indicate an ice-growth wedging mechanism.

As described above, rock-mass quality in the rock-fall source zone is poor as a result of intense brecciation associated with numerous faults in the cut slope. I estimate that the rock quality designation (RQD) of the source-zone rock mass ranged between 0 and 10 percent. Because rock-mass quality does not appear to improve with depth into the rock mass from the cut face, I believe that additional rock-slope failures can be expected here unless some slope-stabilization measures are taken. However, I found no evidence that additional failures that might block the highway are imminent or more likely as a result of the December 11th rock fall.

During my field reconnaissance, a second, smaller rock fall occurred about 2,500 feet to the southwest along a similar north-facing rock-cut slope that resulted in some rock-fall debris spilling onto the highway (attachment 1). I observed that the source area of this rock fall was wetter than surrounding areas, possibly indicating that water- or ice-filled open cracks had been present behind the fallen rock.

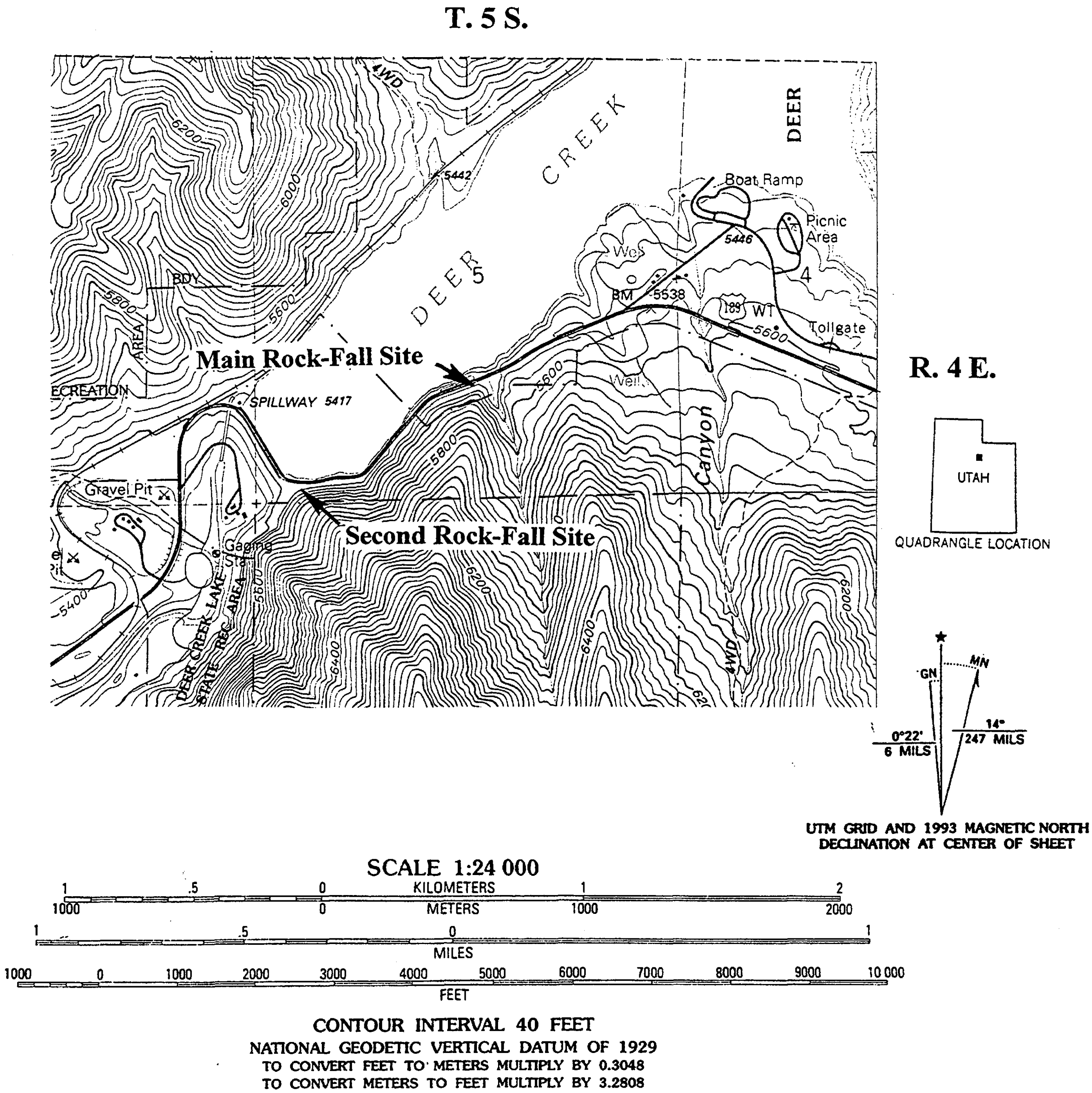
In a cursory reconnaissance of the approximately 1,500 feet of cut slope to the southwest of the main rock-fall zone, I observed evidence for numerous past rock-cut failures including vacated rock wedges and eroded rock-fall zones. Because bedding generally dips parallel to the highway and the cut slope, it does not daylight or dip out of the cut, and therefore failure resulting from planar sliding is unlikely. In a section of the cut slope about 100 feet southwest of the main rock-fall zone, I observed a large wedge-shaped block that is bounded on the northeast by a high-angle fault that obliquely intersects the cut slope. Undercutting of the block has occurred because of the weakened condition of the rock adjacent to the fault and resulted in the fault surface becoming a free face along which bedding daylights. Because of this, a potential exists for a rock-slope failure here that would involve a much larger volume of rock than was involved in the main rock fall investigated in this report. I recommend that at a minimum this area be periodically monitored for indications of imminent slope failure.

Although I found no evidence to suggest a threat of imminent further failure, I predict that rock-slope failures will continue along the entire cut northeast of Deer Creek Dam that may, at times, block the highway. I recommend that, in addition to monitoring of the area 100 feet southwest of the main rock-fall area discussed above, that the entire cut be periodically monitored for evidence of imminent failure.

REFERENCE

Baker, A.A., 1964, Geology of the Aspen Grove quadrangle: U.S. Geological Survey Geologic Quadrangle Map GQ-239, scale 1:24,000.

Attachment 1 Job No. 96-47 Base Map from Aspen Grove U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location of rock falls that occurred December 11, 1996 on State Route 189, Wasatch County, Utah.

REVIEWS

Project:			Requesting Agency:
Review of geologic-hazard study for lot 24, Pole Patch Subdivision, Pleasant View, Utah			Pleasant View City
By: Francis X. Ashland	Date: 1-11-96	County: Weber	Job No: 96-01 (R-1)
USGS Quadrangle: North Ogden (1370)		Number of attachments: none	

INTRODUCTION

At the request of Debbie Jones, clerk for the Pleasant View Planning Commission, I reviewed a report on the geologic hazards for lot 24 in the Pole Patch Subdivision (Delta Geotechnical Consultants, 1995) and a subsequent addendum (Delta Geotechnical Consultants, 1996). Lot 24 is in the SE1/4 SE1/4 NW1/4, section 17, T. 7 N., R. 1 W., Salt Lake Base Line and Meridian, on the Pleasant View salient. The scope of the work for this review included inspection of published geologic maps and aerial photographs (1985, 1:24000 scale; 1937, 1:20,000 scale). No field inspection was performed.

GEOLOGIC HAZARDS

Delta Geotechnical Consultants, Inc. (1995) identifies earthquake ground shaking, surface fault rupture, landslides, rock falls, debris flows, and floods as potential hazards at the lot. This appears to be a complete and accurate listing of the potential hazards present.

Delta's assessment indicates that the lot will likely be subject to strong earthquake ground shaking during moderate to large earthquakes in the area. Delta recommends that the house be designed and constructed to reduce earthquake ground-shaking hazards. Although not specified in the report, construction to the standards for Uniform Building Code seismic zone 3, at a minimum, will satisfy state requirements and should reduce losses from this hazard in future earthquakes.

Delta Geotechnical Consultants, Inc. (1995) is unclear regarding the location of the active trace of the Brigham City segment of the Wasatch fault in its discussion of the surface rupture hazard. Initially Delta indicates that the fault trace is "250 feet northeast of the lot" (p. 3). Later Delta states that the trace "crosses the site" (p. 5). The latter is shown to be correct on their figure A-3 and on a published map by Personius (1990) on which the fault trace is about 250 feet northeast of the proposed homesite rather than the "lot." Delta indicates that no surficial evidence for other faulting is present (Gary Olsen, Delta Geotechnical Consultants Inc., verbal communication, 1995), and concludes therefore that faulting does not pose a significant hazard to the building. I agree with this conclusion and with the recommendation that it would be prudent to conduct an inspection of the home-foundation excavation to ensure that faults are not present.

Delta's assessments indicate that the potential for landslides is low, however I believe the stability of a mapped landslide deposit at the site shown on figure A-3 requires special consideration. As mapped by Personius (1990), this landslide deposit occupies the eastern part of the lot, and is visible on 1:20,000-scale air photos, dated 1937. In its initial report (Delta Geotechnical Consultants, 1995), Delta concludes that there was "no evidence of past landsliding" (p. 5). In a subsequent addendum (Delta Geotechnical Consultants, 1996), Delta revises its conclusion and addresses the stability of the landslide and its relation to the proposed homesite. Delta describes the landslide as an "ancient" debris slide and concludes that the landslide is more than 1,000 years old because it is cut by the scarp from the most recent surface-faulting earthquake on this segment of the Wasatch fault. Delta cites as further support for this age a well-developed, 15- to 18-inch thick, soil A-horizon observed in a recent cut in the landslide deposits.

Delta Geotechnical Consultants, Inc. (1996) observes "no obvious signs of movement on the lot" including cracking, scarps, or hummocky terrain, except for shallow surface soil creep. Delta concludes that excavation for the homesite would not reactivate or destabilize the landslide because the excavation is appreciably smaller than the landslide and would be located only in the southwestern part of its shallow toe. Smaller slides may be initiated by such excavation, however, and it recommends that cuts into landslide materials have a slope of 2 horizontal to 1 vertical or flatter. I further recommend the use of 2 horizontal to 1 vertical slopes for temporary cuts and minor grading and flatter slopes elsewhere. Upslope of the lot, Delta observes no evidence of slope movement that is younger than the most recent surface-rupture event on the Wasatch fault (less than 1,000 years old) and does not recognize a large upslope source of additional material which could become unstable and generate a future landslide. Although Delta does not quantify the stability of the overall landslide, it speculates that because of the apparent long-term stability of the slide, relatively flat slopes, and porous subsoils, the risk of reactivation of the slide is "not very great." In addition, Delta concludes that movement of flat-lying materials upslope of the homesite, if left undisturbed, is even less likely. I concur with this assessment of the stability of the landslide deposit.

Delta Geotechnical Consultants, Inc. (1995) concludes that the rock-fall hazard at the site is low due to a number of factors including the distance to upslope outcrops, the predicted size and shape of the falling rock, and topography. It recommends no special considerations for mitigation or avoidance of rock falls, and I concur.

Delta's assessments indicate that the most probable source of debris flows and floods in the area is the unnamed canyon north and upslope of the lot, but conclude the risk from these hazards is low. Delta believes the canyon experienced a large debris flow about 70 years ago and estimates a recurrence interval for debris flows in the canyon of 500 to 1,000 years. Both these conclusions are undocumented in the report. Delta reports that runoff from snowmelt and rain storms infiltrates a cobble-lined channel before reaching the alluvial fan on which the subdivision is located. The report does not mention that the lot is not on the modern alluvial fan, but rather, on an older, inactive pre-Bonneville fan (Personius, 1990) that is mostly overlain by landside deposits. Because the lot is outside the boundaries of the active fan and is approximately 700 feet from the main channel, I concur with Delta's assessment that the debris-flow and flood hazards are low.

CONCLUSIONS

The conclusions and recommendations in the geologic-hazard report and addendum by Delta Geotechnical Consultants, Inc. (1995; 1996) are prudent and reasonably address the potential for, and reduction of, geologic hazards on the lot. In addition to the recommendations Delta makes in its addendum to avoid disturbance in the landslide area, I recommend that any future proposed construction or modification east of the homesite be reviewed by the city and other qualified professionals to assess the potential for destabilizing the landslide or initiating smaller landslides. I also advise that the existence of Delta's report and addendum and this review be disclosed to future lot or homebuyers who need to understand that, whereas the report and addendum indicate a low likelihood of landsliding, they do not preclude the possibility.

REFERENCES

Delta Geotechnical Consultants, Inc., 1995, Geologic hazards study and excavation inspection, Pole Patch Subdivision lot 24, Pleasant View, Utah: Salt Lake City, Utah, unpublished consultant's report, 9 p.

Delta Geotechnical Consultants, Inc., 1996, Addendum to geologic hazards study: Salt Lake City, Utah, unpublished consultant's memorandum, 3 p.

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 Survey Map I-1979, scale 1:50,000.

Project:			Requesting Agency:
Review of geotechnical and septic-system reports for a lot at 255 Valley View Drive, Springdale, Utah			Town of Springdale
By: Francis X. Ashland	**Date:** 1-24-96	**County:** Washington	**Job No:** 96-02 (R-2)
USGS Quadrangle: Springdale West (74)		**Number of attachments:** none	

In response to a request by Anita Holmes, town planner for Springdale, I reviewed a geotechnical report (Southwest Testing Laboratories, 1994) and a septic-system evaluation report (Southwest Testing Laboratories, 1995) for a proposed homesite lot at 255 Valley View Drive in Springdale, Utah. The lot is located in the SE1/4NE1/4NE1/4, section 6, T. 42 S., R. 10 W., Salt Lake Base Line and Meridian. The scope of work for this review included an inspection of unpublished geologic-hazard mapping by Utah Geological Survey (UGS) geologist, Barry J. Solomon. I performed no field inspection of the lot.

The Southwest Testing Laboratories (1994) report indicates that shallow bedrock is encountered at the lot at depths ranging between 1 and 4.5 feet. Bedrock consists of dense silty shale and claystone of the Triassic Chinle Formation. The shale is overlain by silty clay soils that are locally expansive. Southwest Testing Laboratories' assessment indicates that the expansive soils could be detrimental to proposed buildings if the soils become wet. They recommend that building foundations be placed directly on rock or that silty clay soils be excavated and replaced with compacted granular fill. At this lot expansive clayey soils are likely derived from weathering of underlying shale beds in the Chinle Formation. Because the depth of weathering and expansive characteristics of the Chinle Formation may vary across the homesite, Southwest Testing Laboratories' (1994) recommendations do not preclude the possibility that zones of expansive weathered rock may exist beneath the proposed shallow foundation. If shallow foundations are to be used for the proposed house and garage, I recommend that the homesite excavation be inspected by a qualified geotechnical engineer to evaluate whether expansive weathered rock remains beneath the footings that could affect the structure. I also recommend that where expansive soils are to be excavated and replaced by granular fill a geotechnical engineer specifies the minimum fill thickness based on experience with the Chinle Formation.

The Southwest Testing Laboratories (1995) report indicates that because of shallow bedrock at the lot a conventional septic system is not suitable, and I concur. They propose an experimental mound system to be located northeast of the homesite. The mound would be directly upslope of two abutting properties to the east. The northernmost side of the proposed mound is in a drainage that slopes gently east. The mound design would consist of granular fill directly over shale bedrock. I recommend consulting with the local health department regarding the system design and acceptability. One potential problem is that effluent may flow laterally along the top of the bedrock into abutting properties downslope. This may in turn result in seepage of the effluent at the surface in the drainage.

In addition to the potential hazards discussed above, unpublished UGS geologic-hazards mapping for the town of Springdale indicates that there is a moderate rock-fall-hazard and a high radon-hazard potential in the vicinity of the lot. Rock falls could result as boulders from upslope terrace deposits loosen and roll downslope. I recommend that the lot be evaluated to determine whether rock-fall debris is present, and that the potential hazard be addressed as appropriate. A proposed crawl space beneath the house is shown on plans by Andrew and Assoc., dated July 27, 1995, that would effectively mitigate the potential radon hazard at the homesite. If a slab-on-grade design is chosen, I recommend that, at a minimum, a radon test be performed in the house after it is built. As a precautionary measure, radon-reduction techniques may be considered in the design and construction of the house.

REFERENCES

Southwest Testing Laboratories, 1994, Geotechnical investigation, 225 Valley View Drive, Springdale, Utah: St. George, Utah, unpublished consultant's report, 2 p.

Southwest Testing Laboratories, 1995, Septic system consultation, 225 Valley View Drive, Springdale, Utah: St. George, Utah, unpublished consultant's report, 2 p.

Utah Geological Survey

<table>
<tr><td colspan="3">Project:
Review of "Fault-rupture-hazard report, proposed Almond Street condominiums at 300 North Almond Street, West Capitol Hill neighborhood, Salt Lake City, Utah."</td><td>Requesting Agency:
Salt Lake City Planning Commission</td></tr>
<tr><td>By:
Bill D. Black</td><td>Date:
01-24-96</td><td>County:
Salt Lake</td><td rowspan="2">Job No:
96-03
(R-3)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Salt Lake City North (1254)</td><td>Number of attachments:
None</td></tr>
</table>

This report is a review of an earthquake-hazards report (AGRA Earth & Environmental, 1995) for the proposed Almond Street condominiums at 300 North Almond Street (NE1/4SE1/4 section 36, T. 1 N., R. 1 W., Salt Lake Base Line) in Salt Lake City, Salt Lake County, Utah. Joel Paterson, Salt Lake City Planning Commission, requested the review. The scope of work consisted of a literature review and a field inspection of trench 1 at the site on December 19, 1995. Greg Schlenker (AGRA Earth & Environmental), Frank Ashland (Utah Geological Survey), and Brian Bryant (Salt Lake County Planning Division) were present during the field inspection.

Surface fault rupture is a potential hazard at the site (AGRA Earth & Environmental, 1995), and the site is in the surface-fault-rupture special-study area on Salt Lake County Planning Division (1993) maps. Two inferred south-trending fault traces are mapped roughly 200 feet (61 m) west and 600 feet east (183 m) of the site (Salt Lake County Planning Division, 1993). AGRA Earth & Environmental (1995) excavated four trenches (generally from east to west) across the site. The trenches exposed engineered fill overlying Lake Bonneville sediments, and showed no evidence of deformation from faulting in the past 12,000 years (AGRA Earth & Environmental, 1995). Based on this, AGRA Earth & Environmental (1995) believes the hazard from surface fault rupture is low.

Other potential earthquake hazards at the site include liquefaction, earthquake-induced landslides, and ground shaking (AGRA Earth & Environmental, 1995). There was no evidence of shallow ground water at the site and ground water is expected to be at depths greater than 30 feet (9 m) (AGRA Earth & Environmental, 1995). In addition, native sediments at the site are old enough to have been through at least two major seismic events in the past 6,000 years, but showed no evidence of deformation from liquefaction or earthquake-induced landsliding (AGRA Earth & Environmental, 1995). Based on this evidence, AGRA Earth & Environmental (1995) believes the hazard from liquefaction or earthquake-induced landsliding is low. Regarding ground shaking, AGRA Earth & Environmental (1995) recommends that all structures be designed and constructed in accordance with Uniform Building Code seismic zone 3 requirements for earthquake-resistant design.

I concur with AGRA Earth & Environmental (1995) that the hazard from surface fault rupture is low. I also concur that the hazard from liquefaction and earthquake-induced landsliding is low, assuming that site modifications do not reduce slope stability and ground-water conditions do not change. AGRA Earth & Environmental's (1995) recommendation for earthquake-resistant design is adequate for reducing ground-shaking hazards. Based on this, the AGRA Earth & Environmental (1995) report appears complete and accurate.

REFERENCES

AGRA Earth & Environmental, 1995, Fault rupture hazard report--proposed Almond Street condominiums at 300 North Almond Street, West Capitol Hill Neighborhood, Salt Lake City, Utah: Unpublished consultant's report, 9 p.

Salt Lake County Planning Division, 1993, Surface fault rupture and liquefaction potential study areas, Salt Lake County, Utah: Unpublished Salt Lake County Planning Division map, scale 1:43,000.

Project:			Requesting Agency:
Review of percolation-test results and geotechnical report for the proposed Canyon Springs Estates, Springdale, Utah			Town of Springdale
By: Francis X. Ashland	Date: 1-25-96	County: Washington	Job No: 96-04 (R-4)
USGS Quadrangles: Springdale East (73), Springdale West (74)		Number of attachments: none	

INTRODUCTION

In response to a request by Fay Cope, town manager of Springdale, I reviewed reports describing percolation-test results (Delta Geotechnical Consultants, 1995a) and geotechnical investigations (Delta Geotechnical Consultants, 1995b) for the proposed Canyon Springs Estates in Springdale, Utah. The proposed subdivision is located in the S1/2NE1/4, section 32 and the S1/2NW1/4, section 33, T. 41 S., R. 10 W., Salt Lake Base Line and Meridian. The scope of work included a literature review and an inspection of unpublished geologic-hazard mapping by Utah Geological Survey (UGS) geologist Barry J. Solomon. I performed no field inspection of the property.

SUITABILITY FOR CONVENTIONAL SEPTIC SYSTEMS

The Delta Geotechnical Consultants (1995a) report indicates that soils are suitable for conventional septic-tank soil-absorption (STSA) systems in most of the proposed lots, and I concur. Delta states that soils consist of mostly sand, commonly interbedded with gravel, that have percolation rates from 1.4 to 29.6 minutes per inch. These soils generally exceed 3 feet in thickness and in test borings reach a thickness in excess of 26.5 feet. Where these soils are present the depth to ground water exceeds 6 feet but may fluctuate seasonally. Although these soils are generally suitable for STSA systems, other considerations impose limitations on the design and location of such systems. The Delta Geotechnical Consultants (1995b) report indicates that these granular soils collapse upon wetting. Subsidence caused by soil collapse may damage STSA systems and adjacent buildings, roads, and facilities. Where collapsible soils are encountered, STSA-system designs should allow for differential settlement resulting from collapse. I also recommend locating STSA systems away from paved areas and buried utilities to avoid damage.

Shallow clay soils are present locally. In the southeastern corner of the property, they are underlain by weathered claystone. In this area, percolation rates exceed 60 minutes per inch and subsurface materials are not suitable for a conventional STSA system. The Delta Geotechnical Consultants (1995a) report, however, concludes a conventional STSA system is not feasible only at the southeasternmost lot 24. I concur with the conclusion, but add that insufficient investigation has been made to indicate whether similar conditions exist at lot 23 directly to the south. I recommend that no conclusion be made regarding the suitability of a conventional STSA system at lot 23 until such an investigation is made. Localized shallow clay soils are also present in the northern part of the property. In Delta's test pit TP-11 (lot 39), soils consist of interbedded clay and sand. Although the percolation test, performed in the sand layer, indicates that the site is suitable for a STSA system, the thickness and lateral extent of the sand layer are important factors in determining the long-term performance of the system. Because clay soils above and below are likely unsuitable, the depth of drainlines is critical to the proper functioning of a STSA system. In Delta's test pit TP-22 (lot 36), clay soils extended to a depth of 10 feet. The Delta Geotechnical Consultants (1995a) report indicates that the percolation rate of this soil is 6.3 minutes per inch. This rate is faster than that measured in granular soils and may result from flow in cracks in dry expansive clays. Once wetted, the cracks will eventually close and substantially reduce the percolation rate. Because of these variable soil conditions, some lots may not have suitable soils for STSA systems.

Other considerations related to the suitability of STSA systems at this property include slope stability, the proximity to the FEMA-designated flood plain of the Virgin River, and possible impacts on Virgin River water quality. Loose surficial soils and the underlying Chinle Formation may be susceptible to landsliding upon wetting. Surficial slumping may occur downslope from STSA systems including on downslope abutting properties if systems are located near property lines. Larger landslides may also be initiated if STSA systems result in wetting the top of the Chinle Formation. Care must therefore be taken to avoid placing STSA systems where they may adversely affect slope stability.

The FEMA-designated 100-year flood plain extends onto several lots in the proposed subdivision. A letter by the Southwest Utah Public Health Department, dated November 6, 1995, indicates that lots 1, 2, 5-8, 14, 15, and 29-34 are adjacent to (are partly occupied by) the FEMA-designated flood plain in which septic systems cannot be constructed. Required flood- plain setbacks may limit the use of STSA systems on these lots.

Proposed STSA systems on these lots, and lot 28, may also possibly contaminate the Virgin River. The greatest concern with respect to contamination is from pathogenic bacteria and viruses reaching the river. These organisms can survive up to 250 days in the subsurface (U.S. Environmental Protection Agency, 1987) and can travel up to 40 vertical feet in the unsaturated zone (Kaplan, 1987). In general, the depth to the water table is likely less than 40 feet beneath any of the lots adjacent to the Virgin River and therefore, contaminants will likely reach ground water. To evaluate the potential for effluent reaching the river, the direction of ground-water flow must be determined on the basis of the relative elevation of the river and the water table beneath STSA systems. If flow is toward the river, appropriate setbacks must be established. One method to calculate setbacks is based on flow velocity using the following equation:

$$\text{Setback distance} = 250\,(v)$$

where v is the ground-water flow velocity in feet per day. Ground-water flow velocity can be estimated using the equation:

$$v = 120\ (1/k)\ (i)\ (n_e)$$

where k is the percolation rate in minutes per inch, i is the slope of the water-table surface between the STSA-system location and the Virgin River, and n_e is the effective porosity (the ratio of void space, through which flow can occur, to the total volume). Water-table elevations in the Delta Geotechnical Consultants (1995b) report may not be appropriate for determining the direction of flow or value of i because they likely represent seasonal lows measured in the fall and do not take into account rises in the water table due to STSA systems. I recommend that the maximum water-table elevations be determined in order to establish the steepest likely slope of the water-table surface. These data may also confirm whether, in lots adjacent to the Virgin River, the water table rises enough that its distance beneath the drainlines is less than the required 2 feet.

COLLAPSIBLE SOILS

The Delta Geotechnical Consultants (1995b) report indicates that collapsible soils are present in both the southwestern and north-central parts of the property. Unpublished UGS mapping indicates that the collapsible soils were deposited on Holocene alluvial fans. Tests by Delta indicate that these soils collapse up to 5.4 percent when they became saturated under simulated footing loads. When compared to criteria relating collapse potential to the likelihood of foundation problems (Jennings and Knight, 1975), this amount of collapse may cause "moderate trouble to trouble" with foundations. Delta makes several recommendations to reduce the chance of wetting collapsible soils near structures. Although these recommendations would, if properly implemented, reduce the potential for damage to structures, they do not address the potential damage to roads, other paved areas, and buried utility lines located away from structures. In addition, as discussed above, the potential problems of locating septic systems in collapsible soils are not addressed by Delta. Because the recommendations will ultimately be implemented at the homeowner's discretion, I believe that some damage to structures as well as roads, utilities, and paved areas should be anticipated. Elsewhere in southwestern Utah, collapsible soils have caused significant damage resulting in condemnation of buildings or considerable repair or replacement costs (Kaliser, 1977).

EXPANSIVE SOILS

The Delta Geotechnical Consultants (1995b) report indicates that expansive soils, having swell pressures from 2,000 to 4,000 psf and sufficient to cause foundation heave, are present in the vicinity of lot 24. In my opinion, similar conditions may also exist on lot 23. Delta recommends a pier and grade-beam-foundation system in this area to avoid damage from expansive soils. Recommendations made by Delta should reduce damage to structures, but do not address potential damage to roads and buried utilities, similar to those described in the above section on collapsible soils.

LANDSLIDES

The Delta Geotechnical Consultants (1995b) report recognizes existing and potential future landslide hazards on the property. Delta identifies a large landslide in the north-central part of the property in the northern part of lot 25. Because a proposed road would cross the landslide and provide the sole access to the northern part of the property, the stability of the landslide is critical. Delta's assessment indicates that the landslide could not be stabilized cost effectively and that further cutting of the toe by the Virgin River could reactivate the landslide. In Delta's opinion, the road will continually require maintenance because of localized slope movement. Because of the importance of the road and based on Delta's assessment, I believe a quantitative evaluation of the stability of the landslide and potential effect of road-building on the slide should be conducted. Significant movement of the landslide could isolate residents in the northern part of the proposed subdivision and damage buried utility lines. There is also the potential for the landslide to dam the Virgin River and pose a flood hazard both upstream and downstream. Smaller movements, as described by Delta, could also cause disruption of buried utilities and may temporarily isolate the residents until maintenance could be performed.

In addition to the existing landslide, other landslides may be induced by proposed modifications to the property. Delta states that where water is introduced, the underlying Chinle Formation is "notorious for having...landslides." Proposed drainage modifications, potential lot irrigation, and STSA systems will likely introduce water to the top of the Chinle Formation. Where STSA systems will likely be closely spaced, such as in lots 9-13, they may significantly mound water in the subsurface and initiate landsliding. In addition, loose surficial soils may be susceptible to slumping downslope from septic systems. Delta's recommendation of 1.5:1 slopes for grading on the property will likely also contribute to slumping of surficial soils and possible deeper seated landsliding problems on the property. Delta indicates that for 1.5:1 slopes "sloughing" may occur and "maintenance will be required." Flatter slopes, such as 2:1 or even less steep, would significantly reduce the potential for surficial slumping. Although Delta indicates that the extra excavation costs of such slope designs are prohibitive, its recommendations merely pass on the extra excavation costs to whoever will become financially responsible for continual maintenance.

DEBRIS FLOWS AND FLOODING

Although not addressed in the Delta Geotechnical Consultants (1995b) report, a potential for debris flows, alluvial-fan flooding, and stream flooding exists on the property. UGS mapping indicates that Holocene alluvial fans are present in both the southern and northern parts of the property. The majority of lots in the southern part of the subdivision are located on or adjacent to a well-developed active alluvial fan. In these areas debris-flow and alluvial-fan-flooding hazards exist. Lots in the southeastern corner of the property are crossed by the main stream feeding the fan. The potential for overbank flooding from stream or debris flows along this channel needs to be evaluated. I recommend that Delta address these potential hazards and, as appropriate, recommend hazard-reduction measures to accommodate runoff and debris.

OTHER GEOLOGIC HAZARDS

The Delta Geotechnical Consultants (1995b) report lists additional potential geologic hazards at the property as including earthquake and rock-fall hazards. Potential earthquake hazards include seismically induced landsliding, ground shaking, surface fault rupture, seismically induced flooding, and liquefaction. Delta concludes that the potential for surface fault rupture or seismically induced flooding is very low because of the absence of any fault traces that cross the site and any upslope bodies of water, respectively, and I concur. It predicts that the property will be subject to ground shaking during moderate to large earthquakes in the area. Delta recommends building structures to meet Uniform Building Code seismic zone 2b, as a minimum, and I concur. Delta indicates a hazard from seismically induced landsliding exists on the property. I believe this hazard is greatest in terms of its potential to initiate movements on the existing landslide, however earthquakes may also trigger new landslides. I recommend that future lot owners be made aware of this potential hazard. Delta indicates a moderate liquefaction potential exists in areas adjacent to the Virgin River where loose sandy soils are present. Lots with this potential hazard include 2, 5-8, 33, and 34. Delta recommends that foundations be engineered to accommodate liquefaction and associated differential settlement. This hazard will need to be addressed on a lot-by-lot basis, on these lots and may require additional test borings.

Delta concludes that rock falls are "possible for all structures constructed near the toe of natural slopes" on the property and indicates that the most probable source of rock falls is perched boulders on slopes. Delta recommends that the rock-fall hazard be assessed on a lot-by- lot basis, and I concur. As a minimum, I recommend that the potential rock-fall hazard be disclosed to all future lot buyers.

SUMMARY

Delta's assessment of the suitability of conventional STSA systems is generally reasonable, however unsuitable conditions may be found a few specific locations (lots 23, 36, and 39). In addition, Delta does not consider the potential problems related to landsliding, collapsible soils, flood plains, or surface-water contamination resulting form the use of STSA systems. These issues need to be addressed in lot-by-lot evaluations where appropriate.

Delta's recommendation to reduce problems associated with collapsible and expansive soils are generally reasonable for proposed structures but assuring that they are followed would be difficult. Also, Delta does not address potential damage to roads, paved areas, and buried utilities.

Landslide hazards at various scales are recognized by Delta, but in my opinion, the magnitude of landslide problems is understated. Because significant movement of the existing landslide could isolate the northern part of the subdivision, the stability of the landslide needs to be quantified. Delta's recommended cut slope design of 1.5:1 may result in numerous surficial slumps incurring maintenance costs.

Other hazards, such as liquefaction and rock falls, are addressed by Delta but require additional lot-by-lot assessments. However Delta needs to address potential debris-flow and alluvial-fan-flooding hazards near alluvial fans and their channel ways.

REFERENCES

Delta Geotechnical Consultants, Inc., 1995a, Percolation test results, proposed Canyon Springs Estates, Springdale, Utah: Salt Lake City, Utah, unpublished consultant's report, 6 p.

Delta Geotechnical Consultants, Inc., 1995b, Geotechnical study, proposed Canyon Springs Estates, Springdale, Utah: Salt Lake City, Utah, unpublished consultant's report, 36 p.

Jennings, J.E., and Knight, K., 1975, A guide to construction on or with materials exhibiting additional settlement due to collapse of grain structure: Sixth Regional Conference for Africa on Soil Mechanics and Foundation Engineering, p. 99-105.

Kaliser, B.N., 1977, Ground subsidence in Cedar City, Utah: Utah Geological and Mineral Survey Report of Investigation RI-124, 130 p.

Kaplan, O.B., 1987, Septic systems handbook: Chelsea, Michigan, Lewis Publishers, Inc., 290 p.

U.S. Environmental Protection Agency, 1987, Guidelines for delineation of wellhead protection areas: U.S. Environmental Protection Agency document no. EPA 440/6-87-010.

Project:			Requesting Agency:
Review of a geologic report for the K.B. Smith Subdivision, Snow Basin Road, Weber County, Utah			Weber County
By: Francis X. Ashland	Date: 1-30-96	County: Weber	Job No: 96-05 (R-5)
USGS Quadrangle: Snow Basin (1344)		Number of attachments: none	

INTRODUCTION

In response to a request by Jim Gentry, Weber County Planning Commission, I reviewed a geologic report by Earthtec Testing and Engineering entitled "Geologic evaluation, building lot off Snow Basin Road, Weber County, Utah." The property is located in the S1/2SW1/4 section 23 and the N1/2NW1/4 section 26, T. 6 N., R. 1 E., Salt Lake Base Line and Meridian. The scope of work for this review included an inspection of unpublished geologic mapping by Utah Geological Survey (UGS) geologist Mike Lowe. I performed no field inspection of the property.

LANDSLIDE HAZARDS

Earthtec Testing and Engineering (1996) indicates that no evidence exists of slope movement on the property. However, because slopes locally exceed 35 percent, in my opinion, they could be destabilized by grading or other modifications. Therefore, I recommend that grading plans, which were unavailable at the time of this review, be reviewed by a qualified professional and that the stability of proposed slopes be evaluated if significant grading is proposed.

EXPANSIVE SOILS

Earthtec's tests indicate expansive clays on the property exhibit a swell pressure of 5,000 psf. Earthtec recommends a shallow spread-footing foundation and on-grade floor slab with a minimum of 24 inches and 18 inches of structural (granular) fill beneath the footings and floor slab, respectively. In addition, Earthtec recommends that the area surrounding the homesite be graded and that extended downspouts be used so that runoff drains away from the site. Although the foundation and slab recommendations may be adequate, they need to be reviewed by a qualified geotechnical engineer with experience in expansive soils. My experience indicates that this is not a conservative design for areas with expansive soils. Earthtec also does not address the potential for damage to sidewalks, buried utilities, and paved areas. Care must be taken in landscaping to avoid wetting soils near structures or areas susceptible to damage. Expansive-clay soils also represent a potential problem for the proposed septic-tank soil-absorption (STSA) system on the property.

SOIL SUITABILITY FOR SEPTIC SYSTEMS

The combination of expansive clays, the possible existence of shallow unweathered rock, and sloping terrain poses a significant challenge in locating a suitable site for a STSA system on the property. Earthtec indicates that clay soils range between about 5 and 7 feet thick at the proposed homesite. Clay soils generally have slow percolation rates, but because of their expansive nature, they can also potentially swell upon becoming saturated further reducing their permeability and possibly damaging STSA systems. Pre-soaking of expansive-clay soils (U.S. Environmental Protection Agency, 1980) for a period of at least 15 hours is required prior to performing a percolation test. I recommend approval of a STSA system in these soils only if percolation rates are adequate following a soaking period of the required duration. Earthtec indicates that a sand layer beneath the clays near the proposed homesite could be suitable for a STSA except for its proximity to the proposed house. Additional explorations are required to determine whether an area underlain by a sand layer of adequate thickness, extent, and permeability is present elsewhere on the property.

The presence of shallow indurated rock generally makes an area unsuitable for a STSA system. Relatively shallow, weathered rock is present at the proposed homesite at a depth of 6 feet. Although excavation through the rock was possible in Earthtec's trench, elsewhere on the site shallow indurated rock may be present. Because the depth-to-rock may vary across the site, the potential for shallow indurated rock beneath a proposed STSA system site should be assessed by thorough exploration.

Sloping terrain poses an additional challenge for STSA systems, especially in soils with layers having different percolation rates. On sloping terrain, a potential for effluent to migrate downslope along permeable layers and reach the ground surface exists. I recommend, therefore, that the downslope lateral extent of permeable layers be assessed and considered in the siting of a STSA system.

EARTHQUAKE HAZARDS

Earthquake hazards at the property, although not listed by Earthtec, include ground shaking and earthquake-induced landsliding. Earthtec recommends that the house be constructed to meet Uniform Building Code seismic zone 3 criteria, and I concur. This recommendation should reduce losses from ground shaking that result from a moderate to large earthquake in the area. Earthtec does not evaluate the potential for earthquake-induced landsliding at the site. However, I believe that because of the locally steep slopes and the existence of landslide-prone, expansive-clay soils that earthquake-induced landsliding represents a potential hazard which needs to be addressed if significant site grading is planned.

VARIABLE SITE CONDITIONS

Earthtec's assessments are based solely on one trench excavation in the general vicinity of the proposed homesite. Earthtec indicates that different conditions than those described in the report may be encountered elsewhere on the site, and I concur. I recommend further investigations if development is planned in areas not near the Earthtec trench site.

SUMMARY

The Earthtec (1996) report addresses most of the potential geologic hazards at the property, but Earthtec's assessment of soil suitability and slope stability is incomplete without more information on the proposed location of the STSA system and the extent of grading for the homesite, respectively. Problems related to the functioning of STSA systems where expansive soils are present are not addressed. Earthtec identifies a local sand layer that may be suitable for STSA systems, but proposes no further septic-system suitability investigation. Once a site is chosen, a site-specific study and percolation tests will be required. Other issues related to STSA-system suitability such as the possible existence of shallow rock and sloping terrain will also need to be addressed. Earthtec recognizes no evidence of landslides on the property and considers slopes stable. If site grading is planned, recommendations for stable cut-slope angles and an assessment of the potential for destabilizing soil slopes considering both static and dynamic (earthquake-induced) conditions, are required. Earthtec identifies expansive soils on the property, but the proposed foundation design is not significantly different from designs used where expansive soils are absent. I recommend that a qualified geotechnical engineer evaluate the adequacy of the foundation design. In addition, Earthtec makes no recommendations to reduce or avoid damage to sidewalks, paved areas, and buried utilities. Because of the limited extent of subsurface exploration and the potential for site conditions to vary, Earthtec's assessments may not be applicable to locations other than those near the trench excavation.

REFERENCES

Earthtec Testing and Engineering, 1996, Geologic evaluation, building lot off Snow Basin Road, Weber County, Utah: Ogden, Utah, unpublished consultant's report, 6 p.

U.S. Environmental Protection Agency, 1980, Design manual - Onsite wastewater treatment and disposal systems: Washington, D.C., Report No. EPA-625/1-80-012, 392 p.

Project: Review of a geologic report for the proposed Elkhorn Subdivision, Phase I, Weber County, Utah			Requesting Agency: Weber County
By: Francis X. Ashland	Date: 2-8-96	County: Weber	Job No: 96-06 (R-6)
USGS Quadrangle: Huntsville (1369)		Number of attachments: none	

INTRODUCTION

In response to a request by Craig Barker, Weber County Planning Commission, I reviewed a geologic report by Earthtec Testing and Engineering entitled "Geologic evaluation, Elkhorn Subdivision, Phase I, Weber County, Utah." The proposed subdivision is located in the W1/2SW1/4 section 23, T. 7 N., R. 1 E., Salt Lake Base Line and Meridian. The scope of work included a literature review and an inspection of an unpublished geologic map of the Ogden Valley area by Utah Geological Survey (UGS) geologist Mike Lowe. I performed no field inspection of the property.

EXPANSIVE SOILS

The Earthtec Testing and Engineering (1996) report indicates that the property is underlain by slightly to moderately expansive-clay soils that swell upon wetting between 0.3 and 1.3 percent. Earthtec recommends shallow spread footings on 2 feet of compacted, granular fill and on-grade slabs. In addition, Earthtec recommends foundation drains, extended downspouts, and proper surface grading that drains away from structures to prevent soils from becoming wet. Although the foundation and slab recommendations may be adequate, they need to be reviewed by a qualified geotechnical engineer with experience in expansive soils. My experience indicates that this is not a conservative design for areas with expansive soils. Earthtec also does not address the potential for damage to sidewalks, buried utilities, and paved areas. Care must be taken in landscaping to avoid wetting soils near these areas as well as near buildings.

LOCAL SHALLOW PERCHED GROUND WATER

Earthtec indicates that several areas of shallow perched ground water exist on the property. If shallow ground water is encountered during construction, Earthtec recommends that it be notified so that appropriate design or construction measures can be made, and I concur. Where expansive clay soils are dewatered, shrinkage may result in settlement and possible damage to structures.

OTHER GEOLOGIC HAZARDS

Earthtec also addresses landslide, stream flooding, and earthquake hazards at the property. Earthtec observes no evidence for landslides, however indicates that numerous boulders exist on the property but gives no explanation as to their origin. Lofgren (1955) believes the boulders were carried downslope accompanying slow movement or creep in wet, low permeability, surficial soils. If this is true, this process probably poses no significant hazard to the proposed subdivision. However, the stability of the surficial soils where significant grading is planned should be assessed. I recommend that Earthtec both assess the potential for destabilizing soil slopes and recommend stable slope angles, as appropriate. Earthtec indicates that natural surface drainages can adequately carry runoff from snowmelt and intense, short-duration storms, but does not document this statement. Estimated runoff and channel capacities will need to be determined to design storm drains and culverts at stream crossings. I concur with Earthtec's recommendation that development should not encroach onto channel banks. Earthquake hazards at the property, although not listed by Earthtec, include ground shaking and earthquake-induced landsliding. Earthtec recommends that structures be designed and constructed to meet Uniform Building Code seismic zone 3 criteria to minimize losses from ground shaking during a moderate to large earthquake, and I concur. In addition, I recommend that the potential for earthquake-induced landslides also be considered in any assessment of cut-slope stability. Two large landslides in similar geologic settings are upslope of the property. Mike Lowe (1996, UGS, verbal communication) speculates that they may be earthquake-induced or the result of surface faulting.

SUMMARY

The Earthtec (1996) report addresses most of the potential geologic hazards at the property including expansive soils, landsliding, stream flooding, and earthquake-induced ground shaking. Earthtec identifies expansive soils on the property, but the proposed design for foundations does not differ significantly from designs used where expansive soils are absent. I recommend that a qualified geotechnical engineer evaluate the adequacy of the foundation design. Also, Earthtec makes no recommendations to reduce or avoid damage to sidewalks, buried utilities, and paved areas. In addition, the potential for shrinkage accompanying dewatering of expansive clays in areas of shallow perched ground water may, as needed, require further evaluation. Estimated runoff and channel capacities will be required for proper design of storm drains and culverts to control flooding. If significant grading is planned, Earthtec's assessment of slope stability is incomplete and must discuss the potential for destabilizing natural slopes under both static and dynamic (earthquake-induced) conditions.

REFERENCES

Earthtec Testing and Engineering, 1996, Geologic evaluation, Elkhorn Subdivision, Phase I, Weber County, Utah: Ogden, Utah, unpublished consultant's report, 8 p.

Lofgren, B.E., 1955, Resume of the Tertiary and Quaternary stratigraphy of Ogden Valley, Utah, *in* Eardley, A.J., editor, Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geological Society Guidebook to the Geology of Utah Number 10, p. 70-84.

Utah Geological Survey

<table>
<tr><td colspan="3">Project:
Review of a geologic report for a single residential lot along Snow Basin road, Weber County, Utah</td><td>Requesting Agency:
Weber County Planning Commission</td></tr>
<tr><td>By:
Bill D. Black</td><td>Date:
03-01-96</td><td>County:
Weber</td><td rowspan="2">Job No:
96-07
(R-7)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Snow Basin [1344]</td><td>Number of attachments:
None</td></tr>
</table>

This report is a review of a geologic report (Kaliser, 1996) for a residential lot along Snow Basin Road (NE1/4SW1/4 section 23, T. 6 N., R. 1 W., Salt Lake Base Line) in Weber County, Utah. Jim Gentry, Weber County Planning Commission, requested the review. The scope of work consisted of a literature review and examination of 1:20,000-scale aerial photos (1952). No field visit was made.

Kaliser (1996) identifies landsliding as a potential hazard at the property. A level area (site) Kaliser (1996) considers suitable for a structure exists on an elevated bench between two drainages that cross the property from southwest to northeast. This site is roughly 60 feet (18 m) south of the northernmost drainage. Three small landslides were found on the property along the northern drainage; none was found along the southern drainage (Kaliser, 1996). Kaliser (1996) reports the small slides along the northern drainage are in a layer of shallow colluvium (generally less than 6 feet [2 m] deep) overlying weathered bedrock of the Norwood Tuff. He believes that the landslides probably initiated from increased precipitation during the 1983-84 wet years, and that future slope failures at the property will likely be similar small slope failures in the shallow colluvium. To reduce the hazard from these landslides, Kaliser (1996) recommends structures be set back at least 24 feet (7.3 m) south from existing slide crowns in the northern drainage. This recommendation appears adequate to reduce the hazard from similar small slope failures in shallow colluvium at the site.

Kaliser (1996) dismisses the potential for large landslides involving bedrock, but does not give any supporting evidence. Geologic maps by Harty (1992) and Mike Lowe (unpublished Utah Geological Survey [UGS] map of Ogden Valley) show the Norwood Tuff is prone to such landslides. A large (probably prehistoric) landslide is shown in the northern half of the property on the unpublished UGS map and is evident on 1:20,000-scale aerial photos (1952). The surface slope of this landslide (roughly 8 to 15 degrees) is similar to the overall slope at the site (9 degrees), and is much less steep than the slope along the northern drainage (35 degrees). Several other large landslides are also mapped by Harty (1992) in the vicinity of the property. All of these landslides indicate to me that bedrock slope failures are common in the area, and the potential for such landslides must be assessed. Evidence supporting Kaliser's (1996) dismissal of the hazard must be provided for me to evaluate the adequacy of the investigation and validity of his conclusions.

Kaliser (1996) reports that erosion may be a hazard at the property. However, he includes no discussion or recommendations regarding potential erosion hazards. Care should be taken that site modifications or grading do not promote erosion or reduce stability of slopes at the property. I recommend that plans for any significant site modification and grading be reviewed by a qualified geotechnical engineer.

A potential hazard not addressed by Kaliser (1996) is expansive-clay soils. These soils are common in the Norwood Tuff and were found at a nearby homesite (Earthtec Testing and Engineering, 1996). I recommend a soil-foundation investigation be performed prior to construction to address the potential for these soils and recommend appropriate foundation designs.

In addition to causing possible foundation and pavement damage, expansive-clay soils may also cause problems for wastewater soil-absorption systems because swelling clay can reduce permeability or possibly damage systems. Kaliser (1996) reports that test holes and percolation tests show satisfactory results for use of soil-absorption systems, but gives no test results (such as soil types, depth to bedrock, and percolation rates). I cannot evaluate the recommendation that the site is suitable for a wastewater soil-absorption system without this information.

The hazard from earthquake ground shaking also is not addressed in Kaliser (1996). 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 (at a minimum) in accordance with seismic zone 3 requirements for earthquake-resistant design.

REFERENCES

Earthtec Testing and Engineering, 1996, Geologic evaluation of a building lot off Snow Basin Road, Weber County, Utah: Ogden, Utah, unpublished consultant's report, 6 p.

Harty, K.M., 1992, Landslide map of the Ogden 30' x 60' quadrangle, Utah: Utah Geological Survey Open-File Report 247, scale 1:100,000, 11 p.

Kaliser, B.N., 1996, Geologic evaluation of a single residential lot along Snow Basin Road, Weber County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Project:			Requesting Agency:
Review of documents for the Atlas Corporation uranium mill site in Moab, Utah			Utah Department of Environmental Quality Division of Radiation Control
By: Francis X. Ashland	Date: 4-10-96	County: Grand	Job No: 96-08 (R-8)
USGS Quadrangle: Moab (497)		Number of attachments: none	

INTRODUCTION

In response to a request by Loren Morton, Utah Department of Environmental Quality Division of Radiation Control (DEQ/DRC), I reviewed technical reports for the Atlas Corporation uranium mill site located along the Colorado River in Moab, Utah. Atlas Corporation is currently in the process of dismantling the mill and is proposing to reclaim the site by stabilizing and capping an existing 10.5-million-ton, 130-acre tailings pile. The reports include Cooksley Geophysics, Inc. (1995, 1996), Smith Environmental Technologies Corporation (1995), and Woodward-Clyde Federal Services (1996). These reports assess site geology and potential geologic hazards. I also reviewed sections of draft copies of the Technical Evaluation Report (section 2.0, GEOLOGIC STABILITY, and section 3.0, GEOTECHNICAL STABILITY; NUREG-1532) and Environmental Impact Statement (section 3.2 GEOLOGY, SOILS, AND SEISMICITY; NUREG-1531) by the U.S. Nuclear Regulatory Commission (NRC) (1996a, 1996b). The scope of the review for all these reports included assessment of important geologic issues but did not include proofreading and editing. I discussed aspects of these reports with Utah Geological Survey (UGS) geologists Hellmut Doelling and Gary Christenson and incorporated their comments into this review.

FAULTS AND ESCARPMENTS UNDERNEATH THE SITE

The Cooksley Geophysics, Inc. (CGI) (1995, 1996) reports present interpretations of seismic-reflection surveys near the tailings pile. CGI presents new data that in some cases support and in other cases question the location of previously mapped faults near the tailings pile. CGI indicate that the Moab fault (MF) and two subsidiary faults underlie the northeastern part of the tailings pile and confirm the approximate location of the MF as previously mapped by the UGS (Doelling and others, 1995). CGI (1995) interprets the fault to be nearly vertical, however the reflection data (particularly line A) do not appear to define the dip of the fault. At the surface, the fault dips between 50 and 75 degrees northeast (Doelling and others, 1995), placing the mapped location of the fault somewhat more to the southwest than is shown in CGI's figure. The West Branch Moab fault (WBMF), however, is not observed in either lines A or C despite the resolution of the seismic survey to depths of about 2,000 feet. Cross sections (figures 2-14 and 2-15) in the Woodward-Clyde Federal Services (WC) (1996) report indicate that the WBMF should be present beneath the southwestern edge of the tailings pile at a depth of less than 1,000 feet. The WBMF may not have been recognized by CGI due to the lack of good reflectors beneath the southwestern part of the survey lines (H.H. Doelling, UGS, verbal communication, 1996). Alternatively, the WBMF may steepen with depth and therefore may not underlie the tailings pile.

The buried escarpment shown in WC's figure 2-16 (the unnamed arcuate fault mapped by Doelling and others [1995]) is also not observed in the seismic data (line B). Although an escarpment is not observed in line B, the seismic data show that the alluvium gradually increases in thickness to the south toward the Colorado River. Boring data confirm the existence of the buried escarpment (Canonie Environmental, 1994), however its extent and orientation are not defined by the borehole data. Some evidence (boreholes B-2[14] and ATP-2) suggests that the escarpment underlies the south-southeast slope of the tailings pile (Canonie Environmental, 1994) southwest of the MF. However, the seismic data (CGI, 1995, line B) suggest that northeast of the MF the escarpment may step to the southeast. Although the feature is interpreted to be a fault by Doelling and others (1995), the escarpment may have originated from other processes, including erosion. Because of its likely role in separating zones with different rates of salt-dissolution-induced subsidence, delineating the escarpment is, in my opinion, critical to design of the southeastern side of the pile (see comments below under SALT-DISSOLUTION SUBSIDENCE).

LANDSLIDE AND MIGRATING-SANDS HAZARDS

The Smith Environmental Technologies Corporation (SETC) (1995) report addresses the landslide hazard to the tailings pile and the potential for encroachment of eolian sands into the pile area. SETC indicates no evidence for past large-scale landsliding west of the tailings pile, but recognizes abundant talus debris and local soil creep. In my opinion, the SETC report does not adequately support its conclusion that a significant landslide hazard does not exist. SETC should address the potential for large-scale landsliding toppling, possibly triggered by progressive undercutting, of a large slab of rock from the cliff of Poison Spider Mesa west of the tailings. SETC provides photographic evidence that the talus debris is derived from rock falls from the cliff, and that most rock falls are contained on the talus slope. SETC also indicates that a wide flat area that includes U.S. Highway 279, separates the talus slope from the tailings pile and serves as a catchment west of the tailings pile. Although not stated in the report, some of the photos show little or no rock-fall debris east of the highway. UGS rock-fall-hazard mapping (Mulvey, in preparation) indicates that the tailings pile is outside the rock-fall-hazard area and supports SETC conclusions regarding small-scale rock falls, but does not preclude the possibility of large-scale toppling.

SETC indicates that eolian sands are generally thin and vegetated near the tailings pile, and that the amount and density of vegetation suggests a stable environment. Additional evidence cited by SETC for a stable environment includes the existence of a cryptobiotic crust and only local dunes or blow-outs. I concur with SETC's conclusion that the eolian sands are presently stable, but caution that future climatic or other changes to the environment may result in reactivation and encroachment of the sands.

SEISMIC HAZARDS

The WC (1996) report addresses the earthquake hazard at the tailings pile. WC concludes that there are no capable (active) faults near the tailings site, including the underlying MF, and I concur. Evidence cited by WC that the MF is not a capable fault includes:

1. the lack of associated seismicity,

2. evidence that Quaternary dissolution-related subsidence structures post-date most recent tectonic (?) movement on the MF,

3. reverse topography suggesting a long period of quiescence to allow for differential weathering and erosion,

4. evidence that, where present, late Quaternary deposits (>35,000 years old) bury the fault trace, and

5. the estimate that the MF extends to only about 2 kilometers in depth, making it incapable of generating large earthquakes despite its favorable orientation with respect to the modern stress field.

WC presents similar evidence that most of the other faults in the region are not capable of generating large earthquakes, with the exception of the Uncompahgre fault zone. In addition to regional faults, WC considers the Colorado River seismic zone (CRSZ) as well as background seismicity in the Colorado Plateau in the assessment of seismic source zones. WC suggests that a M_L 5.0 is a reasonably conservative maximum earthquake in the CRSZ on the basis of historical earthquake activity and the lack of evidence for a major deep Precambrian fault. WC also adopted a magnitude M_w 6.25 earthquake for background seismicity in the Colorado Plateau based on historical seismicity and the absence of structures exhibiting surface rupture or deformation. I agree with the geologic input used in WC's seismic-hazard assessment for the area.

Although the UGS does not have seismologists on staff to review the WC probabilistic earthquake-hazard evaluation used to predict ground motions, in my opinion the evaluation appears to be a state-of-the-art and conservative assessment using reasonable attenuation relations and seismic-source data and adequately incorporating uncertainties into the analysis. The method used in dealing with background seismicity is consistent with that recommended by Pechmann and Arabasz (1995). The predicted upper limit for ground acceleration of 0.2 g is greater than shown on other probabilistic maps and is consistent with the preservation of precariously balanced rocks in the vicinity of Moab.

LIQUEFACTION

The WC (1996) report addresses the potential for liquefaction in and surrounding the tailings pile. WC's assessment indicates that soils susceptible to liquefaction or loss in strength exist in both the embankment and surrounding native soils, but they represent only a small fraction of the total number of tested soils. WC concludes that although some soils may liquefy, destabilization of the embankment and tailings due to widespread soil failure is unlikely. This assessment implies that the liquefiable soils are scattered and not clustered in one area, but this is not shown or stated in the report. I believe consideration of the distribution of the liquefiable soils is necessary to fully evaluate the hazard.

INTERPRETATION OF SUBSURFACE GEOLOGY

Inconsistencies exist between subsurface interpretations in the CGI (1995) and WC report (figures 2-14 through 2-16) that need to be resolved. The NRC (1996b) also recognized this and states that subsurface conditions have not been adequately characterized. The following issues should therefore be considered and, if necessary, incorporated into a new subsurface model:

1. the location of the Moab and subsidiary faults as shown in WC's figure 2-18 and a re-evaluation of the fault's dip beneath the pile,

2. the potential absence of the WBMF beneath the southwestern part of the pile,

3. the location of a buried escarpment or fault beneath the south-southeastern part of the pile,

4. whether alluvium in the vicinity of the pile thickens or thins to the southwest, and

5. identification of the rock formation(s) underlying the alluvium and depth to salt/caprock beneath the tailings pile based on seismic and borehole rock-type data.

CGI's (1995) assessment that the alluvium thickens to the southwest in line A is based on an interpretation that a northeast-dipping reflector is the upper contact of an older alluvium. However, an alternate interpretation is that the older unit is rock rather than alluvium (H.H. Doelling, UGS, verbal communication, 1996). Nearby borehole data (WC, 1996) also support the conclusion that shallow rock exists north and west of the tailings pile. Determining whether alluvium increases in thickness southwest of the pile is important in evaluating the style of surface deformation resulting from subsidence and the role of the WBMF in the overall on-going subsidence of the area. Thick alluvium north of the buried escarpment may indicate enhanced dissolution along the WBMF and/or subsidence-induced movement of the fault.

The gradually increasing thickness of the alluvium to the southwest observed in line C may be the result of the line obliquely crossing the buried escarpment. The abrupt increase in alluvium thickness to the southeast across the escarpment appears as a gradual increase in thickness to the southwest as a result of the acute angle between the escarpment and line C.

In an addendum report, CGI (1996) indicates that caprock was not recognized and estimates the depth to salt to be about 1,500-2,000 feet. Implicit in CGI's estimate is the assumption that reflectors beneath the pile represent layered rock units above the Paradox Formation salt. Limited boring data in the WC report suggest sandstone and shale north of the buried escarpment at depths of 85 to 119 feet that is interpreted to be the Moenkopi and Chinle Formations. However, rock descriptions from these boreholes are not adequate to evaluate whether the rock types were assigned to the appropriate formations. Abundant sandstone and shale layers are present in many formations and alternatively could exist as pendants or blocks entrapped in caprock. Sandstone roof pendants have been reported in the Moab Valley salt diapir (Doelling and others, 1995). The depths of penetration of boreholes into rock are inadequate to eliminate this possibility. In addition, no rock descriptions are available to the south of the buried escarpment and to the southeast of the toe of the tailings pile. The depth-to-caprock/salt is important because the presence of caprock/salt at relatively shallow depth, particularly directly beneath alluvium (as shown in WC's figure 2-15), increases the potential hazard of salt-dissolution subsidence. Saline ground water in wells located above where alluvium is believed to directly overlie salt/caprock likely indicates on-going dissolution at the salt/caprock-alluvium interface.

SALT-DISSOLUTION SUBSIDENCE

The WC (1996) report indicates that no direct surficial evidence for Quaternary salt-dissolution subsidence, including sinkholes, surficial soil deformation, or breccia pipes, exists near the tailings pile. WC lists indirect evidence for subsidence in the area to be the absence of Pleistocene terraces and the presence of a marsh consisting of late Holocene deposits along the Colorado River, saline ground water in drill holes, and an apparently truncated fluvial terrace remnant at the mouth of Courthouse Wash. Perhaps the most important evidence for subsidence in the area is the thick alluvium south of the pile recorded in borehole ATP-1. Because the base of the alluvium is at least 400 feet lower than the bedrock thresholds for the Colorado River channel to the northeast and southwest (Doelling and others, 1995), the alluvium is the result of the filling of the Moab Valley basin as it subsides.

WC (1996) presents estimates of both long-term and short-term rates of subsidence near the tailings pile. WC estimates the long-term rate to be between 0.08 and 0.2 mm/yr by assuming the total thickness (125 m) of alluvium south of the pile accumulated in the last 0.7 to 1.6 million years. I believe these are reasonable lower-bound, long-term rates. However, because of the lack of age constraints on the deepest alluvium near the tailings pile, it is possible that the alluvium is younger than 0.7 million years or that a great thickness of the shallow alluvium is younger, such that shorter term rates are much higher. In addition, because of the lack of boreholes to rock south of the pile, the actual thickness of alluvium could be greater than assumed by WC, further yielding higher rates. I also question the reliance on the CGI seismic records as a constraint on the depth-to-rock because of the apparent poor correlation with borehole data elsewhere on the site (see section above).

WC (1996) uses a fluvial terrace remnant at the mouth of Courthouse Wash to estimate an upper-bound, short-term subsidence rate. WC assumes that subsidence occurred south of the mouth of the wash, truncating the terrace, and that incision of the terrace is due to base-level lowering along the Colorado River caused by dissolution-related subsidence. WC measured the height of the terrace and estimated the age of the deposit. WC found that approximately 16 m of incision has occurred subsequent to deposition of the terrace deposits, and estimates the deposit's age to be between 15 and 40 ka on the basis of stage I to II+ carbonates, their coarse-grained texture (typical of Pleistocene deposits in the area), and a one-meter-thick Bk horizon. On this basis, WC estimates the short-term uplift/subsidence rate to be between 0.4 and 1.0 mm/yr and believes that the upper bound of this range is conservative.

WC's (1996) short-term rate appears conservative because it attributes all the incision to subsidence. However, implicit in WC's calculation is the assumption that the Colorado River base level lowers at the same rate as Moab Valley subsides. I believe the two are unrelated, and several lines of evidence, including the Holocene marsh deposits and the thick alluvium south of the pile, suggest that dissolution-related subsidence is out-pacing incision of the Colorado River. WC acknowledges this possibility, but could not constrain the amount that subsidence exceeds base-level lowering. Because of this uncertainty, I believe that additional studies are required to confidently determine a conservative short-term subsidence rate near the tailings pile.

WC (1996) applies the calculated subsidence rate to the Moab fault zone and assumes differential subsidence across the zone. Although this is one possible scenario, I believe the more likely boundary between relatively low and high rates of subsidence is the buried escarpment. Much of the subsurface and geomorphic evidence points to the area south of the pile as being the focus of on-going subsidence and the area most likely to have the highest rate of subsidence in the Moab Valley. I believe that the area north of the escarpment (on which the majority of the pile rests) is probably undergoing a lower rate of subsidence than the area to the south. Therefore, I believe identifying the location of the escarpment is critical to defining where the likely zone of deformation will occur across the pile as a result of differential subsidence. As stated previously, some borehole data (Canonie Environmental, 1994) indicate the escarpment underlies the southern embankment of the tailings pile.

In the absence of quantitative rates of subsidence, the potential for subsidence can to some extent be qualitatively addressed based on subsurface conditions beneath the pile. In general, I believe the greater the depth to salt/caprock beneath the pile, the lower the subsidence hazard (see section above). The potential hazard of salt-dissolution subsidence is generally low where a thick sequence of sedimentary rock (sandstone, limestone, shale) exists between the salt/caprock and the alluvium. The potential hazard of salt-dissolution subsidence increases where caprock/salt is at relatively shallow depth, directly beneath the alluvium. Thus I consider it important to define the depth to salt/caprock and the type and thickness of material below the alluvium, as discussed in earlier sections.

I believe that WC's evaluation of surface deformation in terms of shear strain does not fully characterize the type of surface disturbance that could occur (settlement, changes in slope, and/or deformation). If the escarpment is truly below the embankment's southeast-facing slope and differential subsidence occurs across this zone, then one result is that a portion of the overall slope will become slightly steeper as the toe of the slope subsides. Surface settlements may cause a vshaped trough or swale to develop on the slope, possibly disrupting pile drainage. If the zone of deformation crosses the top of the pile then the radon barrier may be damaged. None of the consequences is so severe, in my opinion, that design modifications could not mitigate the effects of the disturbance, but the surface disturbance has not been addressed.

NRC REPORTS

The Draft Environmental Impact Statement (NUREG-1531; NRC, 1996a) is very general but adequately characterizes the geology, geologic hazards, and impacts. The proposed Plateau site would require further geologic characterization if used as an alternative location for the tailings. An earlier cursory review of the Draft Technical Evaluation Report (NUREG-1532; NRC, 1996b) was performed by the UGS in a letter to DEQ/DRC dated December 28, 1995. The UGS reviewed the document to ensure that all pertinent issues were raised, but did not review the technical content in detail. UGS geologist Hellmut Doelling indicates that some statements made in the document (NUREG-1532; NRC, 1996b) regarding the area's geology require minor clarification or revision, but are not pertinent to the issues. I concur with the NRC's conclusions presented in section 3.5.

SUMMARY AND RECOMMENDATIONS

In general, the reports adequately identify geologic hazards at the site and provide new geologic data to assist in future evaluations. I believe earthquake and migrating-sands hazards have been adequately addressed. Rock-fall hazards have also been adequately addressed but the potential for large-scale toppling failure of a large slab of rock from the nearby cliff has not. I also believe that the distribution of liquefiable soils needs to be addressed in the liquefaction-hazard assessment. My other principal concerns are:

1. discrepancies between the existing subsurface geologic model and new geophysical data, and

2. calculated rates and locations of salt-dissolution-induced subsidence.

The CGI reports present new data that need to be explained and, as necessary, incorporated into the subsurface model for the tailings site. Differences among the seismic reflection, geologic cross sections, and existing borehole data require explanation, particularly because of the importance of a sound subsurface geologic model beneath the pile in assessing the salt-dissolution subsidence-hazard potential. Explaining the differences between the seismic-reflection and other subsurface data may require re-evaluation of the seismic-reflection record presented in the CGI (1995) report, additional seismic studies (refraction/reflection), and boreholes, or a combination of all three.

To determine the potential for salt-dissolution subsidence, I believe the following issues require further assessment:

1. the location of the buried escarpment,

2. short-term rates of subsidence, particularly south of the buried escarpment,

3. lacking calculated subsidence rates, identification of rock types and formations beneath alluvium both north and south of the buried escarpment, and

4. potential surface effects across the pile that result from differential subsidence so that final design modifications, as necessary, can be made.

Additional boreholes or geophysical work may be necessary to evaluate items 1-3 above. The boreholes need to extend deep enough into rock to eliminate the possibility that they penetrate only pendants in caprock and should be logged by a professional geologist familiar with the geology of the Moab area. Any new boreholes, for whatever purpose, should be considered for sampling because they may encounter datable materials (organics, ash) in alluvium that could be used to estimate rates of subsidence. In the absence of these studies, an overly conservative design may be required to compensate for uncertainties in quantifying potential settlement and deformation resulting from salt dissolution beneath the tailings pile.

REFERENCES

Canonie Environmental, 1994, Atlas Corporation ground water corrective action plan uranium mill and tailings disposal area: Englewood, Colorado, unpublished consultant's report, 49 p.

Cooksley Geophysics, Inc., 1995, Reflection seismic survey of Atlas Minerals tailing site three miles northwest of Moab, Utah: Redding, California, unpublished consultant's report, 16 p.

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Project:			Requesting Agency:
Review of "Report, reconnaissance-level geology study for lots 1134 and 1135, Timber Lakes subdivision, Wasatch County, Utah"			Wasatch County
By: Bill D. Black	Date: 03-04-96	County: Wasatch	Job No: 96-09 (R-9)
USGS Quadrangle: Center Creek [1126], Heber Mountain [1125]		Number of attachments: None	

INTRODUCTION

This report is a review of a geologic-hazards report (Dames & Moore, 1995) for lots 1134 and 1135 in the Timber Lakes subdivision (SE1/4NW1/4 section 10, T. 4 S., R. 6 E., Salt Lake Base Line), Wasatch County, Utah. Robert Mathis, Wasatch County Planner, requested the review. The scope of work included a literature review and examination of 1:20,000- and 1:40,000-scale aerial photos (1965 and 1987). No field visit was made. I have only reviewed sections of the report dealing with geologic hazards. Sections discussing earthwork, site modification, and grading should be reviewed by a geotechnical engineer.

LANDSLIDE HAZARDS

Dames & Moore (1995) identifies landsliding as a potential hazard at the property. The property is in a zone of high relative landslide hazard in north-facing slopes bordering Lake Creek (Dames & Moore, 1995; Hylland and Lowe, 1995a). Hylland and Lowe (1995a) show the property, and much of Timber Lakes subdivision, is underlain by a large prehistoric landslide. A historical landslide is also roughly 4,000 feet (1,219 m) downstream to the west of the property, and several smaller historical landslides are in slopes along Lake Creek in the area (Hylland and Lowe, 1995a). Dames & Moore (1995) reports no evidence of recent landsliding at the property and believes slopes there are generally stable.

Based on their reconnaissance-level study, Dames & Moore (1995) recommends no structure be located closer than a 2:1 slope projection from the base of slopes along the northern part of the property. However, Earthstore (1988) recommended using a 3:1 slope set back in previous site studies in the subdivision, and this recommendation has been accepted and used by Wasatch County (Mike Hylland, Utah Geological Survey, verbal communication, 1996). Hylland and Lowe (1995b) considered slopes steeper than 4:1 in glacial and landslide deposits in the area to be potentially unstable. The historical landslide west of the property has a slope of about 3.3:1 (Mike Hylland, Utah Geological Survey, verbal communication, 1996). This suggests to me that Dames & Moore's (1995) recommended 2:1 slope set back may not sufficiently reduce the risk from landsliding, and more work is needed to provide evidence supporting a 2:1 set back. Even using the 3:1 set back only reduces the risk, but does not eliminate it.

These slope set-back recommendations do not consider overall stability of the old landslide beneath the subdivision (and the property). Although evaluating stability of the old landslide is beyond the scope of work of the consultant for this lot, I recommend disclosing its existence to future buyers. I also recommend that Timber Lakes subdivision and Wasatch County consider a larger multi-lot study of this landslide to evaluate its long-term stability.

OTHER HAZARDS

Dames & Moore (1995) recommends controlling excess moisture at the property to improve slope stability and reduce structural settlement. They recommend rain gutters and downspouts to collect and route precipitation from building areas, site grading to channel excess water away from the property, and low-moisture landscaping. I concur with all of these recommendations. However, care should be taken that channelled runoff does not affect adjacent lots by promoting erosion or reducing slope stability.

Dames & Moore (1995) identifies ground shaking as a potential hazard at the property, and recommends all structures be designed and constructed in accordance with seismic zone 3 requirements using a site coefficient of 1.0. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards.

I concur with Dames & Moore's (1995) assessment that the potential for active faulting, rock falls, liquefaction, and debris flows at the property is low. Regarding flooding, aerial photos of the area (1965 and 1987) show an apparent overflow-spillway cut for Witts Lake above the property to the south. If this structure is still present, the potential for overflow flooding at high reservoir levels must be evaluated.

REFERENCES

Dames & Moore, 1995, Report--Reconnaissance-level geology study for lots 1134 and 1135, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 9 p.

Earthstore, 1988, Report--Geotechnical/engineering geology study for plats 19A, 19B, 20A, and 20B, Timber Lakes development located approximately seven miles east of Heber, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 13 p.

Hylland, M.D., and Lowe, Mike, 1995a, Landslide hazard plate 1D, *in* Hylland, M.D., editor, Engineering Geology Map Folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

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Project: Review of "Stone Mountain Estates subdivision fault-rupture-hazard investigation, 4800 South 1550 East, Ogden, Utah"			Requesting Agency: Ogden City Planning Division
By: Bill D. Black	Date: 03-05-96	County: Weber	Job No: 96-10 (R-10)
USGS Quadrangle: Ogden [1345]		Number of attachments: None	

This report is a review of a surface-fault-rupture hazards report (Kaliser, 1996) for phase IV of the Stone Mountain Estates subdivision at approximately 4800 South, 1550 East (SW1/4SE1/4 section 10, T. 5 N., R. 1 W., Salt Lake Base Line), Ogden, Weber County, Utah. Kirk Smith, Ogden City Planning Division, requested the review. The scope of the work consisted of a literature review, and a site visit by Mike Lowe and Mike Hylland (Utah Geological Survey) on January 11, 1996. I have reviewed only sections of the report dealing with surface faulting. Sections containing geotechnical recommendations should be reviewed by a geotechnical engineer.

Kaliser (1996) identifies surface fault rupture as a potential hazard at the property. The property is roughly 1,300 feet (400 m) west of the main trace of the Wasatch fault zone, but the zone of deformation in this area is wide and the property is in the surface-fault-rupture special-study zone (SFRZ) on Weber County Planning Commission maps (Lowe, 1988). Two sub-parallel subsidiary faults (F1 and F3) and a single antithetic fault (F2) cross portions of the property generally from southeast to northwest. Kaliser (1996) excavated 14 trenches (test pits) in the SFRZ to determine the nature and extent of these faults. Kaliser (1996) recommends set-back distances (non-buildable areas) of 25 feet (8 m) on both sides of F1, 20 feet (6 m) east and 28 feet (9 m) west of F2, and 10 feet (3 m) on both sides of F3. The set-back distances are based on fault deformation exposed in the excavations (Bruce Kaliser, consultant, verbal communication, February 1996). Kaliser (1996) also recommends disclosing the potential for surface faulting to future buyers. I concur with his assessment and recommendations. However, F1 was not exposed in trenches in the northern part of the property and lacks clear surficial evidence. Untrenched areas of the SFRZ exist between F2 and the projected trace of F1 in this area. I recommend additional trenching if the property owner wants to build occupied structures in untrenched areas of the SFRZ between F2 and F1.

Kaliser (1996) only addresses surface-fault-rupture hazards. Although the hazard from debris flows, flooding, landslides, liquefaction, and rock falls was not assessed in Kaliser (1996), the property is not in a high-hazard area or special-study zone on existing hazard maps. Regarding earthquake ground shaking, the property is located in Uniform Building Code seismic zone 3 and all structures should be designed and constructed (at a minimum) in accordance with seismic zone 3 requirements for earthquake-resistant design.

REFERENCES

Kaliser, B.N., 1996, Stone Mountain Estates subdivision fault-rupture-hazard investigation, 4800 South 1550 East, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 6 p.

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

Utah Geological Survey

Project: Review of a geologic-hazards report and geotechnical study for Deer Valley subdivision plat C, Layton, Utah.			Requesting Agency: Layton City Planning Department
By: Bill D. Black	Date: 03-12-96	County: Davis	Job No: 96-11 (R-11)
USGS Quadrangle: Kaysville [1320]		Number of attachments: None	

INTRODUCTION

This report is a review of a geologic-hazards report (Kaliser, 1996) and geotechnical study for Deer Valley subdivision plat C (Earthtec Testing & Engineering, 1996) near 2800 North and State Highway 193 (E1/2NE1/4 section 10, and W1/2 NW1/4 section 11, T. 4 N., R. 1 W., Salt Lake Base Line) in Layton, Davis County, Utah. Doug Smith, Layton City Planner, requested the review. The scope of work consisted of a literature review and examination of 1:24,000-scale aerial photos (1985). No field visit was made. I have only reviewed sections of Kaliser (1996) and Earthtec Testing & Engineering (1996) discussing geologic hazards. Sections discussing site grading, cut slopes, foundation design, and drainage systems should be reviewed by a geotechnical engineer.

LANDSLIDE HAZARDS

Kaliser (1996) identifies landsliding as a hazard at the subdivision, and the subdivision is in the area on Davis County Planning Department maps (Lowe, 1989a) where landslide-hazard special studies are required. Proposed lots 1-10 in the subdivision are in a level area along Hobbs Creek in the southern part of the subdivision, about 1,500 feet downstream (southwest) of Hobbs Reservoir. Proposed lots 11-42 are in steep slopes above the creek to the north. Numerous landslides are mapped by Lowe (1989b) in these slopes, and I recognize at least four landslides in the subdivision on aerial photos taken in 1985.

Kaliser (1996) mapped two areas of "soil accumulation" (landslide deposits) in the northern part of the subdivision (in lots 27-29 and 20-23) that he believes resulted from prehistoric landsliding. He also mapped two historical landslides above lots 35-42, and multiple slide scarps from recent failures in lots 40-42. These features generally correspond to landslides evident to me on the 1985 aerial photos. Kaliser (1996) reports they were not evident on aerial photos taken in 1952. He states slope movement in this area damaged about 200 feet (61 m) of a Kaysville Irrigation Company water line in the mid-1980s, and believes the area "has been involved in slope movements over a considerable period of time, as well as the present time." A spring is in lot 39 near this area, and shallow ground water (ranging from 12 to 15 feet [4-5 m] deep) was evident in test pits to the east (Kaliser, 1996). Water was also present near the base of young scarps in lot 40 (Kaliser, 1996).

Kaliser (1996) recommends no building take place on lots 40-42 because of recent slope movement, and I concur. He also states that future slope failures are unlikely to impact the remaining lots, but gives no supporting evidence. My measurements from 1:24,000-scale topographic maps indicate that existing landslides are on slopes of 30 percent or greater. Much of lots 11-39 are on native slopes (25-40 percent) as steep or steeper than the failed slopes. Average steepness of nearby landslides in similar materials in this part of Davis County is also 30 percent (Mike Lowe, Utah Geological Survey, verbal communication, March 1996), and this slope angle has been used to delineate areas susceptible to landsliding in the adjacent subdivision to the northeast (Applied Geotechnical Engineering Consultants, 1994; Solomon, 1995). Slope stability is highly dependent on ground-water conditions, and Kaliser (1996) reports evidence of perched shallow ground water in the subdivision that will reduce slope stability. Young scarps in lot 40 (where shallow ground water is found) are on slopes less than 30 percent. This evidence suggests to me the native slopes may be only marginally stable, particularly those steeper than 30 percent, and I believe Kaliser (1996) has not adequately supported his conclusion that failures are unlikely to impact lots other than lots 40-42.

Kaliser (1996) also does not describe the type of failure involved in landsliding at the subdivision, which is important in assessing areas potentially affected and risk of being impacted by debris from failures upslope. Some failure types (such as earth flows and debris flows) can deposit debris (and damage structures) hundreds of feet downslope from their source area. His conclusion that the areas of "soil accumulation" in lots 27-29 and 20-23 are from landslides upslope indicates to me a potential hazard to lower slopes from debris.

OTHER HAZARDS

Kaliser (1996) identifies a hazard from earthquake ground shaking. The property is located in Uniform Building Code seismic zone 3, and he recommends all structures be designed and constructed in accordance with seismic zone 3 requirements for earthquake-resistant design. Based on soil-test data, Earthtec Testing & Engineering (1996) also recommends using a site coefficient of 1.2 (S2). These recommendations meet local government minimum requirements for reducing the risk from earthquake ground shaking. Kaliser (1996) and Earthtec Testing & Engineering (1996) indicate no evidence of faulting and believe the risk from surface faulting is low. I concur with their assessment.

Kaliser (1996) also identified a hazard from liquefaction. Anderson and others (1994) show liquefaction potential at the subdivision ranges from low in the northern part to high in the southern part along Hobbs Creek. Shallow ground water and susceptible soils in relatively steep slopes may result in liquefaction-induced landsliding. Although Earthtec Testing & Engineering

(1996) collected soil and ground-water data, they did not evaluate the potential for liquefaction at the subdivision or recommend hazard-reduction measures. I recommend disclosing the potential for liquefaction to future buyers of lots in areas of moderate and high potential as shown on Anderson and others (1994), unless a more detailed analysis is done and the potential is found to be low.

Although Kaliser (1996) notes releases of water from Hobbs Reservoir could raise existing ground-water tables in the flood plain of Hobbs Creek, he does not address the potential for flooding. Lots 1-10 straddle the 100-year flood zone on Federal Emergency Management Agency (FEMA) (1982) maps. Development here must be in accordance with FEMA National Flood Insurance Program guidelines as adopted by Layton City. These lots may also be in the flood-inundation zone for possible failure of Hobbs Reservoir, which was not evaluated by Kaliser (1996). The inundation zone from failure of Hobbs Reservoir has been evaluated by the Utah Division of Water Rights, and the potential for flooding should be disclosed to future buyers of lots in the zone. Layton City Planning Department has a copy of this evaluation.

REFERENCES

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Applied Geotechnical Engineering Consultants, 1994, Geotechnical investigation, Canyon View Estates, 2800 North 2200 East, Layton, Utah: Midvale, Utah, unpublished consultant's report, 16 p.

Earthtec Testing & Engineering, 1996, Geotechnical study for Deer Valley subdivision plat C, Layton, Utah: Ogden, Utah, unpublished consultant's report, 14 p.

Federal Emergency Management Agency, 1982, Flood insurance rate map for Layton City, Davis County, Utah, panel 490047 0003 B: Federal Emergency Management Agency, National Flood Insurance Program, scale 1:6,000.

Kaliser, B.N., 1996, Geologic reconnaissance for Deer Valley Hollow subdivision, Layton, Utah: Salt Lake City, Utah, appendix of Geotechnical Study for Deer Valley subdivision, Earthtec Testing and Engineering, unpublished consultant's report, 8 p.

Lowe, Mike, 1989a, Landslide hazard map--Kaysville quadrangle: Davis County Planning Department unpublished map, scale 1:24,000.

---1989b, Slope failure inventory map--Kaysville quadrangle: Davis County Planning Department unpublished map, scale 1:24,000.

Solomon, B.J., 1995, Review of "Geotechnical investigation, Canyon View Estates, 2800 North 2200 East, Layton, Utah", *in* Mayes, B.H., compiler, Technical reports for 1994-1995 Applied Geology Program: Utah Geological Survey Report of Investigation 228, p. 146-148.

Project:			Requesting Agency:
Review of a geologic evaluation for Olympeak Estates along Snow Basin road, Weber County, Utah			Weber County Planning Commission
By: Bill D. Black	Date: 03-18-96	County: Weber	Job No: 96-12 (R-12)
USGS Quadrangle: Snow Basin [1344]		Number of attachments: None	

This report is a review of a geologic report (Kaliser, 1996) for Olympeak Estates along Snow Basin Road (SW1/4SW1/4 section 23 and NW1/4NW1/4 section 26, T. 6 N., R. 1 E., Salt Lake Base Line) in Weber County, Utah. Jim Gentry, Weber County Planning Commission, requested the review. The scope of work consisted of a literature review and examination of 1:24,000-scale aerial photos (1952). No field visit was made.

Kaliser (1996) identifies landsliding as a potential hazard at the property. The property consists of a northern parcel along Snow Basin Road and a southern parcel centered on a hilltop to the south, and is in colluvium and weathered bedrock of the Norwood Tuff (Kaliser, 1996). Kaliser (1996) shows a prehistoric landslide along the western edge of the northern parcel and a prehistoric landslide in the eastern portion of both parcels. Kaliser (1996) also mapped a small translational landslide near the northwestern corner of the southern parcel that he believes initiated in 1983 or 1984.

Kaliser (1996) identifies a historical landslide on the property and believes the eastern prehistoric landslide may potentially impact parts of both parcels. Although he does not state slopes are stable, he reports observing no evidence of active landsliding along Snow Basin Road or in the property and solely on this basis gives no recommendations for reducing the risk of landsliding. I believe the lack of evidence for active landsliding does not sufficiently demonstrate long-term slope stability. Aerial photos taken in 1952 and geologic maps by Harty (1992) and Mike Lowe (unpublished Utah Geological Survey [UGS] map of Ogden Valley) show numerous landslides in the Norwood Tuff in the area. My measurements (from 1:24,000-scale topographic maps) of failed slopes near the property in the Norwood Tuff show they are as gentle as 15 percent. The plat map for Olympeak Estates (I3 Design Studios, 1995) indicates much of the property has slopes greater than 15 percent, which may be unstable. In addition, existing slope stability could be reduced by introduction of water into the ground by septic-tank soil-absorption (STSA) systems, site grading, and drainage modifications. Therefore, I believe the landslide hazard has not been adequately addressed. Kaliser (1996) must either clearly state that he believes slopes at the property are stable and suitable for the proposed development (backed up by additional supporting evidence), recommend where development may proceed at acceptably low levels of risk by delineating potentially unstable areas, or propose other measures to reduce the risk as needed.

Kaliser (1996) also identifies hazards from earthquake ground shaking, flooding, and erosion at the property. The property is located in Uniform Building Code seismic zone 3, and Kaliser (1996) recommends all structures be designed and constructed in accordance with seismic zone 3 requirements for earthquake-resistant design. This recommendation meets state and local government minimum requirements for reducing ground-shaking hazards. Kaliser (1996) indicates a culvert under Snow Basin Road at the north end of the project is blocked, potentially causing flooding in this area. He recommends removing the debris and maintaining the culvert to allow free flow of runoff off the property. I concur with this recommendation. Kaliser (1996) also recommends controlling runoff from the subdivision road to reduce erosion in the northeastern part of the property. I concur, but add that erosion may also occur in other parts of the property (and possibly reduce stability of adjacent slopes) if extensive site modifications are made. Runoff should be directed away from nearby homes, and care should be taken that site modifications and grading do not promote erosion or reduce stability of slopes at the property. If extensive site modification and grading is planned, I recommend the plans be reviewed by a geotechnical engineer.

A potential hazard not addressed by Kaliser (1996) is expansive-clay soils. These soils are common in the Norwood Tuff and were found at a nearby homesite (Earthtec Testing and Engineering, 1996). Carley and others (1980) indicate much of the property has a "severe" limitation for dwellings without basements from expansive-clay soils. Changes in moisture content cause these soils to shrink and swell, possibly damaging building foundations, roads, and STSA systems. I recommend a soil-foundation investigation be performed prior to construction to address the potential for these soils and recommend appropriate foundation (and drainage system) designs.

Kaliser (1996) reports that test holes near the property show encouraging results for finding suitable conditions for STSA systems. However, Carley and others (1980) indicate clayey soils in much of the property that have a "severe" limitation for these systems from steep slopes and low percolation rates. Swelling clay in these soils can further reduce permeability and damage STSA systems. Bedrock may also be shallow over much of the area. I recommend suitability for STSA systems be addressed in subsequent studies.

REFERENCES

Carley, J.A., Jensen, E.H., Campbell, L.B., Barney, Marvin, Fish, R.H., and Chadwick, R.S., 1980, Soil survey of Morgan area, Morgan County and eastern part of Weber County, Utah: U.S. Department of Agriculture, Soil Conservation Service and Forest Service, in cooperation with Utah Agricultural Experiment Station, 300 p.

Earthtec Testing and Engineering, 1996, Geologic evaluation of a building lot off Snow Basin Road, Weber County, Utah: Ogden, Utah, unpublished consultant's report, 6 p.

Harty, K.M., 1992, Landslide map of the Ogden 30' x 60' quadrangle, Utah: Utah Geological Survey Open-File Report 247, scale 1:100,000, 11 p.

Kaliser, B.N., 1996, Geologic evaluation for Olympeak Estates along Snow Basin Road, Weber County, Utah: Salt Lake City, Utah, unpublished consultant's report, 8 p.

I3 Design Studios, 1995, Preliminary plan package for Olympeak Estates residential development located in Weber County, Utah, sheet 3: Park City, Utah, unpublished consultant's report, scale 1:1,200.

Project:			Requesting Agency:
Review of "Addendum, slope stability evaluation, proposed Tyler Ridge condominium development at approximately 1910 South 1275 East, Ogden, Utah."			Ogden City Planning Division
By: Bill D. Black	Date: 03-28-96	County: Weber	Job No: 96-13 (R-13)
USGS Quadrangle: Ogden (1345)		Number of attachments: None	

This report is a review of an addendum (AGRA Earth & Environmental, 1996) to a slope-stability evaluation (AGRA Earth & Environmental, 1995) for the proposed Tyler Ridge condominium development at approximately 1910 South 1275 East (NW1/4NW1/4 section 27, T. 6 N. R. 1 W., Salt Lake Base Line), Ogden, Utah. Korvin Snyder (Planner, Ogden City Planning Division) requested the review. The scope of work consisted of a literature review and discussion with M. Hylland, Utah Geological Survey, who reviewed the original report (Hylland, 1996).

AGRA Earth & Environmental (1995) identified a landslide at the site, and recommended a 15-foot (5-m) set back from the main scarp based on a 2:1 slope projection from the toe of the steepest slope segment in this area. This set-back distance was significantly less than a 100-foot set back recommended by Dames and Moore (1979) for a nearby site bordering the landslide, which was based on slope geometry of the landslide and failure-surface projections for a hypothetical rotational failure. Hylland (1996) believed the 15-foot set back was not prudent unless site-specific geologic data and analyses were submitted to support it.

AGRA Earth & Environmental (1996) and Hylland (1996) agree that the risk from landsliding is lower at the Tyler Ridge site than at the Dames & Moore (1979) site because the scarp is smaller and slopes are more gentle. Because the risk from landsliding is lower at Tyler Ridge, AGRA Earth & Environmental (1996) believes site-specific geologic data and analyses are not needed. In addition, proposed structure locations at Tyler Ridge are at least 30 feet (9 m) from the main scarp, which is farther than the 15-foot (5-m) set back recommended in AGRA Earth & Environmental (1995). Therefore, AGRA Earth & Environmental (1996) believes exposure to the landslide hazard has been adequately reduced. Although AGRA Earth & Environmental (1996) presents no new geologic data, its presumed soil types and ground water levels generally agree with data presented in studies of nearby sites (Gaea Corporation, 1977; Dames & Moore, 1979). However, actual soil and ground-water conditions at the property remain unknown.

I agree with AGRA Earth & Environmental (1996) that the risk of landsliding has been reduced (but not eliminated). As long as the development procedes as proposed (all structures at least 30 feet [9 m] from the main scarp), the risk may be sufficiently low. However, slope stability is highly dependent on ground-water conditions (which are unknown). Locally high perched ground-water levels may be present, and subsequent landscape irrigation could also cause locally high levels. Therefore, I recommend that the existence of these reports and reviews be disclosed to future buyers. I also recommend that steps be taken to ensure that the consultant's recommendations are followed. Care should also be taken that site modifications and grading do not promote erosion or reduce stability of slopes at the site, and drainage should be directed away from the landslide and nearby homes and lots. I recommend that site drainage plans, and plans for any significant site modifications or grading, be reviewed by a geotechnical engineer.

REFERENCES

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

----1996, Addendum, slope stability evaluation, proposed Tyler Ridge condominium development at approximately 1910 South 1275 East, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

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

Gaea Corporation, 1977, Geological investigation of slope stability for the Canyon Cove apartment project, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 47 p.

Hylland, M.D., 1996, Review of "Report, slope stability evaluation, proposed Tyler Ridge condominium development at approximately 1910 South 1275 East, Ogden, Utah", *in* Mayes, B.H., editor, Technical reports for 1994-1995 Applied Geology Program: Utah Geological Survey Report of Investigation 228, p. 149-151.

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:			Requesting Agency:
Review of "Engineering geology site reconnaissance, single-family residential lot 357 on Tree Top Lane, Timber Lakes subdivision, Wasatch County, Utah."			Wasatch County
By: Bill D. Black	Date: 04-01-96	County: Wasatch	Job No: 96-14 (R-14)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

This report is a review of an engineering-geology report for residential lot 357 on Tree Top Lane (NW1/4NE1/4 section 9, T. 4 S., R. 5 E. Salt Lake Base Line), Timber Lakes subdivision, Wasatch County, Utah (AGRA Earth & Environmental, 1996). Robert Mathis, Wasatch County Planner, requested the review. The scope of work included a literature review and examination of 1:40,000-scale aerial photos (1987). No field visit was made. I have only reviewed sections of the report dealing with geologic hazards. Sections discussing foundation and drainage-system designs, site modification, and grading should be reviewed by a geotechnical engineer.

AGRA Earth & Environmental (1996) identifies earthquake ground shaking as a potential hazard at the property and recommends all structures be designed and constructed in accordance with Uniform Building Code (UBC) seismic zone 3 requirements. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. I concur with AGRA Earth & Environmental's (1996) assessment that the potential for active faulting and liquefaction at the property is low.

AGRA Earth & Environmental (1996) also identifies landsliding as a hazard at the property, and observed evidence of past landsliding on steep slopes bordering Lake Creek to the northeast. The property is centered on a low knoll between Clyde Lake to the west and Lake Creek to the north, on slopes up to 20 percent grade underlain by Quaternary glacial till (AGRA Earth & Environmental, 1996). Scarps from a prehistoric landslide and a young landslide (1985 or 1986) are in the northeastern part of the property (attachment 1), and AGRA Earth & Environmental (1996) believes the young landslide is potentially active and therefore unstable. I concur with their assessment, and add that the relative age and position of these scarps suggests active failure may be migrating southward farther into the property. Hylland and Lowe (1995) show the entire property is on a larger, older prehistoric landslide, which is within yet another, larger, ancient landslide that encompasses much of the Timber Lakes subdivision (attachment 1). The stability of these older landslides is unknown.

To reduce the risk from potential slope failures associated with the young scarp, AGRA Earth & Environmental (1996) recommends structures be set back at least 20 feet (6 m). This set back is equivalent to a 3.3:1 to 4:1 slope projection, which is more conservative than the minimum 3:1 slope recommendation by Earthstore (1988) for other areas in the subdivision

(AGRA Earth & Environmental, 1996). The proposed structure will be located in the southeastern part of the lot beyond the 20-foot (6-m) scarp set-back line. Therefore, AGRA Earth & Environmental (1996) believes the risk of landsliding has been adequately reduced. I agree that this set back reduces the risk from slope failure on the young scarp, but it does not consider overall stability of the older landslides beneath the property or the potential for continued southward migration of the active failure into the property. Although I believe evaluating stability of the old landslides is beyond the scope of work for this single lot, a landslide hazard still exists at the property and I recommend disclosing the existence of the landslides, the AGRA Earth & Environmental (1996) report, and this review to all potential future buyers. I also recommend that the Timber Lakes subdivision and Wasatch County consider a larger multi-lot study of the old landslides to evaluate their long-term stability.

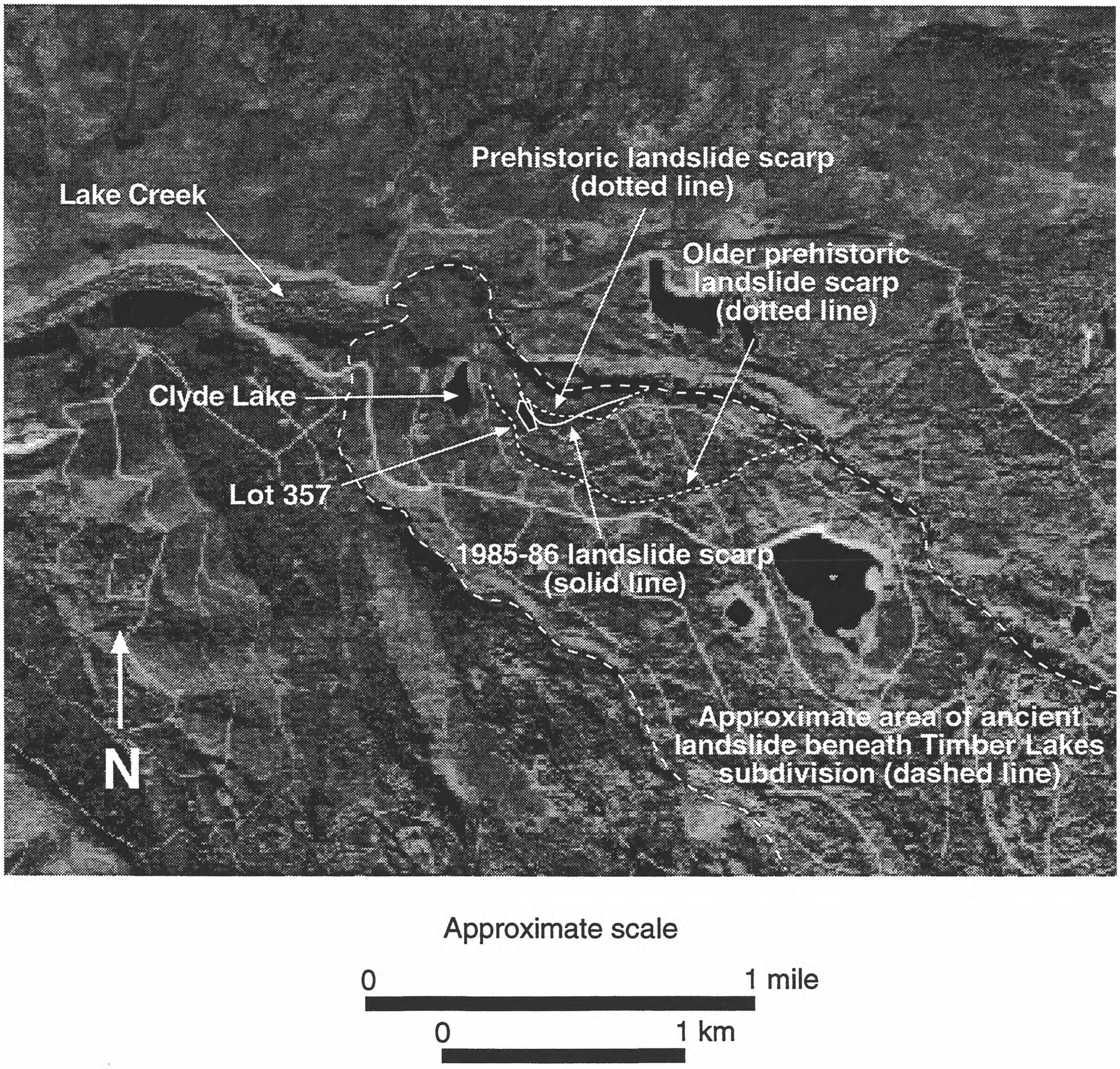
AGRA Earth & Environmental (1996) also recommends locating septic-tank soil-absorption fields to direct effluent away from the active landslide, grading to direct water away from the landslide, and no site modifications northeast of the scarp set-back line. I concur with these recommendations. Care should also be taken that site modifications and grading do not reduce stability of slopes beyond (southwest of) the set-back line and that water is directed away from nearby homes and lots. I recommend that plans for any significant site modifications or grading be reviewed by a geotechnical engineer.

REFERENCES

AGRA Earth & Environmental, 1996, Engineering-geology site reconnaissance for single-family residential lot 357 on Tree Top Lane, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Earthstore, 1988, Report--Geotechnical/engineering geology study for plats 19A, 19B, 20A, and 20B, Timber Lakes development located approximately seven miles east of Heber, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 13 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard plate 1D, *in* Hylland, M.D., editor, Engineering Geology Map Folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.



Attachment 1. Air-photo map of landslides possibly affecting Lot 357 at the Timber Lakes subdivision, Wasatch County, Utah (modified from Hylland and Lowe, 1995; and AGRA Earth & Environmental, 1996).

Project: Review of report "Geotechnical evaluation for a building lot at 217 North Polk Street, Ogden, Utah."			Requesting Agency: Ogden City Community Development
By: Bill D. Black	Date: 04-08-96	County: Weber	Job No: 96-15 (R-15)
USGS Quadrangle: North Ogden (1370)		Number of attachments: None	

This report is a review of a geotechnical report and addendum (Earthtec Testing & Engineering, 1996) for a building lot in the East Ridge subdivision at approximately 217 North Polk Street (NW1/4NW1/4 section 15, T. 6 N., R. 1 W., Salt Lake Base Line) in Ogden, Utah. Doug Smith, Inspection Services Manager for Ogden City Community Development Department, requested the review. The scope of work consisted of a literature review and examination of 1:24,000-scale aerial photos (1985). No site visit was made. I have reviewed only sections discussing geologic hazards. Sections discussing foundation and drainage-system designs should be reviewed by a geotechnical engineer.

Earthtec Testing & Engineering (ET&E) (1996) identifies earthquake ground shaking as a potential hazard at the lot, and recommends all structures be designed and constructed according to Uniform Building Code (UBC) seismic zone 3 standards using a site coefficient of 1.2. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. In an earlier study for the subdivision, Dames & Moore (D&M) (1976) identified a potential hazard from surface fault rupture, which is not addressed by ET&E (1996) for the lot. The main trace of the Wasatch fault zone crosses the lot from southeast to northwest (D&M, 1976; Lowe, 1988b). To reduce the risk from surface fault rupture, D&M (1976) recommended a "construction exclusion corridor" west of the fault where no building should take place. However, neither D&M (1976) or ET&E (1996) performed studies to identify areas of fault deformation to define this corridor. Deformation may extend east of the fault, and the lot is in the surface-fault-rupture special-study zone on Weber County Planning Commission maps (Lowe, 1988b). Present Ogden City ordinances also mandate that new structures be at least 50 feet (15 m) away from an active fault trace (Mike Lowe, Utah Geological Survey, verbal communication, April 1996). The risk from surface faulting has not been addressed for this lot, and I recommend trenching of at least the proposed building foundation prior to construction to identify areas of fault deformation. Faults and zones of deformation should also be defined in the remainder (undeveloped parts) of the subdivision prior to construction.

ET&E (1996) identifies a potential risk from landsliding at the lot, but observed no evidence of major slope instability. However, they indicate visual observation has limited value because of site disturbance, and clearly state that they did not evaluate overall stability of the lower slope. Although ET&E (1996) recommends such an evaluation, their addendum report cites the D&M (1976) report which concluded the risk from landsliding in the subdivision was "improbable". ET&E (1996) presumably therefore believes the D&M (1976) report qualifies as the evaluation. However, Lowe (1988a) shows an active landslide which occurred in the mid-1980s roughly 200 feet (61 m) northwest of the lot. Because the recent landslide initiated in a slope that D&M (1976) considered stable, I believe slope stability should be re-evaluated (particularly because future instability may impact not only this lot but also adjacent lots).

Ground water plays a critical role in slope stability. Although ET&E (1996) indicates no evidence of shallow ground water, seasonal water-table variations, poor site drainage, and landscape irrigation could cause locally high levels that reduce slope stability. ET&E (1996) recommends maintaining proper drainage to avoid ponding of water on the slope that could cause slope instability, and I concur. Care should also be taken to ensure that site modifications, grading, and landscape irrigation do not reduce stability of slopes adjacent to the lot, and to direct surface water away from the active landslide and nearby homes.

ET&E (1996) recommends using rock retainage on cut slopes steeper than 2:1 (horizontal to vertical) up to 12 feet (4 m) high; design specifications for rock-retained slopes are given in the report. However, in at least one case along the Wasatch Front, rocks placed to protect high, steep slopes have become broken and dislodged. The rocks may also be dislodged if subjected to ground shaking during earthquakes, or if underlying soils become unstable from moisture or other causes (Brian Bryant, Salt Lake County Geologist, verbal communication, December 1994). Dislodged or broken rocks could pose a hazard to homes downslope. Any recommendations regarding cut-slope stability, particularly for 2:1 or steeper slopes and rock-retaining structures, should be reconsidered in further, more detailed, slope-stability analyses.

REFERENCES

Dames & Moore, 1976, Report of initial engineering geology study for the proposed East Ridge subdivision development area, Ogden Utah: Salt Lake City, Utah, unpublished consultant's report, 8 p.

Earthtec Testing & Engineering, 1996, Geotechnical evaluation for a building lot at 217 North Polk Street, Ogden Utah: Orem, Utah, unpublished consultant's report dated January 12, 1996, 4 p., and addendum dated February 16, 1996, 2 p.

Lowe, Mike, 1988a, Landslide hazard map, North Ogden quadrangle: unpublished Weber County Planning Commission map, scale 1:24,000.

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

Project:			Requesting Agency:
Review of "Landslide reconnaissance of lot 223, Timber Lakes Estates, Wasatch County, Utah."			Wasatch County
By: Bill D. Black	Date: 05-01-96	County: Wasatch	Job No: 96-16 (R-16)
USGS Quadrangle: Center Creek (1126)		Number of attachments: None	

This report is a review of an engineering-geology report for lot 223 on Lake Pines Road (NW1/4NW1/4 section 9, T. 4 S., R. 5 E., Salt Lake Base Line), Timber Lakes Estates, Wasatch County, Utah (Klauber, 1996). Robert Mathis, Wasatch County Planner, requested the review. The scope of work included a literature review and examination of 1:20,000-scale aerial photos (1962). No field visit was made.

Klauber (1996) identifies landsliding as a potential hazard at the lot. An old deep-seated landslide may encompass much of the lot, and several small, shallow surficial slides are in steep slopes at the lot (Klauber, 1996). The lot is also on the edge of a larger, older landslide that encompasses much of the Timber Lakes subdivision (Hylland and Lowe, 1995). No surficial evidence of active deep-seated landsliding was observed (Klauber, 1996). The lot is on steep (29 to 40 percent) slopes in glacial moraine deposits, and is in an area of high landslide-hazard potential (Hylland and Lowe, 1995; Klauber, 1996). Landslides in glacial moraines at Timber Lakes are commonly found in slopes greater than 25 percent (Hylland and Lowe, 1995). Based on this, Klauber (1996) believes landsliding is a significant hazard and steep slopes at the lot require care in development. I concur with his assessment.

To reduce the potential for landsliding, Klauber (1996) recommends minimizing site modifications and grading that could adversely impact stability of slopes at the lot, and using retaining walls and drainage systems to maintain stability of cut and fill slopes. I concur with his recommendations. Although Klauber (1996) gives some general foundation, drainage-system, and retaining-wall recommendations in his reconnaissance-level investigation, I recommend a detailed geotechnical investigation to provide data on which to base final designs. These investigations address stability of cut and fills, but do not evaluate overall stability of natural slopes and the the old landslide at the lot (which is unknown). I agree with Klauber (1996) that a more quantitative slope-stability analysis may be needed to evaluate overall stability. I recommend at least Klauber's (1996) first study level (quantitative analyses based on estimated soil properties, p. 8), and each successive study level if the previous level indicates instability or marginal stability.

Although Klauber (1996) only addresses landslides hazards, earthquake ground shaking is also a potential hazard at the lot. The lot is located in Uniform Building Code seismic zone 3, and all structures should be designed and constructed (at a minimum) in accordance with seismic zone 3 requirements for earthquake-resistant design.

REFERENCES

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard plate 1D, *in* Hylland, M.D., editor, Engineering geology map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

Klauber, William, 1996, Landslide reconnaissance of lot 223, Timber Lakes Estates, Wasatch County, Utah: West Jordan, Utah, unpublished consultant's report, 10 p.

Project: Review of a geologic-hazard study for lot 23, Pole Patch subdivision, Pleasant View, Utah.			Requesting Agency: Pleasant View City
By: Bill D. Black	Date: 05-14-96	County: Weber	Job No: 96-17 (R-17)
USGS Quadrangle: North Ogden (1370)		Number of attachments: None	

This report is a review of a geologic-hazard study (Delta Geotechnical Consultants, 1995) for lot 23 in the Pole Patch subdivision (SE1/4NW1/4 section 17, T. 7 N., R. 1 W., Salt Lake Base Line) in Pleasant View, Utah. Terri Cragun, Community Development Coordinator for Pleasant View City, requested the review. The scope of work consisted of a literature review. I have only reviewed sections discussing geologic hazards. Sections discussing foundation and retaining-wall design, and site grading should be reviewed by a geotechnical engineer.

Delta Geotechnical Consultants (Delta) (1995) identifies earthquake ground shaking as a potential hazard at the lot. To reduce the risk from earthquake ground shaking, Delta (1995) recommends that structures be designed and constructed according to Uniform Building Code (UBC) seismic zone 3 standards. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. The main trace of the Wasatch fault zone is roughly 400 feet (122 m) northeast of the lot, and Delta (1995) believes the hazard from surface fault rupture is low and I agree.

Delta (1995) also identifies debris flows and floods as potential hazards. Canyon No. 3, roughly 1,000 feet (305 m) to the north of the lot, could produce sufficiently large debris flows or floods that may impact the lot (Delta, 1995). Delta (1995) believes this canyon experienced a large debris-flow event about 70 years ago based on evidence of scouring and lichen growth, and estimates that the canyon experiences such an event roughly every 1,000 years. Therefore, Delta (1995) believes the hazard from debris flows is low. The lot is not on the modern alluvial fan from Canyon No. 3, but rather, on an older inactive pre-Lake Bonneville alluvial fan to the south (Personius, 1990), which supports Delta's (1995) conclusion that the hazard from debris flows is low. To contain or avoid possible floods and thus reduce the risk from flooding, Delta (1995) recommends minimum channel-size requirements, setbacks, and channel maintenance following any deposition. I concur with these recommendations. Delta (1995) observed no evidence of landslides or rock falls and believed the potential for these hazards at the lot is low.

I believe the report adequately assesses geologic hazards at the lot, and gives prudent recommendations that should be followed. I recommend that the Delta (1995) report and this review be disclosed to all potential buyers.

REFERENCES

Delta Geotechnical Consultants, 1995, Geologic hazards study for Pole Patch Subdivision Phase I and Phase II, Pleasant View, Utah: Salt Lake City, Utah, unpublished consultant's report, 38 p.

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 Survey Map I-1979, scale 1:50,000.

Project:			Requesting Agency:
Review of a geologic-hazards report for the proposed Burch Creek Estates subdivision, Ogden, Utah			Ogden City Planning Division
By: Francis X. Ashland	Date: 6-25-96	County: Weber	Job No: 96-18 (R-18)
USGS Quadrangle: Ogden (1345)		Number of attachments: none	

INTRODUCTION

At the request of Korvin Snyder, Ogden City Planning Division, I reviewed a report on the geologic hazards for the proposed Burch Creek Estates subdivision (AGRA Earth &Environmental, Inc. [AGRA], 1996). The proposed subdivision is in the W1/2 section 14, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian. The scope of the work for this review included inspection of published geologic maps and Weber County Planning Division geologic-hazards maps. I performed no field inspection of the property.

GEOLOGIC HAZARDS

The AGRA (1996) report identifies surface fault rupture, debris flows, and landslides as potential hazards at the property and gives recommendations to reduce earthquake ground-shaking hazards. I believe that a potential hazard not addressed in the report is alluvial-fan flooding.

Earthquake Hazards

The AGRA (1996) report indicates that surface fault rupture has occurred at the property on the main and secondary traces of the Weber segment of the Wasatch fault zone as recently a 500 to 1,000 years ago, and I concur. AGRA identifies four fault traces on the property. The main trace of the Weber segment and a nearby secondary sympathetic trace bisect the property and trend roughly northwest. Two antithetic secondary traces cross the southwestern corner of the property. Because these faults offset deposits that are younger than 10,000 years old, AGRA classifies these faults as active, and I concur.

AGRA believes that the required 50-foot setback from the fault traces for occupied structures is excessive because their trenches have located the fault traces that have a history of displacement and could cause damage. Trench logs (figures 3B, 3C, 4A, and 5 A) in the AGRA (1996) report show local zones of backtilting, defined by inclined geologic contacts, that extend as much as 30 to 130 feet from the fault traces. Structures that cross the hinge line or are in the area of the backtilted sediments could be damaged as a result of further backtilting during a surface rupture event. Backtilting will cause a change in grade and backtilted sediments may undergo extension that could cause ground fissures and damage to the structures. I recommend that either AGRA's recommended fault setbacks be increased on downthrown sides of faults to account for backtilting, or that backtilted zones be defined separately and avoided because of the potential for property damage. Such setbacks appear to render lots 1 and 7 unbuildable. Evidence for ending the antithetic fault at the edge of lot 2 also needs to be presented.

AGRA recommends building to seismic zone 3 standards to help reduce losses in a moderate to strong earthquake, and I concur.

Debris Flows

The AGRA (1996) report indicates that the northern part of the property is underlain by debris-flow deposits but concludes that a debris flow is "unlikely." AGRA bases their conclusion on observations that show the upper debris-flow deposits, which record the most recent debris flow, predate the latest surface-rupture event (about 500-1,000 years ago). AGRA believes the thickness of the soil "A" horizon in these deposits also supports their inferred age of the most recent debris flow. I concur that AGRA's observations show that the most recent debris flow happened over 500 to 1,000 years ago, however, in my opinion elapsed time since the last debris flow and the resulting assumed long recurrence interval between debris flows is not sufficient to classify the hazard as "unlikely." I believe that additional studies to determine the characteristics of the Burch Creek drainage basin upslope of the property are required to assess the potential debris-flow hazard. Although AGRA concludes that in the event of a debris flow on the property, "it would be largely confined to the Burch Creek stream channel in lots 17 and 22," no evidence regarding channel capacity and flow volumes is given to support this conclusion. AGRA's trench logs T-3E and T-3W located on the northern boundary of lots 16 and 21, respectively show evidence for multiple debris flows south of the channel and lots 17 and 22. The AGRA (1996) report also does not address the potential for alluvial-fan flooding on the property and the capacity of channels to contain flows.

Landslides

The AGRA (1996) report indicates no evidence of landslides on the property on the basis of a site reconnaissance and analysis of air photographs. Nelson and Personius (1993), however, mapped landslide deposits and a landslide headscarp on the property. According to their mapping, the landslide deposits underlie the majority of lot 11 upslope of the main trace of the Weber segment. AGRA concludes the possibility of landsliding is "remote," but does not specifically discuss the landslide mapped by Nelson and Personius (1993) in the report. Although AGRA's conclusion is partly based on soil descriptions from the trenches, no trenching was done within the bounds of the landslide deposit shown by Nelson and Personius (1993). I recommend that, at a minimum, a lot-specific study to determine the potential for landsliding on lot 11 be performed.

SUMMARY

The AGRA (1996) report addresses surface-fault-rupture, debris-flow, and landslide hazards at the property. AGRA identifies four fault traces on the property, including the main and secondary traces of the Weber segment of the Wasatch fault zone, and concludes that these are active faults which underwent surface rupture in the last 500 to 1,000 years. AGRA's recommended setbacks do not account for the potentially damaging surface effects of backtilting in the fault zone. I therefore recommend that AGRA's setbacks be increased to account for backtilting, or that areas of backtilting be defined and avoided. Additional investigations may be necessary to define setbacks on lots 2 and 3.

AGRA identifies debris-flow deposits in the northern part of the property that it concludes pre-date the most recent surface fault rupturing, and I concur. However, I do not believe evidence is sufficient to conclude a debris flow is "unlikely," based solely on an inferred elapsed time and debris-flow recurrence interval and not on the upslope characteristics of the Burch Creek drainage basin. AGRA also does not address the potential for alluvial-fan flooding nor document its conclusion that a debris flow would be largely contained in the drainage that crosses lots 17 and 22. The latter conclusion appears to be contradicted by evidence for multiple debris-flow events in AGRA's trenches in the northern part of the property.

In addition, although AGRA concludes that the possibility of landsliding is "remote," the report does not discuss landslide deposits and scarps mapped by Nelson and Personius (1993) on lot 11 of the property. I recommend that a lot-specific investigation be conducted on lot 11 to assess the landslide hazard.

REFERENCES

AGRA Earth & Environmental, Inc., 1996, Fault rupture hazard evaluation - proposed Burch Creek Estates subdivision - West ½ section 14, T5N, R1W, SLB & M, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 10 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, 22 p., scale 1:50,000.

Project:			Requesting Agency:
Review of a geotechnical and landslide-hazard report for the proposed Green Hill Country Estates Phase VI, Weber County, Utah			Weber County Planning Commission
By: Francis Ashland	Date: 7-2-96	County: Weber	Job No: 96-19 (R-19)
USGS Quadrangle: Browns Hole (1368)		Number of attachments: none	

INTRODUCTION

At the request of Jim Gentry, Weber County Planning Commission, I reviewed geologic-hazard portions of a geotechnical and landslide-hazard report for the proposed Green Hill Country Estates Phase VI (Applied Geotechnical Engineering Consultants, Inc. [AGEC], 1996). The proposed subdivision is in the SE1/4 section 4 and the N1/2 section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian. The scope of work included a review of unpublished geotechnical data. I performed no field inspection of the property.

LANDSLIDES

The AGEC (1996) report indicates landsliding on the property of clay soils in road cuts with slopes exceeding 3.5:1 (horizontal:vertical). AGEC speculates four existing landslides were triggered by a reduction in strength when soils became wet during infiltration of runoff in spring 1995. In addition, AGEC infers that increases in slope angle due to road cuts may also have contributed to the failures. AGEC recommends lower final cut-slope angles for the soil types at the property and upslope surface drainage that I believe will reduce the likelihood of future landsliding. AGEC also recommends several options for stabilization of the four existing landslides (AGEC, figure 2) including excavation and replacement, regrading to flatter slopes, and regrading to present slope angles in combination with subsurface interceptor drains. I believe these recommendations are adequate to stabilize existing landslides as long as construction is carefully monitored. AGEC's assessment of the landslide hazard at the property is thorough, well documented, and supported by laboratory testing and field observations.

OTHER GEOLOGIC HAZARDS

The AGEC (1996) report lists or makes recommendations to reduce losses from other potential geologic hazards, including expansive soils, shallow ground water, and earthquake ground shaking. AGEC indicates local expansive clay soils on the property that swell upon wetting to nearly 3 percent while under a load of 1 ksf. Because consolidation tests were performed on only two samples, the extent of expansive soils and their maximum swell potential are not well known. AGEC recommends shallow spread footings on "natural undisturbed soil or... compacted structural fill." To reduce foundation heave, AGEC recommends measures to reduce the chance of wetting expansive soils near structures including site grading, installation of underdrains, and a precaution regarding irrigation. AGEC also recommends that a geotechnical engineer observe all footing excavations to identify whether expansive soils are present in the subgrade, and I strongly concur. However, AGEC provides no specific foundation recommendations in the event that expansive soils are present beneath footings. I believe that such lot-specific foundation recommendations should be provided wherever expansive soils are encountered in the foundation subgrade. AGEC indicates that, "ideally", expansive soils beneath floor slabs should be excavated and replaced with structural fill. In addition, AGEC recommends "positive joints" between floor slabs and bearing walls that allow the slab to heave independently, and a perimeter "positive drainage system." Although AGEC's foundation and floor slab recommendations may be adequate, my experience indicates that spread footings and slab-on-grade are not conservative designs for areas with expansive soils. Elsewhere in Utah, expansive soils exhibiting similar amounts of swell under a load of 1 ksf have caused building distress or heave. Also, although AGEC's grading, drainage, and irrigation recommendations would, if properly implemented, reduce the potential for damage to structures, they do not address the potential damage to roads, other paved areas, and buried utilities. Because of the complexity of AGEC's recommendations and the difficulties in implementation, I believe that some damage to structures as well as roads, utilities, and paved areas should be anticipated.

The AGEC (1996) report indicates no ground water in any excavation to a depth of 7 feet. However, because the excavations were made in November, ground-water levels may have been at or near a seasonal low and may not be representative of other times of the year. AGEC indicates shallow perched ground-water conditions are possible during times of runoff or snowmelt and recommends an underdrain system that, if implemented, should be adequate to deal with post-construction shallow ground water. For construction during the late winter or spring, shallow ground water may be encountered during homesite excavation.

AGEC recommends building to seismic zone 3 standards to help reduce losses from ground shaking in a moderate to strong earthquake, and I concur.

SUMMARY

AGEC's assessment of landsliding at the property is thorough and well documented, and I concur with its conclusions and recommendations related to this hazard. AGEC's surface grading, drainage, irrigation, and "positive-joint" system recommendations are reasonable to reduce problems from expansive soils but assuring that they are followed will be difficult. AGEC's recommendation to observe footing excavations to identify expansive soils is adequate, provided lot-specific foundation recommendations are given wherever expansive soils are found in the foundation subgrade. AGEC does not address the potential for damage to roads, utilities, and paved areas, and further assessment of the extent of expansive soils on the property may be necessary to address this issue. I concur with other recommendations to reduce losses from shallow ground water and earthquake ground shaking.

REFERENCE

Applied Geotechnical Engineering Consultants, Inc., 1996, Geotechnical and landslide study - Green Hill Country Estates Phase VI, part of sections 4 and 9, T6N, R2E SLB&M - Weber County, Utah: Midvale, Utah, unpublished consultant's report, 21 p.

Project: Review of "Engineering geologic site investigation - lot 855, Timber Lakes subdivision, Wasatch County, Utah."			Requesting Agency: Wasatch County
By: Francis Ashland	Date: 7-8-96	County: Wasatch	Job No: 96-20 (R-20)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

INTRODUCTION

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geologic-hazard report (Great Basin Earth Science, Inc. [GBES], 1996) for a proposed homesite in the Timber Lakes subdivision. The proposed homesite is located in lot 855 in the NE1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The scope of work included a review of published geologic-hazard maps. I performed no field inspection of the property.

GEOLOGIC HAZARDS

The GBES (1996) report lists earthquakes, surface-water runoff, shallow ground water, and landslides as possible geologic hazards at the property. In my opinion this is an accurate and complete list of the potential geologic hazards at the site.

GBES indicates that there are no active faults near the lot, but that earthquake ground shaking is possible at the site as the result of a moderate or larger earthquake on a more distant fault. GBES indicates the lot is in seismic zone 3 of the Uniform Building Code but does not specifically recommend building to these standards to help reduce losses from earthquake ground shaking. In addition, GBES indicates that because underlying glacial deposits are well graded, the likelihood of liquefaction at the lot is low. GBES does not, however, address the possibility of earthquake-induced landsliding at the lot. I generally concur with GBES' recommendations and conclusions related to earthquake hazards at the lot.

The GBES (1996) report indicates the potential for surface-water-runoff and shallow ground-water hazards. GBES recommends avoiding low-lying areas and swales when selecting the homesite and site grading to reduce impacts from surface-water runoff. Also, GBES recommends avoiding disturbance to soils and vegetation to reduce excessive soil erosion during construction. GBES indicates that ground water was greater than 8 feet deep at the time of the site visit, but cautions that seasonal fluctuations in ground-water levels are possible. GBES recommends that drainage-control measures be considered if the home will have parts that are below grade. Although, GBES recommendations are generalized, I believe they should reduce potential problems related to these hazards if adequately implemented.

GBES indicates that the lot is located on a landslide (attachment 1), called the Pine

Ridge landslide by Hylland and Lowe (in preparation), that is not known to have moved in historic time and forms the steep slope south and west of the lot. The Pine Ridge landslide is located in an area of older landsliding underlying much of Timber Lakes identified by both GBES and Hylland and Lowe (1995) (attachment 1). A 1985-86 landslide, which affected cabins north of Pine Ridge Road, formed at the toe of the Pine Ridge landslide (attachment 1). GBES indicates no evidence that suggests the part of the Pine Ridge landslide underlying lot 859 is active. Although a quantitative assessment of the stability of the Pine Ridge is probably beyond the scope of a lot-specific study, I believe that the qualitative observation that the landslide is not active provides little assurance against future movement. GBES makes no conclusions regarding the potential for or likelihood of reactivation of this landslide, or the effect it may have if reactivated.

GBES describes two ridge-like features on the lot that I believe may indicate past landslide-related deformation. These ridges are about 5 feet high and roughly 150 and 250 feet long, and oriented nearly perpendicular to the landslide scarp. Although GBES makes no conclusion regarding the origin of these ridges, I believe they may be pressure ridges because their trend is compatible with the inferred direction of compression in the upper part of the Pine Ridge landslide. If these features are pressure ridges, then they may reactivate if the Pine Ridge landslide reactivates and cause local deformation on the lot, in addition to the other deformation typically associated with landsliding. I recommend, given the uncertainties, setbacks from the ridges be considered in siting structures on the lot to reduce the possibility of damage if the landslide becomes active in the future.

SUMMARY

In my opinion, recommendations in the GBES (1996) report related to earthquakes, surface-water runoff, and shallow ground water are adequate and will likely reduce losses or problems from these potential hazards, provided construction is to UBC seismic zone 3 standards. GBES' assessment of the landslide hazard at the lot indicates that the lot is located on the Pine Ridge landslide. GBES concludes that no evidence indicates this landslide is active, and I agree. However the report does not address the potential for reactivation or present evidence that the landslide will not reactivate. Although quantitative assessment of the stability of the Pine Ridge landslide is probably beyond the scope of a lot-specific study, I believe there is a possibility for movement in the future, particularly in the event of moderate or strong earthquake ground shaking. I recommend that, at a minimum, the potential for reactivation of the Pine Ridge landslide and the existence of this report and review be disclosed to potential homebuyers.

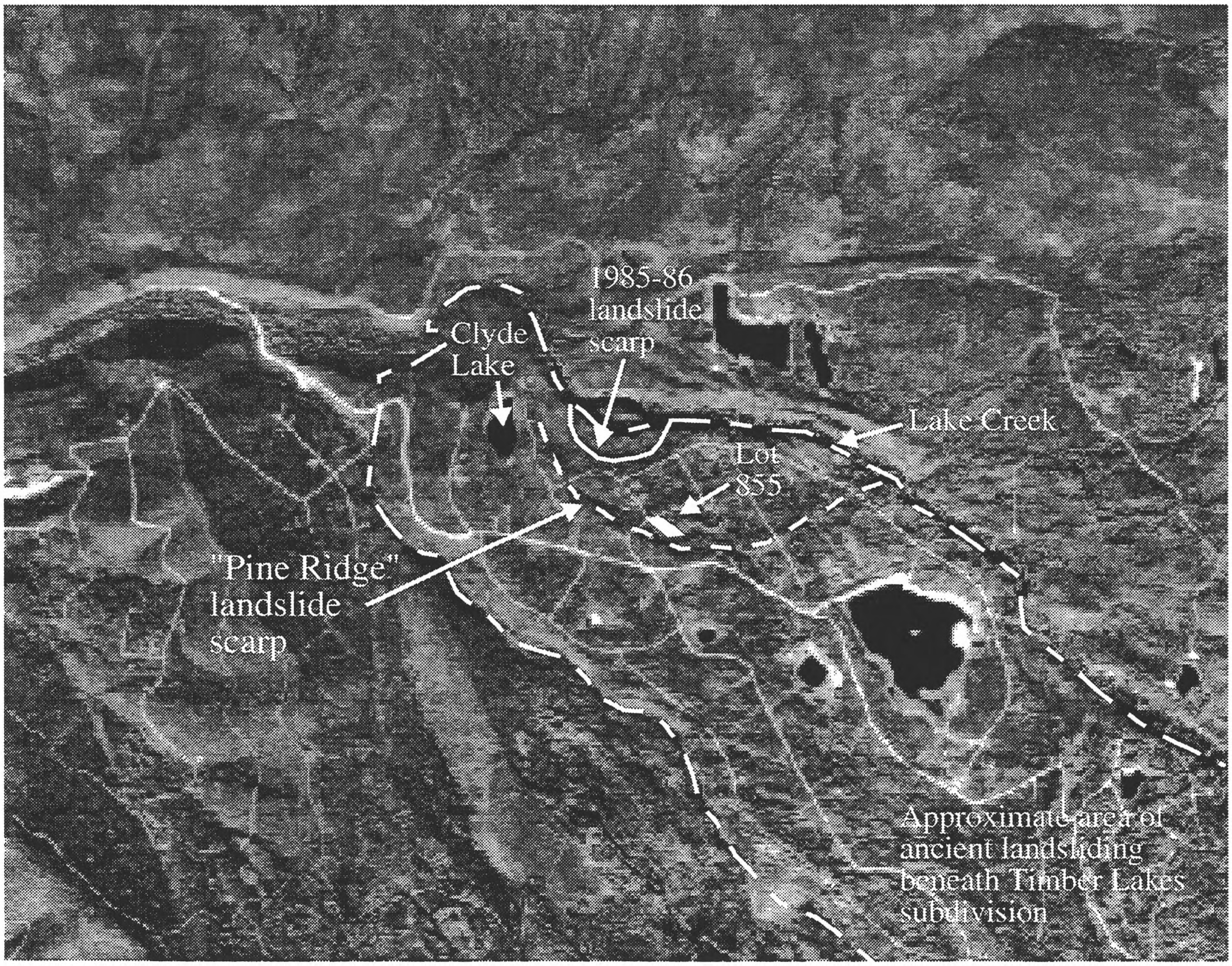
GBES did not consider the potential that ridge features on the lot may have a landslide-origin and may be associated with movement of the Pine Ridge landslide. These features suggest that if the landslide became active in the future, the lot may experience additional deformation and damage to structures at these ridges. I recommend, therefore, that given the uncertainties regarding the stability of the landslide, setbacks from the ridge features be considered in siting structures on the lot.

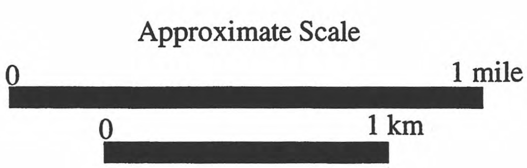
REFERENCES

Great Basin Earth Science, Inc., 1996, Engineering geologic site investigation - lot 855, Timber Lakes Subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Hylland, M.D., and Lowe, Mike, 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

-----in preparation, Geology, hydrogeology, and geologic hazards of western Wasatch County, Utah - a guide for land-use planning: UGS Special Study.





Attachment 1. Air-photo map of the "Pine Ridge" landslide, 1985-86 landslide, and limits of older prehistoric landsliding (Hylland and Lowe, in preparation) possibly affecting lot 855 at the Timber Lakes subdivision, Wasatch County, Utah. Location of scarps and landslide area boundary are approximate.

Project:			Requesting Agency:
Review of "Engineering geologic site investigation - lot 859, Timber Lakes subdivision, Wasatch County, Utah."			Wasatch County
By: Francis Ashland	Date: 7-8-96	County: Wasatch	Job No: 96-21 (R-21)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

INTRODUCTION

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geologic-hazard report (Great Basin Earth Science, Inc. [GBES], 1996) for a proposed homesite in the Timber Lakes subdivision. The proposed homesite is located in lot 859 in the NE1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995) and discussions with Mike Hylland, Utah Geological Survey. I performed no field inspection of the property.

GEOLOGIC HAZARDS

The GBES (1996) report lists earthquakes, surface-water runoff, shallow ground water, and landslides as possible geologic hazards at the property. In my opinion this is an accurate and complete list of the potential geologic hazards at the site.

GBES indicates no active faults near the lot, but that earthquake ground shaking is possible at the site as the result of a moderate or larger earthquake on a more distant fault. GBES indicates the lot is in seismic zone 3 of the Uniform Building Code (UBC) but does not specifically recommend building to these standards to help reduce losses from earthquake ground shaking. In addition, GBES concludes that because underlying glacial deposits are well graded, the likelihood of liquefaction at the lot is low. GBES does not, however, address the possibility of earthquake-induced landsliding at the lot. I generally concur with GBES' recommendations and conclusions related to earthquake hazards at the lot; the potential for landslides, whether or not earthquake induced, is discussed further below.

The GBES (1996) report indicates the potential for surface-water-runoff and shallow ground-water hazards. GBES recommends avoiding low-lying areas and swales when selecting the homesite and site grading to reduce impacts from surface-water runoff. Also, GBES recommends avoiding disturbance to soils and vegetation to reduce excessive soil erosion during construction. GBES indicates that ground water was greater than 8 feet deep at the time of the site visit, but cautions that seasonal fluctuations in ground-water levels are possible. GBES recommends that drainage-control measures be considered if the home will have parts that are below grade. Although GBES' recommendations are generalized, I believe they should reduce potential problems related to these hazards if adequately implemented.

GBES indicates that the lot is located on a large landslide (attachment 1), called the Pine Ridge landslide by Hylland and Lowe (in preparation), that is not known to have moved in historical time and that forms the steep slope south and west of the lot. The Pine Ridge landslide is located in an area of older landsliding underlying much of Timber Lakes identified by both GBES and Hylland and Lowe (1995) (attachment 1). A 1985-86 landslide, which affected cabins north of Pine Ridge Road, formed at the toe of the Pine Ridge landslide (attachment 1). GBES indicates no evidence that suggests the part of the Pine Ridge landslide underlying lot 859 is active. Although a quantitative assessment of the stability of the Pine Ridge landslide is probably beyond the scope of a lot-specific study, I believe that the qualitative observation that the landslide is not active provides little assurance against future movement. GBES makes no conclusions regarding the potential for or likelihood of reactivation of this landslide, or the effect it may have if reactivated.

SUMMARY

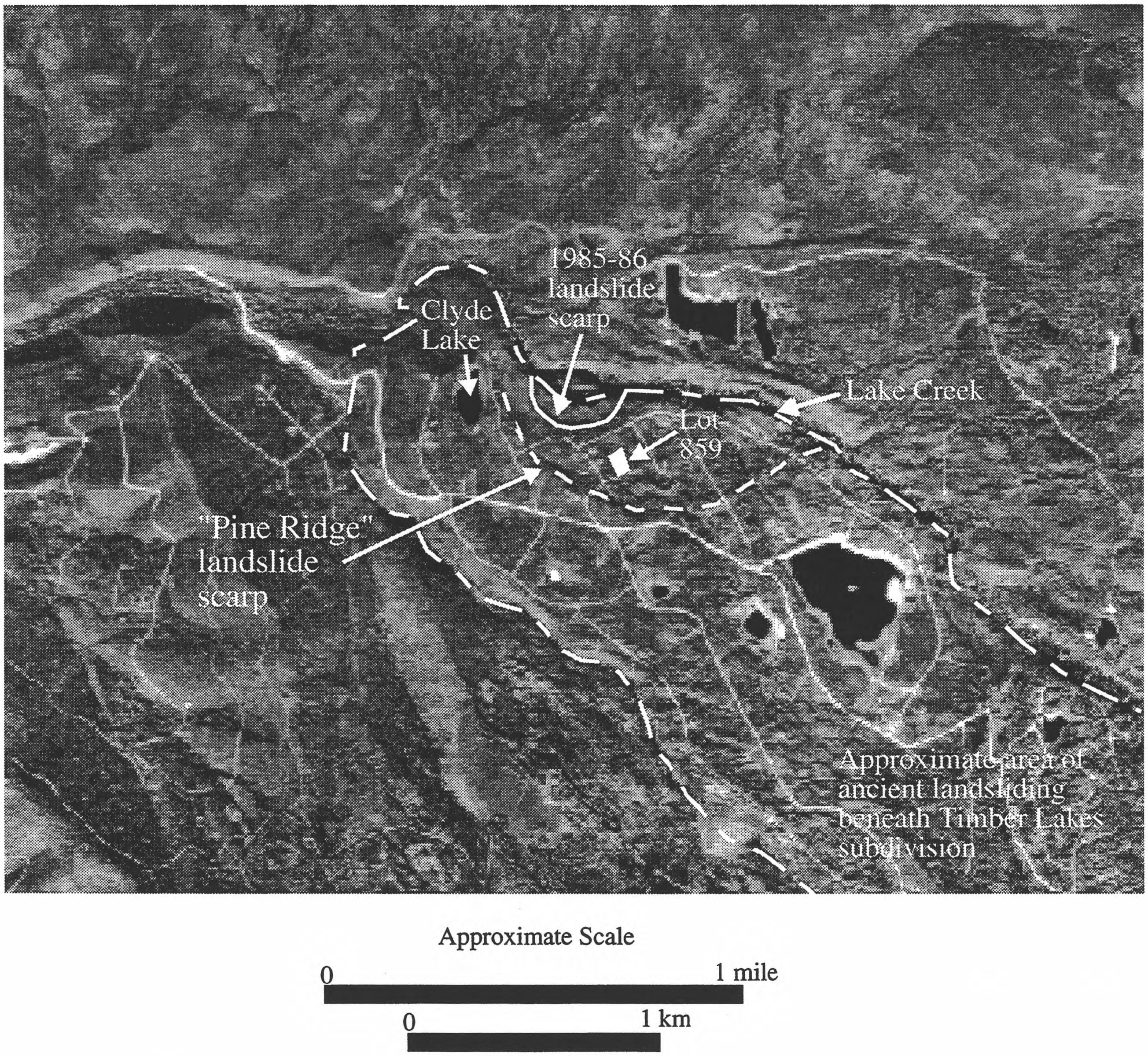
In my opinion, recommendations in the GBES (1996) report related to earthquakes, surface-water runoff, and shallow ground water are adequate and will likely reduce losses or problems from these potential hazards, provided construction is to UBC seismic zone 3 standards. GBES' assessment of the landslide hazard at the lot indicates that the lot is located on the Pine Ridge landslide. GBES concludes that no evidence indicates this landslide is active, and I agree. However the report does not address the potential for reactivation or present evidence that the landslide will not reactivate. Although quantitative assessment of the stability of the Pine Ridge landslide is probably beyond the scope of a lot-specific study, I believe there is a possibility for movement in the future, particularly in the event of moderate or strong earthquake ground shaking. I recommend that, at a minimum, the potential for reactivation of the Pine Ridge landslide and the existence of this report and review be disclosed to potential homebuyers.

REFERENCES

Great Basin Earth Science, Inc., 1996, Engineering geologic site investigation - lot 859, Timber Lakes Subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Hylland, M.D., and Lowe, Mike, 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

---- in preparation, Geology, hydrogeology, and geologic hazards of western Wasatch County, Utah - a guide for land-use planning: UGS Special Study.



Attachment 1. Air-photo map of the "Pine Ridge" landslide, 1985-86 landslide, and limits of older prehistoric landsliding (Hylland and Lowe, in preparation) possibly affecting lot 859 at the Timber Lakes subdivision, Wasatch County, Utah. Location of scarps and landslide area boundary are approximate.

Project:			Requesting Agency:
Review of "Geologic hazard assessment of lot 880, Timberlakes subdivision, Wasatch County, Utah."			Wasatch County
By: Francis Ashland	Date: 7-18-96	County: Wasatch	Job No: 96-22 (R-22)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

INTRODUCTION

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geologic-hazard report (Poulson, 1996) for a proposed homesite in the Timber Lakes subdivision. The proposed homesite is located in lot 880 in the NE1/4SE1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The scope of work included a review of published technical literature and geologic-hazard maps (Hylland and Lowe, 1995). I performed no field inspection of the property.

LANDSLIDES

Poulson's assessment of the potential landslide hazard at the property is generally qualitative and although estimates of certain soil properties are included, is unclear regarding how or if these were used in any calculations. The report also does not acknowledge that the lot is located on a large landslide (attachment 1) shown in Hylland and Lowe (1995) and called the Pine Ridge landslide by Hylland and Lowe (in preparation). The Poulson report indicates no evidence for "back arc fracturing," which I assume refers to extensional cracks or fissures, and describes the "degree of stability" of the area as "dormant." Poulson concludes that the additional weight of the cabin will not affect the area's stability and assigns a qualitative "steady state safety factor" of 1.5, indicative of low risk. Although, I was not able to locate the reference cited or contact the author for clarification, I believe this safety factor is a qualitative estimate and should not be confused with a quantitative assessment of the stability of the Pine Ridge landslide. Although a quantitative assessment of the stability of the Pine Ridge landslide is probably beyond the scope of a lot-specific study, I believe that the qualitative observation that the area is "dormant" with an estimated factor of safety of 1.5 provides little assurance against future movement. Presumably, because he does not identify the landslide, Poulson makes no conclusions regarding the potential for or likelihood of reactivation of this landslide, or the effect it may have on the lot if reactivated.

SOIL EROSION

The Poulson (1996) report indicates that soils are susceptible to rapid erosion where vegetation is absent, but are elsewhere stable, and I concur. Poulson also indicates that the stream that crosses the property is downcutting and recommends stabilization of unvegetated areas near the stream with rip rap or similar measures. I believe implementation of this recommendation will reduce soil erosion on the site.

OTHER GEOLOGIC HAZARDS

Other potential geologic hazards that are not addressed in the Poulson (1996) report include, in my opinion, shallow ground water and earthquake ground shaking. The possibility of shallow ground water is suggested by the presence of a stream that crosses the property and the observation in the Poulson (1996) report of "seeps." The presence of shallow ground water is important in addressing slope stability, basement flooding, and septic tank siting. Although I am aware of no active surface-rupturing faults near the property, there is the potential for earthquake ground shaking as the result of a moderate or strong earthquake in the region.

SUMMARY AND RECOMMENDATIONS

Poulson's assessment of the landslide hazard does not acknowledge that the lot is located on the Pine Ridge landslide and, as a result does not address the potential for reactivation or present evidence that the landslide is unlikely to reactivate. Although quantitative assessment of the stability of the Pine Ridge landslide is probably beyond the scope of a lot-specific study, I believe there is a possibility for movement in the future. I recommend that the potential for reactivation of the Pine Ridge landslide and the existence of this report and review be disclosed to potential homebuyers.

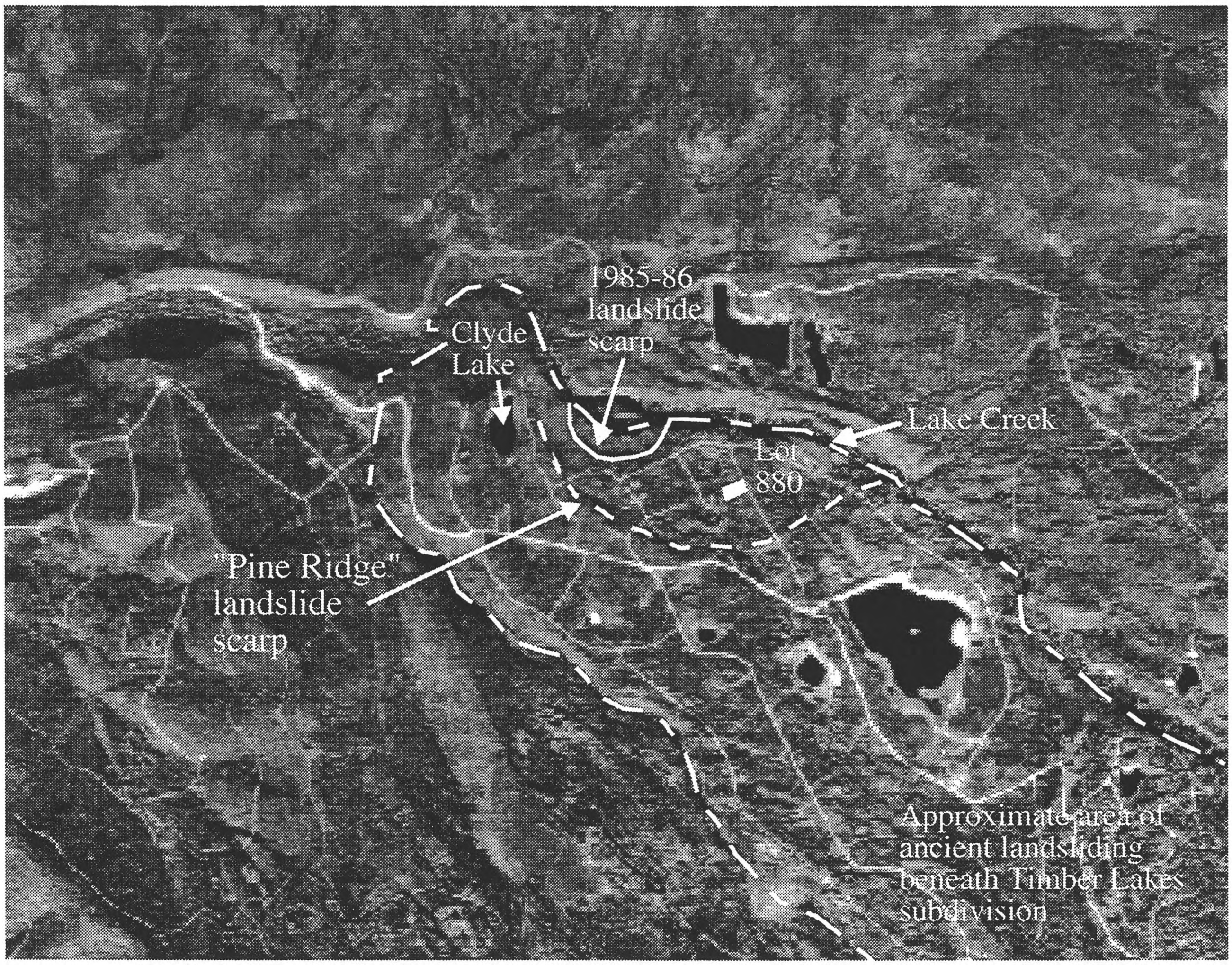
I concur with Poulson's recommendation to reduce soil erosion. The Poulson (1996) report does not address the potential for shallow ground water which must be assessed to evaluate septic-tank suitability and potential for basement flooding. Regarding earthquake ground shaking, no further work is needed as long as the structure complies with construction standards for seismic zone 3 of the Uniform Building Code.

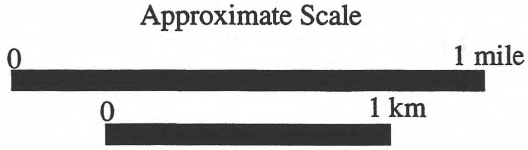
REFERENCES

Poulson, R.D., 1996, Geologic hazard assessment of lot 880, Timberlakes subdivision, Wasatch County, Utah: Mapleton, Utah, unpublished consultant's report, 6 p.

Hylland, M.D., and Lowe, Mike, 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

---- in preparation, Geology, hydrogeology, and geologic hazards of western Wasatch County, Utah - a guide for land-use planning: Utah Geological Survey Special Study.





Attachment 1. Air-photo map of the "Pine Ridge" landslide, 1985-86 landslide, and limits of older prehistoric landsliding (Hylland and Lowe, in preparation) possibly affecting lot 880 at the Timber Lakes subdivision, Wasatch County, Utah. Location of scarps and landslide area boundary are approximate.

Project: Review of an engineering geology site reconnaissance report for lot 709, Timber Lakes subdivision, Wasatch County, Utah			Requesting Agency: Wasatch County
By: Francis Ashland	Date: 7-18-96	County: Wasatch	Job No: 96-24 (R-23)
USGS Quadrangle: Heber Mountain (1125)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed an engineering geology site reconnaissance report (AGRA Earth & Environmental [AGRA], 1994) for a proposed homesite in the Timber Lakes subdivision. The proposed homesite is located in lot 709 in the SE1/4SE1/4 section 10 and the NE1/4NE1/4 section 15, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995). I performed no field inspection of the property.

The AGRA (1994) report lists earthquakes, shallow ground water, and landslides as potential geologic hazards on the property. I believe this is an accurate and complete listing of the potential geologic hazards at the site. The report adequately addresses these hazards and I concur with AGRA's recommendations. I recommend careful construction monitoring to assure that AGRA's recommendations are implemented, and disclosure of the report to future lot buyers. Also, I recommend disclosure of the presence of the lot on an area of older landsliding which underlies much of the Timber Lakes subdivision (Hylland and Lowe, 1995).

REFERENCES

AGRA Earth & Environmental, 1994, Engineering geology site reconnaissance - one-acre single family residential lot - lot 709 on Spring Creek Circle, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Hylland, M.D., and Lowe, Mike, 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

Project:			Requesting Agency:
Review of "Report of subsurface soils exploration - proposed Jordanelle Subdivision near Jordanelle Dam, Utah."			Wasatch County
By: Francis Ashland	Date: 7-23-96	County: Wasatch	Job No: 96-25 (R-24)
USGS Quadrangle: Heber City (1168)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed geologic-hazard aspects of a subsurface exploration report (Terracon, 1995) for a proposed subdivision near the Jordanelle Dam. The proposed subdivision is located in the W1/2 section 31, T. 2 S., R. 5 E., Salt Lake Base Line and Meridian. The scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995) and literature (Sullivan and others, 1986). I performed no field inspection of the property.

The Terracon (1995) report lists or makes recommendations to reduce losses from potential geologic hazards including expansive soils, earthquake ground shaking, and landslides. Terracon also indicates shallow bedrock on the property. The report adequately addresses these hazards and I concur with Terracon's recommendations.

Hylland and Lowe (1995) indicate that surface fault rupture and stream flooding are additional potential geologic hazards at the site. The northwestern corner of the property is in a surface fault-rupture special-study zone and the drainage that crosses the southernmost end of the property is a stream-flood hazard area. Because site plans were not included in the Terracon report, I do not know the potential impact of these two hazards on the proposed construction. I recommend that Terracon address these two hazards as appropriate to the proposed development plans, following the recommendations for disclosure and/or additional studies in Hylland and Lowe (1995).

The Terracon (1995) report indicates that subsurface conditions may vary across the site and could be different from those in the three test pits excavated for the study, and I concur. I believe there should be careful construction monitoring by a qualified geotechnical engineer, as recommended by Terracon, to assess the need for additional exploration and changes in design.

REFERENCES

Terracon, 1995, Report of subsurface soils exploration - proposed Jordanelle Subdivision near Jordanelle Dam, Utah: Salt Lake City, Utah, unpublished consultant's report, 9 p.

Hylland, M.D., and Lowe, Mike, 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, scale 1:24,000.

Sullivan, T.J., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1986, Draft report - regional seismotectonic study for the back valleys of the Wasatch Mountains in northeastern Utah: Denver, Colorado, U.S. Bureau of Reclamation Seismotectonic Section, 317 p.

Utah Geological Survey

Project:			Requesting Agency:
Review of geologic-hazard studies for lots 19 and 21, Pole Patch subdivision, Pleasant View, Utah			Pleasant View City
By: Francis X. Ashland	Date: 7-25-96	County: Weber	Job No: 96-26 (R-25)
USGS Quadrangle: North Ogden (1370)		Number of attachments: none	

INTRODUCTION

At the request of Terri Cragun, Pleasant View Community Development, I reviewed a report on the geologic hazards for lots 19 and 21 in the Pole Patch subdivision (Delta Geotechnical Consultants, 1995). Lots 19 and 21 are in the NW1/4NW1/4 section 17, T. 7 N., R. 1 W., Salt Lake Base Line and Meridian, on the Pleasant View salient. The scope of the work for this review included inspection of published geologic maps. No field inspection was performed of the properties.

GEOLOGIC HAZARDS

Delta Geotechnical Consultants, Inc. (1995) identifies earthquake ground shaking, surface fault rupture, landslides, rock falls, debris flows, and floods as potential hazards at each lot. This appears to be a complete and accurate listing of the potential hazards present. I concur with Delta's conclusions and recommendations related to earthquake ground shaking, surface fault rupture, landslides, and rock falls.

Delta indicates that the most probable source of debris flows and floods for lot 19 is the Ridge Canyon drainage. Delta believes the canyon experienced a large debris flow about 130 years ago and estimates a recurrence interval for debris flows in the canyon of 500 to 1,000 years. In addition, Delta calculated the runout of a debris flow from the mouth of the canyon to be less than the distance to the lot, indicating that a 500- to 1,000-year debris flow would unlikely reach the lot. Although I believe that Delta's assessment of the debris-flow hazard is reasonable, it does not preclude the possibility of a debris flow reaching the lot. Confirmation of whether debris flows have reached the lot could be made by identifying the soil types at the lot to determine whether they are debris-flow or alluvial-fan stream-flow deposits. Delta indicates that the channel that crosses lot 19 is adequate to contain the discharge from a 100-year storm and recommends that buildings should be setback from the active channel. I concur with this recommendation.

Lot 21 is located downslope from an unnamed drainage. Personius (1990) indicates the lot is located on alluvial-fan deposits that extend up the drainage. Neither the debris-flow or stream-flooding hazards related to this drainage are addressed in the Delta report. However, I understand that additional assessments of these hazards are planned (G. Olson, Delta Geotechnical Consultants, Inc., verbal communication, 1996).

SUMMARY AND RECOMMENDATIONS

Delta's (1995) conclusions and recommendations are adequate and reasonably address the potential for, and reduction of, geologic hazards on the lots. Delta's assessment of the debris-flow hazard at lot 19 indicates a low hazard but does not preclude the possibility of a debris flow reaching the lot in the future. I understand that an additional study of the debris-flow and stream-flooding hazards associated with the unnamed drainage upslope of lot 21 is in progress and should, in my opinion, be completed and reviewed prior to approving development on this lot. I also advise that the existence of Delta's report and addendum and this review be disclosed to future lot or home buyers.

REFERENCES

Delta Geotechnical Consultants, Inc., 1995, Geologic hazards study - Pole Patch subdivision Phase I (lots 4, 5, 6) and Phase II (lots 2, 4, 5, 11, 13, 15, 16, 19, 21, 22, 23, 26, 28, 30, 32), Pleasant View, Utah: Salt Lake City, Utah, unpublished consultant's report, 38 p.

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 Survey Map I-1979, scale 1:50,000.

Project: Review of an engineering geology site reconnaissance report for lot 1637, Timber Lakes Estates, Wasatch County, Utah			Requesting Agency: Wasatch County
By: Francis Ashland	Date: 7-30-96	County: Wasatch	Job No: 96-27 (R-26)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed an engineering geology site reconnaissance report (AGRA Earth & Environmental [AGRA], 1996) for a proposed homesite in the Timber Lakes Estates. The proposed homesite is located in lot 1637 in the SE1/4 section 14, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995). I performed no field inspection of the property.

The AGRA (1996) report lists earthquakes, shallow ground water, and landslides as potential geologic hazards on the property. I believe this is an accurate and complete listing of the potential geologic hazards at the site. The report adequately addresses these hazards and I concur with AGRA's recommendations.

AGRA recommends no "structures or septic drain fields" or "modifications, such as earthwork cutting and filling" east of a projected 3:1 (horizontal:vertical) setback line (AGRA, 1996, figure 2). On the remainder of the property, AGRA recommends no construction on "steep sloping areas." I concur with AGRA's recommendations, and conclude that the shape and slope of the remainder of the property west of the setback line imposes limitations on siting of a single-family home and septic-tank soil-absorption (STSA) system. Only about 150 feet of this part of the lot is wider than 40 feet, and it has an overall slope of approximately 30 percent, increasing up to nearly 40 percent in the southwest. I believe that AGRA's recommendation that no construction take place in "steeply sloping areas" limits construction to the northern, flatter part of this area. However, this area may be unsuitable for a STSA system because the overall slope exceeds 25 percent and water from the system may cause slope instability (R317-502-17.1, Division of Water Quality, 1996). These limitations, in addition to any required setbacks from the property line, may leave insufficient buildable area in the lot. I recommend further quantitative study of the slope stability if construction is proposed in an area where slopes exceed 30 percent.

REFERENCES

AGRA Earth & Environmental, 1996, Engineering geology site reconnaissance - single family residential lot - lot 1637 on Aspen Road, Timberlakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

Project:			Requesting Agency:
Review of "Site evaluation report -Timberlakes subdivision, lot #867, 867 Cedar Hollow Court, Wasatch County, Utah."			Wasatch County
By: Francis X. Ashland	Date: 8-1-96	County: Wasatch	Job No: 96-28 (R-27)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

INTRODUCTION

At the request of Robert Mathis, Wasatch County Planner, I reviewed a site evaluation report (RUI Analytical, 1996) for a proposed homesite in Timber Lakes Estates. The proposed homesite is located in lot 867 in the NE1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support site-development recommendations given in the report. The scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995) and inspection of air photos (1987, scale 1:40,000), but did not include a site visit.

GEOLOGIC HAZARDS

The RUI Analytical (1996) report generally addresses shallow ground water and landslides. I believe earthquake ground shaking is an additional potential geologic hazard at the site. However, construction to seismic zone 3 standards as designated by the Uniform Building Code should reduce losses from this hazard. RUI Analytical indicates no evidence for shallow ground water at the lot, and I concur.

RUI Analytical indicates the lot is located on a existing landslide, referred to as the Pine Ridge landslide (attachment 1) by Hylland and Lowe (in preparation), and concludes that development on the lot will not reactivate the landslide. RUI Analytical indicates no evidence of recent slope instability at the lot, but interprets the steep slopes on the site as Holocene landslide scarps. I interpret these scarps as possibly indicating the northeastern part of the Pine Ridge landslide has reactivated in the past. RUI Analytical concludes that reactivation of the Pine Ridge landslide is "possible" but does not assess the potential effect to the proposed buildings if the landslide is reactivated.

I disagree with RUI Analytical's suggestion that mature vegetation on the lot contributes to the stability of the landslide. Whereas the vegetation may help reduce erosion and surficial slumping of soils, in my opinion it likely has a negligible influence on the stability of the deep-seated landslide underlying the lot.

A figure attached to the RUI Analytical (1996) report shows a proposed septic-tank soil-absorption (STSA) system located in the upper part of an area that slopes at about 25 percent. This may not be a suitable location for a STSA system because water from the system may cause slope instability (R317-502-17.1, Division of Water Quality, 1996) in the northern part of the lot.

SUMMARY AND RECOMMENDATIONS

RUI Analytical concludes that the lot is located on the Pine Ridge landslide, but that development on the lot will not impact the slope stability. However, RUI Analytical indicates that reactivation of the landslide is possible, and I concur. I interpret the scarps identified by RUI Analytical as possibly indicating reactivation of the northeastern part of the Pine Ridge landslide in the past. Because of the proximity of the scarps to the proposed structures on the lot, I believe that buildings could be damaged if the landslide reactivates. Whereas quantitative assessment of the stability of the Pine Ridge landslide is probably beyond the scope of a lot-specific study, it is necessary to evaluate the potential for reactivation. Given the uncertainties, I recommend the existence of the RUI Analytical (1996) report and this review be disclosed to future home buyers.

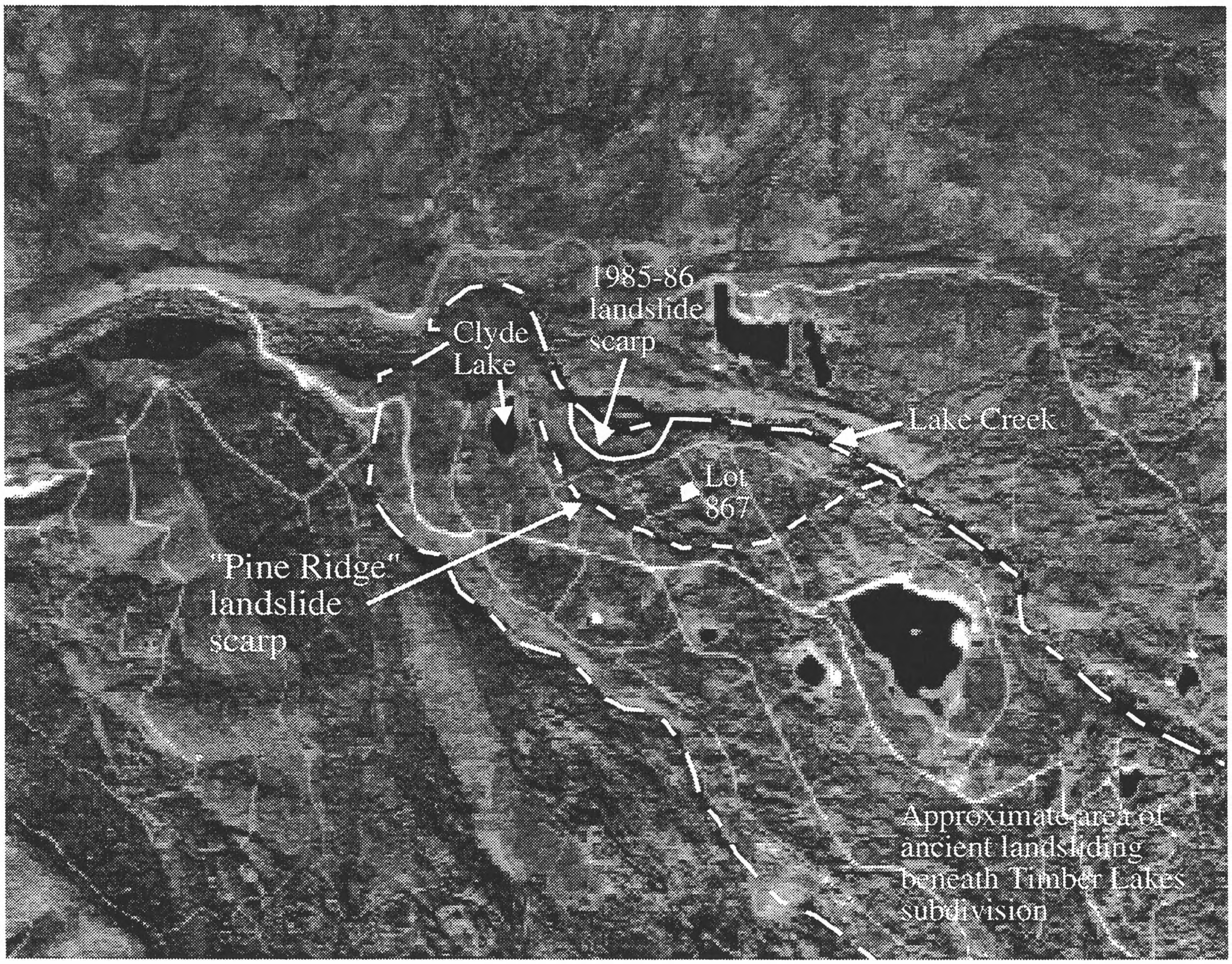
REFERENCES

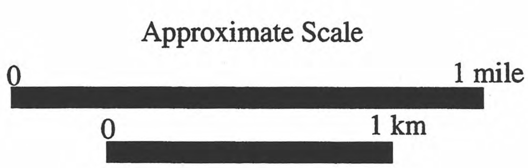
Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

-----in preparation, Geology, hydrogeology, and geologic hazards of western Wasatch County, Utah - a guide for land-use planning: UGS Special Study.

RUI Analytical, 1996, Site evaluation report - Timberlakes subdivision, lot #867, 867 Cedar Hollow Court, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 3 p.





Attachment 1. Air-photo map of the "Pine Ridge" landslide, 1985-86 landslide, and limits of older prehistoric landsliding (Hylland and Lowe, in preparation) possibly affecting lot 867 at Timber Lakes Estates, Wasatch County, Utah. Location of scarps and landslide area boundary are approximate.

Project: Review of geologic and geotechnical reports for the Snowflake subdivision, phases 3-6, Weber County, Utah			Requesting Agency: Weber County
By: Francis X. Ashland	Date: 8-13-96	County: Weber	Job No: 96-29 (R-28)
USGS Quadrangle: Huntsville (1369)		Number of attachments: none	

INTRODUCTION

In response to a request by Jim Gentry, Weber County Planning Commission, I reviewed geologic (Kaliser, 1996) and geotechnical (Earthtec Testing and Engineering [Earthtec], 1996) reports for the Snowflake subdivision, Phases 3-6 in Weber County, Utah. The property is located in the S1/2 section 15, T. 7 N., R. 1 E., Salt Lake Base Line and Meridian. The purpose of this review is to evaluate whether geologic hazards were adequately addressed in the reports such that additional site-specific studies would not be needed for individual lots. The scope of work for this review included an inspection of unpublished geologic mapping by Utah Geological Survey (UGS) geologist Mike Lowe and flood insurance maps (Federal Emergency Management Agency [FEMA], 1983) for the area, but did not include a site visit. Recommendations pertaining to foundation and pavement design in the Earthtec (1996) report should be reviewed by a qualified geotechnical engineer.

GEOLOGIC HAZARDS

The Kaliser (1996) report addresses flooding, landsliding and slope stability, shallow bedrock, shallow ground water, surface fault rupture, and moisture sensitivity (expansive and collapsible characteristics) of site soils. Conclusions and recommendations in the Kaliser (1996) report are based on literature and aerial-photo review, a site reconnaissance, and logging of 14 test pits. The report concludes that some geologic hazards, including flooding, shallow ground water, and moisture-sensitive soils, will impact development on individual lots. The report makes recommendations to reduce potential hazards from flooding, shallow ground water, and landsliding.

Kaliser indicates that lots 12, 13, 14, 15, 16 and 30 are within the 100-year flood plain of Wolf Creek and recommends siting homes outside the flood plain, but does not delineate it. I concur with this recommendation, but my review of figure 2 in the Kaliser (1996; p. 5) report indicates that lots 1 and 2 and the southeast corners of lots 17 and 31 are also crossed by Wolf Creek. Figure 2 (Kaliser, 1996; p. 5) shows some degree of incision of Wolf Creek where it crosses lots 1 and 2, possibly indicating that the 100-year flood may be contained in the channel; however, this is not stated in the report.

Kaliser also recommends that soil cut slopes exceeding 10 feet in height should be reviewed by a geotechnical engineer, and I concur. Kaliser lists lots 25, 26, and 27 as lots that will have such cuts. I believe similar cuts may also be required in lots 28, 29, and 30 and will likewise require review by a geotechnical engineer

The Earthtec (1996) report makes recommendations related to shallow ground water and moisture sensitivity of site soils. Earthtec's recommendations are based on data presented in the geologic report (Kaliser, 1996) and limited laboratory soil testing. I believe Earthtec's recommendations will reduce losses resulting from these hazards.

CONCLUSIONS AND RECOMMENDATIONS

The Kaliser (1996) and Earthtec (1996) reports present adequate recommendations for site development, and I agree with Kaliser's assessment of geologic hazards at the site. I concur with recommendations given to reduce losses resulting from moisture-sensitive soils and shallow ground water. I believe that the 100-year flood plain for Wolf Creek needs to be defined so that all affected lots can be identified, and concur that all cuts that exceed 10 feet in height should be reviewed by a geotechnical engineer. I recommend that the engineer provide the county written verification that cut slopes and retaining structures are constructed in accordance with design recommendations.

REFERENCES

Earthtec Testing and Engineering, 1996, Geotechnical consultation - Snowflake subdivision, Phases 3 through 6, Powder Mountain Road, Eden, Utah: Ogden, Utah, unpublished consultant's report, 6 p.

Federal Emergency Management Agency, 1983, FIRM Flood Insurance Rate Map, Weber County, Utah, Panel 250 of 600, Community Panel Number 490187 0250 B: scale 1:24,000.

Kaliser, B.N., 1996, untitled geologic report for Snowflake subdivision, Phase 3-6, Ogden Valley, Weber County, Utah: Salt Lake City, Utah, unpublished consultant's report, 10 p.

Project:			Requesting Agency:
Review of "Geotechnical and engineering geology study - lot 1230 Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah."			Wasatch County
By: Francis X. Ashland	Date: 8-13-96	County: Wasatch	Job No: 96-31 (R-29)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geotechnical and engineering-geologic report (AGRA Earth and Environmental [AGRA], 1996) for a proposed homesite in Timber Lakes Estates. The proposed homesite is located in lot 1230 in the NE1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support site-development recommendations in the report. The scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer.

The AGRA (1996) report addresses shallow ground water, landslides and slope stability, earthquake ground shaking, surface fault rupture, liquefaction, and problem soils. Conclusions and recommendations in the report are based on a site reconnaissance, logging of two test pits, and limited laboratory testing. The report concludes that no geologic hazards are present that preclude construction of a home in the northeast part of the lot and makes recommendations to reduce potential hazards from seasonal perched shallow ground water and landsliding.

I believe the report adequately addresses geologic hazards at the site and concur with AGRA's recommendations. Plans provided by Troy Ferran, Ferran Construction, show that retaining walls will be used to support permanent cut slopes. I recommend that the retaining walls be designed and inspected by a qualified engineer and that the engineer provide written verification to the county of construction in accordance with design recommendations.

REFERENCES

AGRA Earth & Environmental, 1996, Geotechnical and engineering geology study - lot 1230 Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 11 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

Project:			Requesting Agency:
Review of "Engineering geology site reconnaissance, single-family residential lot - lot 373 on Clyde Lake Drive, Timber Lakes subdivision, Wasatch County, Utah."			Wasatch County
By: Francis X. Ashland	Date: 10-4-96	County: Wasatch	Job No: 96-35 (R-30)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

INTRODUCTION

At the request of Robert Mathis, Wasatch County Planner, I reviewed an engineering-geology site reconnaissance report (AGRA Earth and Environmental [AGRA], 1996) for a proposed homesite in Timber Lakes Estates. The proposed homesite is located in lot 373 in the NE1/4NW1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support site-development recommendations in the report. The scope of work included a review of geologic maps (Hylland and Lowe, 1995; Lowe, unpublished geologic map) and aerial photographs (1987, 1:40,000 scale), and a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction.

GEOLOGIC HAZARDS

The AGRA (1996) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, and liquefaction. The report concludes that none of these geologic hazards preclude construction of a home in the southwest part of the lot, and I concur, and makes a recommendation to reduce the potential hazard from seasonal perched shallow ground water.

The AGRA (1996) report also addresses landslides and slope stability. AGRA indicates landslides abut the property to the northwest and northeast. The landslide to the northwest appears to be a deep-seated slope failure (Lowe, unpublished geologic map), and AGRA indicates it is inactive and reports no evidence of deep-seated failure, such as ground cracking, on the property. AGRA recommends that structures be set back at least 20 feet from this inactive landslide adjacent to the northwest corner of the lot. In addition, AGRA indicates that a shallow landslide caused by surficial sloughing is located about 50 feet northeast of the property on the steep slope adjacent to Lake Creek. To reduce the hazard from slope instability in this area, AGRA recommends that no structures be placed northeast of a setback line that represents the intersection of the ground surface with a plane having a slope of three-horizontal-to-one-vertical (3:1) projected from the base of the natural slope along Lake Creek. In addition, AGRA recommends that no significant earthwork take place northeast of this line and that grading should direct water away from the northeast and northwest parts of the property.

Other slope-stability considerations that are not addressed in the AGRA report include the impact of water from a septic-tank soil-absorption (STSA) system on slope stability and the potential for reactivation of larger landslides that partly underlie the property. Based on the apparent low permeability of the clayey soils observed in a test pit on the property, I believe that water from the septic system may increase the potential for instability (R317-502-17.1, Division of Water Quality, 1996) on moderate to steep slopes on and adjacent to the property. Because of the proximity of a neighboring structure downslope, I believe this possibility should be considered.

Mapping by UGS geologists (Hylland and Lowe, 1995; Lowe, unpublished geologic map) indicates that much of the surrounding area is underlain by large pre-historical landslides (attachment 1). Although not discussed in the AGRA report, the scarps of older landslides may cross the eastern part of the lot (Hylland and Lowe, 1995; Lowe, unpublished geologic map). The youngest of these is referred to as the Pine Ridge landslide (Hylland and Lowe, in preparation). AGRA makes no conclusions regarding the potential for or likelihood of reactivation of this or older landslides, or the effect they may have on the lot if the landslides reactivated.

CONCLUSIONS AND RECOMMENDATIONS

AGRA concludes that a slope-failure hazard is present at the property and makes setback recommendations to reduce the risk from slope instability. I concur with AGRA's recommendations regarding setbacks from the existing landslide abutting the northwest corner of the lot and the steep slopes along Lake Creek. I believe that AGRA's recommendations should be strictly followed unless they are revised based on a more detailed quantitative slope-stability evaluation. I also recommend that the impact on slope stability of a STSA system be evaluated before it is sited and designed.

AGRA's assessment of the landslide hazard does not acknowledge that the lot is crossed by the scarps of older landslides, including the Pine Ridge landslide and, as a result, does not address the potential for reactivation of these landslides. Although quantitative assessment of the stability of the Pine Ridge or other landslides is probably beyond the scope of a lot-specific study, I believe there is a possibility for movement in the future of the landslides abutting the lot. At a minimum, I recommend that the potential for reactivation of the Pine Ridge and other landslides and the existence of the AGRA (1996) report and this review be disclosed to potential home buyers.

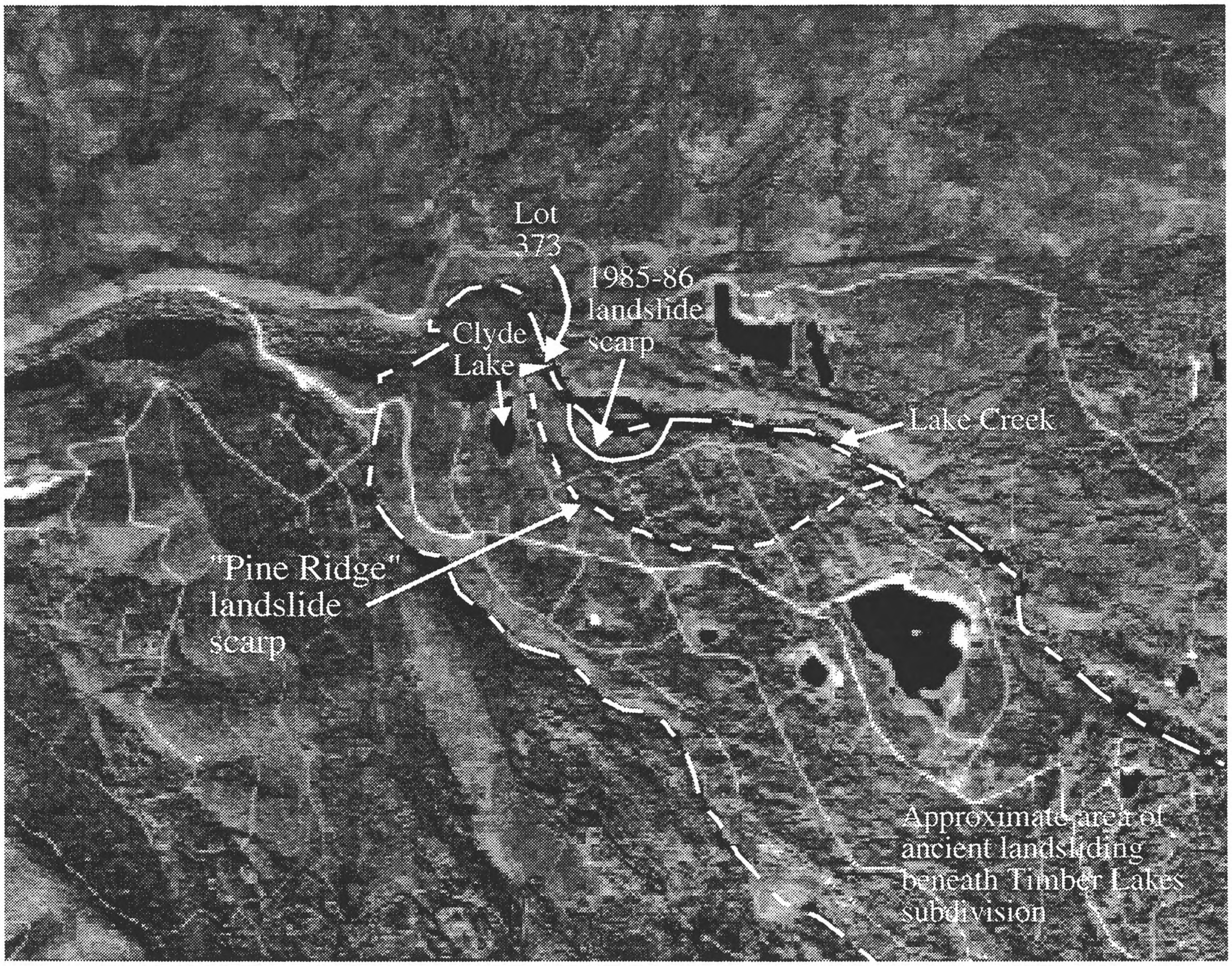
REFERENCES

AGRA Earth & Environmental, 1996, Engineering geology site reconnaissance, single-family residential lot - lot 373 on Clyde Lake Drive, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 8 p.

Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

-----in preparation, Geology, hydrogeology, and geologic hazards of western Wasatch County, Utah - a guide for land-use planning: Utah Geological Survey Special Study.



Approximate Scale

0 1 mile

0 1 km

Attachment 1. Aerial photograph showing the "Pine Ridge" landslide, including a portion which reactivated in 1985-86, and limits of older prehistoric landsliding (Hylland and Lowe, in preparation) in relation to lot 373 at Timber Lakes Estates, Wasatch County, Utah. Locations of scarps and landslide-area boundary are approximate. The landslides which abut lot 373 to the northwest and northeast are not shown.

Project:			Requesting Agency:
Review of geotechnical reports for lot 43, Swiss Mountain Estates, Midway, Utah.			Wasatch County
By: Francis X. Ashland	Date: 10-28-96	County: Wasatch	Job No: 96-36 (R-36)
USGS Quadrangle: Heber City (1168)		Number of attachments: 1	

INTRODUCTION

At the request of Robert Mathis, Wasatch County Planner, I reviewed geologic-hazards portions of geotechnical and addendum reports by Earthtec Testing and Engineering (Earthtec) (1996a, 1996b) for a proposed homesite in lot 43 in Swiss Mountain Estates, Midway, Utah. The lot is located in section 33, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to construction of a home on the lot. The scope of work included a a preliminary slope-stability analysis and review of geologic maps (Bromfield and others, 1970; Hylland and Lowe, 1995) and geotechnical literature (Rollins and Rogers, 1994). Recommendations pertaining to foundation design, excluding recommendations pertaining to collapsible soils, appear adequate for typical residential construction.

COLLAPSIBLE SOILS

The Earthtec (1996a) report identifies moisture-sensitive (collapsible) soils on the lot that undergo between 0.5 and 2.2 percent collapse upon saturation at loads of 1,000 pounds per square foot. Because of the presence of collapsible soils, Earthtec recommends that the foundation subgrade be proof-rolled and footings be supported on a minimum of 24 inches of structural fill, and makes grading, drainage, and irrigation recommendations to avoid wetting foundation soils. Earthtec's recommendation to place footings on compacted structural fill should reduce and render more uniform the total settlement caused by wetting of collapsible soils, but is most effective only when the quantity of water allowed to percolate to the collapsible soils in the foundation subgrade is limited (Rollins and Rogers, 1994).

SLOPE STABILITY

The Earthtec addendum (1996b) report addresses the stability of natural slopes and indicates no evidence for "recent instability." However, the report does not specifically address whether site modifications, including grading, excavation for the home foundation, landscape irrigation, and effluent from a septic-tank soil-absorption (STSA) system will destabilize the slopes. Utah Division of Water Quality (1996) regulation R317-502-17.1 indicates that approval of a STSA system can be denied if the system may cause slope instability. Earthtec indicates a lack of landslide features on the natural slopes, but this does not preclude the potential for instability resulting from site modifications. Earthtec predicts that the slope has an "adequate factor of safety against slope failure," but does not support this statement with geotechnical data or estimates of effective-stress strength parameters for the soils at the lot and fluctuations of ground-water levels. My preliminary geotechnical-engineering assessment (for an explanation of this assessment, see Hylland, 1996) of the slope stability using estimated soil-strength parameters and a simple infinite slope analysis (Duncan and others, 1987) indicates a wide range in the factor of safety of the slope, including potentially marginal stability assuming a cut in the toe of the slope, wet conditions, and low soil strengths . A summary of my evaluation of the adequacy of Earthtec's slope-stability assessment is shown in attachment 1.

CONCLUSIONS AND RECOMMENDATIONS

Earthtec's recommendations related to mitigating settlement from collapsible soils on the lot will likely reduce collapse-induced settlement but may not prevent it. The recommended mitigation measures are dependent on preventing water from percolating to the collapsible soils in the foundation's subgrade. Although an upslope foundation drain is recommended by Earthtec, this may not prevent foundation subgrade soils from becoming wetted and causing collapse-induced settlements that may damage the home. Because of this potential and the related importance of controlling site drainage, I recommend, at a minimum, that the Earthtec (1996a, 1996b) reports and this review be disclosed to future home buyers.

Earthtec's conclusion that there is an "adequate factor of safety against slope failure" is unsupported by geotechnical data and their addendum report (1996b) does not address the potential for instability caused by site modifications. I recommend that Earthtec address this potential for the proposed lot design using: 1) existing slopes, 2) proposed STSA system absorption-field design-location and resulting ground-water conditions, 3) proposed permanent cut/fill slopes (if any) as recommended by the design engineer, and 4) reasonable estimated soil strengths. If a marginal factor of safety is obtained, a detailed geotechnical-engineering evaluation using actual measured soil-strength parameters may be necessary. The work should be reviewed prior to granting approval for construction of a home on the lot.

REFERENCES

Bromfield, C.S., Baker, A.A., and Crittenden, M.D., Jr., 1970, Geologic map of the Heber Quadrangle, Wasatch and Summit Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-864, scale 1:24,000.

Duncan, J.M., Buchignani, A.L., and De Wet, M., 1987, An engineering manual for slope stability studies: Virginia Polytechnic Institute and State University, Blacksburg, 80 p.

Earthtec Testing and Engineering, 1996a, Geotechnical study - lot 43, plat 4, Swiss Mountain Estates, Midway, Utah: Orem, Utah, unpublished consultant's report, 3 p.

-----1996b, Addendum to geotechnical study - lot 43, plat 4, Swiss Mountain Estates, Midway, Utah: Orem, Utah, unpublished consultant's report, 1 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

Rollins, K.M, and Rogers, G.W., 1994, Mitigation measures for small structures on collapsible alluvial soils: Journal of Geotechnical Engineering, v. 120, no. 9, p. 1533-1553.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Attachment 1
Job No. 96-36

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author(s) Earthtec Testing and Engineering Date Of Report(s) September 12 and 28, 1996

Title Of Report(s) Geotechnical study - lot 43, plat 4, Swiss Mountain Estates, Midway, Utah; Addendum to geotechnical study - lot 43, plat 4, Swiss Mountain Estates, Midway, Utah.

UGS File No. Technical Report 96-36 Requesting Agency Wasatch County Planning County Wasatch

USGS 7.5' Quad(s) (BLM No.) Heber City (1168) Sec., T., R. Section 33, T.3 S., R. 4 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]		Adequacy of report(s)	COMMENTS (attach additional sheets if necessary)
1.	List of reference materials used	N	
2.	Vicinity map	D	vicinity map did not show specific location of lot
3.	Site-planning map at suitable scale, showing:	D	suitably scaled and detailed plan not included
3a.	proposed development	–	described in text
3b.	topography	–	
3c.	geology	–	
3d.	subsurface exploration and cross section locations	A	two test pits shown on a figure
3e.	surface water	N	
3f.	landslide features	–	none observed
3g.	hazard-reduction features	N	
4.	Description of site conditions:	A	described in text
4a.	slopes	D	described in original report as 15 percent and in addendum as 15-25 percent
4b.	slope materials	A	test pit logs of soils but geologic origin of soils lacking
4c.	subsurface planar features	N	geologic contacts may act as a failure surface
4d.	surface/ground water	D	depth to ground water exceeds 9-10 feet in September but may be seasonal low
4e.	vegetation	A	described in text
4f.	suspected landslide features	A	none indicated
4g.	surficial processes	N	none described, but may effect slope stability (erosion, soil creep, ...)
4h.	other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

P. 1 of 2

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

SUBJECT		Adequacy of report(s)	COMMENTS (attach additional sheets if necessary)
5.	Description of existing landslides, including items in (4) above, and:	N	
5a.	failed unit(s)	N	
5b.	failure type(s)	N	
5c.	scarp characteristics	N	
5d.	age(s) of failure	N	
5e.	cause(s) of failure	N	
6.	Implications of nearby landslides	N	
7.	Geotechnical-engineering evaluation:	D	impact of site modifications not addressed
7a.	subsurface materials/ground-water characterization	D	no geotechnical data for soils; possible fluctuations in ground-water table levels not addressed
7b.	laboratory testing	D	recommend using at least estimated soil-strength parameters based on soil descriptions
7c.	profiles/cross sections	D	lot not profiled; slopes given in reports are not consistent
7d.	static slope-stability analysis	D	recommend at least a preliminary geotechnical-engineering analysis for the proposed site design
7e.	seismic slope-stability analysis	D	not performed but may be necessary if marginal static stability conditions revealed
	• input ground motions	–	
	• effects on shear strength and pore pressures	–	
	• liquefaction potential	–	
7f.	post-earthquake stability analysis	N	
8.	Conclusions regarding hazard	D	not supported with geotechnical-engineering slope-stability analysis
9.	Recommendations	D	no slope recommendations made but site drainage recommendation included

Additional comments:

Reviewed By Francis X. Ashland   Date Reviewed October 16, 1996

UGS.4/96   P. 2 of 2

Project:			Requesting Agency:
Review of "Slope stability evaluation - BYCO subdivision lot 1, approximately 1850 East 2000 South, Ogden, Utah"			Ogden City Planning Division
By: Francis X. Ashland	Date: 10-28-96	County: Weber	Job No: 96-37 (R-32)
USGS Quadrangle: Ogden (1345)		Number of attachments: 1	

At the request of Corvin Snyder, Ogden City Planning Commission, I reviewed a slope-stability-evaluation report (AGRA Earth & Environmental [AGRA], 1996) for lot 1 in the BYCO subdivision, Ogden, Utah. The lot is near the boundary between the NE1/4 section 27 and the NW1/4 section 26, T. 6 N., R. 1 W., Salt Lake Base Line and Meridian, and is adjacent to a scarp of the Frontage Trough landslide complex of Vandre and Lowe (1995). The purpose of the review was to evaluate whether the slope-stability study supported a recommendation in the report to reduce a setback from the landslide scarp that would allow for the construction of a home on the lot. The scope of work included review of geologic literature (Vandre and Lowe, 1995) and a slope-stability analysis using STED and PC-STABL5M software.

The AGRA (1996) report adequately describes geologic conditions at the lot and indicates that a slope-stability analysis was performed using PC-STABL5 software. AGRA's evaluation included both static and seismic slope-stability analyses using the Modified Bishop's method and a pseudo-static analysis to estimate earthquake forces. The AGRA report does not present the effective-stress strength input values used in their analysis nor the PC-STABL5-generated output plots and results. I obtained the input values from AGRA (J. Helm, written communication, September 30, 1996) which appeared reasonable for the soils identified at the lot, although strength values for the deltaic deposits were not necessarily "conservative." For the cohesionless deltaic deposits described as "predominantly sand and gravel," AGRA used a soil friction angle ($\phi' = 34$ degrees) above the average value (ϕ' ranges from 28 to 36 degrees) described by Vandre and Lowe (1995) and a cohesion value (c') of 100 pounds per square feet. Using appropriate modifications of AGRA's input parameters, such as eliminating the cohesion value used by AGRA for the deltaic deposits, I believe I was able to reproduce, in general, AGRA's slope-stability analysis and I concur with their conclusion that reducing the setback to 80 feet "will introduce no significant additional exposure from the existing landslide hazard..."

On the basis of the results of my slope-stability analysis, I concur with AGRA's conclusion that reducing the building setback from the landslide scarp to 80 feet will not significantly increase the potential risk from slope failure to the proposed house. However, I recommend that the lot owner minimize irrigation in the northern half of the property and avoid making any modifications adjacent to the landslide scarp that could destabilize the slope. A summary of my evaluation of the adequacy of AGRA's slope-stability assessment is shown in attachment 1.

REFERENCES

AGRA Earth & Environmental, 1996, Slope stability evaluation - BYCO subdivision lot 1, approximately 1850 East 2000 South, Ogden, Utah: Salt Lake City, unpublished consultant's report, 11 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, *in* Lund, W.R., editor, Environmental & engineering geology of the Wasatch Front region: Utah Geological Association Publication 24, p. 137-156.

Attachment 1
Job No. 96-37

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author AGRA Earth & Environmental Date Of Report March 29, 1996

Title Of Report Slope stability study - BYCO subdivision lot 1, approximately 1850 East 2000 South, Ogden, Utah

UGS File No. Technical Report 96-37 Requesting Agency Ogden City Planning Commission County Weber

USGS 7.5' Quad(s) (BLM No.) Ogden (1345) Sec., T., R. Sections 26 and 27, T. 6 N., R. 1 W., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]	Adequacy of report	COMMENTS (attach additional sheets if necessary)
1. List of reference materials used	N	
2. Vicinity map	A	
3. Site-planning map at suitable scale, showing:	A	
3a. proposed development	A	
3b. topography	D	topography shown on cross section
3c. geology	D	shown on cross section and described in text
3d. subsurface exploration and cross section locations	A	borehole location shown but section line lacking
3e. surface water	N	
3f. landslide features	A	scarp location shown
3g. hazard-reduction features	A	setback line shown
4. Description of site conditions:	A	described in text
4a. slopes	A	
4b. slope materials	A	geologic cross section included
4c. subsurface planar features	A	geologic contacts shown
4d. surface/ground water	A	depth to ground water indicated
4e. vegetation	A	described in text
4f. suspected landslide features	A	
4g. surficial processes	A	
4h. other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

P. 1 of 2

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT	Adequacy of report	COMMENTS (attach additional sheets if necessary)
5. Description of existing landslides, including items in (4) above, and:	A	
5a. failed unit(s)	A	
5b. failure type(s)	A	
5c. scarp characteristics	A	
5d. age(s) of failure	A	cut by fault scarps of known age
5e. cause(s) of failure	A	refers to Vandre and Lowe (1995)
6. Implications of nearby landslides	A	discusses role of Rainbow Imports landslide to stability at site
7. Geotechnical-engineering evaluation:	A	PC-STABL5 analysis used
7a. subsurface materials/ground-water characterization	D	effective-stress soil-strength input values lacking in report but were submitted in a written communication
7b. laboratory testing	N	soil strength based on testing by others
7c. profiles/cross sections	A	
7d. static slope-stability analysis	D	results not presented in report
7e. seismic slope-stability analysis	A	pseudo-static analysis used
• input ground motions	A	0.18 g used
• effects on shear strength and pore pressures	N	
• liquefaction potential	A	
7f. post-earthquake stability analysis	N	
8. Conclusions regarding hazard	A	supports building setback reduction recommendation
9. Recommendations	A	setback of 80 feet appears adequate

Additional comments:

Reviewed By Francis X. Ashland Date Reviewed October 17, 1996

UGS.4/96 P. 2 of 2

Project:			Requesting Agency:
Review of "Geotechnical and engineering study - lot 1226 Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah"			Wasatch County
By: Francis X. Ashland	Date: 10-29-96	County: Wasatch	Job No: 96-38 (R-33)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

At the request of Robert Mathis, Wasatch County Planner, I reviewed geologic-hazards portions of a geotechnical-engineering report by AGRA Earth & Environmental (AGRA) (1996) for lot 1226 Ridgeline Drive in Timber Lakes Estates, Wasatch County, Utah. The lot is located in the SE1/4 NE1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to construction of a home on the lot. The scope of work included a preliminary slope-stability analysis (using STED and PC-STABL5M software), a review of geologic-hazards literature (Hylland and Lowe, 1995) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), and a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction.

The AGRA (1996) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, and liquefaction. I believe the report adequately addresses these potential geologic hazards and concur with AGRA's conclusions and recommendations.

The AGRA (1996) report also addresses landslides and slope stability and makes cut-slope-angle recommendations for both temporary and permanent cut slopes. AGRA indicates no evidence of landsliding on the lot and states that there is no known landslide within a half mile of the lot. My review of aerial photographs, however, indicates a large landslide about 1,000 feet southeast of the lot that developed on the same northeast-facing slope that lot 1226 is located on. In addition, soils exposed in the foundation excavation on the lot may indicate past landsliding. I observed three distinct soils in the excavation cut that were not identified by AGRA. The two upper soils overlie glacial till and appeared to be colluvium but could also be landslide deposits based on the evidence for nearby landsliding. The AGRA report does not directly address the geologic origin of the soils at the site except to speculate that the soils were derived from the Keetley Volcanics. The AGRA report concludes that deep-seated slope failure is unlikely because of shallow rock. I observed no evidence for shallow rock in the 12-foot-deep foundation excavation. AGRA also concludes that shallow slope failures are possible, particularly where earthwork at the site oversteepens slopes. My preliminary geotechnical-engineering assessment (for an explanation of this assessment, see Hylland [1996]) supports AGRA's conclusion regarding the potential for shallow slope failures. The AGRA report does not specifically address whether landscape irrigation and effluent from a septic-tank soil-absorption (STSA) system will destabilize the slopes. Utah Division of Water Quality (1996) regulations indicate that approval of a STSA system can be denied if the system may cause slope instability. A summary regarding my evaluation of the adequacy of AGRA's slope-stability assessment is shown in attachment 1.

The AGRA (1996) report makes specific cut-slope-angle and slope-stability recommendations that I believe will reduce the possibility of instability if closely followed. Unfortunately, AGRA's recommendation for temporary cut slopes above 4 feet high have already been ignored in the excavation of a 12-foot-high near-vertical foundation cut. Because the upslope basement wall will need to act as a retaining structure (p. 2, AGRA, 1996), I recommend that this and other retaining walls be designed and inspected by a qualified engineer and that the engineer provide written verification to the county of construction in accordance with design recommendations. Determining the origin of the upper soils at the site may be necessary to assess long-term loads on the retaining walls. To control erosion, AGRA states that permanent cut slopes could be made even flatter than they recommend for slope-stability purposes. Because of the uncertainties regarding the stability of the natural slopes, including the possible landslide origin of the upper soils and the apparent susceptibility of soils to landsliding as evident by the large nearby landslide, I also recommend that flatter permanent cut slopes be considered in final site-grading plans.

REFERENCES

AGRA Earth & Environmental, 1996, Geotechnical and engineering study - lot 1226 Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 12 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Attachment 1
Job No. 96-38

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author AGRA Earth & Environmental Date Of Report September 16, 1996

Title Of Report Geotechnical and engineering study - lot 1226 Timber Lakes subdivision, Wasatch County, Utah

UGS File No. Technical Report 96-38 Requesting Agency Wasatch County Planning County Wasatch

USGS 7.5' Quad(s) (BLM No.) Center Creek (1126) Sec., T., R. Section 8, T.4 S., R. 6 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]	Adequacy of report	COMMENTS (attach additional sheets if necessary)
1. List of reference materials used	N	
2. Vicinity map	A	
3. Site-planning map at suitable scale, showing:	D	plan showing proposed septic-system locations and final grading lacking
3a. proposed development	D	described briefly in text
3b. topography	D	described briefly in text
3c. geology	N	described briefly in text;only one mappable surficial unit
3d. subsurface exploration and cross section locations	A	excavation location shown
3e. surface water	N	
3f. landslide features	D	none on lot, but upper soils may indicate past landsliding
3g. hazard-reduction features	N	
4. Description of site conditions:	D	
4a. slopes	A	described briefly in text
4b. slope materials	D	three distinct soils not identified
4c. subsurface planar features	D	geologic contacts may act as failure surfaces
4d. surface/ground water	D	basis for estimated depth to ground water not explained
4e. vegetation	A	described in text
4f. suspected landslide features	D	possible landslide origin of soils not addressed; does not identify nearby large landslide
4g. surficial processes	D	potential for downslope movement of colluvium not addressed
4h. other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT		Adequacy of report	COMMENTS (attach additional sheets if necessary)
5.	Description of existing landslides, including items in (4) above, and:	N	none identified on lot
5a.	failed unit(s)	–	
5b.	failure type(s)	–	
5c.	scarp characteristics	–	
5d.	age(s) of failure	–	
5e.	cause(s) of failure	–	
6.	Implications of nearby landslides	D	susceptibility of soils to landsliding not addressed
7.	Geotechnical-engineering evaluation:	N	quantitative analysis may not be necessary if retaining structures adequately designed and constructed, and other site-grading recommendations followed; design of retaining structures should consider potential landslide origin of upslope soils in estimating lateral loads
7a.	subsurface materials/ground-water characterization	–	
7b.	laboratory testing	–	
7c.	profiles/cross sections	–	
7d.	static slope-stability analysis	–	
7e.	seismic slope-stability analysis	–	
	• input ground motions	–	
	• effects on shear strength and pore pressures	–	
	• liquefaction potential	–	
7f.	post-earthquake stability analysis	–	
8.	Conclusions regarding hazard	D	conclusions related to deep-seated slope failure not supported by observations
9.	Recommendations	A	slope recommendations are adequate, but are not being implemented

Additional comments:

Reviewed By Francis X. Ashland Date Reviewed October 22, 1996

UGS.4/96 P. 2 of 2

Project: Review of "Geological reconnaissance, Timber Lakes subdivision, lot 356"			Requesting Agency: Wasatch County
By: Francis X. Ashland	Date: 11-13-96	County: Wasatch	Job No: 96-39 (R-34)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geological reconnaissance report by American Geological Services, Inc. (AGS) (1996) for lot 356, Ridgeline Drive, in Timber Lakes Estates, Wasatch County, Utah. The lot is located in the NW1/4NE1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to construction of a home in the southern part of the lot. The scope of work included a review of geologic-hazards literature (Hoek and Bray, 1981; Hylland and Lowe, 1995; Black, 1996) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), and discussions with Charles Payton (AGS) and Utah Geological Survey (UGS) geologist Bill Black.

The AGS (1996) report addresses liquefaction, earthquake ground shaking, landslides, and slope stability. I concur with the report's conclusion that the potential for liquefaction of soils at the site is "unlikely" and its recommendation that the home be designed in accordance with UBC seismic zone 3 requirements to reduce losses during earthquake ground shaking.

The AGS (1996) report indicates the lot is bisected by a landslide main scarp that formed in 1985-1986 and that the maximum height of the scarp is 10 feet. AGS also identifies a smaller secondary scarp on the lot to the northeast of the main scarp but indicates no other landslide-related tension cracks or slumps. AGS recommends a 30-foot building setback from the scarp to "avoid potential ground or slope failure associated with the scarp." The setback is based on a three-horizontal-to-one-vertical (3H:1V) projection from the toe of the scarp. In addition, AGS estimates the static slope stability of the southern part of the lot upslope of the toe of the scarp to be greater than 5.0 using circular failure charts by Hoek and Bray (1981) and assuming dry conditions. Assumptions regarding slope, soil, and ground-water conditions used by AGS in its stability estimate appear reasonable for the upslope part of the lot. The estimated factor of safety indicates a low likelihood of shallow circular slope failures upslope of the toe of the scarp, but AGS does not address the possibility of deep-seated failure, similar to that which occurred in 1985-86. A summary regarding my evaluation of the adequacy of AGS's slope-stability assessment is shown in attachment 1.

The proposed homesite is located upslope and south of the main scarp of the 1985-86 landslide. I interpret this landslide to be a reactivated zone of a larger and older landslide referred to as the Pine Ridge landslide by Hylland and Lowe (in preparation). Whereas the AGS (1996) report identifies the 1985-86 landslide as active, it does not address the potential for deep-seated instability, resulting from further reactivation of the Pine Ridge landslide, that may affect the area south of the main scarp. AGS did not consider the potential for scarp development or other deformation south of the 1985-86 main scarp, resulting from deep-seated landsliding, in its 30-foot building-setback recommendation (C. Payton, AGS, verbal communication, November 4, 1996). Building-setback recommendations, in my opinion, should be based on quantitative analysis (see guidelines for preliminary geotechnical-engineering evaluations in Hylland [1996]) of the stability of the 1985-86 landslide that shows an adequate factor of safety for potential deep-seated failure surfaces. An ongoing evaluation by the UGS of the Pine Ridge landslide that includes analysis of a section through the 1985-86 landslide may provide information on the potential for deep-seated landsliding affecting areas south of the scarp. I anticipate the UGS report describing the results of this evaluation will be released in the early part of 1997.

In a recent telephone conversation, the lot owner Lou Trujillo indicated that an unspecified building setback from the 1985-86 landslide scarp was approved by Wasatch County on lot 357, which is adjacent and west of this property (Lou Trujillo, verbal communication, October 15, 1996). A figure in the geologic report (AGRA Earth & Environmental [AGRA], 1996) for lot 357 shows the home will be set back about 140 feet from the scarp, a distance seven times greater than the minimum 20-foot building setback recommended by AGRA. In the UGS review (Black, 1996) of the AGRA (1996) report, Bill Black indicated neither upslope migration of active deep-seated landsliding nor the stability of the Pine Ridge landslide were considered in either AGRA's or the lot owner's self-imposed 140-foot building setback. Although I believe the self-imposed building setback at lot 357 is clearly more conservative than those proposed by either AGRA or AGS, its adequacy likewise cannot be assessed without a quantitative evaluation of the potential for deep-seated landsliding as described above.

The AGS (1996) report concludes that the 1985-86 landslide is "potentially unstable," and I concur. The report also concludes the southern part of the lot is "stable;" however, this conclusion considers only the potential for shallow slope failure (C. Payton, AGS, verbal communication, November 4, 1996). The adequacy of the 30-foot building setback from the 1985-86 landslide scarp cannot be assessed without at least a quantitative preliminary geotechnical-engineering slope-stability evaluation. As previously stated, the UGS is currently performing such an evaluation for the Pine Ridge landslide that may provide information related to the stability of the southern part of lot 356. I disagree with AGS's conclusion that placing the home in the southern part of the lot will "minimize the exposure to slope stability related hazards," but believe that it will reduce the exposure. I concur with AGS's recommendations regarding drain-field siting, surface drainage, and slope modifications, but believe their adequacy can only be evaluated if and when the potential for deep-seated landsliding has been addressed.

REFERENCES

AGRA Earth & Environmental, 1996, Engineering geology site reconnaissance, single-family residential lot 357 on Tree Top Lane, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report. 5 p.

American Geological Services, Inc., 1996, Geological reconnaissance, Timber Lakes subdivision, lot 356: Provo, Utah, unpublished consultant's report, 5 p.

Black, B.D., 1996, Review of "Engineering geology site reconnaissance, single-family residential lot 357 on Tree Top Lane, Timber Lakes subdivision, Wasatch County, Utah": Utah Geological Survey, unpublished Technical Report No. 96-14, 2 p.

Hoek, Evert, and Bray, John, 1981, Rock slope engineering: London, Institute of Mining and Metallurgy, 3rd edition, 402 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *in* Hylland, M.D., editor, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plates 1A-1D, scale 1:24,000.

-----in preparation, Geology, hydrogeology, and geologic hazards of western Wasatch County, Utah- a guide for land-use planning: Utah Geological Survey Special Study.

Attachment 1
Job No. 96-39

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author American Geological Services, Inc.   Date Of Report July 15, 1996

Title Of Report Geological reconnaissance, Timber Lakes subdivision, lot 356

UGS File No. Technical Report 96-39   Requesting Agency Wasatch County Planning   County Wasatch

USGS 7.5' Quad(s) (BLM No.) Center Creek (1126)   Sec., T., R. Section 9, T.4 S., R. 6 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]	Adequacy of report	COMMENTS (attach additional sheets if necessary)
1. List of reference materials used	A	
2. Vicinity map	N	not included, but report references earlier Dames & Moore report with vicinity map
3. Site-planning map at suitable scale, showing:	D	see below
3a. proposed development	D	specific homesite or drain-field locations not shown but described briefly in text
3b. topography	N	described briefly in text and shown on site profile
3c. geology	A	landslide features shown
3d. subsurface exploration and cross section locations	A	profile line shown
3e. surface water	N	
3f. landslide features	A	
3g. hazard-reduction features	A	recommended building setback shown
4. Description of site conditions:	A	
4a. slopes	A	described briefly in text and shown on profile
4b. slope materials	A	soil descriptions in text
4c. subsurface planar features	N	
4d. surface/ground water	N	no data on depth to ground water; assumed greater than 20 feet in southern part of lot
4e. vegetation	A	described in text
4f. suspected landslide features	A	described in text and shown on plan
4g. surficial processes	N	
4h. other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

SUBJECT		Adequacy of report	COMMENTS (attach additional sheets if necessary)
5.	Description of existing landslides, including items in (4) above, and:	D	presence of the deep-seated Pine Ridge landslide underlying entire lot not addressed; description of portion reactivated in 1985-86 adequate
5a.	failed unit(s)	–	
5b.	failure type(s)	–	
5c.	scarp characteristics	–	
5d.	age(s) of failure	–	
5e.	cause(s) of failure	–	
6.	Implications of nearby landslides	D	stability and potential for deep-seated landsliding in Pine Ridge landslide not addressed
7.	Geotechnical-engineering evaluation:	D	quantitative analysis of deep-seated landslides not performed but necessary to assess adequacy of building setbacks
7a.	subsurface materials/ground-water characterization	D	
7b.	laboratory testing	N	estimated soil strengths and properties adequate for preliminary geotechnical-engineering slope-stability evaluations
7c.	profiles/cross sections	D	profile of 1985-86 landslide would be necessary to analyze deep-seated landslides
7d.	static slope-stability analysis	D	
7e.	seismic slope-stability analysis	D	necessary if marginal static stability determined
	• input ground motions	–	
	• effects on shear strength and pore pressures	–	
	• liquefaction potential	–	
7f.	post-earthquake stability analysis	N	
8.	Conclusions regarding hazard	D	no conclusion related to potential for deep-seated slope failure affecting southern part of lot
9.	Recommendations	D	adequacy of 30-foot building setback undocumented; other recommendations adequate if supported by results of quantitative slope-stability study

Additional comments:

Reviewed By Francis X. Ashland Date Reviewed November 5, 1996

UGS.4/96 P. 2 of 2

Project:			Requesting Agency:
Review of reports for the Elkhorn Mountain-Staghorn Village development, northern Wasatch County, Utah			Wasatch County
By: Francis X. Ashland	Date: 11-13-96	County: Wasatch	Job No: 96-40 (R-35)
USGS Quadrangle: Park City East (1209)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed geologic-hazards aspects of two reports (Dames and Moore, 1995; Francis Smith Engineering, Inc. [FSE], 1996) for the proposed Elkhorn Mountain-Staghorn Village development in Wasatch County, Utah. The proposed development is located in two separate areas of northern Wasatch County. Elkhorn Mountain is in the E1/2 section 14, T. 2 S., R. 4 E., and Staghorn Village is in the NW1/4 section 24, T. 2 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of this review was to evaluate whether geologic hazards were adequately addressed to support proposed development plans described in the FSE (1996) report. The scope of work included a review of geologic and geologic-hazards literature (Bromfield and Crittenden, 1971; Hylland and others, 1995), but did not include a site visit. Foundation and earthwork recommendations in the Dames & Moore (1995) report should be reviewed by a geotechnical engineer, but appear adequate for the preliminary-design phase of the proposed development. Recommendations regarding reclamation and closure of abandoned mine workings should be reviewed by the Utah Division of Oil, Gas & Mining.

The Dames & Moore (1995) report addresses shallow rock and ground water, moisture-sensitive soils, rock falls, soil erosion, earthquake ground shaking, surface fault rupture, debris flows, flooding, abandoned mine openings, slope stability, and landslides. In my opinion this is a complete and accurate list of potential geologic hazards at the property. In general, I concur with recommendations and conclusions made in the report regarding geologic hazards, with the exception to its conclusion indicating no "areas of significant slope instability." Hylland and Lowe (1995) show an "older" landslide in the NW1/4SE1/4 section 14, T. 2 S., R. 4 E. that underlies proposed lot 6 and adjacent parts of Elkhorn Mountain Drive. I recommend that the landslide be addressed in a final-design-phase- or site-specific study.

The Dames & Moore (1995) report recommends supplemental site-specific investigations to define areas of expansive soils, assess slope stability, and determine final cut-slope angles, and I concur. In addition, I concur with the report's recommendation for construction-phase monitoring and observation by qualified personnel and suggest that the design engineer provide written verification to the county that construction, earthwork, and other geotechnical work were performed in accordance with design recommendations.

The FSE (1996) report adequately summarizes the observations, conclusions, and recommendations in the Dames & Moore (1995) report, and includes additional information from other sources on geology and geologic-hazards, including the potential for indoor radon gas. Despite a few probable typographical errors in the FSE (1996) report, I believe it adequately addresses geologic-hazards issues for the preliminary-design phase of the proposed development.

REFERENCES

Bromfield, C.S., and Crittenden, M.D., Jr., 1971, Geologic map of the Park City East quadrangle, Summit and Wasatch counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-852, scale 1:24,000.

Dames & Moore, 1995, Engineering geology reconnaissance and geotechnical study - proposed Stag Horn Village development, approximately 218 acres, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 20 p.

Francis Smith Engineering, Inc., 1996, Environmental impact statement - supplemental environmental study: Heber City, Utah, unpublished consultant's report, unpaginated.

Hylland, M.D., Lowe, Mike, and Bishop, C.E., 1995, Hylland, M.D., Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, 12 plates, scale 1:24,000.

Project: Review of "Report of ground-water monitoring, vicinity of Ben Air Drive, Taylorsville, Utah"			Requesting Agency: Taylorsville City
By: Mike Lowe	Date: 11-21-96	County: Salt Lake	Job No: 96-41 (R-36)
USGS Quadrangle: Salt Lake City South (1213)		Number of attachments: none	

At the request of Shane Pace, Taylorsville City, I reviewed a geologic evaluation (Terracon Consultants Western, Inc. [Terracon], 1996) of possible sources of shallow ground water in the vicinity of Ben Air Drive, Taylorsville, Utah. Ben Air Drive is in the NW¼ section 22, T. 2 S., R. 1 W., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether hydrogeologic conditions were adequately addressed to identify the cause of shallow ground-water flooding in the Ben Air Drive area. The scope of work included a literature review, discussions with Edward Keane (Terracon), and site visits on August 6 and November 1, 1996.

I believe the Terracon (1996) report adequately addresses hydrogeologic conditions in the Ben Air Drive area, but additional data supporting the report's conclusions are needed. The report indicates a slight ground-water mound that is being recharged by an unidentified source(s) in the Ben Air Drive area. Although the source(s)of recharge to the mound is not identified, the report concludes that, based on volume of water calculations, an up-gradient cemetery pond is not a source of recharge. Those calculations need to be included in the report for me to evaluate the validity of this conclusion. Similarly, the report indicates the up-gradient Utah and Salt Lake Canal is not a source of recharge, but does not address the canal's new weir west of the cemetery pond or the condition of the canal's liner. In my analysis of the data presented in the report, I find evidence that the canal may be a source of recharge. While the canal was flowing, the ground-water elevation in monitoring well GWMB-11, located at the canal, was consistently higher than or the same as the ground-water elevation in monitoring well GWMB-13, which is topographically uphill from GWMB-11. On October 31, 1996, after the canal had stopped flowing, the water level in monitoring well GWMB-11 at the canal was 1.5 feet lower in elevation than in GWMB-13, indicating a reversal of ground-water gradient and return to a downslope gradient that would be expected under the water-table (unconfined)conditions that occur in the Ben Air Drive area. These issues should also be addressed in the report.

The report recommends that the observation wells established as part of Terracon's study continue to be monitored, and I concur. Water levels should be monitored at least monthly in the winter, and weekly before and after flow in the canal begins and ends. As additional data are collected and evaluated, it may be possible to more positively identify the source(s) of recharge contributing to shallow ground-water flooding in the Ben Air Drive area. However, I believe it likely that numerous sources contribute, and defining quantitatively how much each source contributes may be difficult and require extensive additional study.

REFERENCE

Terracon Consultants Western, Inc., 1996, Report of ground-water monitoring, vicinity of Ben Air Drive, Taylorsville, Utah: Salt Lake City, unpublished consultant's report, 9 p.

Project: Review of "Geologic hazard assessment of lot 425, Timberlakes subdivision, Wasatch County, Utah"			Requesting Agency: Wasatch County
By: Francis X. Ashland	Date: 11-22-96	County: Wasatch	Job No: 96-42 (R-37)
USGS Quadrangle: Heber Mountain (1125)		Number of attachments: 1	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geologic report by Richard D. Poulson (1996) for lot 425 in Timber Lakes Estates, Wasatch County, Utah. The lot is on Aspen Road in the SE1/4 section 14, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to approval of a building permit to allow construction of a home on the lot. The scope of this review included a preliminary geotechnical-engineering slope-stability evaluation, review of geologic-hazards and soil-engineering literature (Holtz and Kovacs, 1981; Hylland and others, 1995), and review of aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit.

The Poulson (1996) report discusses liquefaction, faults, earthquake ground shaking, landslides, and slope stability. In general, all of these issues are inadequately addressed. Regarding liquefaction, the report states that "No definitive clay layers were encountered, so liquefaction does not appear to be a problem...." This statement implies that clay layers are liquefiable, but clay layers are generally not susceptible to liquefaction. Loose, saturated sands and silty sands are most susceptible to liquefaction (Holtz and Kovacs, 1981; Castro, 1987) during earthquake-induced ground shaking. The low liquefaction susceptibility of soils at the lot results not from the absence of clay layers but from the gradation (three out of four samples can be classified as poorly-graded gravels that have low liquefaction susceptibility) and relative density (no indication of liquefaction-susceptible loose soils) of the soils, and the absence of shallow ground water in at least the upper part of the lot (saturated conditions are necessary for liquefaction).

Presumably to address the potential for surface fault rupture, the Poulson (1996) report indicates the Strawberry fault is near the Timber Lakes area but the fault lacks evidence for Holocene movement. Hecker (1993) summarizes recent detailed work by the Bureau of Reclamation on the Strawberry fault which shows evidence for both latest Pleistocene and Holocene faulting and shows that the trace of the Strawberry fault does not cross the Timber Lakes area. Regarding ground shaking, the Poulson (1996) report states that "Utah...is classified as seismic zone 3 of the Uniform Building Code" (UBC). Although it is not correct that all of Utah is in seismic zone 3, much of northern and central Utah, including the Timber Lakes area, is in seismic zone 3, and Poulson correctly indicates that earthquake ground shaking is possible at the lot.

The Poulson (1996) report identifies several landslide features on and near the lot. The report identifies a "hummocky" slope area in the northeastern part of the lot as a landslide and indicates that a steep scarp on an abutting lot dies out in this slope. The curved aspen trunks on the slope described in the report may indicate soil creep. Poulson indicates no "unvegetated" debris-slide scars on the steeply sloping "hummocky" area, but observed others on nearby lots.

The Poulson (1996) report identifies a "terrace" at the crest of the steeply-sloping "hummocky" area and speculates it is a stream terrace or an "old meander bend." The report indicates no evidence that landsliding caused the terrace, based on a comparison of recent and older aerial photographs. I believe that the absence of any historical ground movement of the "terrace" does not give insight into its origin, because the most recent ground movement could predate the oldest available aerial photographs. I also believe that additional field evidence, possibly including trenching across the small scarp that bounds the upslope side of the "terrace," is necessary to determine its origin. My preliminary slope-stability evaluation using PC-STABL5M software, the profile included in the Poulson (1996) report, estimated soil properties based on laboratory tests from similar soils elsewhere in Timber Lakes (Utah Geological Survey, unpublished data), and assumed seasonally fluctuating ground-water conditions, indicates a potential for some critical deep-seated failure surfaces to intersect the ground surface near the "terrace" scarp. In addition, the topographic profile included in the Poulson (1996) report also shows that a three-horizontal-to-one-vertical (3H:1V) line projected from near the toe of the "hummocky" slope includes the terrace and intersects the ground surface at the upslope "terrace" scarp. An EarthStore (1988) report indicated that 3H:1V typically is the maximum stable slope inclination along Lake Creek. I believe that the coincidence of the location of the "terrace" scarp with the projected 3H:1V "stable" slope intersection and the intersection of potential deep-seated failure surfaces from my slope-stability analysis suggests a possible landslide origin of the "terrace."

In addition, Hylland and others (1995) identify a larger deep-seated landslide that underlies most of the lots along the northeastern part of Aspen Road, including lot 425. The scarp of this landslide forms the steep slope southwest of lot 425. The Poulson (1996) report does not address this landslide nor the potential for it to reactivate and cause damage on lot 425.

The Poulson (1996) report also makes some general comments regarding soil properties, soil bearing capacity, and foundation design. Although some soil tests were performed, the report does not recommend specific foundation designs, and is not a geotechnical soil-foundation report. Foundation-design issues may be addressed by a qualified geotechnical engineer, as appropriate, prior to construction of a home on the lot.

Although the report inadequately addresses hazards at the site, only the landslide hazard requires additional work to define the buildable area. The Poulson (1996) report concludes that there is adequate buildable area in the southwestern part of the lot, but this estimate includes the "terrace" area. The "terrace" however, is within the building-exclusion zone (EarthStore, 1988) using the 3H:1V projection from the toe of the slope, and the report has not adequately demonstrated that the "terrace" was not caused by slope failure and is stable. In addition, even if sufficient buildable area is present above the terrace, the report has not addressed the stability of the larger deep-seated landslide beneath the entire lot. This landslide includes many lots, and needs at least a preliminary geotechnical-engineering slope-stability analysis (see Hylland, 1996). A summary regarding my evaluation of the adequacy of Poulson's slope-stability assessment is shown in attachment 1.

REFERENCES

Castro, Gonzalo, 1987, On the behavior of soils during earthquake-liquefaction, *reprinted from* Cakmak, A.S., editor, Soil dynamics and liquefaction: Elsevier, 36 p.

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

Hecker, Suzanne, 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p.

Holtz, R.D., and Kovacs, W.D., 1981, An introduction to geotechnical engineering: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 733 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Hylland, M.D., Lowe, Mike, and Bishop, C.E., 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, 12 plates, scale 1:24,000.

Poulson, R.D., 1996, Geologic hazard assessment of lot 425, Timberlakes subdivision, Wasatch County, Utah: Mapleton, Utah, unpublished consultant's report, 8 p.

Attachment 1
Job No. 96-42

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author Richard D. Poulson. Date Of Report October 3, 1996

Title Of Report Geologic hazard assessment of lot 425, Timberlakes subdivision, Wasatch County, Utah

UGS File No. Technical Report 96-42 Requesting Agency Wasatch County Planning County Wasatch

USGS 7.5' Quad(s) (BLM No.) Heber Mountain (1125) Sec., T., R. Section 14, T.4 S., R. 6 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]		Adequacy of report	COMMENTS (attach additional sheets if necessary)
1.	List of reference materials used	D	some inaccuracies in report a result of out-of-date references
2.	Vicinity map	D	vicinity map incorrectly referenced; inadequate to identify site location
3.	Site-planning map at suitable scale, showing:	N	report intended to identify buildable areas prior to development
3a.	proposed development	–	lot owner intends to build cabin on lot
3b.	topography	–	
3c.	geology	–	
3d.	subsurface exploration and cross section locations	–	
3e.	surface water	–	
3f.	landslide features	–	
3g.	hazard-reduction features	–	
4.	Description of site conditions:	D	
4a.	slopes	A	described briefly in text and shown on profile
4b.	slope materials	D	no engineering soil classification given; glacial deposits described as "glacial waste"
4c.	subsurface planar features	N	
4d.	surface/ground water	A	
4e.	vegetation	A	
4f.	suspected landslide features	D	identifies "hummocky" area as indicative of landsliding; insufficient documentation for non-landslide origin of "terrace"
4g.	surficial processes	A	curved aspen trunks noted
4h.	other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

SUBJECT	Adequacy of report	COMMENTS (attach additional sheets if necessary)
5. Description of existing landslides, including items in (4) above, and:	D	presence of the deep-seated landslide underlying entire lot not addressed; non-landslide origin of "terrace" not supported
5a. failed unit(s)	–	
5b. failure type(s)	D	discussion of potential deep-seated slope failure lacking
5c. scarp characteristics	A	
5d. age(s) of failure	D	lack of evidence on aerial photographs cited as evidence for stability
5e. cause(s) of failure	D	non-earthquake origin of slope failure not supported
6. Implications of nearby landslides	D	stability and potential for deep-seated landsliding not addressed; origin of "terrace" requires further evaluation
7. Geotechnical-engineering evaluation:	D	quantitative analysis of deep-seated landslides not performed but necessary to assess slope stability
7a. subsurface materials/ground-water characterization	D	
7b. laboratory testing	N	estimated soil strengths and properties adequate for preliminary geotechnical-engineering slope-stability evaluation (see Hylland, 1996)
7c. profiles/cross sections	A	
7d. static slope-stability analysis	D	
7e. seismic slope-stability analysis	D	necessary if marginal static stability determined
• input ground motions	–	
• effects on shear strength and pore pressures	–	
• liquefaction potential	–	
7f. post-earthquake stability analysis	N	
8. Conclusions regarding hazard	D	potential for deep-seated slope failure affecting lot not addressed
9. Recommendations	D	adequacy of building setback recommendation undocumented; origin of "terrace" should be determined prior to allowing construction; stability of larger landslide underlying this and adjacent lots needs to be evaluated

Additional comments:

Reviewed By Francis X. Ashland

Date Reviewed November 13, 1996

UGS.4/96

P. 2 of 2

Project:			Requesting Agency:
Review of "Geologic evaluation, Lakewood Estates Phase II, alternative wastewater disposal, Duchesne County, Utah"			Uintah Basin Public Health Department
By: Mike Lowe	Date: 11-26-96	County: Duchesne	Job No: 96-43 (R-38)
USGS Quadrangle: Rabbit Gulch (1038)		Number of attachments: none	

At the request of Lowell Card, Uintah Basin Public Health Department, I reviewed a geologic evaluation (RB&G Engineering, Inc. [RB&G], 1996) for alternative wastewater-disposal systems for the proposed Lakewood Estates Phase II. The proposed 41-lot subdivision is located in section 33, T. 3 S., R. 6. W., Uinta Base Line and Meridian. The purpose of the review was to evaluate whether geologic conditions were adequately addressed to show that alternative wastewater-disposal systems in rock will function properly and not contaminate any drinking-quality ground water. The scope of work included a literature review and discussions with Michael N. Hansen (RB&G), but did not include a site visit.

The RB&G (1996) report adequately addresses depth and quality of regional ground water. It also adequately addresses site-specific: (1) slopes at proposed drain fields, (2) evidence for periodic surface-water flooding, (3) evidence for seasonal ground water within 4 feet of the bottom of the proposed drain fields, (4) host-rock test-pit percolation rates, and (5) potential for wastewater to surface or reach a culinary well or spring within 250 days ground-water time of travel. The report indicates a lack of available site-specific ground-water-quality data for aquifers underlying the proposed subdivision but, based on available regional data, notes that the total-dissolved-solids concentrations of underlying ground water are believed to be between 1,000-3,000 mg/L, and are likely greater than 1,500 mg/L. To obtain site-specific water-quality data, a well would need to be drilled at the site and the water tested.

The RB&G (1996) report concludes that lots 27, 32, 35, 36B, 37, 38, 42, 43, 44, 46, 47, 48, 49, 50, 53, 55, 58, 59, 62, and 65 are not suitable, based on the site-specific data collected, for alternative wastewater-disposal systems because of unsuitable (generally high) host-rock test-pit percolation rates or the potential for periodic surface-water flooding. The report recommends relocating test pits on these lots and performing additional percolation tests to try to find suitable locations. It may be possible to reduce the number of new test pits by using the more conservative of two alternative system designs allowed by Duchesne County, and by performing hydrologic modeling in areas of potential surface-water flooding. The RB&G (1996) report does not specify which of the two designs will be used, but for those lots that had test-pit percolation rates faster that 1 minute/inch, Alternative Disposal System B (Shallow Ground-Water System) may be used (John Kennington, Utah Division of Water Quality, verbal communication, October 31, 1996). The type B system requires that the distribution trenches be 5.5 feet wide (instead of 3 feet wide for the type A system), with a minimum of 2 feet of approved filter sand underneath and on both sides of the infiltrator system lines (instead of 1 foot below the infiltrator lines and 6 inches on the sides as is required for the type A system) (Uintah Basin Public Health Department, 1996). Whichever alternative system is used, it may be necessary to line the trenches with an appropriate geotextile fabric filter to prevent the loss of filter sand down the fractures in the trenches. Also, before excluding those test pits in areas of periodic surface-water flooding, the unsuitable parts of these lots may be further refined (and perhaps reduced) through hydrologic modeling of the 100-year flood. Through such modeling existing test pits may be found to be in the remaining suitable parts of the lots.

Lowe (1996) provides guidelines for preparing hydrogeologic reports addressing suitability for alternative wastewater-disposal systems in rock. Based on those guidelines, the following additional information may still need to be submitted to determine if the proposed subdivision is suitable for alternative wastewater-disposal systems: (1) a detailed geologic map and geologic cross sections showing the geology and topography at and near the proposed subdivision, if any geologic units are present in the shallow subsurface that may impede downward flow and cause surfacing of effluent; (2) more detailed descriptions of the characteristics of faults and joints (particularly aperture) observed in the test pits to assess the need for lining trenches with a geotextile fabric filter; and (3) identification and characterization of the aquifer system below the site to demonstrate the applicability of regional ground-water-quality data, including a description of topographic and geologic controls on the ground-water system and the potential for local perched aquifers above the regional aquifer beneath the subdivision. I recommend that the developer provide the information identified above prior to approval of alternative wastewater-disposal systems for lots within this proposed subdivision.

REFERENCES

Lowe, Mike, 1996, Guidelines for hydrogeologic reports addressing suitability for alternative wastewater-disposal systems in rock in Duchesne County, Utah (preliminary): Salt Lake City, unpublished Utah Geological Survey Guidelines, 6 p.

RB&G Engineering, Inc., 1996, Geologic evaluation, Lakewood Estates Phase II, alternative wastewater disposal, Duchesne County, Utah: Provo, Utah, unpublished consultant's report, 40 p.

Uintah Basin Public Health Department, 1996, Proposal for the installation of experimental wastewater disposal systems in the Green River and Duchesne River Formations in Duchesne County, Utah (draft): Vernal, Utah, unpublished Uintah Basin Public Health Department proposal, 3 p.

Project:			Requesting Agency:
Review of "Engineering geology site reconnaissance - single-family residential lot, lot 717 on Spring Creek Drive, Timberlakes subdivision, Wasatch County, Utah.			Wasatch County
By: Francis X. Ashland	Date: 11-29-96	County: Wasatch	Job No: 96-44 (R-39)
USGS Quadrangle: Heber Mountain (1125)		Number of attachments: 1	

At the request of Robert Mathis, Wasatch County Planner, I reviewed an engineering-geology report by AGRA Earth & Environmental (AGRA) (1996) for lot 717 in Timber Lakes Estates, Wasatch County, Utah. The lot is located on Spring Creek Drive in the SE1/4 section 10, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to construction of a home on the lot. The scope of this review included a preliminary geotechnical-engineering slope-stability analysis (using STED and PC-STABL5M software), a review of geologic-hazards literature (Hylland and others, 1995) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction.

The AGRA (1996) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, liquefaction, and moisture-sensitive soils. I believe the report adequately addresses these potential geologic hazards and concur with AGRA's conclusions and recommendations. However, the AGRA (1996) report does not adequately address landslides and slope stability.

AGRA indicates that the steep slope in the north-central part of lot 717 is potentially unstable but observed no evidence for "past, present, or imminent slope instability." AGRA supports this statement with observations that mature fir trees and other vegetation are present on the slope and that the active channel of Lake Creek is presently located about 140 feet north of the toe of the slope. On the basis of these observations, AGRA concludes that a building setback based on a two-horizontal-to-one-vertical (2H:1V) projection from the toe of the steep slope is adequate to reduce the exposure from landslide hazards. This proposed 2H:1V projection is less conservative than the 3H:1V projection that has been used elsewhere in the Timber Lakes area (EarthStore, 1988). This EarthStore building-setback recommendation is based on their statistical evaluation of landslides in Timber Lakes Estates which indicated that 70 percent of these existing landslides had reached assumed stable conditions at 3 to 3.5H:1V slopes.

I do not believe that AGRA has demonstrated the adequacy of a building setback based on a 2H:1V projection from the toe of the slope. My preliminary geotechnical-engineering slope-stability evaluation (for an explanation of this method see Hylland, 1996) indicates that the steep slope is susceptible to shallow debris slides in both wet and dry conditions, and that deep-seated landslides which could impact the southern part of the lot beyond the 2H:1V projection are possible during wet conditions. The presence of mature vegetation does not preclude the potential for either shallow or deep-seated slope failure as is evident by numerous recent debris slides in areas of mature vegetation elsewhere in the Timber Lakes area and recent deep-seated landslides in areas covered by mature vegetation, such as the 1985-86 landslide north of Ridge Pine Drive. My evaluation also suggests that slope stability is more sensitive to changes in ground-water levels than undercutting of the toe of the slope by Lake Creek. Therefore, although the present distance of the active channel of Lake Creek from the toe of the slope reduces the likelihood of undercutting, this alone is not a significant justification for using a less conservative building setback at the lot. To justify a setback distance less than the 3H:1V projection, I believe that, at a minimum, a preliminary geotechnical-engineering slope-stability evaluation that incorporates data on late spring-early summer ground-water levels must be performed and show that an adequate factor of safety for deep-seated slope failure exists. A summary regarding my evaluation of the adequacy of AGRA's slope-stability assessment is shown in attachment 1.

REFERENCES

AGRA Earth & Environmental, 1996, Engineering geology site reconnaissance - single-family residential lot, lot 717 on Spring Creek Drive, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 7 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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Attachment 1
Job No. 96-44

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author AGRA Earth & Environmental   Date Of Report October 17, 1996

Title Of Report Engineering geology site reconnaissance - single-family residential lot, lot 717 on Spring Creek Drive, Timberlakes subdivision, Wasatch County, Utah

UGS File No. Technical Report 96-44 Requesting Agency Wasatch County Planning   County Wasatch

USGS 7.5' Quad(s) (BLM No.) Heber Mountain (1125) Sec., T., R. Section 10, T. 4 S., R. 6 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]	Adequacy of report	COMMENTS (attach additional sheets if necessary)
1. List of reference materials used	A	
2. Vicinity map	A	
3. Site-planning map at suitable scale, showing:	D	report intended to define buildable area; needs a map showing buildable area at an appropriate scale
3a. proposed development	–	
3b. topography	–	
3c. geology	–	
3d. subsurface exploration and cross section locations	–	
3e. surface water	–	
3f. landslide features	–	
3g. hazard-reduction features	–	
4. Description of site conditions:	D	
4a. slopes	A	described briefly in text; shown on profile
4b. slope materials	A	glacial till
4c. subsurface planar features	N	
4d. surface/ground water	D	lack of seeps or springs on slopes may be related to dry season in which study was performed
4e. vegetation	A	described in text
4f. suspected landslide features	A	nearby large landslides described
4g. surficial processes	A	soil creep identified
4h. other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

SUBJECT	Adequacy of report	COMMENTS (attach additional sheets if necessary)
5. Description of existing landslides, including items in (4) above, and:	N	none identified on lot
5a. failed unit(s)	–	
5b. failure type(s)	–	
5c. scarp characteristics	–	
5d. age(s) of failure	–	
5e. cause(s) of failure	–	
6. Implications of nearby landslides	D	nearby landslides indicate susceptibility of steep slope to landsliding
7. Geotechnical-engineering evaluation:	D	quantitative analysis necessary to demonstrate adequacy of recommended building setback based on a 2H:1V projection from the toe of steep slope
7a. subsurface materials/ground-water characterization	D	slope stability appears sensitive to high ground-water levels
7b. laboratory testing	N	estimated soil strength parameters will be adequate
7c. profiles/cross sections	N	profile included in report is adequate
7d. static slope-stability analysis	D	
7e. seismic slope-stability analysis	N	may be necessary if marginal static stability determined
• input ground motions	–	
• effects on shear strength and pore pressures	–	
• liquefaction potential	–	
7f. post-earthquake stability analysis	N	
8. Conclusions regarding hazard	D	conclusions related to potential for slope failure ignore implications of failures on nearby slopes
9. Recommendations	D	building-setback recommendations are not adequate in absence of quantitative slope-stability evaluation

Additional comments:

Reviewed By Francis X. Ashland Date Reviewed November 14, 1996

UGS.4/96 P. 2 of 2

Project:			Requesting Agency:
Review of "Geologic hazard assessment of lot 1139, Timberlakes subdivision, Wasatch County, Utah."			Wasatch County
By: Francis X. Ashland	Date: 12-2-96	County: Wasatch	Job No: 96-45 (R-40)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geologic report by Richard D. Poulson (1996) for lot 1139 in Timber Lakes Estates, Wasatch County, Utah. The lot is located on Aspen Road in section 10, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to approval of a building permit to allow construction of a home on the lot. The scope of this review included a preliminary geotechnical-engineering slope-stability evaluation, review of geologic-hazards and soil-engineering literature (Holtz and Kovacs, 1981; Hylland and others, 1995) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit.

The Poulson (1996) report discusses liquefaction, faults, earthquake ground shaking, landslides, and slope stability. In general, all of these issues are inadequately addressed. Regarding liquefaction, the report states that "no definitive clay layers were encountered, so liquefaction does not appear to be a problem...." This statement implies that clay layers are liquefiable, which generally they are not. Loose, saturated sands and silty sands are most susceptible to liquefaction (Holtz and Kovacs, 1981; Castro, 1987) during earthquake-induced ground shaking. The low liquefaction susceptibility of soils at the lot results not from the absence of clay layers but from the gradation (three out of four samples can be classified as poorly-graded gravels that have low liquefaction susceptibility) and relative density (no indication of liquefaction-susceptible loose soils) of the soils, and the absence of shallow ground water in at least the upper part of the lot (saturated conditions are necessary for liquefaction).

Presumably to address the potential for surface fault rupture, the Poulson (1996) report indicates the Strawberry fault is near the Timber Lakes area but the fault lacks evidence for Holocene movement. Hecker (1993) summarizes recent detailed work by the Bureau of Reclamation on the Strawberry fault which shows evidence for both latest Pleistocene and Holocene faulting and shows that the trace of the Strawberry fault does not cross the Timber Lakes area. Regarding ground shaking, the Poulson (1996) report states that "Utah...is classified as seismic zone 3 of the Uniform Building Code" (UBC). Although it is not correct that all of Utah is in seismic zone 3, much of northern and central Utah, including the Timber Lakes area, is in seismic zone 3, and Poulson correctly indicates that earthquake ground shaking is possible at the lot.

The Poulson (1996) report indicates no evidence of slumping or fractures related to landsliding on the lot. In addition, the report states that trees on the steep slopes in the northeast part of the lot "appeared to be...stationary" indicating no recent landsliding or soil creep. Poulson observed evidence for ground movement on nearby lots and the report states that "soils are moving," and also indicates an area of sloughing with unvegetated scarps on abutting lot 1138. The report indicates lot 1139 consists of a relatively flat portion in the southwest and a steeply sloping portion in the northeast, and recommends a 25-foot building setback from the break-in-slope to reduce the risk from potential landslide hazards. The report, however, provides no basis for this recommendation. In a previous study for parts of the Timber Lakes area, EarthStore (1988) recommended that building setbacks be determined based on the intersection of an imaginary plane with a slope of three-horizontal-to-one-vertical (3H:1V) projected from the toe of the slope adjacent to Lake Creek. EarthStore's recommendation was based on their statistical analysis of assumed stable slopes in landslides in the Timber Lakes area.

The Poulson (1996) report also makes some general comments regarding soil strength that are related to foundation design, however the report does not recommend specific foundation designs and is not a geotechnical soil-foundation report. Foundation-design issues may be addressed by a qualified geotechnical engineer, as appropriate, prior to construction of a home on the lot.

Although the report inadequately addresses hazards at the site, only the landslide hazard requires additional work to define the buildable area. The Poulson (1996) report concludes that there is a "fairly large area" that is "suitable for building a home" in the flatter southwestern part of the lot, assuming that a 25-foot building setback from the break-in-slope is adequate to reduce the risk associated with landslide hazards. I believe the adequacy of the 25-foot building setback has not been demonstrated and, based on EarthStore's (1988) results, recommend a minimum setback based on a 3H:1V projection from the toe of the slope be used unless either the 25-foot building setback is shown to be more conservative or a proposed steeper slope can be shown to be stable by at least a preliminary geotechnical-engineering slope-stability analysis (see Hylland, 1996). Estimates of the buildable area may change once a setback line based on a 3H:1V projection or other stable slope angle has been determined. A summary regarding my evaluation of the adequacy of Poulson's slope-stability assessment is shown in attachment 1.

REFERENCES

Castro, Gonzalo, 1987, On the behavior of soils during earthquake-liquefaction, *reprinted from* Cakmak, A.S., editor, Soil dynamics and liquefaction: Elsevier, 36 p.

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

Hecker, Suzanne, 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p.

Holtz, R.D., and Kovacs, W.D., 1981, An introduction to geotechnical engineering: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 733 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah

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Hylland, M.D., Lowe, Mike, and Bishop, C.E., 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, 12 plates, scale 1:24,000.

Poulson, R.D., 1996, Geologic hazard assessment of lot 1139, Timberlakes subdivision, Wasatch County, Utah: Mapleton, Utah, unpublished consultant's report, 8 p.

Attachment 1
Job No. 96-45

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author Richard D. Poulson Date Of Report October 21, 1996

Title Of Report Geologic hazard assessment of lot 1139, Timberlakes subdivision, Wasatch County, Utah

UGS File No. Technical Report 96-45 Requesting Agency Wasatch County Planning County Wasatch

USGS 7.5' Quad(s) (BLM No.) Center Creek (1126) Sec., T., R. Section 10, T.4 S., R. 6 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]		Adequacy of report	COMMENTS (attach additional sheets if necessary)
1.	List of reference materials used	D	some inaccuracies in report a result of out-of-date references
2.	Vicinity map	A	
3.	Site-planning map at suitable scale, showing:	D	report intended to identify buildable areas prior to development; needs a map showing buildable area at an appropriate scale
3a.	proposed development	–	
3b.	topography	–	
3c.	geology	–	
3d.	subsurface exploration and cross section locations	–	
3e.	surface water	–	
3f.	landslide features	–	
3g.	hazard-reduction features	–	
4.	Description of site conditions:	D	
4a.	slopes	D	described briefly in text; no detailed slope map or profile to help determine building setback line provided
4b.	slope materials	D	no engineering soil classification given; glacial deposits described as "glacial waste"
4c.	subsurface planar features	N	
4d.	surface/ground water	A	
4e.	vegetation	A	
4f.	suspected landslide features	N	none identified on lot
4g.	surficial processes	N	
4h.	other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information.*

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

	SUBJECT	Adequacy of report	COMMENTS (attach additional sheets if necessary)
5.	Description of existing landslides, including items in (4) above, and:	N	none identified on lot
5a.	failed unit(s)	–	
5b.	failure type(s)	–	
5c.	scarp characteristics	–	
5d.	age(s) of failure	–	
5e.	cause(s) of failure	–	
6.	Implications of nearby landslides	D	nearby landslides and "moving" soils indicate susceptibility of slope to shallow and deep-seated landsliding
7.	Geotechnical-engineering evaluation:	N	not necessary unless a setback less than the 3H:1V projection is proposed
7a.	subsurface materials/ground-water characterization	–	
7b.	laboratory testing	–	
7c.	profiles/cross sections	–	
7d.	static slope-stability analysis	–	
7e.	seismic slope-stability analysis	–	
	• input ground motions	–	
	• effects on shear strength and pore pressures	–	
	• liquefaction potential	–	
7f.	post-earthquake stability analysis	–	
8.	Conclusions regarding hazard	D	potential for deep-seated slope failure affecting lot not addressed
9.	Recommendations	D	adequacy of 25-foot building-setback recommendation undocumented

Additional comments:

Reviewed By Francis X. Ashland Date Reviewed November 15, 1996

UGS.4/96 P. 2 of 2

Project: Review of "Engineering geology site reconnaissance - single-family residential lot, lot 1278 on Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah"			Requesting Agency: Wasatch County
By: Francis X. Ashland	Date: 12-2-96	County: Wasatch	Job No: 96-46 (R-41)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed an engineering geology report by AGRA Earth & Environmental (AGRA) (1996) for lot 1278 in Timber Lakes Estates, Wasatch County, Utah. The lot is located on Ridgeline Drive in the NW1/4NE1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to preliminary approval of construction of a home on the lot. The scope of work included a review of geologic-hazards literature (Hylland and others, 1995) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction. Although the AGRA report does not address septic-tank suitability, I have included comments related to this issue at Mr. Mathis' request because of potential problems at the site.

The AGRA (1996) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, liquefaction, and moisture-sensitive soils. With the exception of the potential for shallow ground water, I believe the report adequately addresses these potential geologic hazards and concur with AGRA's conclusions and recommendations. AGRA estimates the depth to the ground-water table to be about 30 feet at the site based primarily on the absence of springs on the lot but indicates that perched ground water is possible, especially during the late spring and early summer. I concur that perched ground water is possible, but believe that the absence of evidence indicating shallow ground water, which may, in part, reflect the timing of AGRA's site visit near the end of the dry part of the year and when the lot was partly covered by snow, is insufficient to estimate a 30-foot depth to ground water.

The AGRA (1996) report also does not discuss the potential for shallow rock. In addition to the possible role of shallow rock as a less permeable layer for perched ground water, the potential for shallow rock has important implications for foundation conditions, excavatability, and suitability of a septic-tank soil-absorption (STSA) system. Hylland and others (1995) indicate soils at the lot are "generally unsuitable" for STSA systems as a result of shallow bedrock; however, this does not necessarily preclude the possibility of siting a STSA system on the lot. AGRA indicates that soils on the site "may be clayey" but does not discuss the implications of this with respect to the potential for perched ground water or STSA-system suitability.

The AGRA (1996) report also preliminarily addresses landslides and slope stability and is adequate for the intended purpose. The report indicates no evidence of landsliding on the lot, although evidence for landsliding may have been obscured by partial snow cover during AGRA's visit. AGRA indicates site grading and earthwork may cause "small shallow slope failures" if slopes are oversteepened, but does not specifically address whether other site modifications, including landscape irrigation and effluent from a STSA system, will destabilize the slopes. Utah Division of Water Quality (1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability.

AGRA concludes that the site is "not exposed to undue geologic hazards" and that "under existing conditions, exposure...to slope stability...hazards is low." Regarding slope stability, AGRA could not, lacking a site development plan, specifically address the potential for slope instability resulting from site modifications that include grading, landscape irrigation, and a STSA system. Because AGRA indicates a potential for instability resulting from site modifications, at a minimum, a preliminary geotechnical-engineering study or appropriate site-specific design recommendations will be needed to address this issue once a specific site development plan is proposed for the lot. An addendum report describing the results of the study and/or design recommendations should be completed and reviewed prior to approval of a building permit for the lot.

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AGRA Earth & Environmental, 1996, Engineering geology site reconnaissance - single-family residential lot, lot 1278 on Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 6 p.

Hylland, M.D., Lowe, Mike, and Bishop, C.E.,1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, 12 plates, scale 1:24,000.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

APPENDIX

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Black, B.D., Lund, W.R., Schwartz, D.P., Gill, H.E., and Mayes, B.H., 1996, Paleoseismology of Utah volume 7 - Paleoseismic investigation on the Salt Lake City segment of the Wasatch fault zone at the South Fork Dry Creek and Dry Gulch sites, Salt Lake County, Utah: Utah Geological Survey Special Studies 92, 22 p.

Black, B.D., and Solomon, B.J., 1996, Radon-hazard potential of the lower Weber River area, Tooele Valley, and southeastern Cache Valley, Cache, Davis, Tooele, and Weber Counties, Utah: Utah Geological Survey Special Studies 90, 56 p.

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Solomon, B.J., 1996, Radon-hazard potential of the central Sevier Valley, Sevier County, Utah: Utah Geological Survey Special Studies 89, 48 p.

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Christenson, G.E., editor, 1996, The September 2, 1992 M_L 5.8 St. George earthquake, Washington County, Utah: Utah Geological Survey Circular 88, 41 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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-----1996, Radon-hazard potential in Tooele Valley, Tooele County, Utah: Utah Geological Survey Public Information Series 42, 2 p.

-----1996, Radon-hazard potential in western Salt Lake Valley, Salt Lake County, Utah: Utah Geological Survey Public Information Series 43, 2 p.

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-----1996, Radon-hazard potential in the Ogden Valley, Weber County, Utah: Utah Geological Survey Public Information Series 36, 2 p.

-----1996, Radon-hazard potential in the St. George area, Washington County, Utah: Utah Geological Survey Public Information Series 35, 2 p.

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Ashland, F.X., Bishop, C.E., Lowe, Mike, and Mayes, B.H., 1996, The geology of the Snyderville basin and its relation to ground-water conditions: Utah Geological Survey Open-File Report 337, 124 p.

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Christenson, G.E., and Lowe, Mike, 1996, Ground-water studies in the Applied Geology Program: Survey Notes, v. 28, no. 1, p. 1.

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