TECHNICAL REPORTS FOR 1989-1990
APPLIED GEOLOGY PROGRAM

compiled by

Bill D. Black

UTAH GEOLOGICAL AND MINERAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
REPORT OF INVESTIGATION 220 **1990**

CONTENTS

Appendix

Illustration

PREFACE

The Applied Geology Program is a part of the Utah Geological and Mineral Survey. The program is responsible for mapping and defining geologic hazards, as well as providing assistance to tax-supported entities (i.e. cities, towns, counties, state agencies, and school districts) on matters where engineering geologic factors are of concern. In this aspect, emphasis is placed on site evaluations of critical public facilities such as police and fire stations, hospitals, water treatment plants, and schools. The program also conducts investigations to answer specific geologic or hydrologic questions from state and local government agencies, such as evaluations of protection zones required for culinary springs and investigations of slope stability or soil problems in developing areas for county planning departments. These projects are usually of short duration (a month or less) and are performed at no cost to the requesting agency, although services in kind are usually provided. The Applied Geology Program also conducts studies of a longer and more detailed nature. These studies are also intended to meet specific needs, and are performed on a cost-sharing basis with the entity requesting the study. In addition to these projects, the Applied Geology Program reviews and comments on technical reports submitted by consultants to state and local government agencies.

Information dissemination is a major goal of the UGMS. Applied Geology Program studies considered of general interest to the public are published in several UGMS formats. Many Applied Geology Program projects address specific problems of interest to a limited audience. These studies are commonly presented in a technical report or letter and are distributed on a need-to-know basis. Copies of the reports are maintained in the Applied Geology Program files and are available for inspection upon request.

The purpose of this Report of Investigation is to present, in a single document, the 24 technical reports and letters generated by the Applied Geology Program in 1988 and 1989 (fig. 1) which received limited distribution. The reports are grouped by topic, and the author(s) and requesting agency are indicated on each report. Minor editing has been performed for clarity and conformity, but no attempt has been made to upgrade the original graphics, most of which were produced on a copying machine. This report represents the sixth periodic compilation of Applied Geology Program studies, and is intended to make the results of the Applied Geology Program projects available to the general public.

Bill D. Black

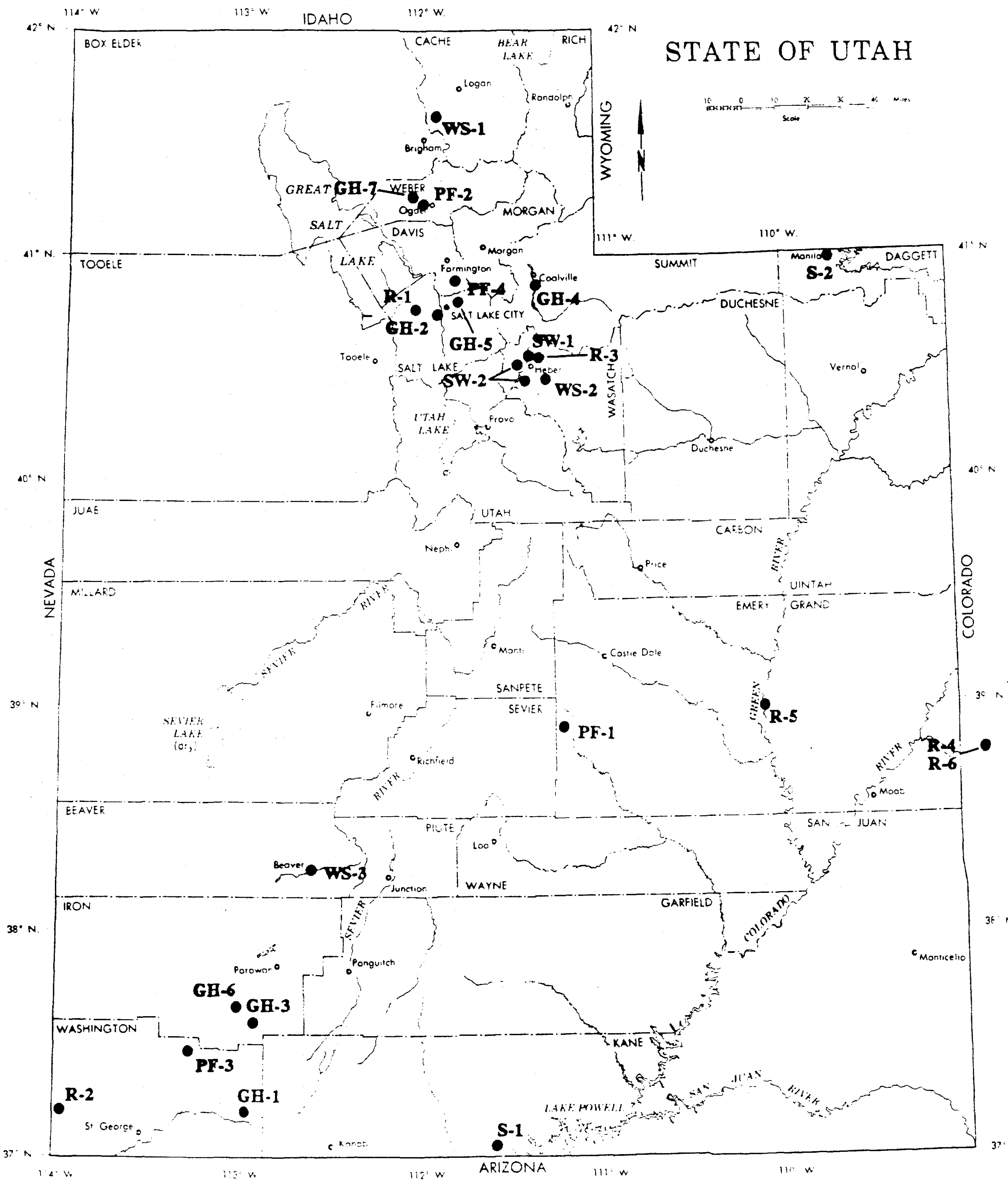


Figure 1. Location map.

PUBLIC FACILITIES

Project:			Requesting Agency:
Town of Emery, Emery County Municipal Water Treatment Plant			Castle Valley Special Services District, Mr. D.V. Leamaster, Manager
By: W.E. Mulvey	Date: 1-7-88	County: Emery	Job No.: 88-01(PF-1)
USGS Quadrangle: Emery West #633			

PURPOSE AND SCOPE

In response to a request by Mr. Darrel V. Leamaster, manager of the Castle Valley Special Services District, the Utah Geological and Mineral Survey made a geologic hazards investigation of the proposed site for a municipal water treatment plant in Emery, Utah. The site is located in T.22 S., R.6 E., section 4, Salt Lake Baseline and Meridian (attachment 1). The investigation was conducted November 11, 1987, for the purpose of evaluating the site for potential geologic hazards that could adversely effect the facility. In addition to the site reconnaissance the scope of the project included a review of available geologic and hydrologic literature for the site vicinity and logging of three test pits.

SETTING

Located immediately northwest of the town of Emery, the water treatment plant will replace an existing pump house which supplies culinary water to the town from two nearby ponds (attachment 2). The property is characterized by gentle topography with slopes averaging 1 to 3 degrees on a dissected alluvial fan. Approximately 1/2 mile away, on the northwest portion of the property, slopes steepen to over 30 degrees and rise to a gravel-capped bench (pediment surface). To the west, the Wasatch Plateau rises in a series of steep cliffs.

The alluvial fan at the site originates from a natural amphitheater formed by headward erosion of drainages at the base of the cliffs and bench. Ephemeral drainages on the fan surface are from 2 to 4 feet deep and appear to be actively eroding. Total relief across the property is 120 feet, with elevations ranging from 6440 feet at the top of the bench to 6320 feet immediately east of the building site. Annual precipitation for the region is 6 to 11 inches, supporting a vegetation community of galletagrass, shadescale, and greasewood with some juniper and pinyon pine present on slopes above the site.

GEOLOGY AND SOILS

The site is located in the Colorado Plateau physiographic province in the southwest portion of Castle Valley. Castle Valley is bounded by the Wasatch Plateau on the west and the San Rafael Swell on the east. Locally, the area is characterized by Cretaceous-age bedrock that dips gently to the west and forms the eastern escarpment of the

Wasatch Plateau. The escarpment is composed, from oldest to youngest, of the Mancos Shale, Emery Sandstone, Masuk Shale, Star Point Sandstone, and Black Hawk Formation. Several normal faults offset these units west of the study area in the Wasatch Plateau. The closest is the Paradise fault, approximately 3/4 of a mile away, which forms the eastern boundary of the Joes Valley fault zone (Hayes and Sanchez, 1979). The Joes Valley fault zone has been active during Quaternary time (1.8 my B.P. to present) (Foley and others, 1987).

The predominate bedrock in the site vicinity is the Mancos Shale, which underlies the valley floor to a depth of several hundred feet. Castle Valley owes its origin to the soft, easily erodible nature of the Mancos Shale (Stokes and Cohenour, 1956). The Mancos Shale in Castle Valley is overlain by a thin veneer of unconsolidated Quaternary deposits derived from the weathering and erosion of sandstone bedrock units to the west. Alluvial fans cover the Mancos Shale in the site area to a depth of approximately 30 feet as indicated in well log data (D. V. Leamaster, oral commun., 1987). North of the building site, erosional remnants of the Mancos Shale rise above the alluvial fan and form the bench (pediment surface) which is in turn capped by mid-Pleistocene gravels (>150,000 yr B.P.). Gravels on the surface were derived from streams that originated on the Wasatch Plateau.

At the plant site, Quaternary alluvial fans overlie the Mancos Shale. Surface soils consist of the Ravola-Billings-Penoyer association which are generally deep, well to moderately well drained, and medium to moderately fine textured (Swenson and others,1970). Three test pits were excavated within the building area to a depth of 8 to 10 feet (attachment 2). Test pit soils were described according to the Unified Soil Classification System (USCS) (appendix A). All test pits showed similar soils, predominately fine to medium grained; well to poorly graded sand (SP-SW) and sand with silt (SM) (appendix B). These soils were at least 8 to 10 feet thick in the test pits, and it is believed that they extend to a depth of 30 feet below the site.

GEOLOGIC HAZARDS

FLASH FLOODING

Flooding potential for the site is low to moderate. The Federal Emergency Management Agency (FEMA) has not published flood hazard maps for the town of Emery. However, FEMA emphasizes that although the area may not be subject to the 100-year flood, floods of a greater magnitude could occur there and may cause localized damage to structures (FEMA, 1978). Sudden cloudburst storms may cause localized flows in ephemeral streams draining the mountain slopes west of the site. To avert flash-flood damage, a diversion ditch was excavated behind the lower storage pond and has reportedly been successful in containing runoff (attachment 2). However, during large cloudburst storms, this diversion ditch might possibly be overtopped and allow surface water to enter the storage ponds.

EROSION

Surface erosion potential on the site is moderate. Lack of vegetation cover and the presence of easily erodible soils is offset by gentle slopes and low annual precipitation. However, sudden cloudburst storms may cause localized erosion problems. Ephemeral drainage channels (2 to 4 feet deep) are actively eroding the fan surface northwest of the building site. These channels drain toward the pond north of the proposed site, and sediment carried in them could partially fill the diversion ditch protecting the pond, reducing its capacity to contain flood waters.

ADVERSE SOIL CONDITIONS

Soils at the site are fine to medium grained and well drained with little or no shrink-swell capacity. The underlying Mancos Shale, however, contains materials which have a high shrink-swell capacity. Should excavation for building foundations expose the Mancos Shale, the potential for damage from shrink-swell soils would greatly increase.

Due to the nature of the alluvial-fan sediments, it is essential that they be properly compacted if used for fill material during construction. Cracks observed in the concrete block pump house now at the site were formed by settlement of the building foundation due to poor compaction during construction. Ponding of surface runoff due to inadequate drainage at the site caused the soils to settle and further damage the structure (D.V. Leamaster, oral commun., 1987).

GROUND WATER

No shallow ground water was encountered in test pits or reported in water well logs in the area. Thus, no hazards are believed to exist at the site relating to shallow ground water. Water wells in the area are deep (1500 feet) and produce water contaminated by alkaline minerals derived from the Mancos Shale (D.V. Leamaster, oral commun., 1987).

EARTHQUAKE HAZARDS

The site is located in seismic zone U-2 as established by the Utah Seismic Safety Advisory Council (USSAC) and in zone 2 of the Uniform Building Code (UBC). These zonations indicate the relative hazard due to ground shaking, and divide Utah into four USSAC and three UBC seismic zones, with zone 2 having a low to moderate ground shaking hazard with expected Modified Mercalli intensities of I - VII (attachment 3, appendix A).

No active faults occur at the site. The nearest such fault, the Paradise fault, is located 3/4 mile west of the study area and has been active during the Quaternary (1.8 my B.P.). From stratigraphic relationships observed in a graben at the mouth of Muddy Creek, immediately north of the town of Emery, it was determined that the fault was active prior to 150,000 yr B.P., but has not been active since that time (Foley and others, 1986). Based on these findings, no surface fault rupture hazard is thought to exist at the site. Other earthquake hazards such as liquefaction and earthquake-induced slope failures are low because of favorable soil and ground-water conditions and lack of steep slopes at the site.

CONCLUSIONS AND RECOMMENDATIONS

Overall, geologic hazards at the site are few and include chiefly localized erosion and problems associated with the drainage of surface runoff. The structures built on the site should be designed with these geologic limitations in mind. Incised drainages on the alluvial-fan surface north of the building site show recent erosion by surface water draining from the mountain front. These drainages flow into a diversion ditch immediately behind the lower storage pond. The ditch is adequate for low intensity cloudburst storms, but may not completely contain water from a high intensity-short duration event. It is recommended that the ditch design be evaluated to determine if modifications are needed to accommodate maximum expected flood flows.

Soil logs from the three test pits excavated on the site indicate that the soils are well drained and have little or no shrink-swell capacity. However, caution should be taken in construction excavations to avoid exposing the Mancos Shale, due to its high shrink-swell capacity and potential for damage to buildings. Poor compaction of construction fill has damaged existing structures. Therefore, the UGMS recommends that a qualified soils engineer conduct a soil foundation investigation to determine soil bearing strengths and provide specifications for compaction of construction fill prior to constructing buildings on the site. Care should be taken to direct surface drainage and roof runoff away from the foundation of the building. The site is in an area where moderate damage may occur due to earthquakes with maximum Modified Mercalli intensities of VII, and buildings should be constructed to conform to UBC seismic zone 2 standards.

BIBLIOGRAPHY

Federal Emergency Management Agency, 1978, Flood hazard boundary map, Emery County, Utah: Community No. 490058 0001-0049, scale 1:24,000.

Foley, L.L., Martin, R.A., Jr., and Sullivan, T.J., Seismotectonic study for Joes Valley, Scofield and Huntington north dams, Emery County and Scofield projects, Utah: U.S. Bureau of Reclamation Seismotectonic Report No. 86-7, 132 p.

Hayes, P.T., and Sanchez, J.D., 1979, Geologic map and coal resources of the Emery West Quadrangle, Emery and Sevier Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map C-82, scale 1:24,000.

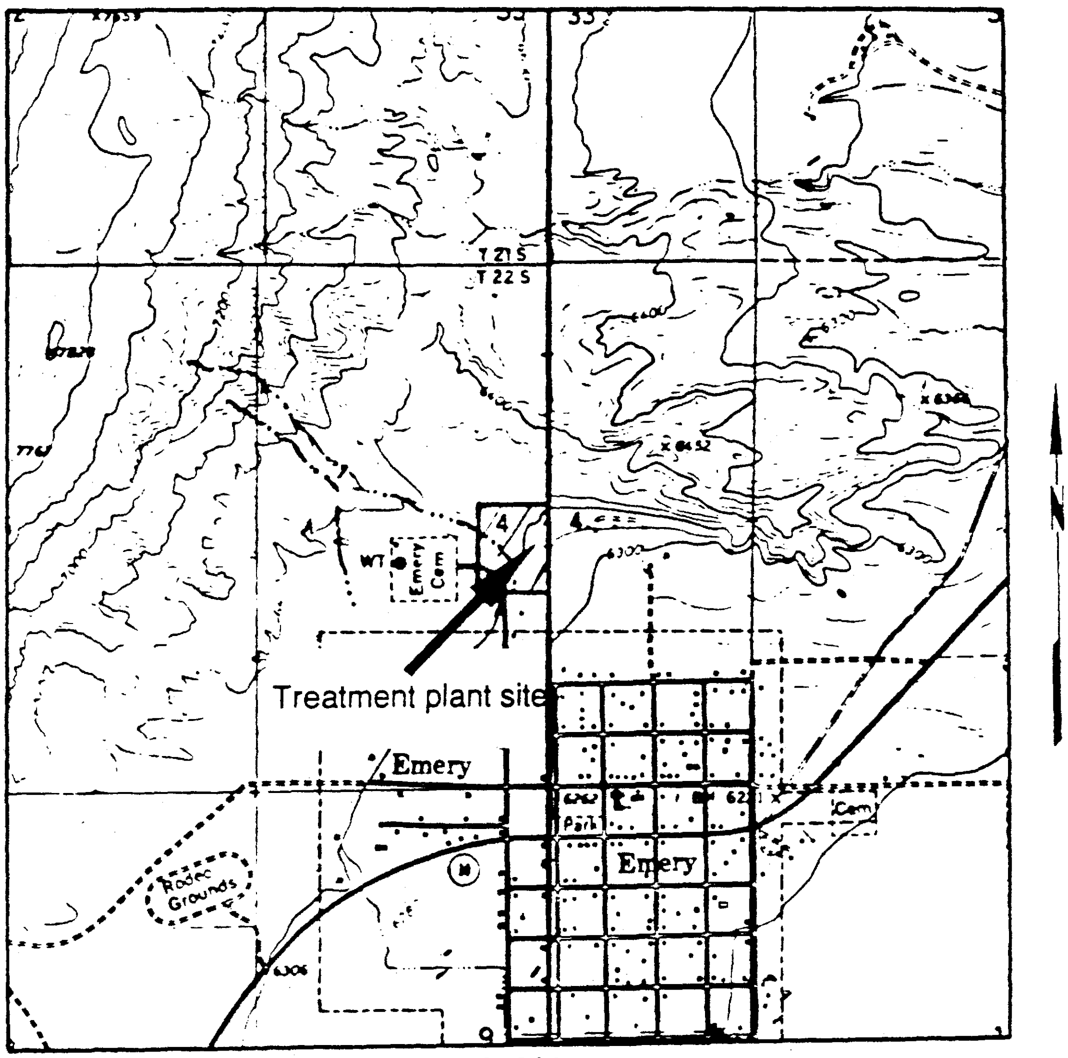
Hepworth, R.C., 1963, Heaving in the subgrade of highways constructed in the Mancos Shale: Unpub. University of Utah Department of Geology and Geophysics, Masters Thesis, 98 p.

Mundorff, J.C., 1979, Reconnaissance of chemical quality of surface water and fluvial sediment in the Price River Basin, Utah: Utah Department of Natural Resources Technical Publication No. 39, 55 p.

Stokes, W.L., and Cohenour, R.E., 1956, Geologic Atlas of Utah, Emery County: Utah Geological and Mineral Survey Bulletin 52, 91 p.

Swenson, J.L. Jr., and others, 1970, Soil survey of the Carbon-Emery area, Utah: U.S. Soil Conservation Service, 78 p.

Attachment 1, Job No. 88-01(PF-1)

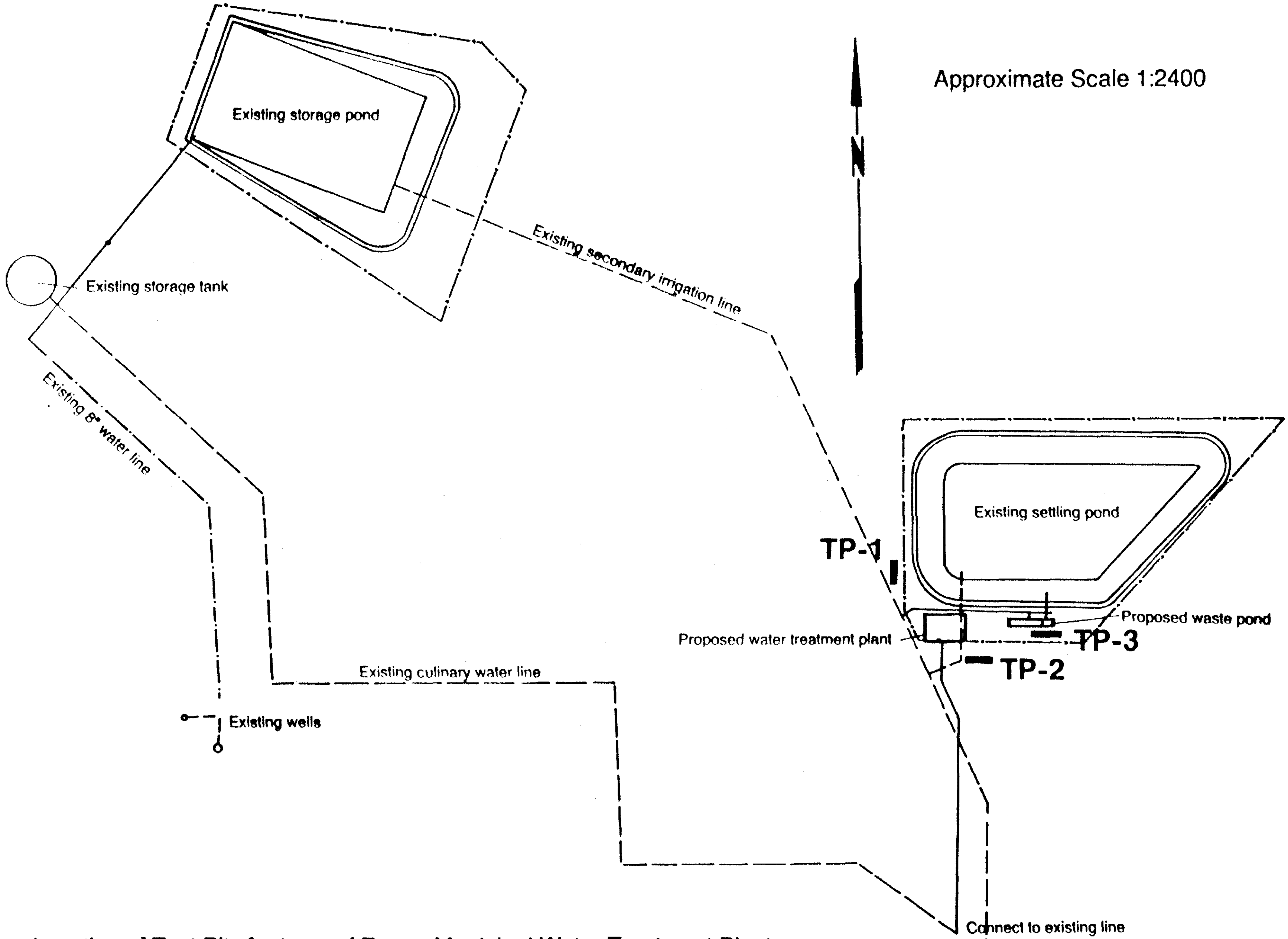


Scale 1:24000

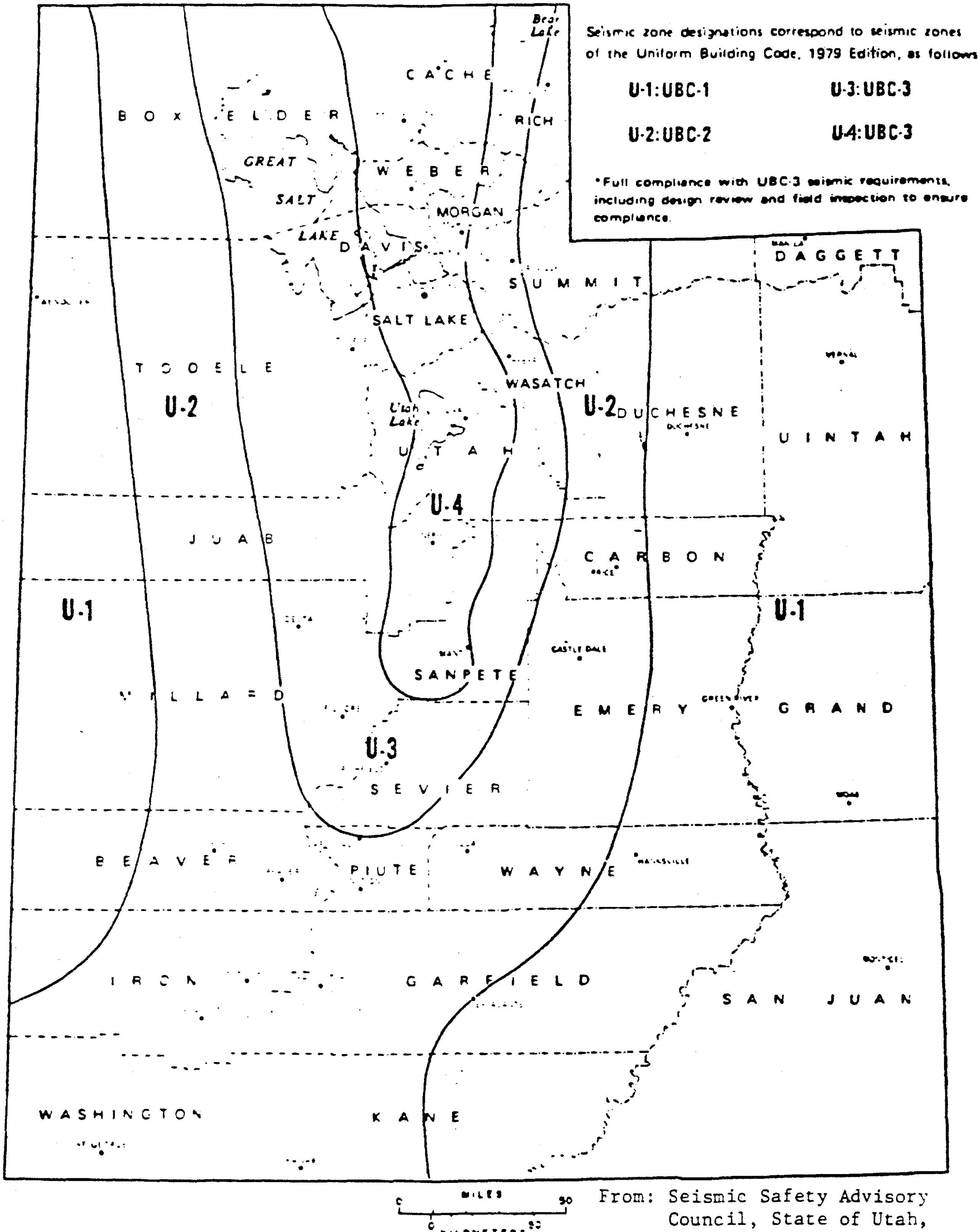
General location map, Town of Emery water treatment plant site

Utah Geological and Mineral Survey

Applied Geology



Location of Test Pits for town of Emery Municipal Water Treatment Plant.



From: Seismic Safety Advisory Council, State of Utah, 1979.

SEISMIC ZONES
January 1980

Appendix A

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building; standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Source: Earthquake Information Bulletin 6 (5), p. 28, 1974.

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

* Based on the material passing the 3-in. (75-mm) sieve.

Unified Soils Classification System (USCS)

Appendix C

Test Pit Logs
Town of Emery Surface Water Treatment Plant

Test Pit 1

0.0' - 2.7' Poorly graded sand with silt (SP/SM); low density, low plasticity, dry; 90 percent fine, subangular to subrounded sand; very pale brown, noncemented, strong reaction to HCL; fill material.

2.7' - 5.4' Poorly graded sand with silt (SP), very pale brown, medium density, none to low plasticity, dry; noncemented, 90 percent fine, angular to subangular sand, strong reaction to HCL, early stage I caliche development from 2.7 to 3.7 feet: Discontinous lenses of well-graded, fine to medium sand (SW); loose, nonplastic, dry; 95 percent medium, angular to subangular sand, strong reaction to HCL, sand lenses 1 - 5 inches thick with no lateral continuity.

5.4' - 7.5' Poorly graded sand with silt (SP/SM); very pale brown, medium to low density, none to low plasticity, dry; 95 percent fine, angular to subangular sand, noncemented, strong reaction to HCL.

Test Pit 2

0.0' - 2.4' Poorly graded sand with silt (SP/SM); very pale brown, medium to high density, none to low plasticity, dry; noncemented, 90 percent fine, angular to subangular sand, strong reaction to HCL; fill compacted by earth moving equipment with chunks of coal present in upper 1 foot.

2.4' - 4.9' Poorly graded sand with silt (SP), very pale brown, none to low plasticity, dry; noncemented, 90 percent fine, angular to subangular sand, strong reaction to HCL: Discontinous lenses of fine to medium sand (SW); low density, nonplastic, dry; 95 percent fine to medium, angular to subangular sand, noncemented, strong reaction to HCL, sand lenses 2 to 5 inches thick with limited lateral continuity.

4.9 - 7.4' Poorly graded sand with silt (SP/SM); very pale brown, medium to low density, none to low plasticity, dry; 85 percent fine, angular to subangular sand, noncemented, strong reaction to HCL: Discontinous lenses of well graded sand with gravel (SW); low to moderate density, nonplastic, dry; 5 percent gravel to 4 inches in diameter, 30 percent gravel, 65 percent fine, angular to subangular sand, strong reaction to HCL, channel cut into main unit.

Appendix C continued

Test Pit 3

0.0' - 1.5'	Poorly graded sand with silt (SP/SM); low density, nonplastic, dry; 90 percent fine, angular to subangular sand, none to weak cementation, strong reaction with HCL, early stage I caliche development; isolated coarse sand lenses.
1.5' - 3.3'	Well graded sand-well graded sand with gravel (GW/SW); low density, nonplastic, dry; 50 percent gravel, 50 percent fine, angular to subangular sand, noncemented, strong reaction with HCL.
3.3 - 6.1'	Poorly graded sand (SP); low density, nonplastic, dry; 95 percent fine, angular to subangular sand, noncemented, strong reaction to HCL, early stage I caliche development

Project: Geologic hazards investigation of a proposed 2 million-gallon water tank site, City of Riverdale, Weber County, Utah			Requesting Agency: City of Riverdale
By: Kimm M. Harty	Date: 1-10-89	County: Weber	Job No.: (PF-2) 89-01
USGS Quadrangle: Roy (1346)			

PURPOSE AND SCOPE

This report presents the results of a Utah Geological and Mineral Survey (UGMS) investigation conducted at a proposed 2 million gallon water tank site for the City of Riverdale in Weber County. The purpose of the investigation was to identify any existing or potential geologic hazards that could adversely affect the water tank and surrounding area. The scope of work included a review of pertinent published and unpublished literature and maps, review of 1:20,000-scale air photographs, and a field reconnaissance on January 4, 1989. Mr. Dean Steel, City Administrator of Riverdale, requested the study and was present during the field reconnaissance.

GEOLOGIC SETTING AND SITE DESCRIPTION

The site is located approximately 1000 feet south of the center of section 13, T. 5 N., R. 2 W., Salt Lake Baseline and Meridian (attachment 1). The proposed water tank will be located adjacent to an existing 1 million-gallon water tank also owned by Riverdale. The proposed tank will be constructed at about 4595 feet elevation, the same elevation as the existing tank.

The site is atop a bench which is a remnant of a delta deposited in ancient Lake Bonneville by the Weber River. As the lake receded, the Weber River cut down into the delta, leaving the bench over 200 feet above the present river level. The site is on the northeast rim of the bench, as is the Davis-Weber canal (attachment 1), which, until recently, flowed between the water tank site and the edge of the bench. The canal is currently being re-routed toward the west to a location south of the water tank site (attachment 1) (Dean Steel, oral commun., Jan., 1989).

The existing water tank is on a small terrace about 10 feet higher than the bench surface (attachment 2), and is approximately 100 feet from the rim of the bench. The proposed water tank will be built partly on this small terrace, approximately 125 feet from the rim of the bench. Much excavation and grading will be required, as the foundation of the proposed water tank will be larger than the remaining undeveloped portion of this terrace surface (attachment 2).

SOIL CONDITIONS AND GEOLOGIC HAZARDS

No test pits were dug during the field investigation, and visual inspection of the ground surface was hampered by the presence of a deep snow cover. However, spoil piles from the canal re-routing project and previous nearby excavations show the soil to be predominantly sand and gravel. The U.S. Department of Agriculture soil survey of the area (Erickson and Wilson, 1968) shows the site vicinity to be covered by two soils, the Kilburn and Francis Series. The Kilburn soil (KmA) is a gravelly sandy loam exhibiting moderately rapid to rapid permeability, low shrink-swell capacity, high shear strength, slight compressibility, and good compaction. In the Unified Soil Classification System, the Kilburn soil is a silty gravel (GM) or silty sand (SM). In addition, the soil absorbs moisture readily and is somewhat excessively drained. Surface runoff occurs slowly, and the hazard from water erosion is deemed none to slight (Erickson and Wilson, 1968). The Francis soil (FcB), occurring primarily west of the study area, is a loamy fine sand which exhibits many of the same properties as the Kilburn soil. A notable exception is that it has a high susceptibility to wind erosion (Erickson and Wilson, 1968).

Because of the deep snowcover, evidence of any recent landsliding on the bench slope near the water tank site could not be determined. Landsliding along the bench face has occurred in the past, however, especially during the recent wet years of 1983-1984. A landslide map of the area (Lowe, 1988) shows an extensive landslide zone on steep slopes just to the southeast of the proposed water tank site (attachment 3). Just east of the site, the landslide zone turns north, following a lower bench slope. According to Mike Lowe (former Weber County geologist, oral commun., Jan., 1989), clay beds in the bench caused many of these landslides, and he believes the beds pinch out where the landslide zone diverges northward. It may be that the clay beds were deposited at the lower bench elevations during a period when Lake Bonneville was deep, and that the sands and gravels were deposited on the upper bench when the lake was regressing. Near the water tank site, the slope of the bench averages approximately 35 percent, but is steeper in its upper portion. Metal pipes protruding from the slope rim just northeast of the site appeared to have been placed as slope re-enforcements, but the exact nature and extent of this work could not be determined because of the snowcover. Houses located at the base of the slope (attachment 2) did not experience landslide problems during 1983-1984 (Dean Steel, oral commun., Jan., 1989).

Depth to ground water was not assessed during the field investigation. A literature and well log search revealed no data on the depth to the water table at the site. The soil survey report for the area indicates the water table to be deep (Erickson and Wilson, 1968). The water table is likely near the elevation of the Weber River, more than 200 feet below the bench. Residents living on the bench slope have reported springs issuing from the base of the slope (M. Lowe, oral commun., Jan., 1989); this indicates the possibility of perched ground-water zones in the bench above river level.

Earthquakes present a variety of potential hazards. The greatest earthquake hazard to the water tank would be from ground shaking during a moderate to large earthquake. For the proposed site, there is a 10 percent chance that peak ground accelerations will exceed 0.06-0.07g in a 10-year period, 0.25-0.30g in a 50-year period, and 0.50-0.60g in a 250-year period (Youngs and others, 1987). No active faults have been identified at or near the site; the closest such fault is the Wasatch fault about five miles to the east. Maps at 1:48,000 scale showing soil liquefaction potential from earthquake ground shaking (Utah State University, 1988) show the bench surface to be in a zone of very low potential. The bench slope and base are in the moderate liquefaction potential zone.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards are present at the site which would make it unsuitable for construction of the water tank. The re-routing of the Davis-Weber canal away from the rim of the bench near the water tank site will ensure that any future canal leakage will not affect the water tank, the bench slope, or the residential area at the slope base. Any surface drainage should be routed away from the water tank site. Drainage could easily be routed into the new canal. Although no landslides have been identified on the slopes in the immediate vicinity of the water tank, the possibility of landsliding exists. To minimize the potential for damage from slope failure, the water tank should be set back from the bench slope as far as possible. If the tank is to be placed any closer than is presently planned (approximately 125 feet), a factor of safety analysis of the slope should be considered. In addition, it is recommended that the geotechnical firm performing soil foundation investigations for the water tank be consulted as to the necessity of a slope stability study of the bench to determine safe setback distances.

The site lies in Uniform Building Code (UBC) seismic zone 3 and Utah Seismic Safety Advisory Council (USSAC) zone U-4, areas of highest ground shaking hazard in the respective zonation schemes. The most recent work indicates peak ground accelerations of 0.06-0.07g, 0.25-0.30g, and 0.50-0.60g can be expected with a 10 percent probability of exceedence for exposure times of 10, 50, and 250 years, respectively. Appropriate earthquake-resistant design and construction should be used, with careful inspection and monitoring as recommended for USSAC zone U-4 (Utah Seismic Safety Advisory Council, 1979). The hazard from earthquake fault rupture at the site is low.

Prior to construction, a thorough soil foundation investigation by a qualified geotechnical firm should be performed. This report should address soil and ground-water conditions at and below the foundation level. Because a water tank is a critical facility and the assessment that liquefaction potential at the site is low is based on generalized maps, the soil foundation investigation should also address liquefaction potential. Because considerable site grading will be required, engineering specifications for cuts and fills should be included.

REFERENCES CITED

Erickson, A.J., and Wilson, Lemoyne, 1968, Soil survey of Davis-Weber area, Utah: U.S. Department of Agriculture Soil Conservation Service in cooperation with Utah Agricultural Experiment Station, 149 p.

Lowe, M.V., 1988, Slope failure inventory maps for Weber County, Utah: Weber County Planning Department unpublished maps, scale 1:24,000.

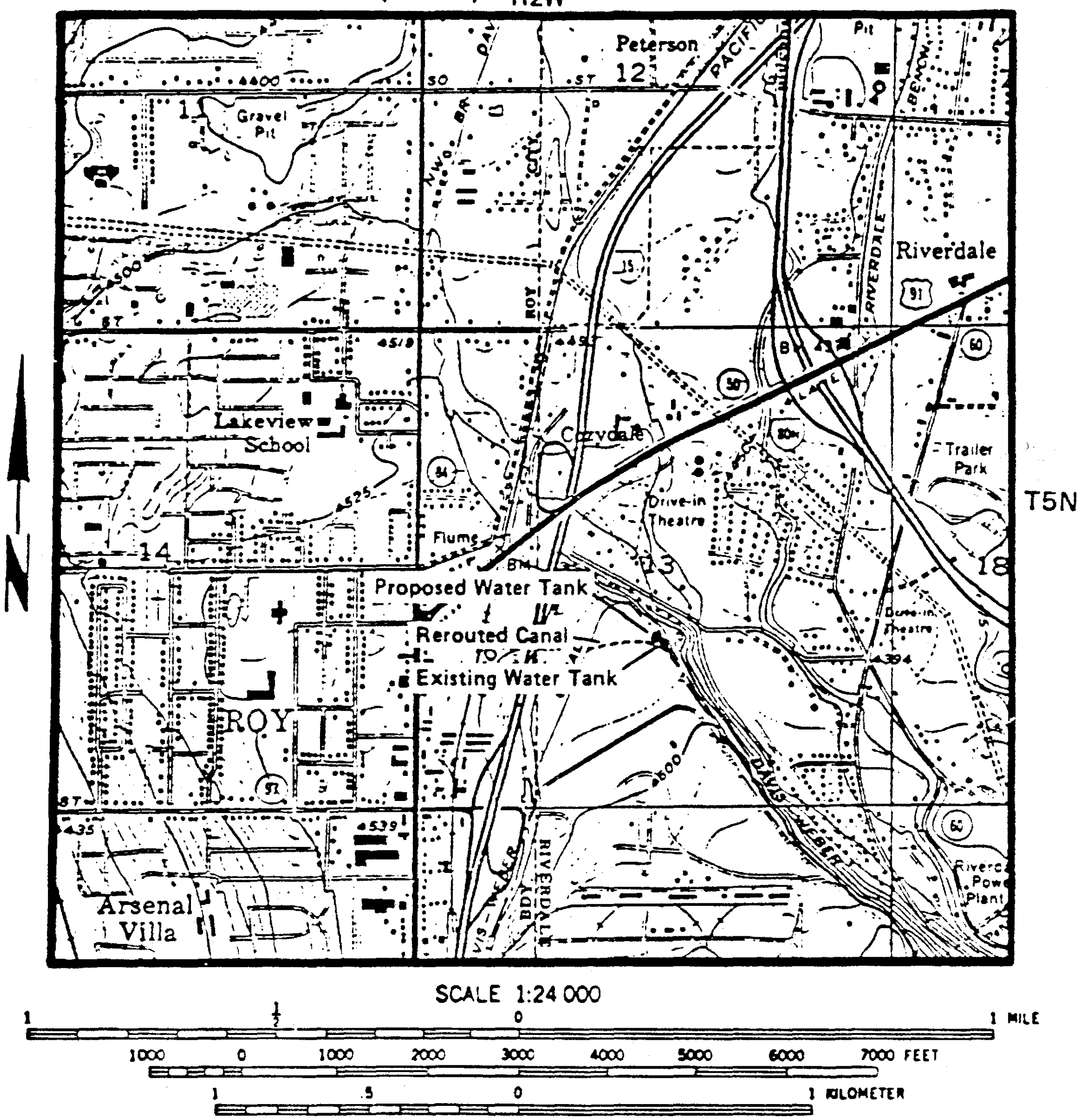
Utah Seismic Safety Advisory Council, 1979, Seismic zones for construction in Utah; Delbert B. Ward, Executive Director, 13 p.

Utah State University, 1988, Liquefaction potential maps for Weber County, Utah: Utah State University Department of Civil Engineering unpublished maps, scale 1:48,000.

Youngs, R.R., Swan, F.H., Power, M.S., Schwartz, D.P., and Green, R.K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, in Gori, P.L., and Hays, W.W., (eds.), Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Open-File Report 87-585, v. II, p. M1-M110.

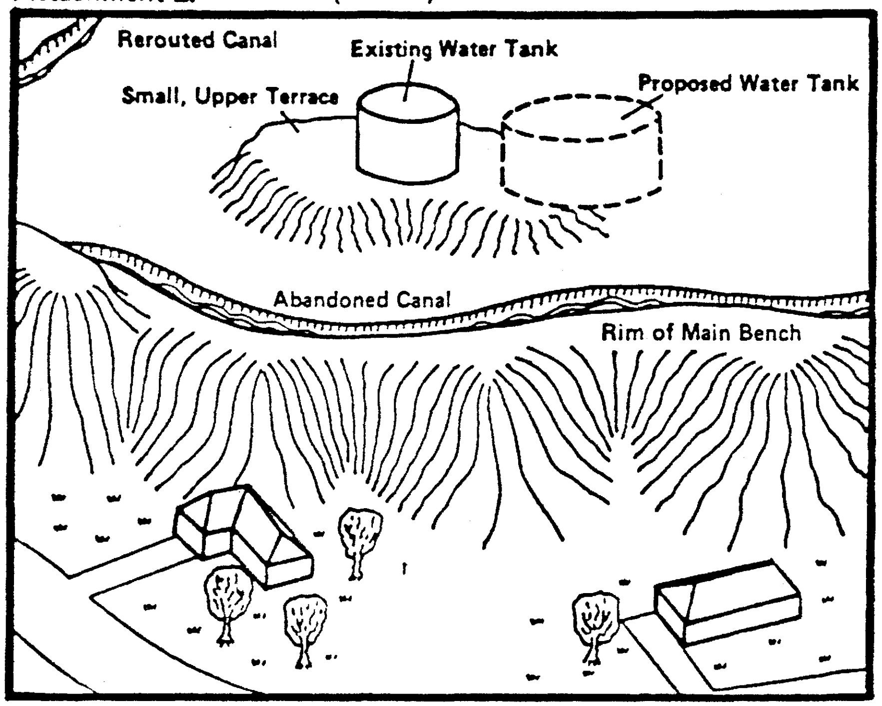
Base map from: Roy 7-½' quadrangle

Attachment 1. Job 89-01(PF-2)



Attachment 1. Location map showing proposed water tank site and associated structures.

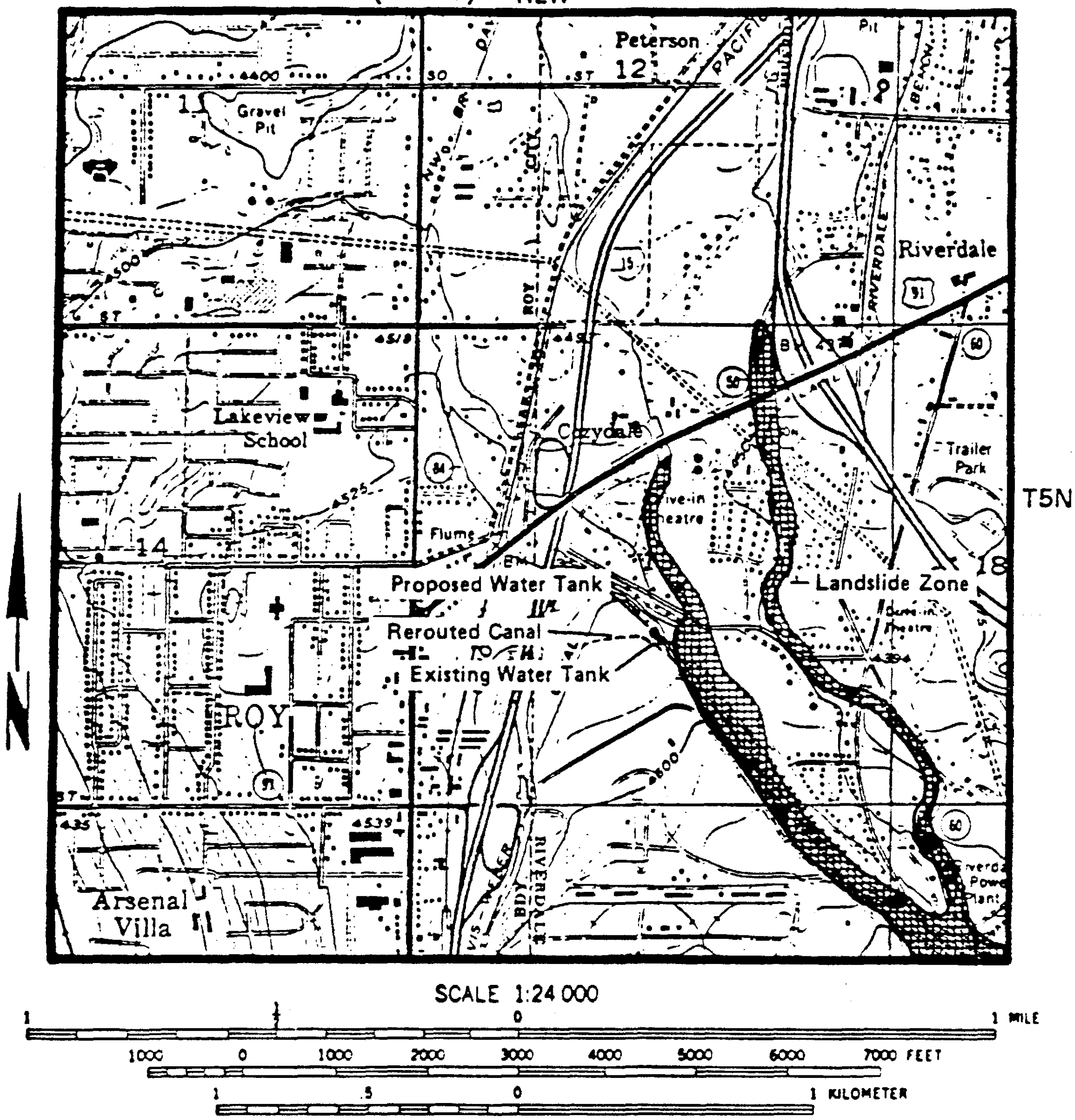
Attachment 2. Job 89-01(PF-2)



Drawn by Bill Black

Attachment 2. Sketch of proposed water tank site. Not drawn to scale, view looking towards the southwest.

Attachment 3. Job 89-01(PF-2) R2W



Attachment 3. Map showing landslides near the study area. Dark areas within the landslide zone designate recent landlsides. (Lowe, 1988)

Project:			Requesting Agency:
Geologic hazards investigation of a proposed water tank site, New Harmony, Washington County, Utah			Town of New Harmony
By: K.M. Harty	Date: 10-20-89	County: Washington County	Job No.: (PF-3) 89-14
USGS Quadrangle: New Harmony (158)			

INTRODUCTION AND SCOPE

On behalf of the town of New Harmony, Utah, Marvin J. Wilson of Sunrise Engineering requested that the Utah Geological and Mineral Survey perform a geologic hazards investigation for a proposed 100,000-gallon water tank site in New Harmony. The proposed site is in the NE1/4, SE1/4, SW1/4, section 16, T. 38 S., R. 13 W., Salt Lake Baseline and Meridian (fig. 1). The tank is to be built about 15 feet northwest of an existing 150,000-gallon, 16-foot high, 42-foot diameter water tank that currently supplies New Harmony (Marvin Wilson, oral commun., Oct., 1989). Like the existing water tank, the proposed smaller tank will be constructed of reinforced concrete and will be partially buried. The scope of the investigation included a literature search, review of geologic and topographic maps, and a field reconnaissance that took place on October 12, 1989.

SETTING AND GENERAL GEOLOGY

The town of New Harmony, in north-central Washington County, is near the eastern base of the Pine Valley Mountains. About three miles west of the town, the mountains rise to nearly 10,000 feet elevation. On average, the area receives about 20 inches of precipitation annually (Jeppson and others, 1968). Rocks in the Pine Valley Mountains are mainly volcanic in origin, erupted during the late Tertiary Period (34 to about 2 million years ago - Ma) (Cook, 1960). The water tank site is atop alluvial-fan deposits at the base of the mountains on a finger-like bench that rises approximately 30 feet above the surrounding land surface. The bench is believed to be composed of late Pleistocene-age (about 30 to 10 thousand years old - Ka) stream and mud-flow deposits that were left as an uneroded remnant as streams cut down into the older alluvial-fan deposits (Proctor, 1949; Cook, 1957). Vegetation on the bench includes small trees, sagebrush, short grasses, and cacti. Patches of bare soil are especially common in the area surrounding the existing water tank.

SOIL CHARACTERISTICS

No test pits were excavated during the investigation, and there were no vertical soil exposures to examine at the site. However, a soil survey conducted by the U.S. Department of Agriculture (Mortensen and others, 1977) gives an indication of the types of soil to be encountered to a depth of five feet. The soil at the surface of the proposed site is poorly sorted, light brown to brown in color, with the fine fraction containing clay, silt, and abundant sand. The survey shows that the site is covered by very stony, sandy loam soils of the Nehar Series. Unified Soil Classification System soil types

Base Map from NEW HARMONY, U.S.G.S. 7-½' topographic quadrangle.

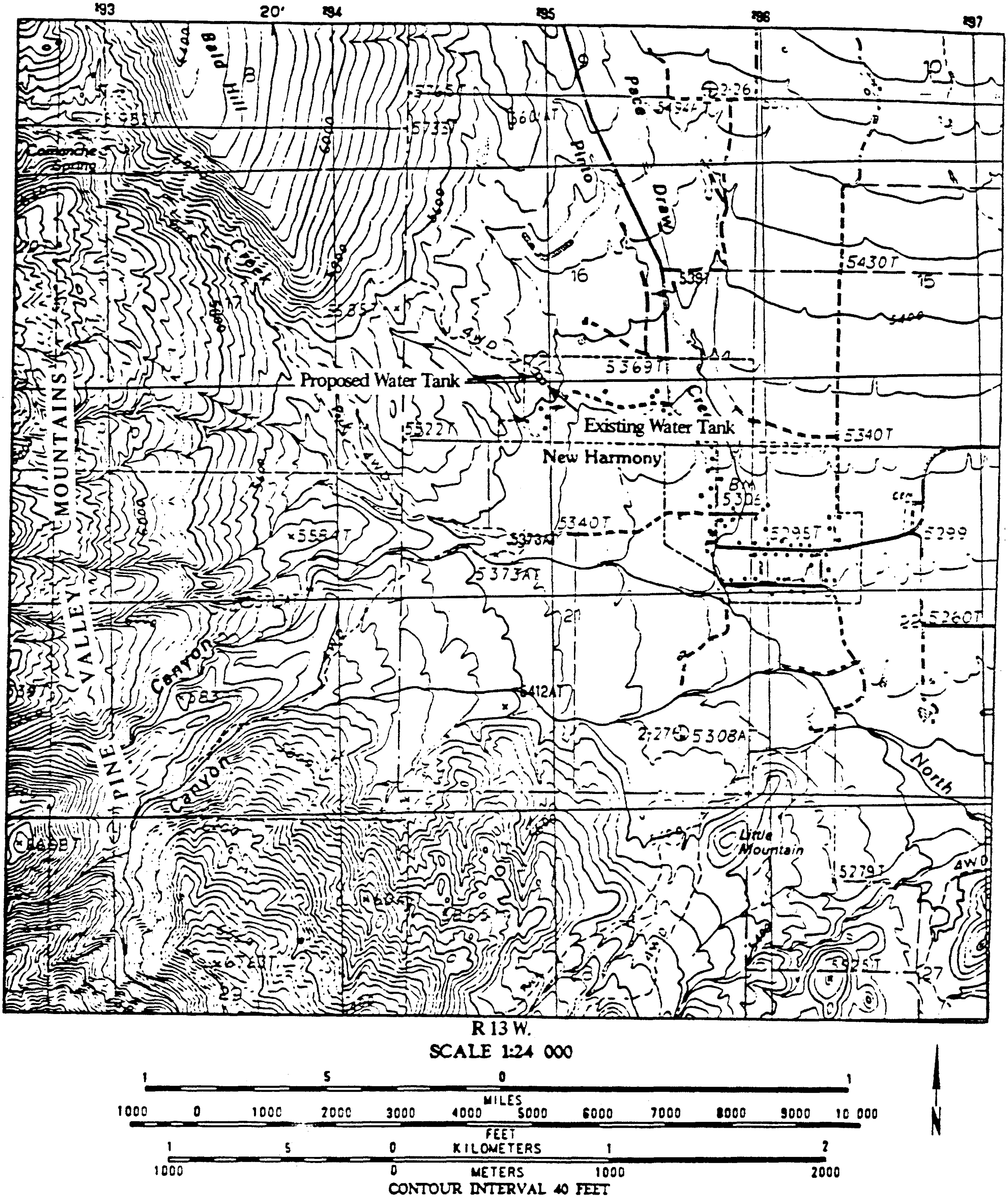


Figure 1. Location map showing location of existing and proposed water tanks.

represented in the Nehar Series include SC, SM, CL, and GM, with about 45-55 percent by weight coarse fraction greater than three inches (Mortensen and others, 1977). Field observations confirmed this relatively high percentage of coarse material. Cobbles of quartzite and especially igneous volcanic rocks are abundant on the bench. Boulders are less numerous, with the largest visible one measuring three feet in maximum dimension. Thin caliche (calcium carbonate) rinds were observed on a few cobbles at the site.

Nehar soils generally exhibit the following characteristics: moderate shrink-swell potential, medium to low shear strength, low to medium compressibility, low compacted permeability, medium to low susceptibility to piping, slow runoff, and good to fair compaction. In addition, the soils rate a "moderate" in excavation limitation and erosion hazard (Mortensen and others, 1977). A gully four feet deep has formed in the south-facing bench slope where a drainpipe from the existing water tank discharges near the base of the bench.

Ground subsidence in geologically young, sandy and silty alluvial soils containing clay, particularly debris-flow deposits, is well documented in the Hurricane Cliffs area of southwestern Utah. Subsidence or hydrocompaction can occur in void-rich sediments that have been rapidly deposited without sufficient water to allow normal consolidation. The soil survey indicates there may be susceptible soils (SC) at the water tank site. However, because soils at the site are greater than 10,000 years old, sufficient geologic time may have passed since deposition to have permitted adequate consolidation.

GEOLOGIC HAZARDS

Depth to ground water is unknown at the proposed site, but the static water table is greater than about 30 feet below the bench surface. However, zones of perched ground water could exist within the bench. The hazard from stream flooding and erosion is low. There is a large, flat-floored ravine west of the bench that shows evidence of having transported runoff in the past. The proposed site is elevated about 30 feet above the floor of the ravine, and is set back a safe distance.

No evidence of slope instability was observed during the field reconnaissance, and no landslides appear on maps of the area. The two slopes bordering the proposed site are low to moderate, with the steepest, west-southwest-facing slope averaging about 17 percent grade. The site is far from any cliffs, thus the rock-fall hazard is low. In addition, the potential hazard from debris flows is low due to the elevation of the water tank above potential flow routes.

Surface fault rupture hazard is low. Geologic maps show no active faults traversing the proposed site. The closest known potentially active fault is the Hurricane fault, six miles east of the site at the base of the Hurricane Cliffs. The time of last movement on this portion of the fault is postulated to have been between 10-130 Ka, during the late Pleistocene (Anderson and Christenson, 1989). However, a lack of evidence for surface rupture on the fault during Holocene time (0-10 Ka) indicates that the recurrence rate of surface-rupturing earthquakes on this fault is low (Anderson and Christenson, 1989).

The largest historical earthquake in the region (Richter magnitude 6.3) occurred in 1902 near Pine Valley, about 13 miles southwest of New Harmony (Anderson and Christenson, 1989). The greatest hazard posed by earthquakes occurring in the region is from ground shaking. For the proposed site, there is a 10 percent chance that effective maximum peak ground accelerations will exceed 0.15 g in a 50-year period (FEMA-95, 1988). The generally coarse soils and likelihood of ground water greater than 30 feet deep indicate the potential for soil liquefaction during earthquake ground shaking is probably low.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards are present at the proposed site that would make it unsuitable for construction of the water tank. The hazard from flooding, landslides, rock falls, debris flows, and surface fault rupture is low. The water table is below the excavation depth of the water tank, but shallow ground water could be encountered in perched zones.

The site is in an area where the maximum peak effective acceleration is 0.15 g on rock with a 10 percent chance of exceedence in 50 years (FEMA-95, 1988). This corresponds to Uniform Building Code (UBC) seismic zone 2B, with a Z factor of 0.20 (Uniform Building Code, 1988 edition). Appropriate earthquake-resistant design and construction should be used in accordance with UBC specifications.

Gully erosion has occurred near the existing water tank. Drainage for the proposed water tank should be directed well away from the bench and bench slope, to prevent slope erosion and undermining. Excavation for the foundation could be difficult because of the large quantity of coarse material at the site. Depending on the degree of consolidation of the subsurface soil, excavation walls may require sloping. Prior to site excavation, a thorough soil foundation investigation by a qualified geotechnical firm should be performed. This report should include an assessment of the soil and ground-water conditions at and below the foundation level, and the potential for hydrocompaction. No cracks or other visible signs of foundation distress were observed on the existing water tank, but only the top and upper 12 inches of the structure were visible.

The existing and proposed water tanks are upslope and close to a number of houses in the northwest part of New Harmony. Design plans should consider the impact of floodwaters on these residences should the water tank(s) breach, and provide a pathway for diversion of floodwaters if necessary.

CITED REFERENCES

Anderson, R.E., and Christenson, G.E., 1989, Quaternary faults, folds, and selected volcanic features in the Cedar City 1 degree x 2 degree quadrangle, Utah: Utah Geological and Mineral Survey Miscellaneous Publication 89-6, in press.

Cook, E.F., 1957, Geology of the Pine Valley Mountains, Utah: Utah Geological and Mineral Survey Bulletin 58, 111 p.

Cook, E.F., 1960, Geologic atlas of Utah, Washington County: Utah Geological and Mineral Survey Bulletin 70, 1234 p.

FEMA-95, 1988, NEHRP recommended provisions for the development of seismic regulations for new buildings: Seismic Safety Council, Earthquake Hazards Reduction Series 17, Part I, 158 p.

Jeppson, R.W., Ashcroft, G.L., Huber, A.L., Skogerboe, G.V., and Bagley, J.M., 1968, Hydrologic atlas of Utah: Utah Water Research Laboratory, Utah Agricultural Experiment Station, and Utah State University in cooperation with Utah Division of Water Resources, p. 31.

Mortensen, V.L., Carley, J.A., Crandall, G.C., Donaldson, K.M., and Leishman, G.W., 1977, Soil survey of Washington County area, Utah: U.S. Department of Agriculture Soil Conservation Service, U.S. Department of the Interior Bureau of Land Management and National Park Service in cooperation with Utah Agricultural Experiment Station, 140 p.

Proctor, P.D., 1949, Geology of the Harrisburg (Silver Reef) mining district, Washington County, Utah: Ph.D. dissertation, University of Indiana.

Project:	Requesting Agency:
Geologic-Hazards Investigation, for a Proposed Woods Cross City Water-Tank Site, Davis County, Utah	Woods Cross City

By:	Date:	County:	Job No.:
Mike Lowe	11-08-89	Davis County	(PF-4) 89-17

USGS Quadrangle:
Salt Lake City North (1254)

INTRODUCTION

The purpose of this investigation, requested by Tim Stephens (Woods Cross City Planner), is to identify potential geologic hazards at a proposed Woods Cross City water-tank site. The site is just south of the South Davis Junior High School in the SE1/4NW1/4SW1/4 sec. 31, T. 2 N., R. 1 E., at approximately 400 W. 2600 S., Bountiful, Utah (attachment 1). An old buried water tank currently located at the site will be removed prior to construction. Two other Woods Cross water tanks may eventually be constructed just to the north on the property. The scope of investigation include a review of pertinent literature (including geologic-hazard maps compiled by myself during my tenure as Davis County Geologist from 1985-1989), an examination of aerial photographs (1985, 1:24,000 scale), and a field inspection on November 29, 1989.

GEOLOGY AND GEOLOGIC HAZARDS

The site is located at an approximate elevation of 4,485 feet and is underlain by sand and silt deposited into Pleistocene Lake Bonneville (Nelson and Personius, 1989). The thickness of these lacustrine sediments is not known.

Fault scarps of the Weber segment of the Wasatch fault zone (Machette and others, 1987) are mapped approximately 5,000 feet to the east and 2,000 to the south of the site (Nelson and Personius, 1989). This fault zone is considered capable of generating earthquakes up to magnitude 7.0 - 7.5, with surface-fault rupture and severe ground shaking (Schwartz and Coppersmith, 1984). No evidence of surface faulting is present at the site which is outside of the surface-fault rupture sensitive area overlay zone (Potential Surface-Fault Rupture Sensitive Area Overlay Zone - Salt Lake City North Quadrangle, Davis County Planning Commission, 1989).

Because the site is in an active seismic area along the Wasatch fault zone, there is a potential for strong ground shaking accompanying earthquakes. Youngs and others (1987) indicate that peak horizontal ground accelerations with a 10 percent probability of exceedance in 250 years could be as high as 70 percent the force of gravity and peak horizontal ground accelerations with a 10 percent probability of exceedance in 50 years could as high as 35 percent the force of gravity. The liquefaction potential is mapped as very low (Anderson and others, 1982).

The site is located just south of the North Canyon alluvial fan (Nelson and Personius, 1989) and is outside of the debris-flow hazard special study zone (Debris-Flow Hazard Special Study Zone Map - Salt Lake City North Quadrangle, Davis County Planning Commission, 1989). No landslides are mapped in the vicinity of the site (Slope-Failure Inventory Map - Salt Lake City North Quadrangle, Davis County Planning Commission, 1989) and the site is outside the landslide-hazard special study zone (Landslide-Hazard Map - Salt Lake City North Quadrangle, Davis County Planning Commission, 1989). This investigation confirmed that landslide and debris-flow hazards are not found at the site. The site is more than 5,000 feet from the mountain front and, therefore, rockfall hazards are very low.

Federal Emergency Management Agency Maps (1982) show the site to be in Zone C, an area of minimal flooding. The site is approximately three miles from Great Salt Lake and approximately 280 feet above the highest elevation reached by the lake during the last 10,000 years. Flooding due to climate-induced lake-level rises or tectonic subsidence is not expected to occur at the site.

No subsurface investigations were performed for this study and soil conditions at the foundation level for this water tank are unknown. The shrink-swell potential of surficial soils at the site is rated as moderate to low (Erickson and others, 1968), but collapsible (hydrocompactable) or compressible soils may occur and cause differential settlement. Differential settlement may also occur when a structure is placed on more than one type of sediment, if the compressibility characteristics of the sediments are sufficiently different. Although the water table is generally about 35 to 58 feet deep here (Anderson and others, 1982), shallow perched ground-water problems may occur. If shallow ground water is present, the liquefaction potential may be higher than shown on regional maps by Anderson and others (1982).

CONCLUSIONS AND RECOMMENDATIONS

Surface-fault rupture, debris flows, landslides, rock fall, stream flooding, and climate- or tectonic-subsidence-induced lake flooding are hazards that are not expected to occur at the proposed water tank site. Adverse soil foundation conditions due to either problem soils (collapsible, compressible, or liquefiable) or shallow ground water may occur and should be evaluated prior to construction by conducting a standard soil foundation investigation. If shallow ground water (less than 30 feet) is found, the liquefaction potential should be addressed in the soil foundation study as well. The site is in Uniform Building Code (UBC) Seismic Zone 3 and Utah Seismic Safety Advisory Council (USSAC) Seismic Zone U-4, the zones of highest risk in Utah in the respective zonations. Construction should incorporate earthquake-resistant design with careful monitoring by the Woods Cross Building Inspector. These recommendations also apply to future water tanks constructed on the property. Please contact the Utah Geological and Mineral Survey when the foundation has been excavated so that we may inspect it.

REFERENCES CITED

Anderson, L. R., Keaton, J. R., Aubry, Kevin, and Ellis, S. J., 1982, Liquefaction potential map for Davis County, Utah: Department of Civil and Environmental Engineering, Utah State University, Logan, Utah, and Dames and Moore Consulting Engineers, Salt Lake City, Utah, 50 p.

Erickson, A. J., Wilson, Lemoyne, Hughie, V. K., Neilson, Woodrow, and Chadwick, R. S., 1968, Soil survey of Davis-Weber area, Utah: U. S. Department of Agriculture, Soil Conservation Service, in cooperation with Utah Agricultural Experiment Station, 149 p.

Federal Emergency Management Agency, 1982, Flood insurance rate map, Davis County, Utah, (Unincorporated areas), panel 255: Federal Emergency Management Agency, 1:1,000 scale.

Machette, M. N., Personius, S. F., and Nelson, A. R., 1987, Quaternary geology along the Wasatch fault zone: segmentation, recent investigations, and preliminary conclusions, in Hays, W. W., and Gori, Paula, eds., Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, Volume I: U. S. Geological Survey Open-File Report 87-585, p. 1-72.

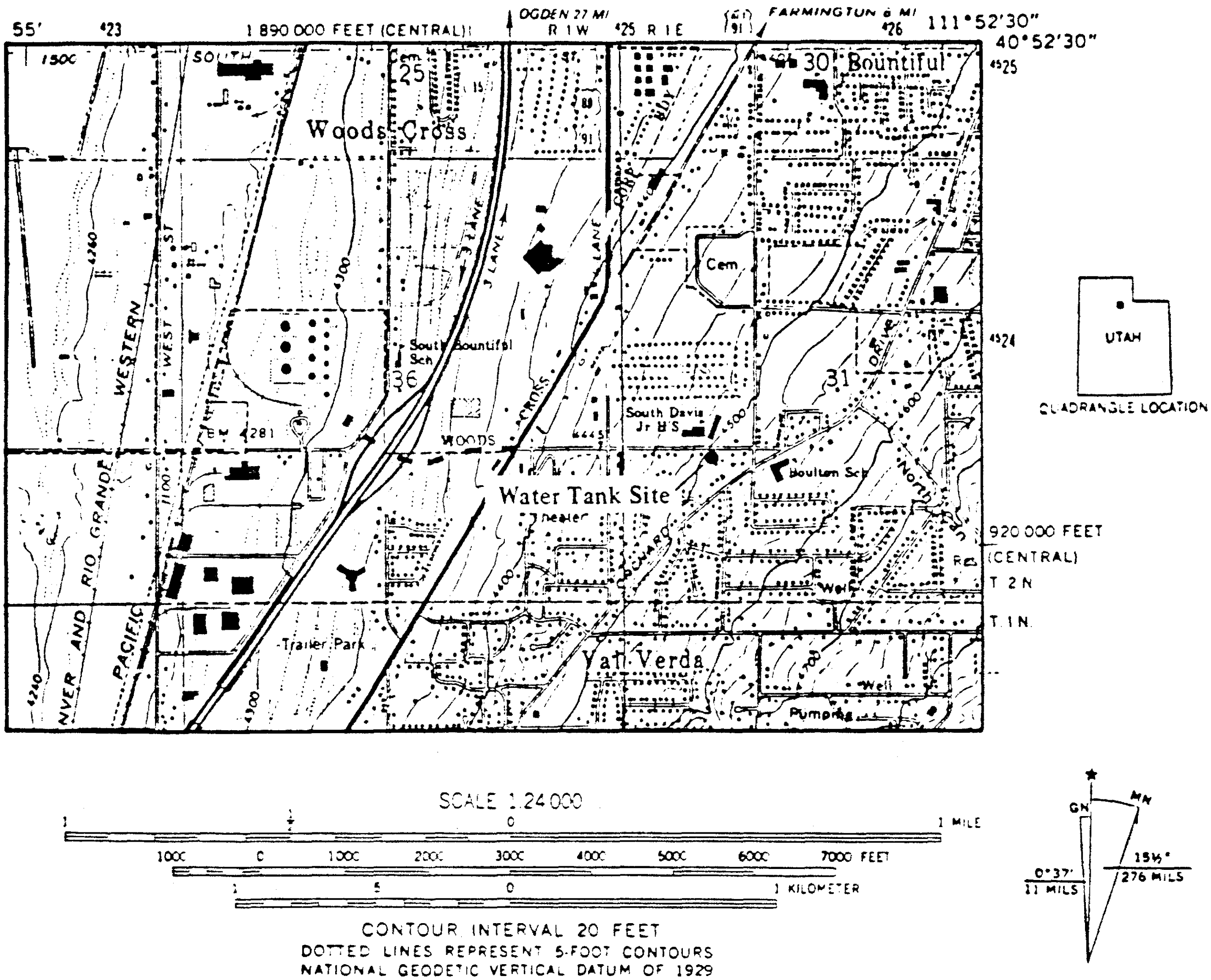
Nelson, A. R., and Personius, S. F., 1989, Surficial geologic map of the Weber segment of the Wasatch fault, Weber and Davis Counties, Utah: U. S. Geological Survey Miscellaneous Investigations Map, 1:50,000 scale, in prep.

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

Youngs, R. R., Swan, F. H., Power, M. S., Schwartz, D. P., and Green, R. K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, in Hays, W. W., and Gori, P. L., eds., Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, v. II: U. S. Geological Survey Open-File Report 87-585, p. M-1-110.

Job No. 89-17(PF-4)

Base Map from SALT LAKE CITY NORTH, U.S.G.S. 7-½' topographic quadrangle.



Attachment 1. Location map.

SCHOOLS

Project: Geologic hazards investigation of proposed school sites in Big Water (Glen Canyon City), Kane County, Utah			Requesting Agency: Kane County School District
By: Suzanne Hecker	Date: 8-16-90	County: Kane	Job No.: (S-1) 89-11
USGS Quadrangle: Glen Canyon City (22)			

PURPOSE AND SCOPE

The purpose of this investigation by the Utah Geological and Mineral Survey (UGMS) was to evaluate geologic hazards within an 80-acre parcel of BLM-administered land at the north end of Big Water, also known as Glen Canyon City (attachment 1). The parcel was chosen for a high school, a middle school, and two elementary schools. Although the suitability of the entire parcel was considered, emphasis was given to a 10-acre site (attachment 1) for initial construction of an elementary school. The investigation was requested by Tom Willardson, Business Manager of the Kane County School District (7/25/89 letter and 8/4/89 office visit). The scope of work for this study consisted of a review of the literature, examination of maps and aerial photographs, and a field reconnaissance on August 4, 1989. Kimm M. Harty (UGMS) participated in the field reconnaissance.

GEOLOGY

The 80-acre parcel is located on a stream terrace approximately 200 ft above Wahweap Creek, and is covered by windblown sand deposits (Waldrop and Sutton, 1967; Doelling and Davis, 1989). Thin, low-relief alluvial fans at the mouths of two small drainages (not mapped by Waldrop and Sutton, 1967; not differentiate from mixed windblown and alluvial sand by Doelling and Davis, 1989) extend into the western and southern portions of the parcel (attachment 2).

Exposures in a gravel pit about a quarter mile east of the 10-acre site (attachment 1) provide an indication of the character and thickness of the near-surface deposits in the parcel. Approximately 5-7 ft of wind-deposited quartz sand, layered into horizons of pink and white sand, overlie a thick (minimum of about 15-20 ft) sequence of coarse-grained stream deposits comprised of sand, gravel, and cobbles. No prominent soil horizons or caliche (indurated carbonate horizons) were noted in the exposures. However, Waldrop and Sutton (1967) described terrace deposits in the region as being locally well cemented by caliche.

Bedrock, which dips to the east along a monoclinal flexture, is exposed east of the gravel pit in the canyon wall above Wahweap Creek (Waldrop and Sutton, 1967; Doelling and Davis, 1989; attachment 2). There, the bedrock lies beneath the surficial (stream and windblown) deposits at a depth of perhaps 20-30 feet (estimated from mapping by Waldrop and Sutton, 1967). Doelling and others (1989) estimated the thickness of the stream deposits exposed in the canyon wall east of town to be generally 10-12 ft, and locally as much as 20 ft. The depth to bedrock within the parcel is not known, but is expected to be generally comparable to that exposed in the canyon wall. The Entrada

Sandstone lies beneath surficial deposits within the parcel (west of the concealed contacts of the Dakota Formation in section 11, attachment 2). The Carmel Formation (interbedded sandstone, conglomeratic sandstone, mudstone, and shale) may underlie the western end of the parcel and, together with the Thousand Pockets Tongue of the Navajo Sandstone and windblown sand, occurs in the source area of the alluvial-fan deposits.

GEOLOGIC HAZARDS

Wind erosion and redeposition of sand is believed to be the primary geologic hazard which may affect structures built on the 80-acre parcel. The sand is presently semi-stabilized by clumps of desert vegetation, forming coppice dunes. Removal of vegetation could increase the susceptibility of the sand to movement by the wind and cause erosion and/or deposition of sand adjacent to structures.

The flood hazard on the parcel is generally low. Precipitation on the nearly flat surface of the sand-covered stream terrace would quickly infiltrate because of the high permeability of the deposits. However, the alluvial fans (attachment 2) may be subject to flash floods. An east-west-trending swale within the southern portion of the 10-acre site was noted in the field, and may be related to alluvial-fan drainage.

The landslide hazard is low. The parcel is a quarter mile or more from the cliff above Wahweap Creek (attachment 1), and all landslide deposits mapped in the area occur in the Tropic Shale and Straight Cliffs Formation (which do not underlie the parcel) along the cliff face on the opposite (northeast) side of the creek (Waldrop and Sutton, 1967; Doelling and Davis, 1989).

Shallow ground water (less than 10 ft deep) is not expected to occur within the parcel, given the presumed thickness and permeability of the surficial deposits. However, possible occurrences of impermeable caliche within the stream deposits (Waldrop and Sutton, 1967) could allow shallow perched water to develop locally. Also, there may be potential for shallow ground water if bedrock occurs at shallow depths.

The earthquake hazard within the parcel is moderate to low. The area around Big Water has had a fairly low level of historical seismicity (Arabasz and others, 1987), and surface faults with evidence for young (Quaternary-age) activity have not been identified in the region (Anderson and Miller, 1979; Hecker, 1989).

CONCLUSIONS AND RECOMMENDATIONS

The 80-acre parcel, including the 10-acre site targeted for immediate development, is potentially suitable for construction of the proposed school(s). The following conclusions and recommendations are based on the information described in preceding sections.

1. Because of potential problems associated with destabilized sand dunes, care should be taken to avoid unnecessarily disturbing the natural vegetation during construction and to stabilize impacted areas, perhaps by planting vegetation or paving.

2. The flash flood hazard is generally low, but is greater in the western and southern portions of the parcel where alluvial fans occur (attachment 2). If construction proceeds in these areas,

flood mitigation measures should be considered.

3. Neither shallow ground water nor shallow bedrock are anticipated to occur within the parcel. However, a detailed soil foundation study should be performed at the selected site(s) prior to construction to determine soil properties and ground-water conditions. If bedrock is encountered, it is likely to be Entrada Sandstone and difficult to excavate. If shale or mudstone of the Carmel Formation is encountered (at the west end of the parcel), it may be weathered and easily excavated, but may contain expansive clays requiring special foundation design. Alluvial-fan deposits derived from the Carmel Formation may likewise contain expansive clays.

4. The area lies within Uniform Building Code (UBC-1988 edition) seismic zone 2B, but is near the boundary with seismic zone 1. Because schools are considered critical facilities, construction should comply with specifications for zone 2B.

REFERENCES

Anderson, L.W., and Miller, D.G., 1979, Quaternary fault map of Utah: Fugro, Inc., Long Beach, California, 35 p.

Arabasz, W.J., Pechmann, J.C., and Brown, E.D., 1987, Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch front area, Utah, in Gori, P.L. and Hays, W.W., eds., Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah: U.S. Geological Survey Open-File Report 87-585, p. D-1 - D-58.

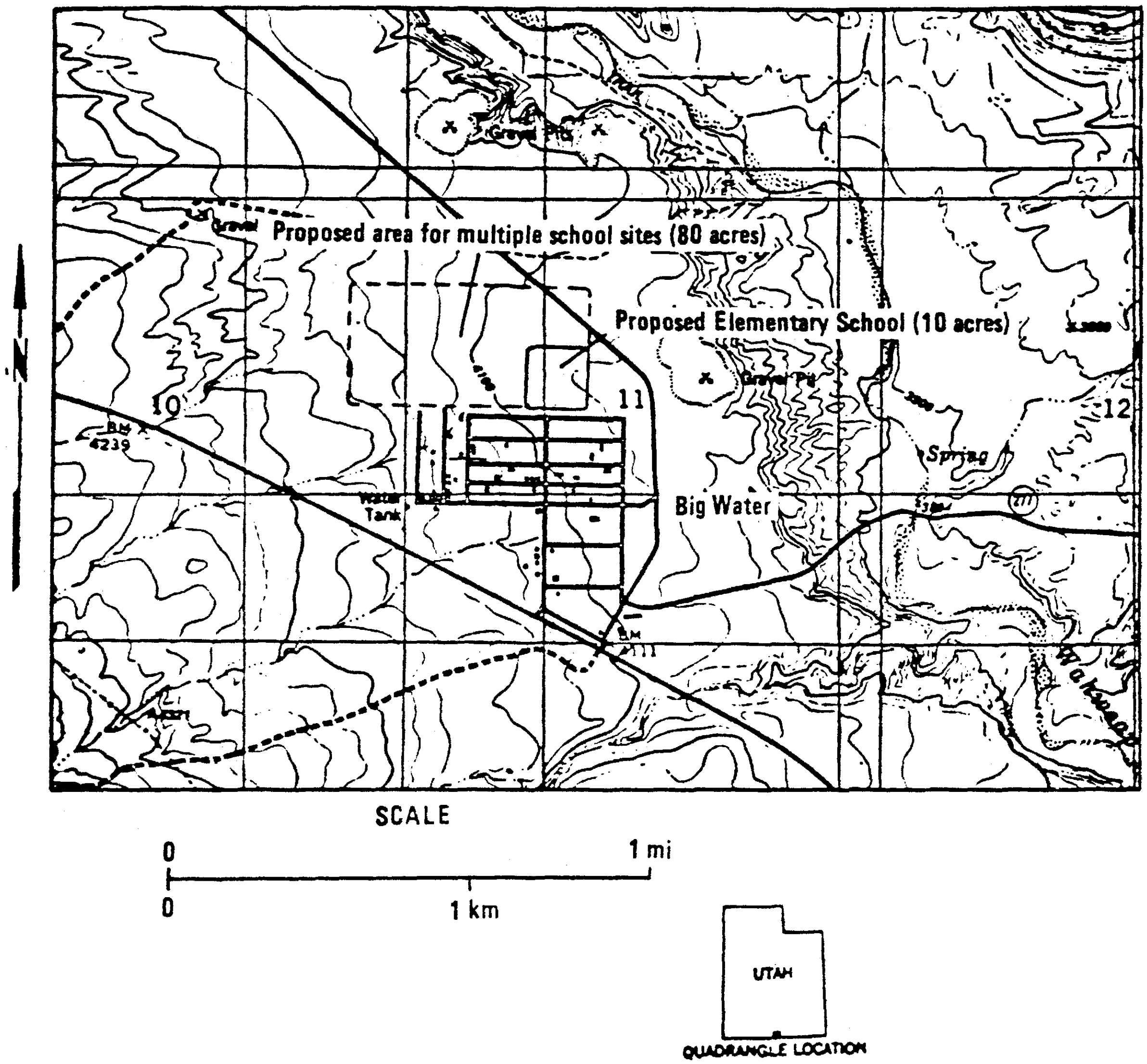
Hecker, Suzanne, 1989, Quaternary tectonic map of Utah: Utah Geological and Mineral Survey Map, in preparation.

Doelling, H.H., and Davis, F.D., 1989, The geology of Kane County, Utah: Utah Geological and Mineral Survey Bulletin 124, 192 p.

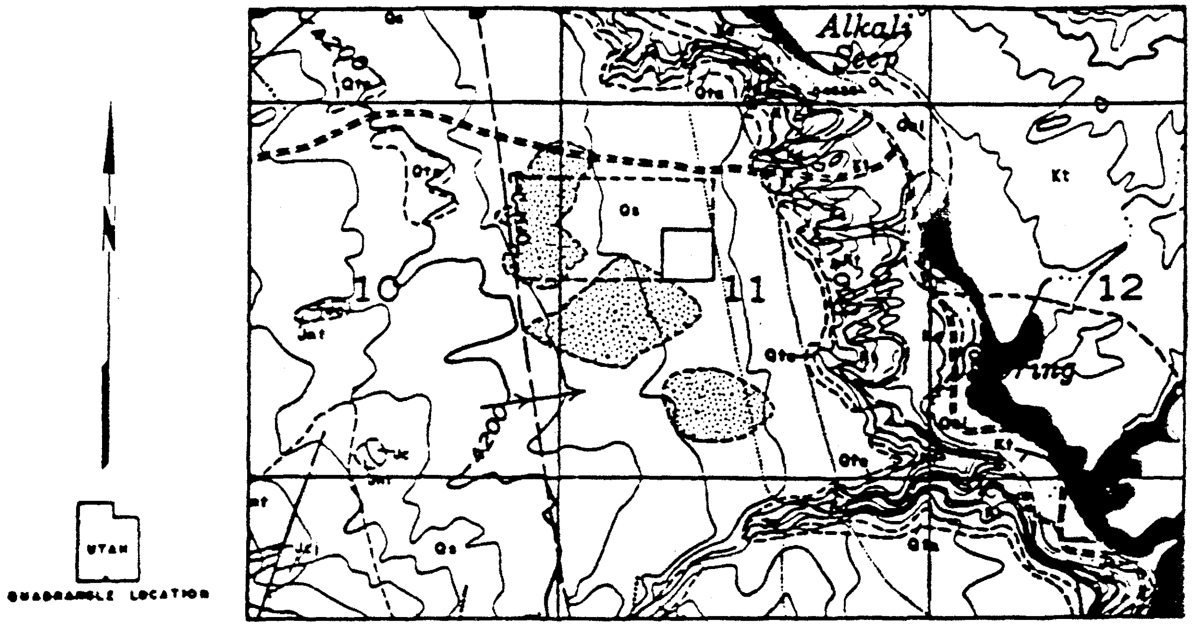
Waldrop, H.A., and Sutton, R.L., 1967, Preliminary geologic map and coal deposits of the southwest quarter of the Nipple Butte quadrangle, Kane County, Utah and Coconino County, Arizona: Utah Geological and Mineral Survey Map 24-D, scale 1:31,680.

Job No. 89-11(S-1)

Base map from Glen Canyon City U.S.G.S. 7-½ topographic quadrangle



Attachment 1. Location map.



EXPLANATION

- Qal — Stream alluvium
- Qs — Windblown sand
- Alluvial-fan deposits (boundaries are gradational)
- Qts — Terrace deposits
- Kt — Tropic Shale
- Kd — Dakota Formation
- Je — Entrada Sandstone
- Jc — Carmel Formation
- Jnt — Thousand Pockets Tongue of Navajo Sandstone
- Jcj — Judd Hollow Tongue of Carmel Formation

SYMBOLS

Contact

Long dashed where approximately located; short dashed where inferred or indefinite

Concealed contact

Used only where thinness or discontinuity of overlying surficial units permits location of contact to be deduced

U ? D

Fault

Long dashed where approximately located; short dashed and queried where probable; dotted where concealed. U, upthrown side; D, downthrown side

Monocline

Showing trace and plunge of line drawn along midpoint of limb. Long dashed where approximately located

41

Strike and dip of beds

SCALE

0 — 1 mi

0 — 1 km

Attachment 2. Geologic map showing location of study area (modified from Waldrop and Sutton, 1967).

Project:			Requesting Agency:
Geologic hazards investigation of a proposed High School site, Manila, Daggett County, Utah			Daggett County School District
By: W.E. Mulvey	Date: 10-10-89	County: Daggett County	Job No.: (S-2) 89-13
USGS Quadrangle: Manila (1277)			

INTRODUCTION

The Daggett County School District is selecting a site for a new high school building in Manila, Utah. The existing building has experienced damage due to differential settlement of the foundation and is being replaced. At the request of the Daggett County Board of Education, the Utah Geological and Mineral Survey (UGMS) conducted a geologic hazards investigation of the site for the new school building. Located at 200 North Street and 100 West Street, (section 13, T. 3 N., R. 19 E. Salt Lake Baseline and Meridian), the site covers about 2 acres and is presently the parking lot immediately east of the old school building (fig. 1).

The scope of work included a review of pertinent literature, and a field investigation including excavation of five test pits at the site on September 15, 1989. Ron Kendrick of the Daggett County School District was present during the field investigation.

GEOLOGY AND GEOLOGIC HAZARDS

The geology of the site vicinity is shown on figure 2 (Hansen and Bonilla, 1956). The site is covered by alluvium varying in thickness from one foot or less to more than seven feet (fig. 2; appendix 1). The alluvium is derived from erosion of the Wasatch Formation in hillslopes to the west. It is composed of sands, silts, and some gravel. In test pit 3 in the northeast corner of the site this deposit is seven feet thick (fig. 3; appendix 1), perhaps representing a topographic low in the underlying rock that was filled by the alluvium.

Beneath the alluvium and over the entire site are weathered sandstones of the Wasatch Formation. These sandstones were found in four of the five test pits (fig. 3; appendix 1). The Wasatch Formation ranges in color from reddish-orange to yellow and gray. It varies greatly in composition and resistance to weathering, being both easily erodible and a resistant cliff-former. This variability is visible at the site. Resistant layers crop out east of the existing building and in the center of the parking lot. Less resistant rock has been graded to construct most of the parking area.

Dips measured on beds in the Wasatch Formation in three of the five test pits range from N. 30° W. to N. 36° W. Hansen and Bonilla (1956) also measured dips near the site of N. 40° W., indicating that the predominant dip of the Wasatch Formation at the site is to the northwest. They also mapped the Henrys Fork fault immediately west of

Job No.89-13(S-2)

Base map from DUTCH JOHN,
U.S.G.S. 30'x60' topographic quadrangle.

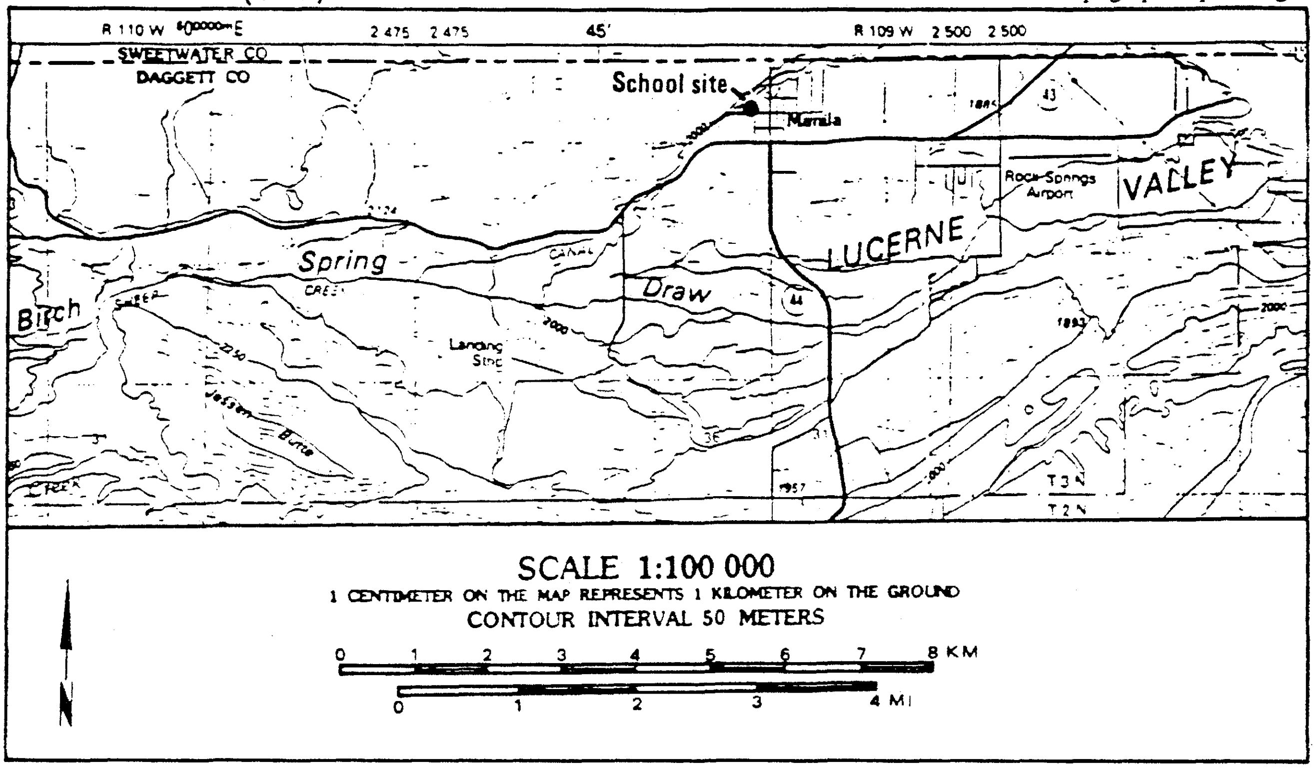


Figure 1. Location map of study site.

Base map from MANILA
U.S.G.S. 7-½' topographic quadrangle.

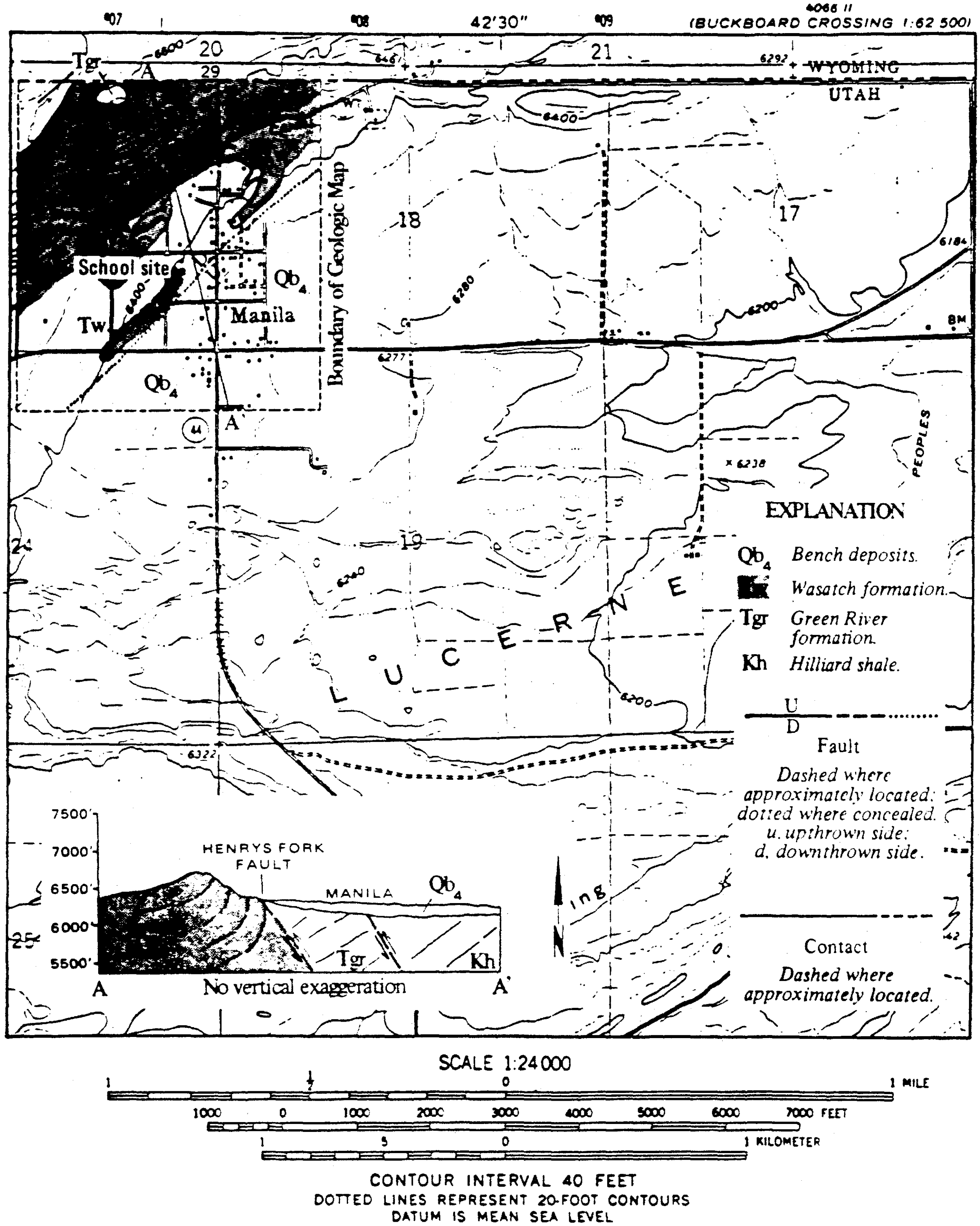


Figure 2. Geologic map and cross section at study site, showing Wasatch formation and Henrys Fork fault (modified from Hansen and Bonilla, 1956).

approximate scale 1" equals 25 ft (7.5 m)

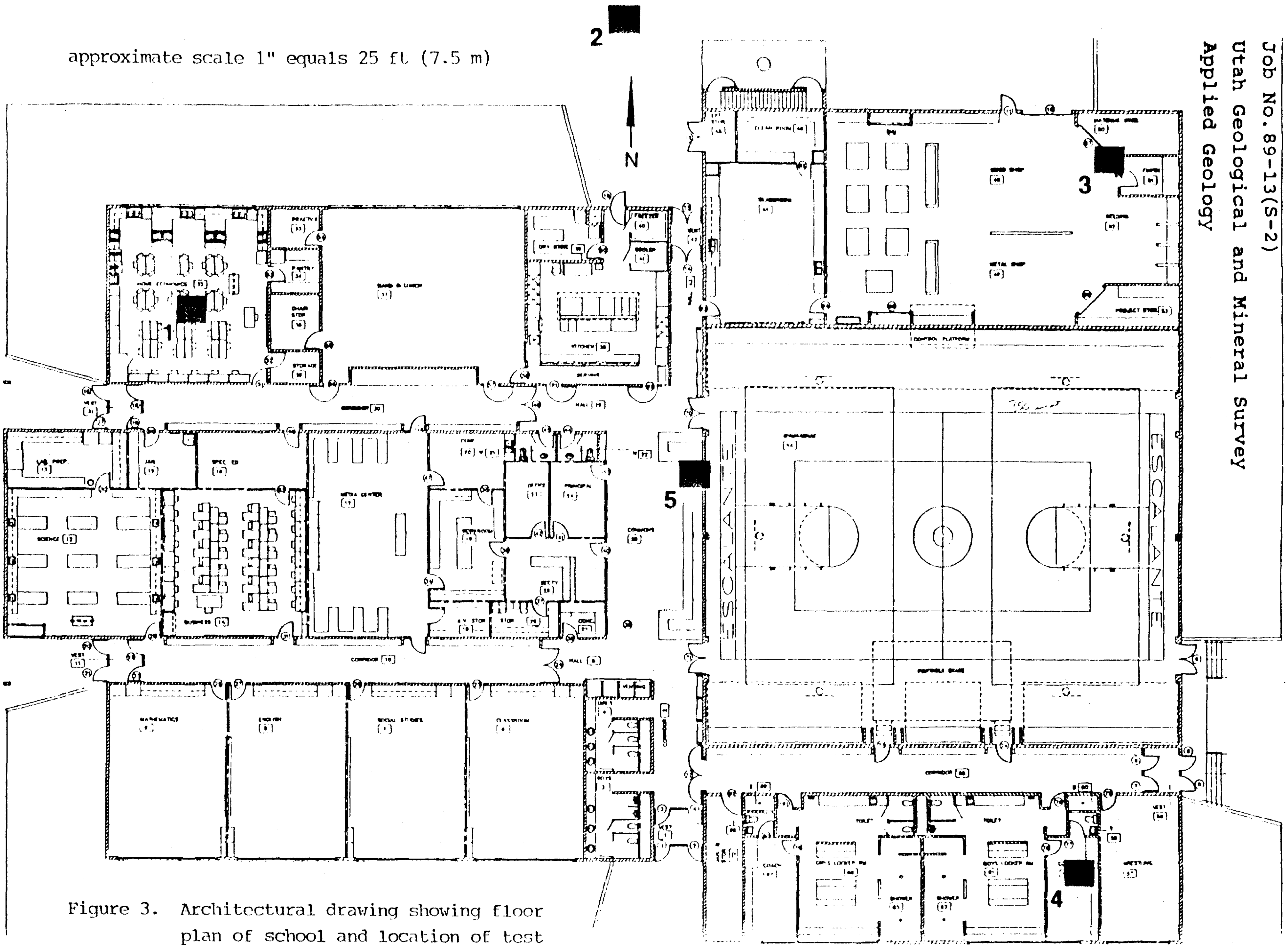


Figure 3. Architectural drawing showing floor plan of school and location of test pits 1-5.

the school site in the Wasatch Formation and determined it to be post-Eocene in age (57 to 36 million years ago).

Geologic hazards do not appear to pose significant problems at the site.Recent mapping of Quaternary faults in Utah by Anderson and Miller (1985) and Hecker (in progress) show no evidence of recent surface faulting on or near the school site. This indicates that the hazard from surface fault rupture is low. The town of Manila is in the Unified Building Code (UBC) zone one, the zone of lowest earthquake risk in Utah, where damaging earthquakes are not likely to occur (UBC 1988 edition). The potential for associated hazards induced by earthquakes such as ground shaking and liquefaction is likewise low. The potential for damage to the structure from slope failure, rock fall, and flooding is also low.

GROUND WATER

Information pertaining to ground water in the Manila area is limited, consisting only of general statements about the aquifer potential of the Wasatch Formation. Aquifer potential of sandstone and conglomerate beds within the formation is low due to their low to moderate permeabilities (Schlotthauer and others, 1981). The Wasatch Formation dips to the northwest, potentially directing water away from the site. However, the porous nature of the sediments and the possibility of fault-induced fractures could allow water to enter the building's foundation (fig. 2).

Permeability in the rock units can also be influenced by fracturing, and all rocks in the area display fractures. Immediately north of the site the Wasatch Formation is displaced by the Henry's Fork fault (fig. 2). Faulting generally increases the number and size of fractures within the rock, effectively increasing rock permeability. In many places ground water surfaces as springs along fault traces. The area north of the existing school has had perennial seeps or springs before and after construction of the old school (Dr. V. S. Barney, oral commun., 1989). These springs and seeps may be the result of ground water moving along the fault or fault-generated fractures in the Wasatch Formation. Water tolerant plants are present to the north of the school and new school site along the Sheep Creek Canal. They may represent leakage from the canal, or seepage from the fault trace, on which the canal is built (fig. 2). This is supported by the fact that the existing high school building has experienced perennial ground-water problems (Karren, 1989; Kendrick, oral commun., 1989). In a structural engineering investigation, Karren (1989) states "ground water often ran across the floor of the boiler room, the west side of the lunch room, equipment room north of the kitchen, and the storage room north of the shop". Water seepage has also been observed immediately north of and on the site for the new school building. No ground water was observed in test pits in this area, but this may be because this investigation was performed during is the driest time of the year.

FOUNDATION CONDITIONS

Foundation problems at the existing building may result from differential settlement caused by the variable composition and resistance to weathering of the underlying Wasatch Formation. However, the problems could also relate to improperly compacted fill beneath the structure. Exploratory test pits showed that rock at the new site ranges from relatively fresh to highly weathered sandstone and silty sandstone. Consolidation characteristics of these units will vary and, if the foundation is not engineered properly, may cause problems similar to those at the existing building.

Another potential foundation problem involves settling of materials overlying the abandoned buried trench-type wastewater disposal system in the northwest corner of the building site. Constructed to filter wastewater, this drainfield is porous and loosely compacted. When loaded, it may settle differentially. Blueprints for the existing school originally served by the system showed the system was only two feet deep.

CONCLUSIONS

No geologic hazards were found at the site which would endanger the structure or preclude its construction. However, this reconnaissance investigation indicates that foundation conditions at the site are similar to those at the existing high school, and have the potential to cause similar differential settlement problems if not considered in foundation design. Shallow ground water flooding of the new building through fractures in rock or from seepage from springs or the Sheep Creek Canal is also a potential hazard particularly in light of the history of problems at the existing site. It is recommended that a thorough soil foundation investigation be performed to address these problems. One solution may be to excavate soil and weathered rock over the entire site, including the abandoned wastewater disposal system, and replace it with properly compacted fill. It would also be wise to provide a drainage system in the foundation to collect ground water and to direct it away from the structure.

SELECTED REFERENCES

Anderson, L.W., and Miller, D.G., 1979, Quaternary fault map of Utah: Fugro, Incorporated, Long Beach, California, 35 p.

Christenson, G.E., 1981, Inspection of Captain's Cove Subdivision, Manila, Daggett County: Utah Geological and Mineral Survey Technical Memorandum, 4 p.

Hansen, W. R., and Bonilla, M. G., 1956, Geology of the Manila Quadrangle, Utah - Wyoming: U. S. Geological Survey Miscellaneous Geologic Investigations Map I - 156, scale 1:24,000.

Hansen, W. R., 1965, Geology of the Flaming Gorge Area Utah - Colorado - Wyoming: U. S. Geological Survey Professional Paper 490, 196 p.

Hecker, Suzanne, in progress, Quaternary tectonic map of Utah: Utah Geological and Mineral Survey Map.

Karren, K. W. 1989, Manila High School Daggett County, Utah: Karren and Associates, P.C. unpublished consultant's report, 6 p.

Montgomery, S. B., 1973, Ground water potential of Daggett County, Manila vicinity: Utah Division of Water Resources memorandum, 6 p.

Ravenholt, Hal, in progress, Henrys Fork Area soil survey of Utah - Wyoming, parts of Daggett and Summit Counties Utah, and Sweetwater and Uinta Counties, Wyoming: U.S. Soil Conservation Service.

Appendix 1

MANILA SCHOOL SITE TEST PITS

Test Pit 1

0.0'- 1.0' Fill material; buff to tan, sand and gravel.

1.0'- 3.0' Silty sand (SM); red-orange, medium to high density, low plasticity, dry; 15 percent fines, crude bedding, weak cementation, strong reaction to HCL, no odor, roots throughout the deposit, some carbonate nodules; weathered Wasatch Formation sandstone.

3.0'- 3.7' Clayey sand (SC); variegated pink to orange, medium to high density, low to medium plasticity, dry; 15 percent fines, crude bedding, strong reaction to HCL, no odor, roots throughout the deposit, carbonate nodules; weathered Wasatch Formation sandstone.

3.7'- 5.0' Wasatch Formation (Tw); purple to red, silty sandstone, moderate reaction to HCL, fractured, friable, bedding apparent, carbonate stringers, roots penetrate through horizon, highly weathered.

Test Pit 2

0.0'- 2.0' Wasatch Formation (Tw); tan to gray, sandstone, no reaction to HCL, no bedding, roots throughout horizon, apparent dip at contact with unit below, N. 26°W., very highly weathered sandstone can be removed with hand.

2.0'- 5.5' Wasatch Formation (Tw); maroon to brick red, silty sandstone, low reaction to HCL, fractured, friable, bedding apparent, carbonate stringers, roots penetrate through horizon, highly weathered, apparent dip N. 26°W., same unit as in base of test pit.

Test Pit 3

0.0'- 7.1' Poorly graded sand (SP); buff to orange, medium density, non plastic, dry, 5 percent fines, no structure, non-cemented, strong reaction to HCL, no odor, carbonate coatings on clasts, clasts are sandstone, roots penetrate throughout horizon; unit is alluvium derived from erosion of Wasatch Formation.

Test Pit 4

0.0'- 1.0' Fill; reddish orange, sands and gravels.

1.0'- 2.3' Poorly graded sand (SP); white to buff, low density, nonplastic, 5 percent fines, no structure, non-cemented, weak reaction to HCL, no odor, roots penetrate throughout horizon, apparent dip at contact with unit below is N. 32° W., weathered Wasatch Formation.

2.3'-4.0' Wasatch Formation (Tw); white to buff, sandstone, strong reaction to HCL, bedding apparent, carbonate nodules, roots penetrate throughout horizon, apparent dip at contact with unit above N. 32° W., excavation difficult.

Test Pit 5

0.0'- 0.6' Fill; brown, sand and gravel.

0.6'- 2.5' Wasatch Formation (Tw); sandstone, tan to orange, strong reaction to HCL, bedding apparent, carbonate nodules and stringers, roots penetrate throughout horizon, excavation difficult.

WATER SUPPLY

Project:	Requesting Agency:
Preliminary evaluation of the potential for contamination of Wellsville City springs by wastewater from proposed residential development at Sherwood Hills, Cache County	Wellsville City

By:	Date:	County:	Job No.:
Gary E. Christenson	6-5-89	Cache	(WS-1) 89-07

USGS Quadrangle:
Mt. Pisgah (1420)

INTRODUCTION

At the request of Don Hartle, Wellsville City Manager, an investigation was made of the area around the Wellsville City springs (Leatham Springs, SW1/4 sec. 17, T. 10 N., R. 1 W., Salt Lake Baseline and Meridian) about 3 miles west of Wellsville in Wellsville Canyon (fig. 1). The purpose of the investigation was to assess the potential effect on water quality of proposed residential development at Sherwood Hills about 3/4 mi south of the springs. Sherwood Hills plans about 30 new single-family homes in the areas shown in figure 1, 25 south and 5 north of the existing lodge, condominiums, and restaurant. All wastewater from existing facilities is disposed in a large community soil absorption field beneath the nearest fairway (hole no. 1) in the golf course several hundred feet east of the structures. The new homes will only be occupied seasonally (second homes), and will also use individual soil absorption systems to dispose of wastewater.

The scope of investigation included a literature search, field reconnaissance, inspection of existing excavations and outcrops, and discussions with those involved in the project. Mr. Hartle and Brad Harvey, Utah State Health Department, were present during parts of the field investigation on May 18, 1989. Dr. Craig Forester, Utah State University Department of Geology, contributed some helpful suggestions in evaluating the ground-water system.

GEOLOGY AND SOILS

Figure 2 includes a generalized geologic map (Williams, 1958; Davis, 1985) and cross section to show the relationship between geologic units, springs, and topography. Bedrock in the area consists chiefly of Paleozoic sedimentary rocks, including limestone, dolomite, shale, sandstone, and quartzite. The predominant rock types are limestone and dolomite, and these are probably the principal bedrock aquifers (Mundorff, 1971; Rice, 1987). Bedding in the rocks strikes approximately northwest and dips steeply to the northeast (fig. 2). A road cut near the springs exposes a shear zone (fault) and associated joints trending N 30o W (dip 66o SW). The zone trends through the spring area and parallels the east side of the valley.

The bottom of Wellsville Canyon is covered by unconsolidated Quaternary deposits, chiefly alluvium, of unknown thickness. At Sherwood Hills, these are very coarse-grained alluvial-fan deposits. Test pits along the water line from the springs to Sherwood Hills (excavated earlier this year to look for water-line leaks) exposed a

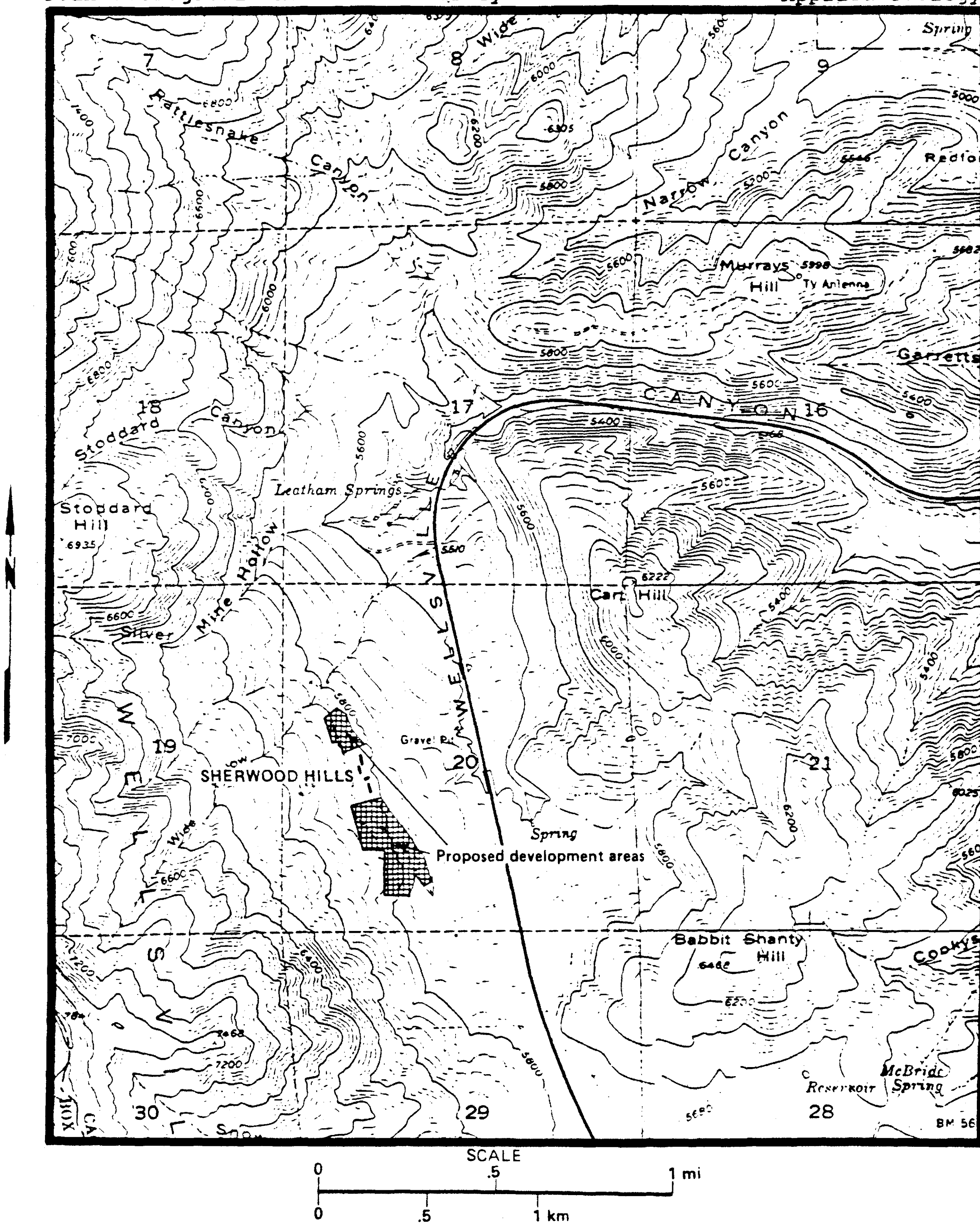
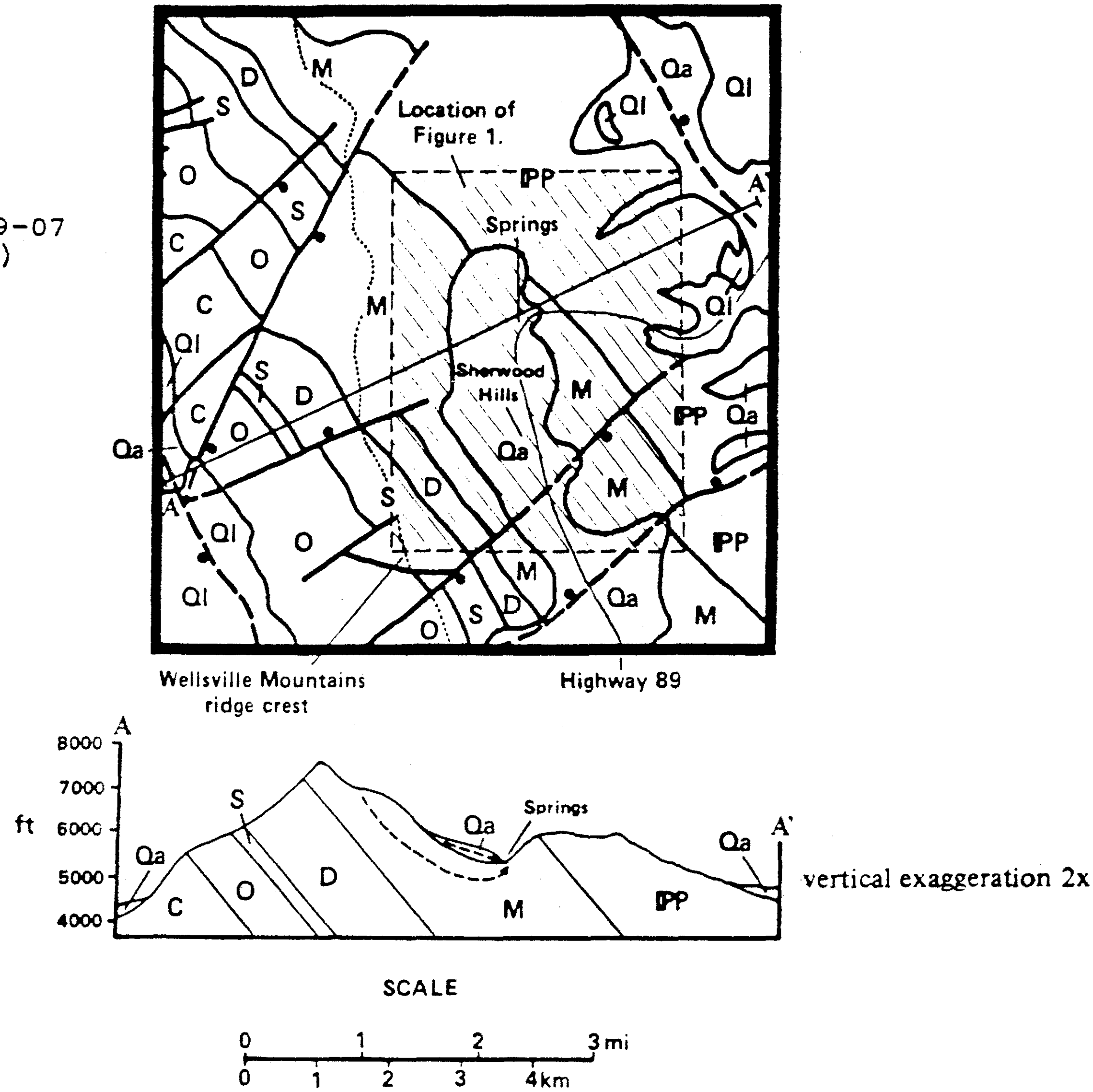


Figure 1. Location map showing Wellsville City springs (Leatham Springs) and proposed areas of development at Sherwood Hills.

Job No. 89-07
(WS-1)



EXPLANATION

Qa	Alluvium (Quaternary)
Ql	Lake Bonneville deposits (Quaternary)
IPP	Limestone, siltstone, sandstone, quartzite (Permian-Pennsylvanian)
M	Limestone, dolomite, sandstone, shale (Mississippian)
D	Dolomite (Devonian)
S	Dolomite (Silurian)
O	Limestone, quartzite, dolomite (Ordovician)
C	Dolomite (Cambrian)

Fault

dashed where inferred,
bar and ball on downthrown side

Contact

Possible ground-water flow paths

Figure 2. Generalized geologic map and cross section, Wellsville Canyon area (Williams, 1958, Davis, 1985).

thick (average 2 feet) organic horizon at the surface overlying clayey, sandy gravel with cobbles to the bottom of the test pits (about 4-5 feet deep). These soils become finer-grained toward the springs. John Booth, co-owner of Sherwood Hills (oral commun., May 18, 1989), indicated that the soils in the area of the existing soil absorption system are very rocky, and the infiltration rates at the resort are high as evidenced by loss of water from a leaking water reservoir, and rapid infiltration of water when draining swimming pools. These observations are confirmed by the U.S.D.A. Soil Conservation Service soil survey of Cache County (Erickson and Mortensen, 1974) which indicates well-drained, moderately permeable, coarse-grained soils at the site.

Unconsolidated alluvium in the valley reaches a maximum exposed thickness of at least 200 feet near the springs, and thins toward the mountain front and Sherwood Hills area (fig. 2). The alluvium at the surface is underlain, at least along the axis of the valley east of Sherwood Hills, by an unconsolidated fine-grained white clay bed exposed in road cuts between the Sherwood Hills turnoff and the springs. This bed is probably of low permeability, but it is unlikely that it extends beneath Sherwood Hills. The total thickness and type of soil at depth at Sherwood Hills is not known. No water well logs are on record at the State Engineer's office, and no other subsurface data are available.

GROUND WATER

Water at the springs is collected in perforated pipes buried 10-20 feet in unconsolidated deposits along stream channel bottoms in the spring area. Flow measurements taken from April, 1988, to present by Don Hardle ranged from maxima in late spring of around 650 gallons per minute (gpm)(May, 1988) and 875 gpm (April, 1989), to a minimum of around 400 gpm in late summer (1988). These measurements were taken during low-precipitation years, and older records indicate greater flows (1170 gpm on June 5, 1956; Mundorff, 1971).

The potential recharge area above the springs is underlain by bedded sedimentary rocks and unconsolidated alluvium. To understand the ground-water system and the source of recharge for the springs, it is important to determine whether the water comes chiefly from bedrock or unconsolidated alluvial aquifers. Although this cannot be determined from existing data, several inferences can be made.

Rice (1987) studied recharge to ground-water systems in the nearby Dry Lake and Mantua areas, and determined that 49 percent of the annual precipitation goes to recharge ground-water aquifers. This amounts to 12.2 to 14.7 in. of annual recharge, and assuming that this applies here as well, a total annual recharge to the approximately 1.5 square miles of alluvium in the bottom of the canyon can account for about 600 to 700 gpm of spring flow. Because this is nearly equal to the measured flow, it is possible that the springs are fed chiefly by recharge to alluvium, and that it is the principal aquifer discharging at the springs. In such a ground-water system, water infiltrates into the alluvium and percolates downward into a shallow, unconfined water table, perhaps perched on the less permeable underlying bedrock. It then flows downgradient toward the lowest point in the aquifer and discharges at the springs. To derive a greater understanding of flow in such a system, monitoring wells in the alluvium would be required. These wells could yield information on the saturated thicknesses of alluvium and elevation of the water table, and from these the quantity of water stored in the system and direction of flow could be estimated.

Despite the fact that calculated recharge to the alluvium can account for most flow at the springs, it is probable that at least some of the recharge to the springs is from deeper circulation through bedrock aquifers. The principal bedrock aquifer supplying the springs would be unit M (fig. 2), which is chiefly limestone. Bedrock is exposed in a road cut south of the lower spring collection box, and bedrock is likely to be very shallow in the spring area. A fault zone and relatively impermeable rock layer (shale at the top of unit M, fig. 2) are found in the spring area, and both may direct water from bedrock aquifers to discharge at the springs. The various bedrock layers in the recharge area probably interconnect along throughgoing fractures and form a single, unconfined bedrock aquifer with water moving along bedding planes and fractures. It is unlikely that primary rock permeability is significant in comparison to fracture permeability, particularly in limestone aquifers (Rice, 1987). The amount of interaction between bedrock and alluvial aquifers in unknown. The cross section in figure 2 shows possible ground-water flow paths to the springs.

POTENTIAL FOR CONTAMINATION OF SPRINGS

The Bear River Health Department reports that no contamination of the springs has been observed due to wastewater disposed at Sherwood Hills to date (Joel Hoyt, oral commun., May 17, 1989). Because soils at Sherwood Hills are coarse grained with little filtering capacity, the ground-water system in the area is relatively susceptible to contamination. However, soils become finer grained toward the springs, and contain more silt and clay important for the renovation of effluent. The lack of contamination to date is probably due to the great distance of travel (about 3/4 mi), dilution of effluent in the ground-water reservoir, and renovation by finer-grained soils as the water moves toward the springs.

Mr. Hartle indicated that Sherwood Hills presently uses about 2 million gallons (mg) of water per month, or about 24 mg/yr. The percentage of this amount that is disposed as wastewater in the soil absorption system is not known, but the total water used accounts for about 5-10 percent of the average annual spring flow of approximately 300-400 mg/yr. If the proposed 30 homes were permanently occupied and each used 8400 gallons/week (estimated for a three-bedroom home in an urban area using guidelines from the Utah State Health Department), this would add an additional 13 mg/yr, or about half again as much as is presently disposed. This is not a major increase, and it is a maximum because these homes will only be occupied seasonally and not all the water used will be contaminated and disposed in the soil absorption system. Although it cannot be determined how much additional wastewater may be disposed in the area before the effects are detectable at the springs, these rough calculations and the lack of contamination to date from the large drainfield, which is closer to the springs than most of the proposed systems, indicate that it is possible that the proposed homes around the lodge will not significantly affect water quality. However, because of the relative susceptibility of the ground-water system to contamination and lack of natural safeguards to protect it, the possibility of contamination cannot be ruled out.

RECOMMENDATIONS

If the proposed development is permitted, it is recommended that special attention be given in approving individual soil absorption systems to see that percolation rates and depths to ground water comply with State and District Health Department regulations. It is possible that percolation rates in some areas may be too high to meet requirements for soil absorption systems, and health officials may wish to consider more strict requirements if percolation rates are uniformly high and near the upper limit allowed.

The State is presently working on developing a wellhead protection program to provide for the protection of public water supplies. The program would apply to both springs and wells, and provide guidance in defining protection zones. At this point, the only existing regulation requires a 1500-foot protection zone upgradient from the springs, and we believe that as a minimum this should be enforced at the Wellsville City springs until more information is available to better define a protection zone.

The conclusions and recommendations included in this report are preliminary and based on very limited information. To make a more definitive determination of the potential for contamination, several types of investigations could be undertaken. A ground-water tracer could be introduced into the soil absorption field presently serving Sherwood Hills, and if it was detected at the springs could help to determine flow paths, velocities, and perhaps dilution factors. However, an approximate calculation of flow time through alluvium from Sherwood Hills to the springs, assuming average hydraulic conductivities and porosities for gravel as given in Freeze and Cherry (1979), indicates that it may take up to several months. Because of this and the possibility that finer grained soils along the flow path may greatly increase this time, this technique has a low likelihood of success.

Subsurface exploration at Sherwood Hills and between the resort and the springs to determine the thickness and types of unconsolidated deposits and depth to water would be helpful. Such an investigation is expensive, but would yield valuable data regarding flow directions, the ability of soils to renovate effluent, and possible interactions between bedrock and alluvial aquifers. Detailed analysis of water chemistry by a hydrochemist may also help to define recharge areas and residence times for this ground-water system.

REFERENCES

Bjorklund, L.J., and McGreevy, 1971, Ground-water resources of Cache Valley, Utah and Idaho: Utah Department of Natural Resources Technical Publication No. 36, 72 p.

Davis, F.D., compiler, 1985, Geology of the northern Wasatch Front: Utah Geological and Mineral Survey Map 53-A, scale 1:100,000.

Erickson, A.J., and Mortensen, V.L., 1974, Soil survey of the Cache Valley area, Utah: U.S. Soil Conservation Service and Forest Service in cooperation with Utah Agricultural Experiment Station, 192 p.

Freeze, R.A., and Cherry, J.A., Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 604 p.

Mundorff, J.C., 1971, Nonthermal springs of Utah: Utah Geological and Mineral Survey Water-Resources Bulletin 16, 70 p.

Rice, K.C., 1987, Hydrogeology and hydrochemistry of springs in Mantua Valley and vicinity, north-central Utah: Unpublished Master's Thesis, Utah State University, 113 p.

Williams, J.S., 1958, Geologic atlas of Utah, Cache County: Utah Geological and Mineral Survey Bulletin 64, 104 p.

Project:			Requesting Agency:
Preliminary hydrogeologic investigation of a spring in Center Creek Canyon, Wasatch County			Wasatch County Health Department
By: Gary E. Christenson	Date: 6-21-89	County: Wasatch	Job No.: (WS-2) 89-10
USGS Quadrangle: Center Creek (1126)			

INTRODUCTION

At the request of Phil Wright, Wasatch County Health Department, an investigation was made of a spring in Center Creek Canyon which the unincorporated community of Center Creek would like to use in its culinary water system. The spring is along the east side of the canyon in the SW1/4 sec. 24, T. 4 S., R. 5 E., Salt Lake Baseline and Meridian (fig. 1). The purpose of the investigation was to determine geologic and hydrologic conditions to provide information for delineation of a protection zone around the spring to aid Center Creek in protecting the water quality. At present, no specific plans for development near the spring exist, but it is anticipated that homes with septic tank soil absorption systems may be proposed for the canyon bottom area within the 1500-foot upgradient protection zone defined under State Heath Department guidelines.

The scope of work included a review of literature, air photo interpretation, and field reconnaissance. LeRoy Sweat and John Kocinski of the Center Creek Culinary Water System and Mr. Wright were present during the field investigation on June 12, 1989.

GEOLOGY

The spring is on the east side of Center Creek Canyon at the base of the fill emplaced for the main road providing access along the east side of the canyon (fig. 1). Bedrock in the canyon wall in this area is quartzite of the Wallsburg Ridge Member of the Oquirrh Formation (fig. 2). Bedding dips moderately to the north and northeast (Baker, 1970). Although no outcrops are present near the spring, the rock is believed to be highly fractured as indicated by the cobbly and bouldery talus accumulations above the spring. Rocks of the Keetley Volcanics (rhyodacite and andesitic tuff and breccia) are also present in the potential recharge area of the spring north of Center Creek (fig. 2). No detailed geologic mapping has been completed in the area, so little more is known of the bedrock geology.

The floor of Center Creek Canyon is covered by gravelly alluvium. Two wells are present in the vicinity of the springs, and the depth to bedrock (thickness of alluvium) varies from 70 to 98 feet (fig. 1). Center Creek is incised 6-8 feet into the alluvium, and flows along the opposite edge of the valley from the spring. Just south of the spring an alluvial fan at the mouth of a small eastern side-canyon has forced Center Creek to the west side of the valley. The

Job No. 89-10(WS-2)

Base map from: U.S.G.S. Topo. Quad., Center Creek, Utah.

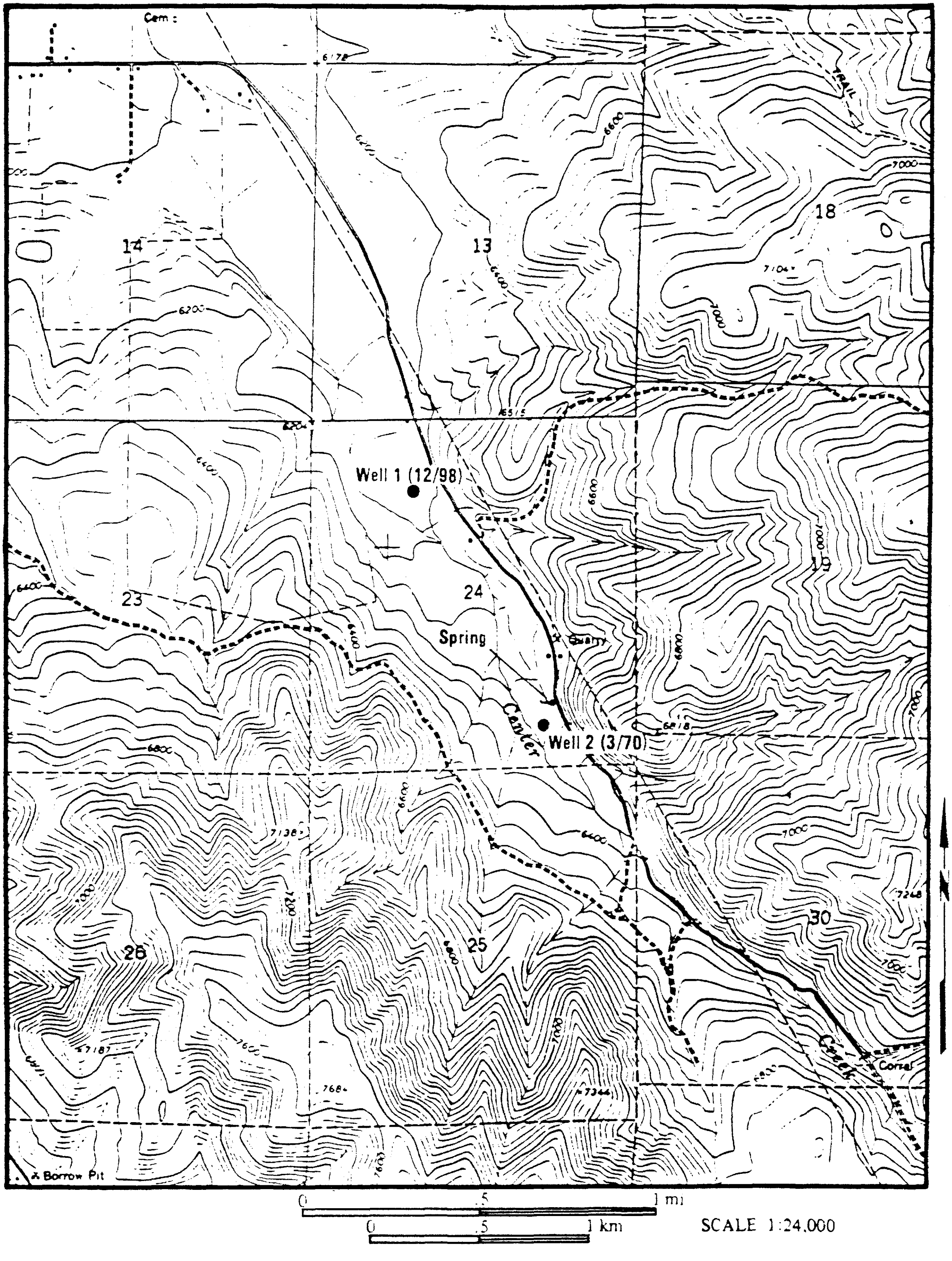
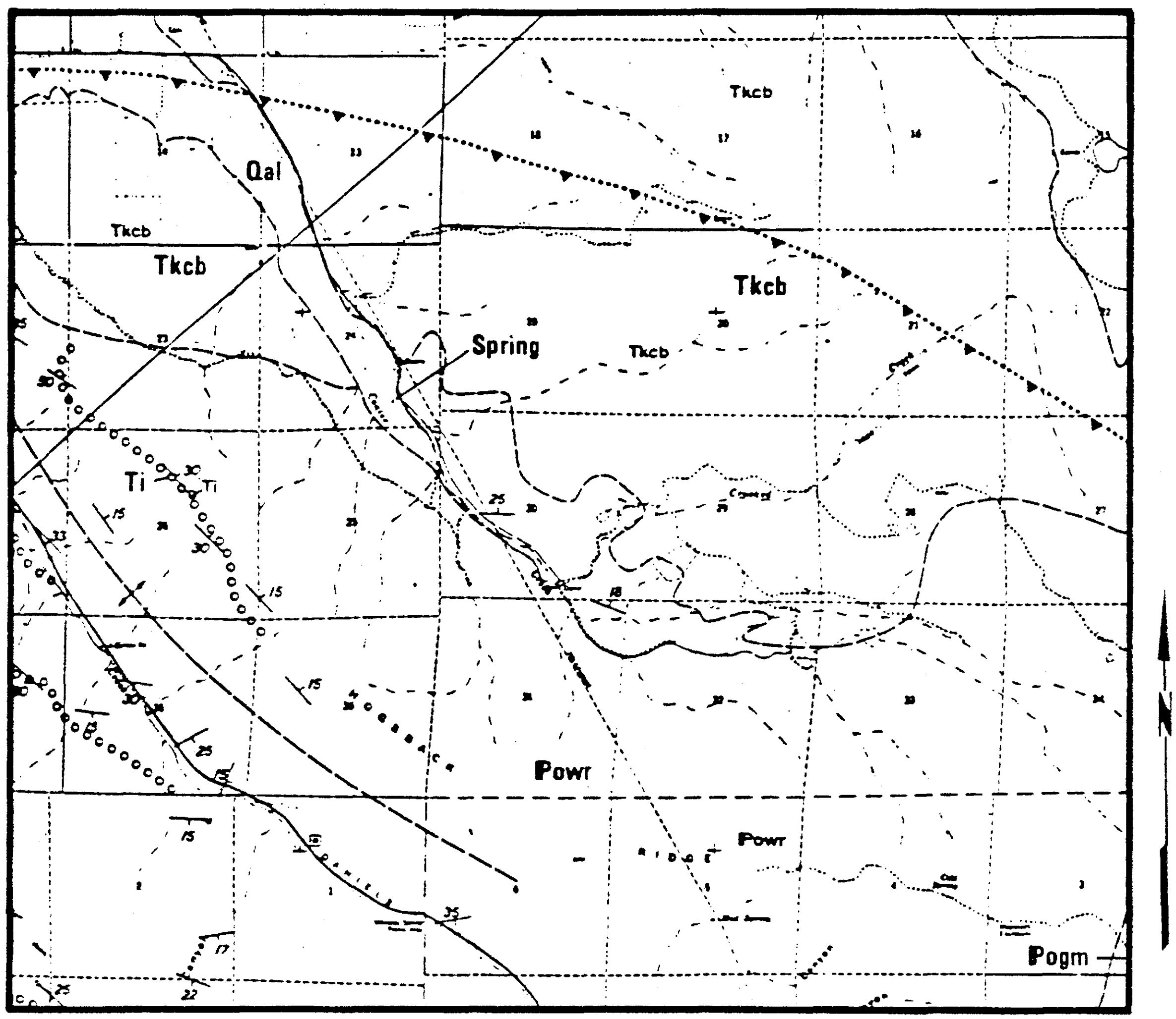


Figure 1. Location of spring and wells (depth to water in feet/depth to rock in feet).

Job No. 89-10(WS-2)



0 1 2 mi

0 1 2 km

SCALE 1:63,360

Qal	Alluvium
Tkcb	Keetley Volcanics
Pogm	Granger Mountain Member, Oquirrh Formation
Powr	Wallsburg Ridge Member, Oquirrh Formation

Contact, dashed where approximate

Thrust fault

Anticline

Ti

Limestone Marker

40

Strike and dip

Figure 2. Geologic map (after Baker, 1976).

canyon bottom is flood irrigated, and water was flowing in irrigation ditches at the time of the investigation.

GROUND WATER

In order to delineate a protection zone for the spring, the recharge area and potential zone of influence must be determined. Although no record of flow at the spring has been kept, LeRoy Sweat (oral commum., June 12, 1989) indicated that it flows year-round and was measured at about 90 gallons/minute earlier in the year. Although annual fluctuations have not been recorded, Mr. Sweat indicated that he has not noted any increase in flow during the irrigation season and believes flow to be constant with little variation. Water quality analyses indicate that the water meets drinking water standards.

The spring occurs at a location in the valley bottom near the toe of the alluvial fan deposited from the eastern side-canyon south of the spring. Phreatophyte vegetation and grass in the valley bottom downstream from the spring and fan toe indicates that shallow ground water is present in the alluvium. The well near the spring (well 2, fig. 1) reported a depth to water of 12 feet at the time of drilling, with a static water level of 3 feet after completion on September 11, 1971. This is interpreted to indicate that the depth to the water table in the unconfined alluvial aquifer is 12 feet, but that water in a confined aquifer under artesian pressure was encountered deeper in the hole. A test well drilled in the same general area (exact location unknown) recorded a depth to water of 12 feet, and a well downstream about a mile recorded a depth to water of 16 feet (well 1, fig. 1). There is thus a shallow water table in alluvium, probably recharged by irrigation, flow from side canyons, and spring flow. The role of Center Creek may change annually from a drain during the irrigation season to a source of recharge during dryer times of the year.

The shallow alluvial aquifer is not, however, the likely source of flow at the spring. Because of its location at the canyon margin slightly above the valley bottom, and the reported constant flow with no noticeable increase during flood irrigation, the spring is believed to be discharging from a bedrock aquifer and not the valley-bottom alluvial aquifer. The recharge area is then chiefly in the hills on the east side of Center Creek Canyon. Although the boundaries of the recharge area are unknown, the aquifer feeding the spring is likely fractured bedrock of the Oquirrh Formation. This formation yields water to wells and springs elsewhere (Baker, 1970), and is believed also to be the aquifer tapped by wells in the valley bottom causing the artesian pressure in well 2 near the spring (fig. 1). The presence of the spring indicates a water level in the rock aquifer above the perforated interval in the well (20-143 feet), possibly accounting for the rise of water in the well above the water table in the unconfined alluvial aquifer.

SPRING DEVELOPMENT AND PROTECTION ZONE

If the spring is to be developed as a culinary water source, care will be required to ensure that it does not become contaminated. To reduce the possibility that water will be collected from the shallow alluvial aquifer, collection lines and structures should be placed at the present elevation of the spring rather than being buried in the valley bottom. If lines are placed at an elevation below the present spring, it is possible that they will tap the alluvial aquifer as well as the bedrock aquifer, greatly increasing the potential for contamination and requiring the protection zone to include the portion of the 1500-foot protection zone on the valley bottom from Center Creek to the road on the east side of the valley.

The spring is already in an area with a high potential for contamination from the road, an irrigation ditch along the fence on the west side of the road, and from cattle in pastures in the hills above and east of the spring. The 1500-foot protection zone above the spring east of the road is needed. If the spring is developed such that only the flow from rock is captured and lines are above the present valley floor, it will probably not be necessary to protect valley bottom areas except along the road at and above the spring. The irrigation ditch between the road and the fence southeast of the spring will need to be abandoned or diverted well upstream to ensure that infiltration from the ditch does not recharge the spring. It would be prudent to define a protection zone in the valley bottom along the road and base of the hill upstream from the spring to minimize the potential for contamination. The width and upstream extent of the zone cannot be determined without a detailed knowledge of ground-water conditions, but it probably need not extend more than 50-100 feet west of the road for 1500 feet upstream.

REFERENCES

Baker, A.A., 1976, Geologic map of the west half of the Strawberry Valley quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-931, scale 1:63,360.

Baker, C.H., Jr., 1970, Water resources of the Heber-Kamas-Park City area, north-central Utah: Utah Department of Natural Resources Technical Publication No. 27, 79 p.

Lund, W.R., 1983, Unpub. Utah Geological and Mineral Survey letter to Phillip Wright (April 15, 1983) regarding Center Creek springs, 7 p.

Project:			Requesting Agency:
Potential Reduction to Spring Discharge as a Result of Changing from an Open-Ditch Irrigation System to a Piped Pressure Irrigation System, Beaver City, Utah			Beaver City
By: Mike Lowe	Date: 11-15-89	County: Beaver County	Job No.: (WS-3) 89-16
USGS Quadrangle: Beaver, Utah (440)			

INTRODUCTION

The purpose of this study, requested by Robert H. Lee, Beaver City Mayor, is to assess potential impacts on spring flow in the southwest part of Beaver City that may occur as a result of Beaver City changing from a open-ditch irrigation system to a piped pressure irrigation system. Beaver City is located in Beaver Valley just west of the Tushar Mountains in southwestern Utah (attachment 1). The scope of work included a 2-hour field investigation of the area on November 9, 1989, and a literature review. Mayor Lee and Conrad Grimshaw, City Councilman, were present during the field investigation. During the literature review it was determined that Palmer Wilding, Consulting Engineers, had already investigated the potential impact that changing to a pressure irrigation system by Beaver City might have on the spring-fed Beaver Fish Hatchery, and that, to some extent, the conclusions reached by Palmer Wilding probably apply to other springs along the southwest margin of Beaver City as well.

HYDROGEOLOGIC SETTING

Adobe Slough and Big Slough are the principle spring-fed drainages in the southwest portion of Beaver City. The springs are located near the contact between late Pleistocene (10,000 - 125,000 years before present) terrace alluvium (Qty, attachment 2) and Holocene (0 - 10,000 years before present) flood-plain alluvium (Qfp, attachment 2). The terrace alluvium consists of medium to coarse sand and bouldery gravel deposits that form a low terrace which is slightly elevated above the flood-plain alluvium and which was formed by the coalescing late Pleistocene flood-plains of the Beaver River and North Creek (Machette and others, 1984). The Holocene flood-plain alluvium consists of coarse sand and bouldery gravel deposits of the Beaver River which form the broad, slightly dissected surface southwest of Beaver (Machette and others, 1984). Numerous seeps and springs indicate that the ground-water level is near the ground surface in the Holocene flood-plain alluvium. Marsh deposits have also been identified in the flood-plain alluvium (Machette and others, 1984), indicating that shallow ground water may have been present in the area during much of Holocene time. Attachment 3 is a block diagram illustrating ground-water conditions in Beaver Valley. Beaver City would be located on the terrace in the foreground near the base of the Tushar Mountains. As shown on attachment 3, the source of water flowing from springs feeding Adobe Slough and Big Slough is perched and water-table aquifers which intercept the ground surface at the base of the late Pleistocene terrace alluvium.

EVALUATION OF CONCLUSIONS IN THE 1982 PALMER WILDING REPORT

The U. S. Geological Survey (Mower, 1978) determined that the irrigation efficiency of Beaver River irrigation water, applied using flood-irrigation methods, was 27 percent and that 73 percent went to recharge the ground-water reservoir. Based on a graph taken from a Division of Water Resources feasibility report, which assumes that the availability of a pressure irrigation system will result in a change from flood irrigation to sprinkler irrigation, Palmer Wilding estimated that the irrigation efficiency of sprinkler-irrigation water would be 60 percent and that a maximum of 40 percent could go to recharge the ground-water reservoir.

Palmer Wilding determined from flow measurements taken in 1979 at the Beaver Fish Hatchery, and from the potential irrigation diversion by Beaver City (based on water rights), that during low-flow periods springs and city drains accounted for 25 to 30 percent of streamflow at the fish hatchery. During the irrigation season, Palmer Wilding determined that springs and city drains accounted for 50 to 60 percent of streamflow at the fish hatchery. The lag time between the beginning of irrigation and significant increase in discharge from the drains and springs was determined by Palmer Wilding to be about 2 to 4 weeks.

Approximately 4 to 9 cubic feet per second flowed through the Beaver Fish Hatchery during the 1979 irrigation season (Palmer Wilding, 1982). Based on the information provided above, Palmer Wilding concluded that a change to a pressure irrigation system using sprinkler-irrigation application methods could theoretically reduce flow at the fish hatchery during the irrigation season to 1 and 2 cubic feet per second.

Although, based on the information in the report, the conclusions reached by Palmer Wilding appear reasonable, the effect of changing to a pressure irrigation system may have been overestimated because of their assumptions that:

1) all of the irrigation diversion rights available to Beaver City in 1979 were being used by the city within the area which will now go to pressure irrigation. Not all of the water flowing in the City Ditch is used for irrigation (Conrad Grimshaw, oral commun. 1982). Some of the water eventually reaches other canals, sloughs, and ultimately the Beaver River as surface flow. Seepage from the canal bottoms was determined by the U. S. Geological Survey to be only 2.4 percent of the available water, therefore little of any unused irrigation water would have gone to recharge the ground-water reservoir.

2) the City Ditch was the only irrigation canal contributing to spring flow reaching the Beaver Fish Hatchery. The City Ditch is not the only irrigation canal up gradient (northeast) of springs issuing from southwest Beaver City. Attachment 4 shows the location of some of the other canal systems in the vicinity of Beaver City. Some existing irrigation canals, such as the Willis Ditch, are not shown on attachment 4. Other canals, including the Mammoth Canal which carries more water than the City Ditch (Cruff and Mower, 1976), are also contributing water to the ground-water reservoir. Also, water derived from seasonal spring runoff may be contributing to the ground-water reservoir during the high spring-flow period.

3) the same number of people will use the pressure irrigation system that used the open-ditch irrigation system and that everyone

will change to sprinkler-irrigation application methods. Many residents currently living in Beaver City do not maintain green lawns, probably because of the problems associated with using the current open-ditch irrigation system (Conrad Grimshaw, oral commun., November 9, 1989). Some of these residents are likely to use the pressure irrigation system in the future due to the relative ease of application. Some of the residents may continue to use flood-irrigation methods after the change to a pressure irrigation system.

RECOMMENDATIONS

Geologic evidence indicates that shallow ground water probably existed in the Beaver City area prior to the start of irrigation by man. Irrigation in the Beaver City area has probably increased spring flow, particularly during the irrigation season. Although it is possible that changing from an open-ditch irrigation system to a piped pressure irrigation system will result in lower summer spring flows, the resulting lower spring flow may not be as much as indicated in the Palmer Wilding report.

To document the actual effect of changing irrigation systems once it has occurred, it would be necessary to monitor spring flow at several locations before and after the change. Several locations were identified during the November 9, 1989, field investigation that could be used as monitoring points without having to construct flumes. The quantity of water pumped from wells and amounts of precipitation in the Beaver City area for a period before and after the change would also have to be monitored and factored into the analysis.

To estimate in advance the actual reduction of spring flow caused by changing water systems, it would be necessary to work out a complete water balance for the springs and to define recharge areas and aquifer flow directions. Hydrographs for springs showing discharge as a function of time, records of amounts of irrigation flow and schedule of flow in canals and ditches, and records of precipitation and well pumping rates would need to be collected. Placement of piezometers in the aquifer with mapping of water-table changes during irrigation would also be helpful in evaluating recharge areas, flow directions, and how much irrigation presently contributes to flow at each spring. Once that is done, estimates of changes in the amount and efficiency of irrigation with the pressure system would need to be made and the resulting difference calculated.

REFERENCES CITED

Cruff, R. W., and Mower, R. W., 1976, Seepage study of canals in Beaver Valley, Beaver County, Utah: Utah State Department of Natural Resources Technical Publication No. 52, 45 p.

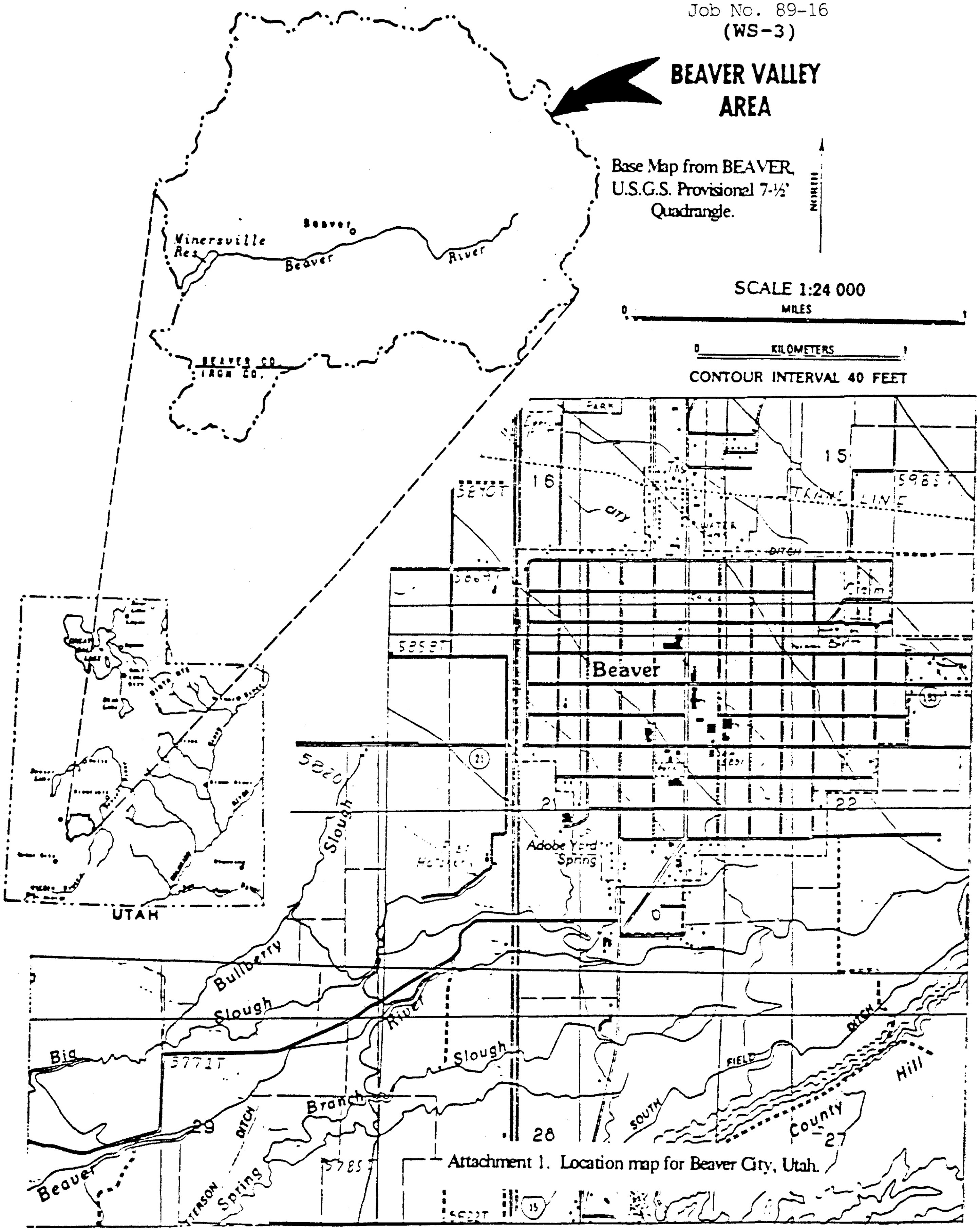
Machette, M. N., 1982, Guidebook to the Late Cenozoic geology of the Beaver basin, south-central Utah: U. S. Geological Survey Open-File Report 82-850, 42 p.

Machette, M. N., Steven, T. A., Cunningham, C. G., and Anderson, J. J., 1984, Geologic map of the Beaver Quadrangle, Beaver and Piute Counties, Utah: U. S. Geological Survey Map I-1520, 1:24,000 scale.

Mower, R. W., 1978, Hydrology of the Beaver Valley, Beaver County, Utah, with emphasis on ground water: Utah State Department of Natural Resources Technical Publication No. 63, 90 p.

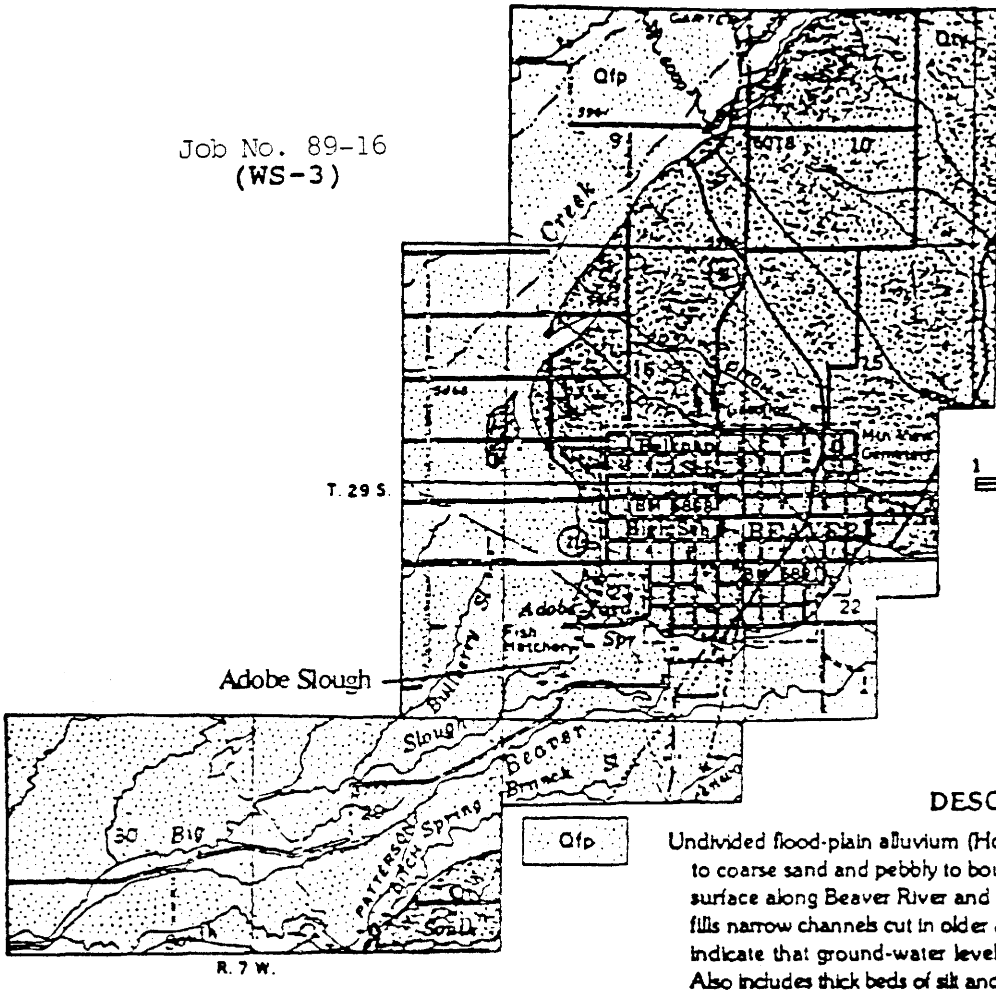
Palmer Wilding, Consulting Engineers, 1982, Future water supply evaluation for Beaver Fish Hatchery: Consultant's report for Utah Division of Wildlife Resources, 12 p.

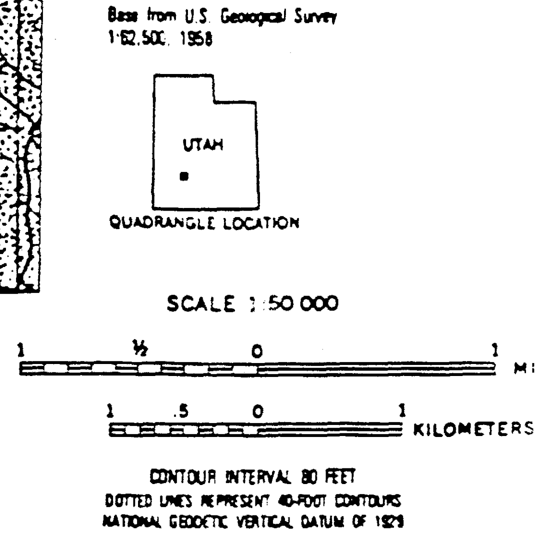
Job No. 89-16
(WS-3)

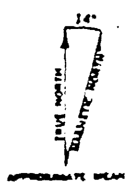


Attachment 1. Location map for Beaver City, Utah.

Job No. 89-16
(WS-3)







DESCRIPTION

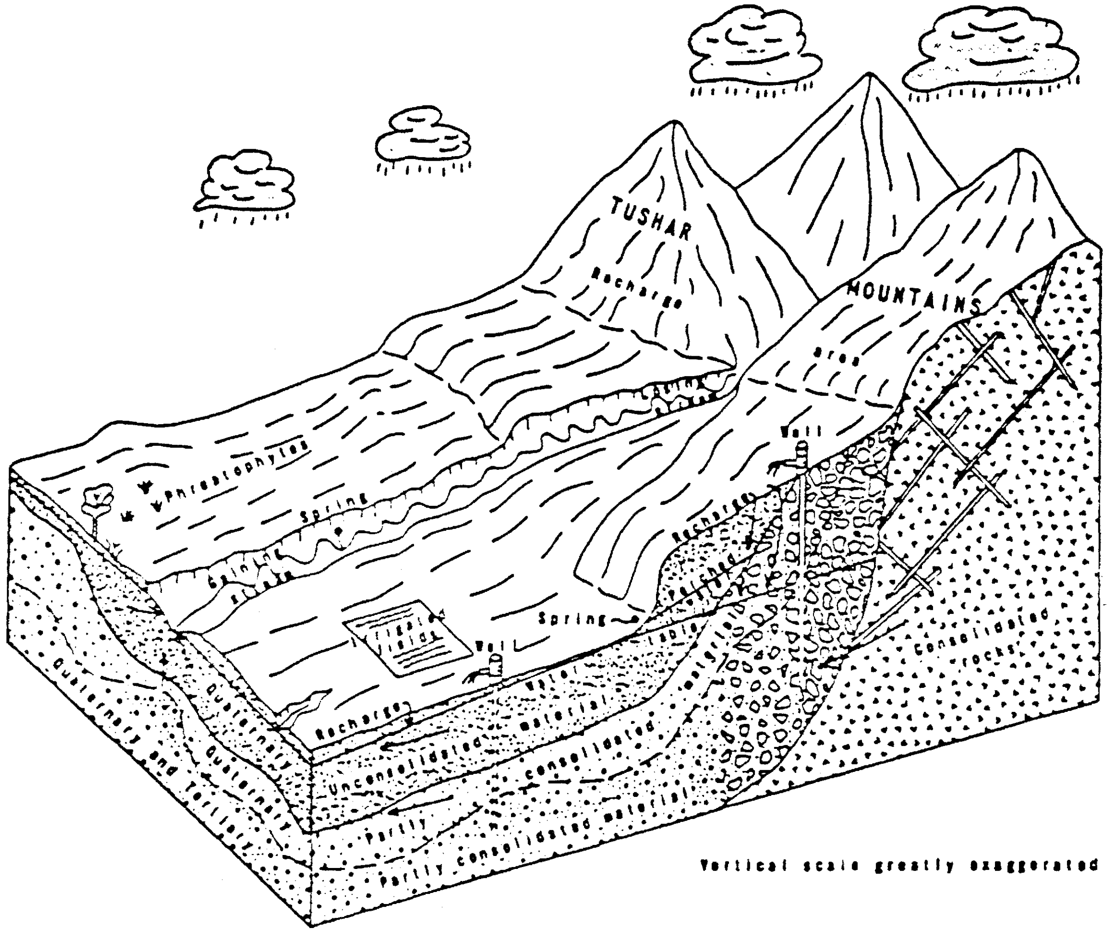
Qfp — Undivided flood-plain alluvium (Holocene)—Light-brown to light-gray, medium to coarse sand and pebbly to bouldery gravel. Forms broad, slightly dissected surface along Beaver River and North Creek, and toward Tushar Mountains fills narrow channels cut in older alluvial deposits. Numerous seeps and springs indicate that ground-water level is near surface of unit along Beaver River. Also includes thick beds of silt and fine sand containing abundant organic matter and calcium carbonate that fill deeply excavated channels along lower parts of Wildcat and Indian Creeks and their tributaries. These beds were deposited in a marsh environment. Thickness at least 5 m, base covered

Qty — Young terrace alluvium (upper Pleistocene)—Light-brown to light-reddish-brown, medium to coarse sand and pebbly to bouldery gravel. Forms broad, slightly elevated and coalesced former flood plains of Beaver River and North Creek near Beaver, and downstream forms terrace 5 – 6 m above modern floodplain of Beaver River, near Adamsville (3 km west of quadrangle). Near Manderfield, terrace is 3 – 5 m above Indian Creek. Soil has weak argillic B horizon and Cca horizon, but near Beaver is generally noncalcareous or only weakly calcareous (stage I of Gile and others, 1966) because of high water table. Mainly glacial outwash and associated alluvium of most recent major glaciation, the Pinedale, which may have ended about 12,000 to 15,000 yrs ago in this region. Major source of high-quality sand and gravel. Thickness 2 – 4 m; more than 4 m along Beaver River and North Creek

FAULT—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side.

Attachment 2. Geologic map of Beaver City area, Utah (modified from Machette and others, 1984).

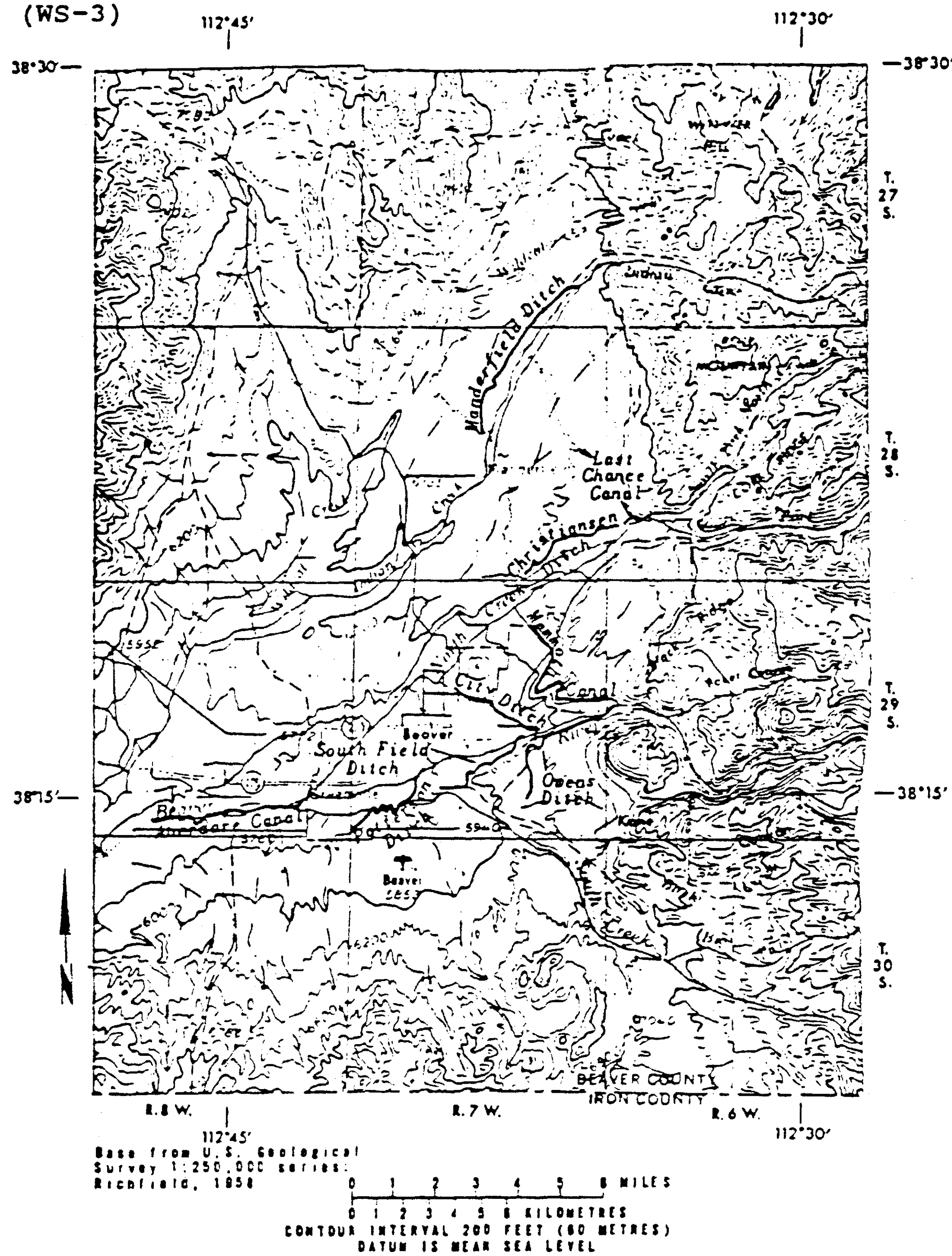
Job No. 89-16
(WS-3)



Sketch illustrating general location of recharge areas, types of occurrence, location of water table, direction of ground-water movement, and discharge points in Beaver Valley. Well at right withdraws only from partly consolidated material; well at left, like most large-yielding wells in the valley, withdraws water from both the unconsolidated and the partly consolidated material.

Attachment 3. Ground-water conditions in Beaver Valley, Utah (from Mower, 1978).

Job No. 89-16
(WS-3)



Attachment 4. Map showing location of some of the irrigation canals and ditches in the Beaver City area, Utah (from Cruff and Mower, 1976).

SOLID WASTE DISPOSAL

Project:			Requesting Agency:
Preliminary geologic investigation for Wasatch County Municipal Landfill site, North Western Heber Valley, Wasatch County, Utah			Wasatch County Health Department
By: William E. Mulvey	Date: 12-21-88	County: Wasatch	Job No.: (SW-1) 88-07
USGS Quadrangle: Heber City (1168)			

INTRODUCTION

Wasatch County is currently looking for a new sanitary landfill site following closure of their existing one on November 1, 1988. Phillip Wright of the Wasatch County Health Department (WCHD) requested that the Utah Geological and Mineral Survey (UGMS) investigate a parcel of land in northwestern Wasatch County as a potential site for the new landfill. The parcel is in the northwestern part of Wasatch Mountain State Park two miles south of the Jordanelle damsite at the northern end of the Heber Valley. It encompasses sections 12 and 13 in T. 3 S., R. 4 E., Salt Lake Baseline and Meridian (fig 1).

The purpose of this investigation was to assess the geologic and hydrologic suitability of the area for a landfill. Principle geologic concerns in landfill siting are to avoid contamination of surface and ground water and to minimize cost of design, construction, and operation caused by adverse soil conditions and geologic hazards. The scope of work included a review of pertinent geologic and hydrologic literature covering the proposed landfill site, and a brief reconnaissance survey of the property on November 16, 1988.

SETTING

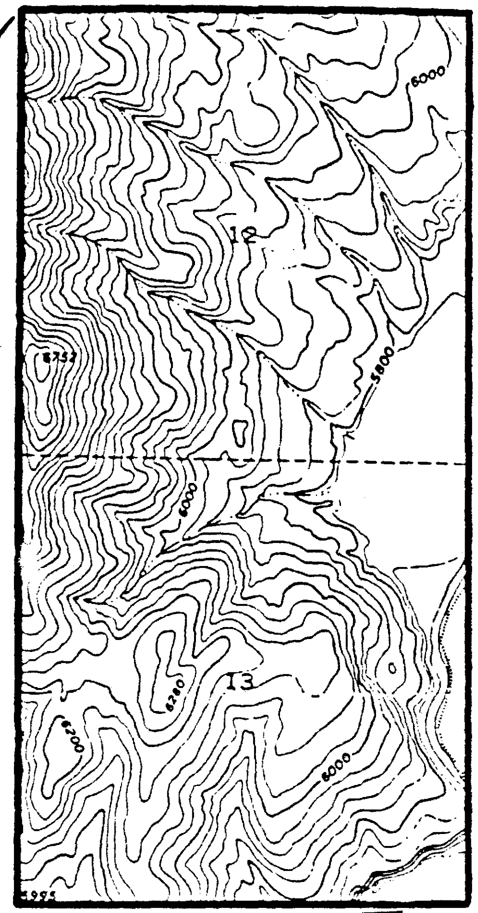
The eastern part of the parcel is in the modern flood plain of the Provo River. In section 12 elevations rise westward onto a bench and low ridge (fig. 1). The bench forms a broad surface that slopes gently to the east, rising to the ridge crest in the west. The majority of section 13 is a ridge that trends east-west, bordered on the east by the Provo River and the west by the Dutch Hollow drainage. The right-of-way for rerouted U.S. Highway 40 follows the eastern edge of section 12. Four ephemeral drainages cross the parcel, and the Provo River flows through the eastern part of section 13. Elevations range from 6700 feet at the ridge crest to 5800 feet on the Provo River flood plain. Vegetation is mostly sage brush, scrub oak, and maple with a few cottonwood trees along the river bottom.

GEOLOGY

The parcel can be broken into areas dominated by bedrock at the surface and areas covered by unconsolidated surficial deposits. It is underlain by four formations which are exposed in the western part of section 12 and throughout section 13. These are the Pennsylvanian Weber Quartzite and the Triassic Park City Formation, Woodside Shale, and Thaynes Formation (fig. 2). The Weber Quartzite is a gray to tan weathering quartzite and sandstone that forms the ridge crest in the western part of the two sections. The Park City Formation is a gray-weathering limestone with some tan and orange sandstone interbeds that form steep slopes just below the ridge crest. A small part of both sections 12 and 13 is underlain by the Woodside Shale, a dark purple/red shale, siltstone, and sandstone.

Job No. 88-07
(SW-1)

Source: U.S. Geological Survey 30'x60' Quadrangle of Salt Lake City, Utah.



Source: U.S. Geological Survey 7.5 minute Quadrangle, Heber City, Utah.

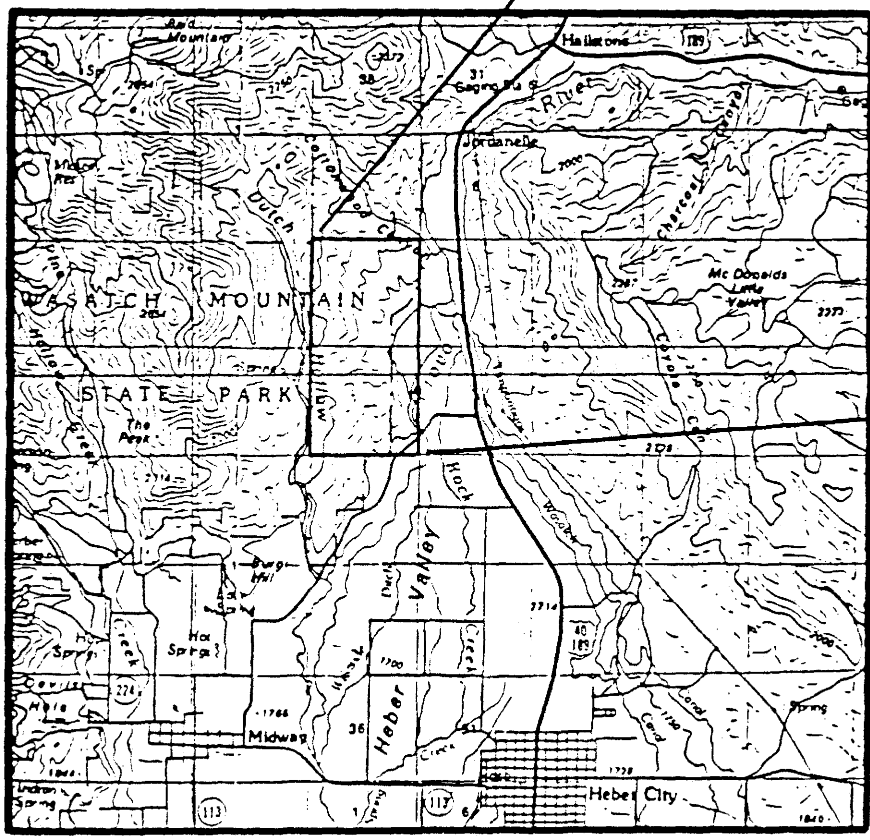
SCALE

CONTOUR INTERVAL

40 feet

miles

0 ½ 1



SCALE

CONTOUR INTERVAL

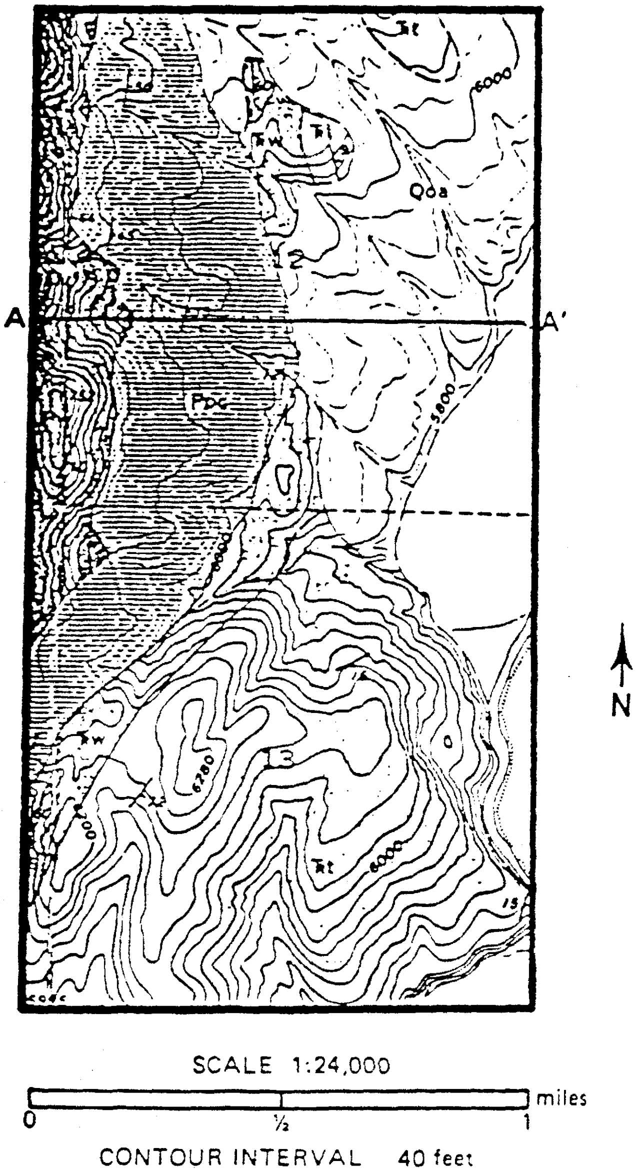
50 meters = 170 feet

miles

0 1 2 3 4 5

N

Figure 1. Location map.



Qal	Qoa

Surficial deposits

Qal, *stream gravel and valley fill*
Qoa, *older alluvium, generally forms terraces*

Ŧt

Thaynes Formation

Brown weathering fine-grained limy sandstone and siltstone, interbedded with olive-green to dull-red shale and gray fine-grained fossiliferous limestone

Ŧw

Woodside Shale

Dark- and purplish-red shale, siltstone, and very fine grained sandstone

Ppc

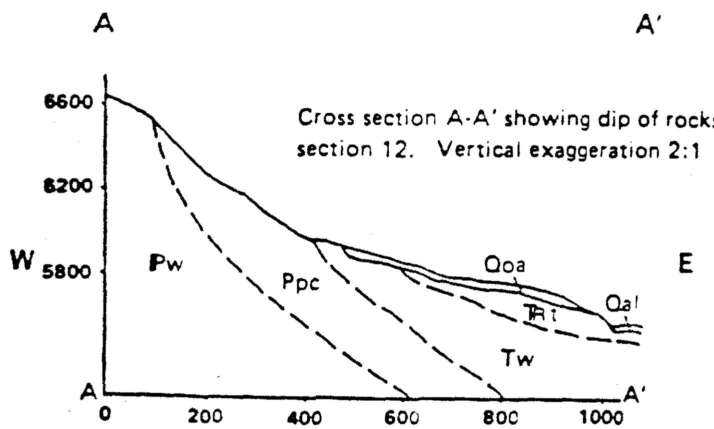
Park City Formation

Pale-gray-weathering cherty and fossiliferous limestone and pale-orange and tan sandstone. As mapped includes a medial phosphatic shale (Meade Peak Phosphatic Shale Member of Phosphoria Formation)

Pw

Weber Quartzite

Pale-gray- and tan-weathering quartzite and limy sandstone; some interbedded gray to white limestone and dolomite



Cross section A-A' showing dip of rocks in section 12. Vertical exaggeration 2:1

Contact

Dashed where approximately located; short dashed where inferred

Utah Geological and Mineral Survey

Applied Geology

Job No. 88-07
(SW-1)

Figure 2. Geologic map and cross section, sections 12&13, T.3S., R.4E., SLBM. (Source: Bromfield, C.S. and others, 1970)

Most of section 13 is underlain by the Thaynes Formation, a brown/red to olive green sandstone, siltstone, and shale (Bromfield, 1970). It forms the low ridge that dominates the section and most likely underlies the older alluvium covering the eastern part of section 12. Rocks in section 12 dip to the east, and those in section 13 dip to the southeast (fig. 2).

Unconsolidated deposits in both sections are composed of alluvium of varying ages. The youngest alluvium is on the modern flood plain of the Provo River and forms the flat landform on the eastern edge of the two sections. In section 12 the bench above the modern flood plain is covered by an older alluvium. A road cut just north of section 12 indicates that this older alluvium is up to 15 - 20 feet thick. The alluvium in the Provo River flood plain is probably much thicker.

Various geologic hazards are found in the northern Heber Valley that could potentially affect the proposed landfill, although none appears to pose a significant hazard. Investigations by the U.S. Bureau of Reclamation have not found evidence of surface faulting, indicating that the hazard from fault rupture is low and that large earthquakes (magnitude 6.5 and larger) are not likely (Sullivan, 1988).

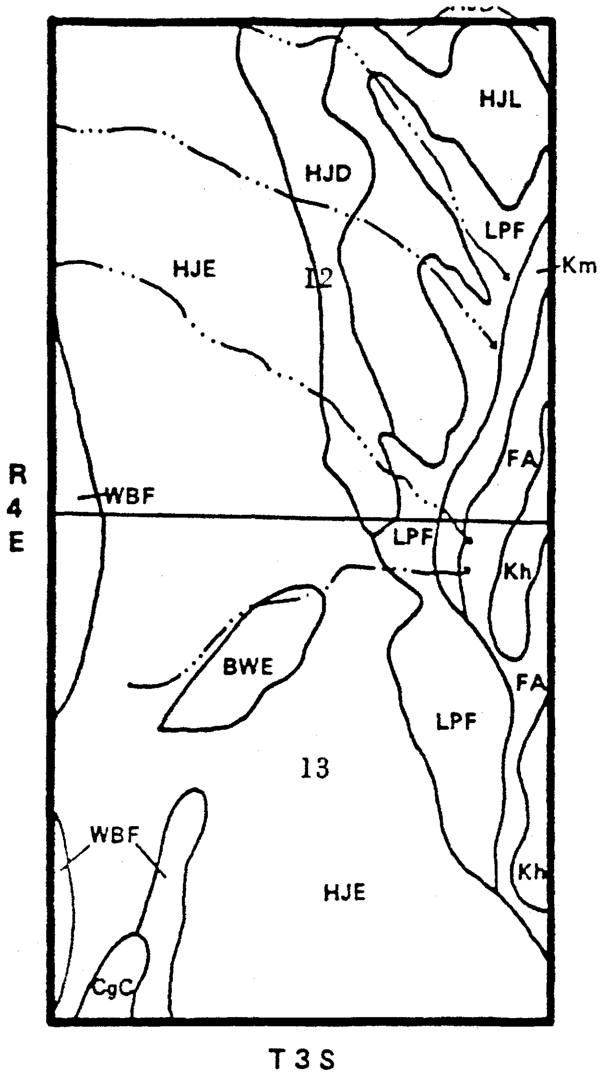
However, an earthquake of magnitude 6.5 or less could occur anywhere in the area (Arabasz and others, 1983), possibly causing strong ground shaking at the site. Such shaking poses a threat to structures and unsupported excavation walls, but geologic hazards associated with ground shaking such as rockfall, slope failure, and liquefaction appear to be low.

Geologic mapping by the U. S. Bureau of Reclamation identified several landslides immediately north of section 12 in volcanic bedrock. These failure-prone volcanic rocks do not extend into the parcel. Although no landslides have been mapped in sections 12 and 13, oversteepening of hillslopes by excavation for roads or landfill trenches could cause local slope instability, particularly in clayey unconsolidated deposits. Flooding could occur in the bottoms of ephemeral drainages and the Provo River flood plain. Flood potential of the Provo River will be reduced with the completion of the Jordanelle Dam. Flood control measures would be required in ephemeral drainages if landfill sites or access roads are planned in the drainages.

SOILS

The U.S. Soil Conservation Service (SCS) (Woodward and others, 1970) indicates a complex assemblage of soils in the parcel (fig. 3). These soils are classified by the SCS using the Unified Soil Classification System (USCS; appendix) as mostly silts (SM) and lean clays (CL), in the bench and ridge area to the west, with gravels (GP) in the modern flood plain of the Provo River. Our observations in the bench area of section 12 indicate that many of the soils are clayey gravels (GC) or silty gravels (GM), and in general are coarser-grained than indicated by the SCS.

The SCS indicates that the majority of soils have severe limitations for trench-type landfills due to high clay content, numerous cobbles and boulders, and/or shallow depths to bedrock. Soils on the bench above the modern flood plain of the Provo River in section 12 are 15 to 20 feet thick, as seen in a road cut to the north. Soils on mountainsides are thin, particularly in the steep hilly terrain in much of section 13.



SCALE
1:24,000

CONTOUR INTERVAL
40 feet

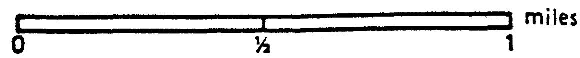


Figure 3. Soil characteristics, sections 12&13, T.3S., R.4E (modified from Woodward and others, 1976)

Utah Geological and Mineral Survey
Applied Geology

Job No. 88-07
(SW-1)

Soil Series Designation	USCS Symbol	Limitations for trench type landfills
BWE	CL to ML	Severe - steep slopes, coarse material.
CgC	CL to ML	Variable - steep slopes, if greater than 25% shallow bedrock likely.
FA	no interp.	Severe - high water table, coarse material.
HJC HJD HJE	CL to ML	Severe - clayey and cobbly soil, shallow bedrock may be a problem.
Kh Km	GC to GM	Severe - high water table, coarse material.
LFP	CL	Severe - steep slopes, coarse material, shallow soils.
WBF	SC to SM	Variable - thin soils over shallow bedrock.

GROUND WATER

Ground water in the region is found in both rock and unconsolidated materials, with major producing wells located in unconsolidated alluvial deposits of the major stream valleys such as the Heber Valley (Baker, 1970). Bedrock in the region is highly fractured, and these fractures act as avenues for ground-water movement in the Heber Valley. They occur in all formations, and therefore any may be, at least locally, water bearing (Baker, 1970). Bedrock aquifers generally recharge the unconsolidated alluvial aquifers.

In areas where bedrock is shallow, there is a high potential for leachate infiltration through fractures into the ground water, with little treatment by soils. Depths to ground water in the parcel are unknown, with the exception of the modern Provo River flood plain, where depths range from 3 to 20 feet (Baker, 1970). Ephemeral drainages in section 12 were vegetated, but most likely contain water only during snowmelt and storm runoff. Running water and water tolerant plants were observed in the ephemeral drainage in the northern part of section 13 during the field survey, indicating a persistent shallow water table. The origin of the water is unknown, but it is probably from a spring in bedrock. Although not observed, perched ground water could be present in bedrock and in the older alluvium forming the bench in section 12.

SUMMARY AND CONCLUSIONS

This reconnaissance investigation indicates that a suitable landfill site may exist in sections 12 and 13, but that conditions are not optimal and engineering measures will be required to develop an environmentally safe site. Adverse siting conditions found in both sections are thin soils over shallow bedrock, possible shallow groundwater and easily contaminated bedrock aquifers, and probable poor soils from the stand point of excavatability, permeability, and use as cover material. The western part of section 12 and all of section 13 are underlain by shallow bedrock with steep slopes and thin soils. These present excavation problems and the need to import cover material, as well as a high potential for ground-water contamination. Because of this, these areas are generally not well suited for a landfill.

The eastern portion of section 12 is covered by a mantle of alluvium of varying thickness and the area that is most suitable for a landfill in the two sections is shown in figure 4. Soils in this section are up to 20 feet thick, and are easily excavated but contain high percentages of clay, cobbles, and boulders that can cause compaction and workability problems. Coarse clasts may increase excavation difficulty, and should be removed from excavated material before using it for cover. There is also potential for contamination of local ground water from leachate infiltration through gravelly soils into fractures in bedrock. If trenches are excavated in the alluvium down to bedrock, or if the alluvium is too coarse grained to filter leachate and impede its flow into the bedrock, ground water could be contaminated. On the modern flood plain of the Provo River, alluvium is thick but its coarseness, close proximity to the Provo River, and shallow depth to ground water preclude its use for a landfill. Any landfill placed on the flood plain would need to be lined, perhaps pumped to lower the water table, and cover would need to be imported.

Because potential problems exist at all sites, further study is required to identify a suitable site. The area with the most potential is in the eastern part of section 12 (fig. 4), and it would be prudent to begin further study in this area.

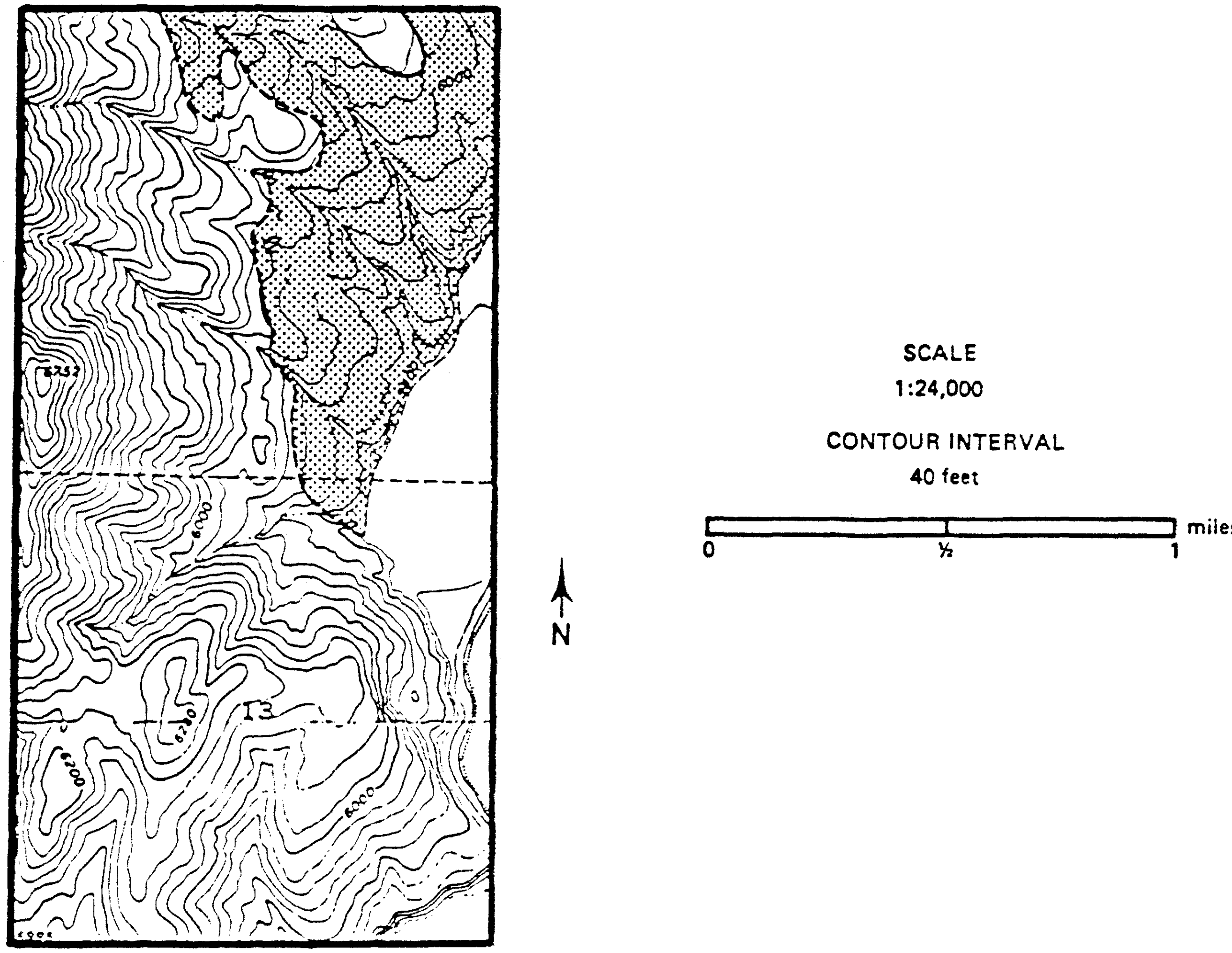


Figure 4. Potentially suitable area (::::) for a landfill in sections 12&13, conditions are variable and stratigraphic investigations are required to demonstrate site suitability and to provide information for site design and construction.

Such studies should determine soil depth and type, ground-water quality and depth, and geologic hazards. Based on these data, conclusions should be made with regard to soil excavatability, permeability, workability, and suitability for use as cover; potential for ground water contamination; and measures needed to reduce impacts of hazards. The UGMS is available to review reports from such studies for Wasatch County upon request.

REFERENCES

Arabasz, W.J., Jahns, R.H., and Peck, R. B., 1983, Review and analysis of geologic, seismotectonic, and design data for the proposed Jordanelle Dam, Bonneville Unit, Central Utah Project, Utah: Unpublished consultant's report for U.S. Bureau of Reclamation, 87 p.

Baker, C.H., Jr., 1970, Water resources of the Heber-Kamas-Park City area, north-central Utah: Utah Department of Natural Resources Technical Publication, No. 27, 79 p.

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

Christenson, G.E., 1983, Investigation of geology and soil conditions for wastewater disposal, Strawberry Lake Estates Area C, Wasatch County, in Lund, W.R., ed., Technical letters and memoranda for 1983, Site Investigation Section: Utah Geological and Mineral Survey Report of Investigation 190, p. 181-186.

Holmes, W.F., Thompson, K.R., and Enright, Michael, 1986, Water resources of the Park City area, Utah with emphasis on ground water: Utah Department of Natural Resources Technical Publication No. 85, 81 p.

Martin, R.A., Sullivan, J.T., and Foley, L.L., 1988, Seismotectonic study for Jordanelle Dam, Bonneville Unit, Central Utah Project, Utah: U.S. Bureau of Reclamation Seismotectonic Report 88-6, 76 p.

Sullivan, J.T., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1988, Final draft - regional seismotectonic study for the back valleys of the Wasatch Mountains in northeastern Utah: U.S. Bureau of Reclamation unpublished report, 317 p.

Unitex Corporation, 1987, A hydrogeologic evaluation of the proposed Jordanelle Reservoir, Utah, for U.S. Department of the Interior Bureau of Reclamation: Unpublished consultant's report, 57 p.

Woodward, Lowell, Jensen, E.H., and Harvey, J.L., 1976, Soil survey of the Heber Valley area, Utah - parts of Wasatch and Utah Counties: U.S. Soil Conservation Service, 124 p.

Appendix

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

* Based on the material passing the 3-in. (75-mm) sieve.

Unified Soils Classification System (USCS)

Project:			Requesting Agency:
Preliminary geologic investigation for proposed landfill sites, Wasatch County, Utah			Wasatch County Planning Department
By: William E. Mulvey	Date: 5-5-89	County: Wasatch	Job No.: (SW-2) 89-06
USGS Quadrangle: Charleston (1127) Heber City (1168)			

INTRODUCTION

Wasatch County is currently looking for a new sanitary landfill site following the closure of their existing one on November 1, 1988. The Wasatch County Commissioners requested that the Utah Geological and Mineral Survey (UGMS) investigate two sites in the Heber Valley (fig. 1). The north site is northeast of Midway in Wasatch Mountain State Park at the mouth of Dutch Hollow (NE 1/4 section 23 and NW 1/4 section 24 in T. 3 S., R. 4 E., Salt Lake Baseline and Meridian) (fig. 1). The second (south) site is south of Daniels and east of Charleston along Daniels Creek in the southern Heber Valley (SE 1/4 section 13 NE 1/4 section 23 in T. 4 S., R. 4 E., Salt Lake Baseline and Meridian) (fig. 1).

The purpose of this investigation was to assess the geologic and hydrologic suitability of the areas for a landfill. Principle geologic concerns in landfill siting are to avoid contamination of surface and ground water and to minimize the cost of design, construction, and operation caused by adverse soil conditions and geologic hazards. The scope of work included a review of pertinent geologic and hydrologic literature covering the proposed landfill sites, and field investigations that included excavating and logging soil test pits at each site on April 18, 1989 (fig. 1, appendix 1). Present at the field investigation were Robert Mathis, Moroni Besendorfer, and Susan Olig.

SETTING

The north site covers approximately 120 acres on Wasatch Mountain State Park property and is bisected by the north-south trending Dutch Hollow (fig. 1). The majority of the property is hilly with a gently sloping valley in the northwest part of section 24. A perennial stream draining Dutch Hollow, and an ephemeral stream north of Donkey Ridge flow through the two sections. Access to the property is a dirt road which intersects the paved River Road south of the park boundary.

The south site is along Daniels Creek in generally flat terrain (fig. 1). To the south of Daniels Creek terrain steepens to mountain slopes. Daniels Creek crosses the site from east to west and is joined to the west by an ephemeral stream that runs parallel to U.S. Highway 189. Access to the property is a dirt road off the highway.

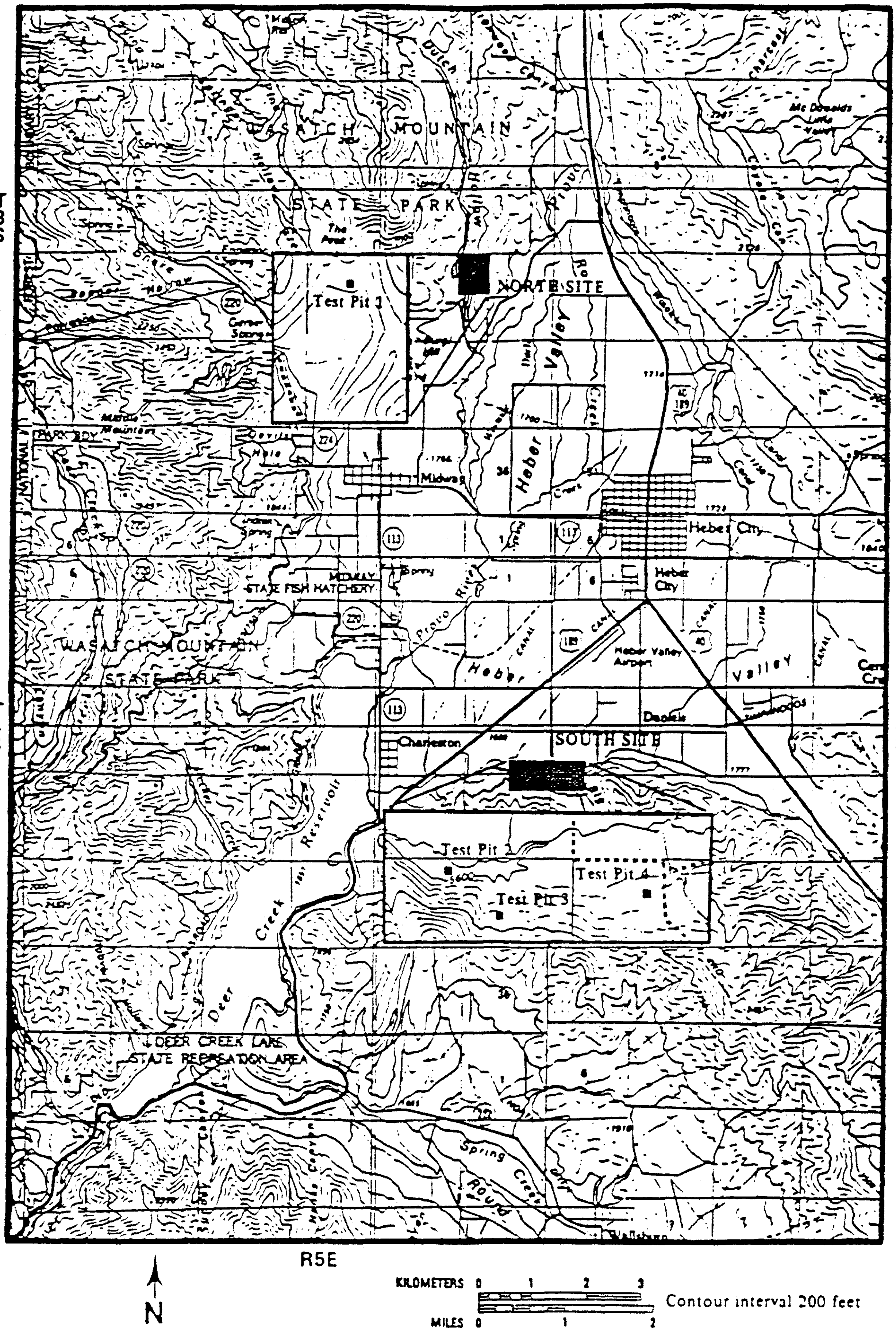


Figure 1. Location map of study sites.

Utah Geological and Mineral Survey

Applied Geology

GEOLOGY

Both the north and south sites are along mountain fronts with bedrock exposed in hillside areas and unconsolidated surficial deposits on flat valley floors. The north site is underlain by the Triassic Thaynes Formation, a brown/red to olive green sandstone, siltstone, and shale (Bromfield, 1970) (fig. 2). It forms the crest of Donkey Ridge and the ridge east of the creek in Dutch Hollow. Unconsolidated late Pleistocene alluvial deposits cover the floor and side slopes along Dutch Hollow. These deposits overlie the Thaynes Formation and are of an unknown thickness.

The Wallsburg Ridge Member of the Pennsylvanian Oquirrh Formation is the only bedrock unit exposed at the south site (fig. 2). It is a light-gray to red quartzite and forms steep slopes to the south. The majority of the site is underlain by Pleistocene alluvium, into which Daniels Creek has incised its channel.

Various geologic hazards are found in and around the Heber Valley that could potentially effect the proposed landfill, although none appear to pose a major hazard. Investigations by the U.S. Bureau of Reclamation have not found any evidence of surface faulting at the north site, and geologic mapping by Baker (1970) shows similar conclusions for the south site. This was confirmed during our site investigation, and indicates that the hazard from surface fault rupture at the sites is low. Large earthquakes (magnitude 6.5 and larger) may occur in the area however, as evidence for Quaternary-age surface fault rupture is present in Round Valley, 6 miles southwest of the south site (Sullivan, 1988). A moderate earthquake without associated surface rupture could occur anywhere in the area (Arabasz and others, 1983), possibly causing strong ground motion at either site. Such ground motion can damage structures and cause unsupported excavation walls to collapse. Figure 3 shows peak ground accelerations in soil that have a 10% probability of being exceeded in 10, 50, and 250 years in the area and indicate that both sites are in a "seismic impact zone" as defined in the proposed EPA regulations. Landfills in such zones must be engineered to withstand the expected maximum horizontal acceleration in bedrock, (appendix 2) which at these sites is approximately 0.048 g. Geologic hazards associated with ground shaking such as rockfall, slope failure, and liquefaction appear to be low.

No landslides have been mapped in either the north or south sites, but oversteepening of hillslopes by excavation for roads or landfill trenches could cause local slope instability, particularly in unconsolidated deposits. Flooding could occur in the bottoms of ephemeral streams and drainages, and along Daniels Creek from cloudburst storms or snowmelt runoff. Flood control measures will be required in these areas if landfill sites or access roads are planned in or near the drainages.

SOILS

The U.S. Soil Conservation Service (SCS) maps a complex assemblage of soils in both sites (Woodward and others, 1970) (fig. 4). At the north site the SCS classifies the soil as silts (ML) and lean clays (CL) to a depth of five feet (fig. 4). We inspected a test pit at the site and found lean clays to a depth of 2.5 feet, and fat clays

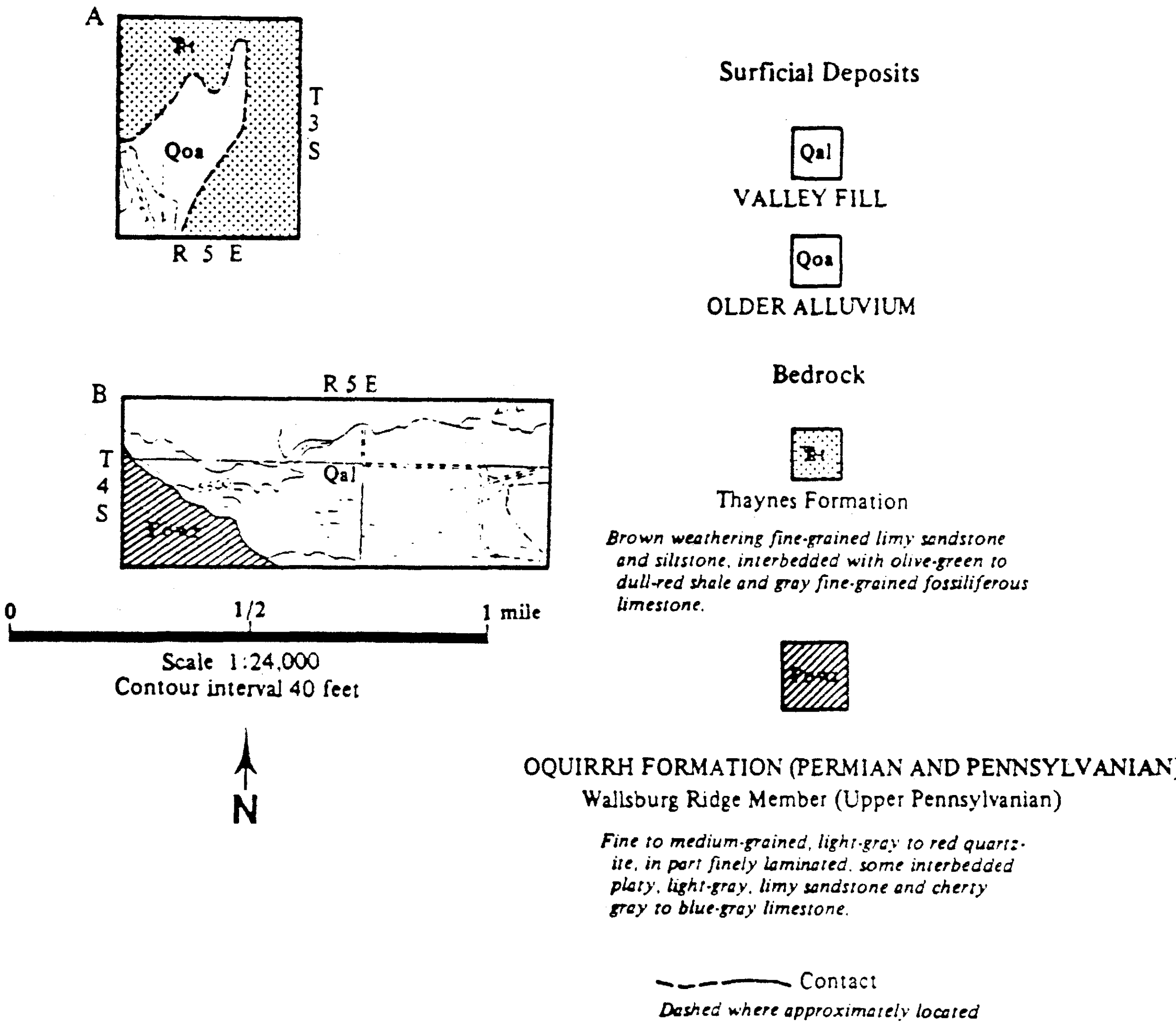


Figure 2. A) Geologic map of north site (from Bromfield, 1970); B) Geologic map of south site (modified from Baker, 1976)

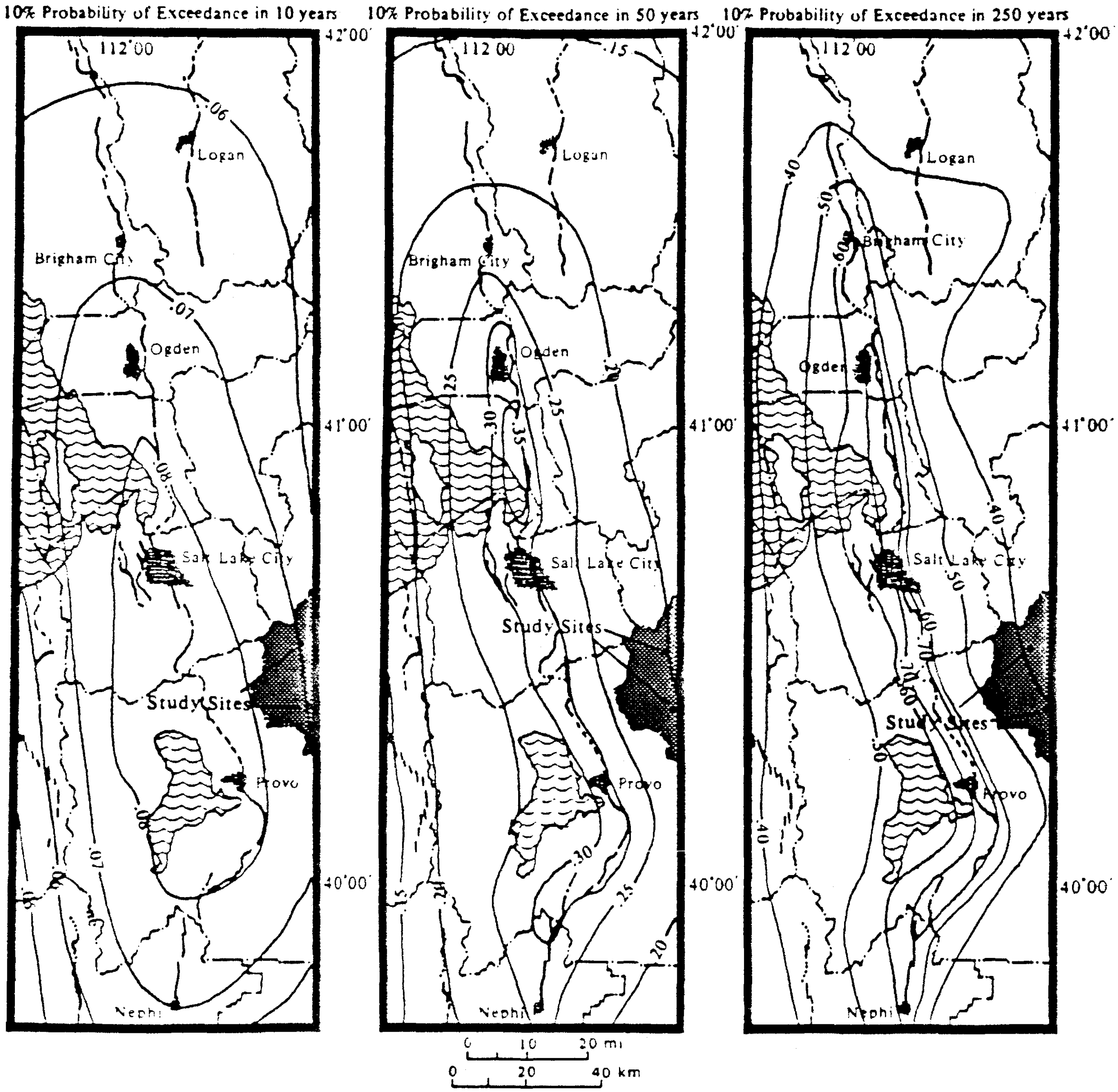
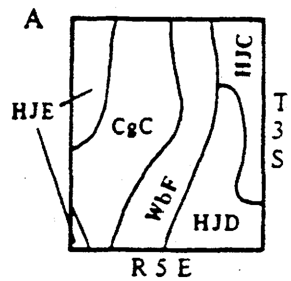
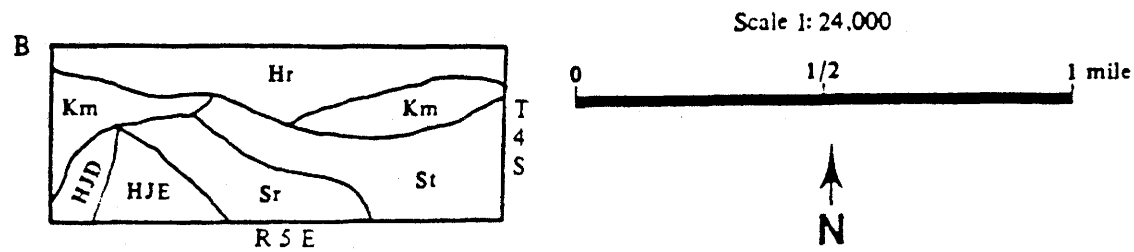


Figure 3. Contours of peak ground acceleration on soil sites with 10 percent probability of being exceeded in 10 years, 50 years and 250 years. Peak accelerations on rock sites are expected to be approximately 10 percent higher than the values shown on the map for 10 percent probability of exceedance in 10 years and approximately 20 percent higher than the values shown on the maps for 50 and 250 years (modified from Youngs and others, 1987).





Soil Series Designation	USCS Symbol	Limitations for trench-type landfills
CgC	CL to ML	Variable - steep slopes, if greater than 25%, shallow bedrock likely.
HJC HJD HJE	CL to ML	Severe - clayey and cobbly soil, shallow bedrock may be a problem.
WBF	SC to SM	Variable - thin soils over shallow bedrock.
Hk Hr	GM - GC	Severe - rapid permeability, coarse material.
Km	GC to GM	Severe - high water table, coarse material.
St Sr	SC	Severe - rapid permeability, coarse material.

Figure 4. Soil characteristics in A) north site and B) south site (modified from Woodward and other, 1976).

to the pit floor at six feet (appendix 1).

In contrast to the north site, soils in the south site along Daniels Creek are classified by the SCS as clayey and silty gravels (GC-GM) (fig. 4). Our inspection of a test pit at the site confirmed this. On slopes immediately to the south, two additional pits were excavated to examine soils for use as liner material for the landfill. Both pits exposed soils that were fat clays for the entire depth of the pit (appendix 1).

For both north and south sites soils the data indicate that there are severe limitations for trench type landfills (fig. 4). Both sites require an impermeable liner to protect surface and ground water. Therefore, the type of soil present at each site does not influence siting criteria. Coarse soils at the south site make it especially susceptible to ground water contamination by landfill leachate.

GROUND WATER

Ground water in the region is found in both rock and unconsolidated materials, with major producing wells located in unconsolidated alluvial deposits of the major stream valleys such as the Heber Valley (Baker, 1970). Bedrock in the region is highly fractured, and these fractures act as conduits for ground-water movement into the Heber Valley. They occur in all formations, and therefore any formation may be, at least locally, water bearing (Baker, 1970). Bedrock aquifers generally recharge the unconsolidated alluvial aquifers.

In areas where bedrock is shallow, there is a high potential for leachate infiltration through fractures into the ground water with little treatment by soils. However, in areas covered by alluvium, ground water may be shallow, less than thirty feet (Hecker and others, 1987), and leachate may also reach the water table with little treatment by soils. Depths to ground water in the north study site are unknown except at the mouth of Dutch Hollow, where depths to ground water are 5 to 10 feet (Baker, 1970). Unconsolidated deposits in the south site have ground water at depths of 10 to 40 feet, depending on time of year (Baker, 1970). Ground water was not encountered in any of the test pits dug for this investigation. Daniels Creek crosses the property from east to west, but is diverted for irrigation during the spring and summer months. During these times the channel of the creek is dry.

SUMMARY AND CONCLUSIONS

This reconnaissance investigation indicates that suitable areas for a landfill may exist at both the north and south sites. No major adverse conditions were observed at either site, but engineering measures will be required to develop an environmently safe landfill at both locations. At the north site, soils are clayey and provide suitable material if compacted properly, to provide a low permeability liner for a landfill. Because they are clayey, these soils will pose workability problems during wet periods and are also not suitable for use as cover for refuse material each day. Blending with imported granular material may be required to provide suitable cover. Because the depth to ground water and bedrock is unknown but probably shallow at this site, it will be important to define these depths and to determine the potential for contamination of ground water by leachate from the landfill if this site is chosen.

The south site is in alluvium that covers the Heber Valley to depths of 800 feet in places (Baker,1970). This material is a mixture of cobbles and gravel, and is not well suited for a landfill due to its high permeability, poor compactability, and workability problems. Its coarseness and lack of filtering capacity increases the potential for contamination of the local ground water with leachate from a landfill. Test pits 2 and 3 immediately south of this site contain fat clays which can be used as liner material, and to blend with on-site granular soils to provide suitable cover. The close proximity to Daniels Creek is a hazard, and leachate and refuse from the landfill has the potential to contaminate the creek and ultimately Deer Creek Reservoir downstream. This hazard will need to be considered in the design of the site to prevent flooding and contamination of surface waters.

Newly proposed EPA regulations regarding landfill siting, which may potentially affect the sites, are included in appendix 2. Specific regulations that effect the proposed sites are those concerning ground shaking (seismic impact zone) and flood plains. The ground shaking restriction applies to both the north and south sites which are in a "seismic impact zone," and proposes that the landfill be designed to resist the maximum horizontal acceleration at the site. Flood-plain restrictions apply chiefly to the south site due its close proximity of Daniels Creek. Restrictions state that the landfill shall not restrict the flow or result in a washout of solid waste from the landfill.

A ground water monitoring well system approved by the state must be installed as close as possible from the landfill boundary based on proposed EPA regulations included in the appendix. This system is designed to sample the uppermost aquifer in the region and insure that it is not contaminated by landfill leachate. Both north and south sites have ground water at shallow depths, and would require monitoring wells to detect contamination of these ground water sources.

REFERENCES

Arabasz, W.J., Jahns, R.H., and Peck, R. B., 1983, Review and analysis of geologic, seismotectonic, and design data for the proposed Jordanelle Dam, Bonneville Unit, Central Utah Project, Utah: Unpublished consultant's report for U.S. Bureau of Reclamation, 87 p.

Baker, C.H., Jr., 1970, Water resources of the Heber-Kamas-Park City area, north-central Utah: Utah Department of Natural Resources Technical Publication No. 27, 79 p.

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

Christenson, G.E., 1983, Investigation of geology and soil conditions for wastewater disposal, Strawberry Lake Estates Area C, Wasatch County, in Lund, W.R., ed., Technical letters and memoranda for 1983, Site Investigation Section: Utah Geological and Mineral Survey Report of Investigation 190, p. 181-186.

Hecker, Suzanne, Harty, K.M., and Christenson, G.E., 1988, Shallow ground water and related hazards in Utah: Utah Geological and Mineral Survey Map 110, 17 p.

Holmes, W.F., Thompson, K.R., and Enright, Michael, 1986, Water resources of the Park City area, Utah with emphasis on ground water: Utah Department of Natural Resources Technical Publication No. 85, 81 p.

Lund, W.R., and Black, B.D., 1987, Field reconnaissance of four proposed sanitary landfill sites in Wasatch County, Utah: Utah Geological and Mineral Survey Report of Investigation 87-017, 14 p.

Martin, R.A., Sullivan, J.T., and Foley, L.L., 1988, Seismotectonic study for Jordanelle Dam, Bonneville Unit, Central Utah Project, Utah: U.S. Bureau of Reclamation Seismotectonic Report 88-6, 76 p.

Mulvey, W.E., 1988, Preliminary geologic investigation for Wasatch County Municipal Landfill site, northwestern Heber Valley, Wasatch County, Utah: Utah Geological and Mineral Survey Technical Report 88-07, 11 p.

Sullivan, J.T., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1988, Final draft - regional seismotectonic study for the back valleys of the Wasatch Mountains in northeastern Utah: U.S. Bureau of Reclamation unpublished report, 317 p.

Unitex Corporation, 1987, A hydrogeologic evaluation of the proposed Jordanelle Reservoir, Utah, for U.S. Department of the Interior Bureau of Reclamation: Unpublished consultant's report, 57 p.

Woodward, Lowell, Jensen, E.H., and Harvey, J.L., 1976, Soil survey of the Heber Valley area, Utah - parts of Wasatch and Utah Counties: U.S. Soil Conservation Service, 124 p.

Youngs, R.R., Swan, F.H., Power, M.S., Schwartz, D.P., Green, R.K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah: U.S. Geological Survey Open-File Report 87-585, p. M1-110.

APPENDIX 1
Test Pit Logs

North Site

Test Pit 1 Wasatch Mountain State Park property

0.0' - 2.3' Lean clay (CL); dark brown, medium density, medium plasticity, moist; 100 percent fines, blocky structure, noncemented, no reaction to HCL, roots throughout the deposit, slight organic odor, occasional highly weathered cobbles; residual soil.

2.3' - 6.8' Fat clay (CH); orange-brown, medium density, high plasticity, moist; 95 percent fines, blocky structure, noncemented, no reaction to HCL, roots throughout the deposit, isolated weathered cobbles.

South Site

Test Pit 2: valley fill (alluvium)

0.0' - 1.3' Lean clay with sand (CL); dark brown, medium density, medium plasticity, moist; 85 percent fines, blocky structure, noncemented, no reaction with HCL, slight organic odor, roots throughout the deposit; residual soil.

1.3' - 1.8' Lean clay with sand (CL); orange-brown, medium density, medium plasticity, moist; 80 percent fines, blocky structure, noncemented, no reaction to HCL, roots throughout the deposit; residual soil.

1.8' - 5.0' Well-graded gravel with sand and clay (GW-GC); orange-brown, low density, nonplastic, moist; 15 percent fines, poorly bedded, noncemented, no action to HCL, roots throughout the deposit; alluvium.

Test Pit 3 State Property, hillslopes south of test pit 1

0.0' - 1.6' Fat clay (CH); dark brown, high density, high plasticity, moist; 95 percent fines, blocky structure, noncemented, no reaction to HCL, roots throughout the deposit, slight organic odor; residual soil, 20 to 25 % slope.

1.6' - 6.0' Fat clay (CH); orange-brown, high density, high plasticity, moist; 95 percent fines, blocky structure, noncemented, no reaction to HCL, roots throughout the deposit, clay skins present, occasional quartz cobbles.

Test Pit 4 State Property, fan at mouth of Big Hollow

0.0' - 2.0' Fat clay (CH); dark brown, high density, high plasticity, moist; 95 percent fines, slightly blocky structure, noncemented, no reaction to HCL, roots throughout the deposit, slight organic odor, occasional quartz cobbles; residual soil.

2.0' - 6.5' Fat clay (CH); orange-brown, high density, high plasticity, moist; 95 percent fines, blocky structure, noncemented, no reaction to HCL, roots throughout the deposit, clay skins present, occasional quartz cobbles.

APPENDIX 2
Excerpts from proposed EPA
regulations for location and design of landfills

waste, nonhazardous sludge, and industrial solid waste. Such a landfill may be publicly or privately owned.

"New unit" means any solid waste disposal unit that has not previously received solid waste prior to the effective date of this part. A new unit also means lateral expansions as defined in this section.

"Open burning" means the combustion of solid waste without:

(1) Control of combustion air to maintain adequate temperature for efficient combustion,

(2) Containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and

(3) Control of the emission of the combustion products.

"Operator" means the person responsible for the overall operation of a facility or part of a facility.

"Owner" means the person who owns a facility or part of a facility.

"Run-off" means any rainwater, leachate, or other liquid that drains over land from any part of a facility.

"Run-on" means any rainwater, leachate, or other liquid that drains over land onto any part of a facility.

"Saturated zone" means that part of the earth's crust in which all voids are filled with water.

"Sludge" means any solid, semi-solid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility exclusive of the treated effluent from a wastewater treatment plant.

"Solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges that are point sources subject to permits under 33 U.S.C. 1342, or source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

"Solid waste disposal unit" means a discrete area of land used for the disposal of solid wastes.

"State" means any of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

"Waste management unit boundary" means a vertical surface located at the hydraulically downgradient limit of the unit. This vertical surface extends down into the uppermost aquifer.

§ 258.3 Consideration of other Federal laws.

The owner or operator of a municipal solid waste landfill unit must comply with any other applicable Federal rules, laws, regulations, or other requirements.

§§ 258.4-258.9 [Reserved]

Subpart B—Location Restrictions

§ 258.10 Airport safety.

A municipal solid waste landfill unit that may attract birds and is located within 10,000 feet (3,048 meters) of any airport runway used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway used by only piston-type aircraft shall not pose a bird hazard to aircraft.

§ 258.11 Floodplains.

(a) A municipal solid waste landfill unit located in the 100-year floodplain shall not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste so as to pose a hazard to human health and the environment.

(b) For purposes of this section:

(1) "Floodplain" means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, that are inundated by the 100-year flood.

(2) "100-year flood" means a flood that has a 1-percent or greater chance of recurring in any given year or a flood of a magnitude equalled or exceeded once in 100 years on the average over a significantly long period.

(3) "Washout" means the carrying away of solid waste by waters of the base flood.

§ 258.12 Wetlands.

(a) New municipal solid waste landfill units shall not be located in wetlands, unless the owner or operator can make the following demonstrations to the State:

(1) There is no practicable alternative that would have less adverse impact on the wetlands and would have no other significant adverse environmental consequences;

(2) The landfill will not

(i) Cause or contribute to violations of any applicable State water quality standard,

(ii) Violate any applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act,

(iii) Jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of a critical habitat, protected under the Endangered Species Act of 1973, and

(iv) Violate any requirement under the Marine Protection, Research, and Sanctuaries Act of 1972 for the protection of a marine sanctuary;

(3) The landfill will not cause or contribute to significant degradation of wetlands;

(4) Appropriate and practicable steps have been taken to minimize potential adverse impacts of the landfill on the wetlands; and

(5) Sufficient information is available to make a reasonable determination with respect to these demonstrations.

(b) As used in this section, "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include, but are not limited to, swamps, marshes, bogs, and similar areas.

§ 258.13 Fault areas.

(a) New units of a municipal solid waste landfill shall not be located within 200 feet (60 meters) of a fault that has had displacement in Holocene time.

(b) For the purposes of this section:

(1) "Fault" means a fracture along which strata on one side have been displaced with respect to that on the other side.

(2) "Displacement" means the relative movement of any two sides of a fault measured in any direction.

(3) "Holocene" means the most recent epoch of the Quarternary period, extending from the end of the Pleistocene to the present.

§ 258.14 Seismic impact zones.

(a) At a new municipal solid waste landfill unit located in a "seismic impact zone," all containment structures, including liners, leachate collection systems, and surface water control systems, must be designed to resist the maximum horizontal acceleration in lithified material for the site.

(b) As used in paragraph (a) of this section, "seismic impact zone" means an area with a 10 percent or greater probability that the maximum horizontal acceleration in hard rock, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in 250 years.

(c) As used in paragraph (a) of this section, the "maximum horizontal acceleration in lithified material" means the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment.

§ 258.15 Unstable areas.

(a) The owner or operator of a municipal solid waste landfill unit located in an unstable area must demonstrate to the State that engineering measures have been incorporated into the unit's design to ensure the stability of the structural components of the unit. The owner or operator must consider the following factors, at a minimum, when determining whether an area is unstable:

(1) On-site or local soil conditions that may result in significant differential settling;

(2) On-site or local geologic or geomorphologic features; and

(3) On-site or local human-made features or events (both surface and subsurface).

(b) As used in this section, "structural components" means liners, leachate collection systems, final covers, run-on/run-off systems, and any other component necessary for protection of human health and the environment.

(c) Existing units of a municipal solid waste landfill located in unstable areas that cannot make the demonstration specified in paragraph (a) of this section must close within 5 years of the effective date of this part in accordance with § 258.30 of this part and conduct post-closure activities in accordance with § 258.31 of this part.

(d) The deadline for a closure required by paragraph (c) of this section may be extended by the State after considering, at a minimum, the following factors:

(1) Availability of alternative disposal capacity; and

(2) Potential risk to human health and the environment.

§§ 258.16–258.19 [Reserved].

Subpart C—Operating Criteria

§ 258.20 Procedures for excluding the receipt of hazardous waste.

(a) The owner or operator of a municipal solid waste landfill unit must implement a program at the facility for detecting and preventing the disposal of regulated hazardous wastes as defined in Part 261 of this title and polychlorinated biphenyls (PCB) wastes as defined in Part 761 of this title. This program must include at a minimum:

(1) Random inspections of incoming loads;

(2) Inspection of suspicious loads;

(3) Records of any inspections;

(4) Training of facility personnel to recognize regulated hazardous waste; and

(5) Procedures for notifying the proper authorities if a regulated hazardous waste is discovered at the facility.

(b) As used in this section, "regulated hazardous waste" means a solid waste that is a hazardous waste, as defined in 40 CFR 261.3, that is not excluded from regulation as a hazardous waste under 40 CFR 261.4(b) or was not generated by a conditionally exempt small quantity generator as defined in § 261.5 of this title.

§ 258.21 Cover material requirements.

(a) The owner or operator of a municipal solid waste landfill unit must cover disposed solid waste with suitable materials at the end of each operating day, or at more frequent intervals if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging.

(b) The State may grant a temporary waiver from the requirement of paragraph (a) of this section if the State determines that there are extreme seasonal climatic conditions that make meeting such requirements impractical.

§ 258.22 Disease vector control.

(a) The owner or operator of a municipal solid waste landfill unit must prevent or control on-site populations of disease vectors using techniques appropriate for the protection of human health and the environment.

(b) For purposes of this section, "disease vectors" means any rodents, flies, mosquitoes, or other animals, including insects, capable of transmitting disease to humans.

§ 258.23 Explosive gases control.

(a) The owner or operator of a municipal solid waste landfill unit shall ensure that:

(1) The concentration of methane gas generated by the facility does not exceed 25 percent of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components); and

(2) The concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary.

(b) The owner or operator of a municipal solid waste landfill unit must implement a routine methane monitoring program to ensure that the standards of paragraph (a) of this section are met.

(1) The type and frequency of monitoring must be determined based on the following factors:

(i) Soil conditions;

(ii) The hydrogeologic conditions surrounding the disposal site;

(iii) The hydraulic conditions surrounding the disposal site; and

(iv) The location of facility structures and property boundaries.

(2) The minimum frequency of monitoring shall be quarterly.

(c) If methane gas levels exceeding the limits specified in paragraph (a) of this section are detected, the owner or operator must:

(1) Take all necessary steps to ensure immediate protection of human health;

(2) Immediately notify the State of the methane gas levels detected and the immediate steps taken to protect human health; and

(3) Within 14 days, submit to the State for approval a remediation plan for the methane gas releases. The plan shall describe the nature and extent of the problem and the proposed remedy. The plan shall be implemented upon approval by the State.

(d) As used in this section, "lower explosive limit" means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25°C and atmospheric pressure.

§ 258.24 Air criteria.

(a) A municipal solid waste landfill shall not violate any applicable requirements developed under a State Implementation Plan (SIP) approved or promulgated by the Administrator pursuant to section 110 of the Clean Air Act, as amended.

(b) Open burning of solid waste, except for the infrequent burning of agricultural wastes, silvicultural wastes, land-clearing debris, diseased trees, debris from emergency clean-up operations, or ordnance, is prohibited at municipal solid waste landfill units.

§ 258.25 Access requirement.

The owner or operator of a municipal solid waste landfill unit must control public access and prevent unauthorized vehicular traffic and illegal dumping of wastes to protect human health and the environment using artificial barriers, natural barriers, or both, as appropriate.

§ 258.26 Run-on/run-off control systems.

(a) The owner or operator of a municipal solid waste landfill unit must design, construct, and maintain:

[Note to § 258.40(b): EPA is considering alternatives to the 1×10^{-4} to 1×10^{-7} risk range. The Agency specifically requests comment on a fixed risk level of 1×10^{-6} or an upper bound risk level of 1×10^{-4} (with the States having discretion to be more stringent) as alternatives to the proposed risk range. A fixed risk level of 1×10^{-6} would provide a uniform level of protection across all States. On the other hand, setting an upper bound risk level of 1×10^{-4} would allow States greater flexibility in establishing more stringent risk levels based on site specific conditions].

(c) When establishing the design necessary to comply with paragraph (a) of this section, the State shall consider at least the following factors:

(1) The hydrogeologic characteristics of the facility and surrounding land;

(2) The climatic factors of the area;

(3) The volume and physical characteristics of the leachate;

(4) Promixity of gound-water users; and

(5) Quality of ground water.

(d) A State may establish an alternative boundary to be used in lieu of the waste management unit boundary. The alternative boundary shall not exceed 150 meters from the waste management unit boundary and shall be located on land owned by the owner or operator of the MSWLF. The establishment of the alternative boundary shall be based on analysis and consideration of at least the following factors:

(1) The hydrogeologic characteristics of the facility and surrounding land;

(2) The volume and physical and chemical characteristics of the leachate;

(3) The quantity, quality, and direction of flow of ground water;

(4) The proximity and withdrawal rate of the ground-water users;

(5) The availability of alternative drinking water supplies;

(6) The existing quality of the ground water, including other sources of contamination and their cumulative impacts on the ground water;

(7) Public health, safety, and welfare effects; and

(8) Practicable capability of the owner or operator.

(e) Existing municipal solid waste landfill units must be equipped at closure with a final cover system that is designed to prevent infiltration of liquid through the cover and into the waste.

§§ 258.41–258.49 [Reserved]

Subpart E—Ground-Water Monitoring and Corrective Action

§ 258.50 Applicability.

(a) The requirements in this Part apply to municipal solid waste landfill units, except as provided in paragraph (b) of this section.

(b) Ground-water monitoring requirements under § 258.51 through § 258.55 of this Part will be suspended for an MSWLF unit if the owner or operator can demonstrate to the State that there is no potential for migration of hazardous constituents from that unit to the uppermost aquifer during the active life, including the closure period, of the unit and during post-closure care. This demonstration must be certified by a qualified geologist or geotechnical engineer, and must incorporate reliable site-specific data. If detailed hydrogeologic data are unavailable, the owner or operator must provide an adequate margin of safety in the prediction of potential migration of hazardous constituents by basing such predictions on assumptions that maximize the rate of hazardous consituent migration.

(c) Within 6 months of the eifective date of the rule, the State must specify a schedule for the owners or operators of MSWLF units to comply with the ground-water monitoring requirements specified in §§ 258.51–258.55. This schedule must be specified to ensure that 25 percent of MSWLF units are in compliance within 2 years of the effective date of this rule; 50 percent (50%) of landfill units are in compliance within 3 years of the effective date of this rule; 75 percent of the landfill units are in compliance within 4 years of the effective date of this rule; and all landfill units are in compliance within 5 years of the effective date of this rule. In setting the compliance schedule, the State must consider potential risks posed by the MSWLF unit to human health and the environment. The following factors should be considered in determining potential risk:

(1) Proximity of human and environmental receptors;

(2) Design of the landfill unit;

(3) Age of the landfill unit; and

(4) Resource value of the underlying aquifer, including:

(i) Current and future uses;

(ii) Proximity and withdrawal rate of users; and

(iii) Ground-water quality and quantity.

(d) If the State does not set a schedule for compliance as specified in paragraph (c) of this Section, the following compliance schedule shall apply:

(1) Existing landfill units less than 1 mile from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§ 258.51–258.55 within 3 years of the effective date of this rule;

(2) Existing landfill units greater than 1 mile but less than 2 miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§ 258.51–258.55 within 4 years of the effective date of this rule;

(3) Existing landfill units greater than 2 miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§ 258.51–258.55 within 5 years of the effective date of this rule; and

(4) A new landfill unit must be in compliance with the ground-water monitoring requirements specified in §§ 258.51–258.55 before waste can be placed in the unit.

(e) Once established at a unit, ground-water monitoring shall be conducted throughout the active life and post-closure care of that municipal solid waste landfill unit as specified in § 258.31.

§ 258.51 Ground-water monitoring systems.

(a) A ground-water monitoring well system approved by the State must be installed at the closest pacticable distance from the waste management unit boundary or the alternative boundary specified by the State under § 258.40. Where subsurface conditions cause hazardous constituents to migrate horizontally past the boundary specified under this paragraph before descending to the uppermost aquifer, the State can designate another appropriate downgradient location for the ground-water monitoring wells.

(b) A ground-water monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths, to yield ground-water samples from the uppermost aquifer that:

(1) Represent the quality of background ground water that has not been affected by leakage from a landfill unit; and

(2) Represent the quality of ground water passing the locations specified under paragraph (a) of this section.

(c) If approved by the State, separate ground-water monitoring systems are not required for each landfill unit when the facility has several landfill units, provided the multi-unit ground-water monitoring system will be as protective of human health and the environment as individual monitoring systems for each unit.

(d) Monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must be screened or perforated and packed with gravel or sand, where necessary, to enable collection of ground-water samples. The annular space (i.e., the space between the bore hole and well casing) above the sampling depth must be sealed to prevent contamination of samples and the ground water.

(1) The design, installation, development, and decommission of any monitoring wells, piezometers and other measurement, sampling, and analytical devices must be documented in the operating record; and

(2) The monitoring wells, piezometers, and other measurement, sampling, and analytical devices must be operated and maintained so that they perform to design specifications throughout the life of the monitoring program.

(e) The number, spacing, and depths of monitoring systems shall be proposed by the owner or operator and approved by the State based upon site-specific technical information that must be developed by the owner or operator and must include thorough characterization of:

(1) Aquifer thickness, flow rate, and flow direction; and

(2) Saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, including, but not limited to: thicknesses, stratigraphy, lithology, hydraulic conductivities, and porosities.

§ 258.52 Determination of ground-water trigger level.

(a) The State must establish, before a Phase I monitoring program is initiated, ground-water trigger levels that are protective of human health and the environment for all Appendix II constituents.

(b) The levels are to be specified by the State as:

(1) Maximum Contaminant Level (MCL) promulgated under § 1412 of the Safe Drinking Water Act (codified under 40 CFR Part 141, Subpart B; or

(2) For constituents for which MCLs have not been promulgated, an appropriate health-based level established by the State that satisfies the following criteria:

(i) The level is derived in a manner consistent with Agency guidelines for assessing the health risks of environmental pollutants (51 FR 33992, 34006, 34014, 34028);

(ii) Is based on scientifically valid studies conducted in accordance with the Toxic Substances Control Act Good Laboratory Practice Standards (40 CFR Part 792) or equivalent;

(iii) For carcinogens, the level represents a concentration associated with an excess lifetime cancer risk level (due to continuous lifetime exposure) within the 1×10^{-4} to 1×10^{-7} range; and

(iv) For systemic toxicants, the level represents a concentration to which the human population (including sensitive subgroups) could be exposed to on a daily basis that is likely to be without appreciable risk of deleterious effects during a lifetime.

[Note to § 258.52(b)(2)(iii): EPA is considering alternatives to the 1×10^{-4} to 1×10^{-7} risk range. The Agency specifically requests comment on a fixed risk level of 1×10^{-6} or an upper bound risk level of 1×10^{-4} (with the States having discretion to be more stringent) as alternatives to the proposed risk range. A fixed risk level of 1×10^{-6} would provide a uniform level of protection across all States. On the other hand, setting an upper bound risk level of 1×10^{-4} would allow States greater flexibility in establishing more stringent risk levels based on site specific conditions].

(3) For constituents for which no health-based level is available that meets the criteria in § 258.52(a)(1) or (2) the State may establish a trigger level that shall be:

(i) An indicator for protection of human health and the environment, using the exposure assumptions specified under § 258.52(a)(2), or

(ii) The background concentration.

(4) For constituents for which the background level is higher than health-based levels established under § 258.52(b)(1)–(3), the trigger level shall be the background concentration.

§ 258.53 Ground-water sampling and analysis requirements.

(a) The ground-water monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of ground-water quality at the background and downgradient wells installed in compliance with § 258.51(b) of this part. At a minimum, the program must be documented in the operating record and must include procedures and techniques for:

(1) Sample collection;

(2) Sample preservation and shipment;

(3) Analytical procedures;

(4) Chain of custody control; and

(5) Quality assurance and quality control.

(b) The ground-water monitoring program must include sampling and analytical methods that are appropriate for ground-water sampling and that accurately measure hazardous constituents and other monitoring parameters in ground-water samples.

(c) The sampling procedures and frequency must be protective of human health and the environment. The sampling requirement must ensure that the statistical procedure used to evaluate samples has an acceptably low probability of failing to identify contamination.

(d) Ground-water elevations must be measured in each well immediately prior to sampling. The owner or operator must determine the rate and direction of ground-water flow in the uppermost aquifer each time ground-water gradient changes as indicated by previous sampling period elevation measurements.

(e) The owner or operator must establish background ground-water quality on a hydraulically upgradient well(s) for each of the monitoring parameters or constituents required in the particular ground/water monitoring program that applies to the municipal solid waste landfill unit, as determined under § 258.54(a), or § 258.55(a) of this part. The minimum number of samples used to establish background ground-water quality must be consistent with the appropriate statistical procedures determined pursuant to paragraph (h) of this section.

(f) Background ground-water quality at existing units may be based on sampling of wells that are not upgradient from the waste management area where:

(1) Hydrogeologic conditions do not allow the owner or operator to determine what wells are upgradient; and

(2) Sampling at other wells will provide an indication of background ground-water quality that is as representative or more representative than that provided by upgradient wells.

(g) The State may determine alternate background ground-water quality on a site-specific basis if true background ground-water quality cannot be detected on site. The alternate background ground-water quality should be based on monitoring data from the uppermost aquifer that is available to the State.

(h) Statistical procedures are as follows:

(1) Ground-water monitoring data for each phase of the monitoring programs of §§ 258.54, 258.55 and any other applicable section of this rule will be collected from background wells (except as allowed in § 258.53(g)), and at monitoring wells as specified pursuant to § 258.53(a). Based on the site-specific conditions identified in § 258.54(c), the owner or operator must select the appropriate statistical procedure to determine if a statistically significant increase over background value for each parameter or constituent has occurred.

(2) The owner or operator must employ one of the following statistical

GEOLOGIC HAZARDS

Project: Geologic investigation of a landslide in Springdale, Washington County, Utah			Requesting Agency: City of Springdale
By: Kimm M. Harty	Date: 7-29-88	County: Washington	Job No.: (GH-1) 88-04
USGS Quadrangle: Springdale West (74)			

The Utah Geological and Mineral Survey (UGMS) was requested by Dave Conine, planner for the City of Springdale, to investigate a landslide that occurred on BLM land and private property owned by Bob Ralston of Springdale. The purpose of the investigation was to document the slope failure so that the City may use the information in future planning decisions. The slide is located at 970 Zion Park Blvd., in the SE 1/4 of sec. 29, T. 41 S., R. 10 W., Salt Lake Baseline and Meridian (attachment 1). In addition to the field investigation, the scope of work included a review of published reports and geologic maps. Bob Ralston was present during the investigation on July 18, 1988.

In early May, 1988, Mr. Ralston completed construction of a large slab-on-grade storage shed. The shed was built at the base of a slope between two drainages (attachment 1). Prior to construction, the lower portion of the slope was removed to provide a flat area for the shed. On May 4, 1988, the slope failed, severely damaging the concrete floor of the shed, and moving the structure 6.75 feet eastward. According to Mr. Ralston, approximately 2500 ft^3 of slide material was removed from the toe area of the slide prior to this investigation. This activity created a steep cut slope about 10 feet behind the storage shed.

The landslide occurred in the Chinle Formation, which contains abundant clay and is particularly susceptible to landsliding. Geologic maps of the area (Marshall, 1956; Cook, 1960) show the entire slope to be underlain by this formation. Pockets of "blue clay", typical of the Chinle Formation, were visible in the slide, especially at the intersection of the slide's northern flank and the basal cut slope. Also involved in the slide was colluvium that armours the slope. Contained in the colluvium are large rock-fall boulders derived from the Kayenta Formation that forms steep cliffs upslope.

The landslide is an earth slump (attachment 2), and has a clearly-defined, 20-ft high main scarp. A 25-ft wide trough separates the main scarp from the head of the slump. Numerous transverse cracks intersect the distinct lateral flanks of the slide. The slump appears to have moved as a coherent unit, and there were no minor scarps visible in the main body of the slide. No crown cracks were seen. The slide plane was not exposed, but extends and likely daylights beneath the shed. From the main scarp to the toe, the slump measured 154 feet long; the toe location had to be estimated due to its removal. The width varied from 78 feet at the crown to 161 feet at the basal cut slope behind the shed. The slump and the trough area comprise approximately 0.4 acres, and the slide faces almost due east (N 85^0 E). Due to excavation at the toe of the slope, an average slope gradient prior to failure could not be determined.

Weather records for Zion National Park, the closest station to Springdale, show a total of 4.33 inches of precipitation between April 15th and 24th, with 1.73

inches falling on April 21st, and 0.5 inches on the following day. With the exception of slight precipitation on May 1st, none was recorded between April 25th and May 4th.

The slump was probably caused by excavation of the base of the slope, which removed support. Nearly 3 inches of rain fell in the six-day period between April 19th and April 24th, ten days before the slide occurred. Infiltrating precipitation may have facilitated the slope failure. According to Mr. Ralston's observations shortly after the slide occurred, the main scarp was wet from the ground surface down about four feet. No moisture was observed anywhere in the slide vicinity during this investigation.

Mr. Ralston said that the slide has not moved since its initial failure. At present, the basal cut slope behind the shed is about 17 feet high. Mr. Ralston indicated he intends to grade the slump to a 3:1 slope by removing additional material from the main body, and rebuild the shed at approximately the same location. I advised him that should the slide reactivate, either in its present form or after modifications, it could further impact the shed. I also advised Mr. Ralston against rebuilding the shed in its present location. The slide would likely not affect Mr. Ralston's house, which is farther downslope. Mr. Ralston indicated he does not intend to modify the 20-ft high main scarp of the landslide. This scarp, as well as the upper portion of the slump, is on BLM land. The main scarp is steep, and left in its current state will probably slough material into the trough below. It is unlikely that this activity will impact any structures.

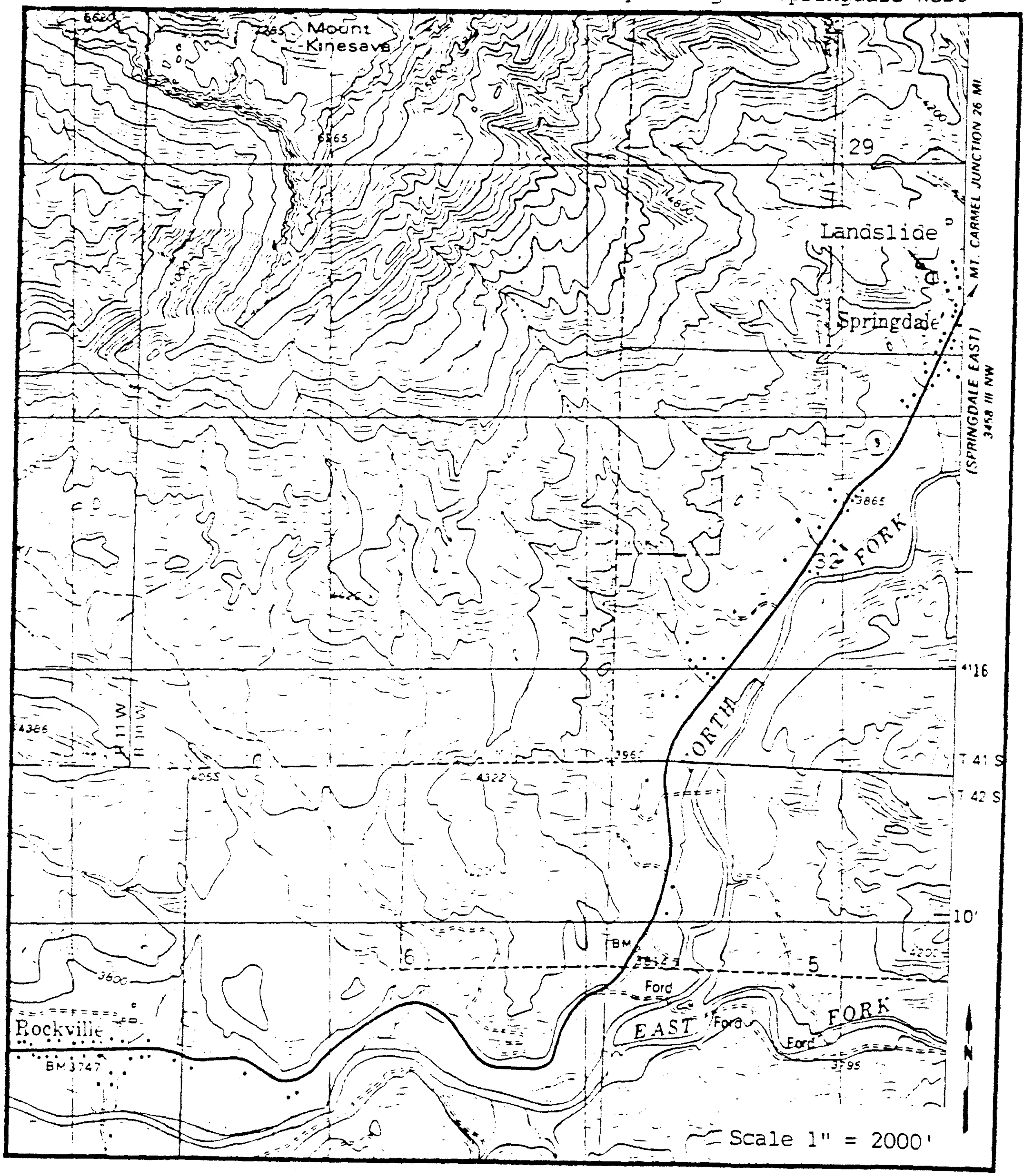
References Cited

Cook, E.F., 1960, Geologic atlas of Utah: Utah Geological and Mineralogical Survey Bulletin 70, 124 p.

Marshall, C.H., 1956, Photogeologic map of the Virgin NE Quadrangle, Washington County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-161, Scale 1;24,000.

Varnes,D.J., 1978, Slope movement types and processes, in Schuster, R.L., and Krizek, R.J., (eds.), Landslides-analysis and control: National Academy of Sciences Transportation Board Special Report 176, p. 12-33.

Base map USGS 7½' topographic quadrangle: Springdale West



Location map showing landslide.

Project:			Requesting Agency:
Fault investigation - SW corner of 4200 South Redwood Road			Salt Lake County Planning Division - Craig Nelson
By: Susan Olig	Date: 3-6-89	County: Salt Lake	Job No.: 89-04 (GH-2)
USGS Quadrangle: Salt Lake City South 7.5 Quad (BLM No. 1213)			

Phillips petroleum company is currently building a service station and car wash at 4200 South Redwood Road, Salt Lake County. At the request of Craig Nelson, Salt Lake County geologist, I inspected two trench exposures for evidence of faults at this site. Craig Nelson and Douglas Hawkes, a geologist with Chen-Northern, were present during this inspection on March 6, 1989. Chen-Northern, Inc. is the geotechnical consultant for the project, and is addressing fault surface rupture hazards from the West Valley fault zone, which transverses the site.

Both trenches exposed late Pleistocene sediments that were faulted and warped down to the east. In the northern trench, a discrete, NNE-striking, steeply E-dipping fault clearly truncated a laminated green to red clay unit. A cursory examination of this unit revealed white, fine-sand lenses and ostracods. These sediments are probably associated with the late Pleistocene Bonneville Lake Cycle, either as deep-lake or lagoonal deposits. The clay unit was in the footwall and was warped down to the east. Non-stratified, poorly-sorted, pinkish tan clayey silt and sandy silt was exposed in the hanging wall for almost the entire depth of the trench. A silty-sand layer with non-distinct bedding was exposed at the trench base within the hanging wall. The age of these units is unknown. The minimum vertical separation across the fault was 1.5 m. Excavation disturbance, soil development, and bioturbation within the uppermost few feet of the exposure precluded distinguishing the fault or original character of the sediments near the surface without a more detailed investigation.

In the southern trench, a discrete, N-striking, steeply E-dipping fault cuts similar units to those exposed in the northern trench. The main difference was a clean, subangular, medium- to coarse-sand layer containing well-rounded pebbles and cobbles. This sand layer was exposed near the base of the footwall, below the clay unit.

Excavation at the site has completely destroyed any geomorphic evidence of a fault scarp. However, from interpretation of 1937 and 1946 aerial photographs, Keaton and others (1987) identified a NNW-striking fault scarp transecting this site. The scarp was part of the Taylorsville fault named by Marine and Price (1964). Although the fault scarp was partially modified by human disturbance, it was still visible in 1986, when I profiled the scarp and obtained a scarp height of approximately 1.5 m. The scarp was approximately coincident with the location of the fault exposed in the two trenches.

The age of the last movement of the Taylorsville fault at this site can only be constrained as post-Lake Bonneville. However, approximately 4 km to the north, the Taylorsville fault offsets deposits of the Gilbert shoreline, indicating movement within the last 12 ka (Keaton and others, 1987).

Keaton, J. R., Currey, D. R., and Olig, S. J., 1987, Paleoseismicity and earthquake hazards evaluation of the West Valley fault zone, Salt Lake City urban area, Utah: Report to U. S. Geological Survey, contract no. 14-08-0001-22048, 88 p.

Marine, I. W., and Price, D., 1964, Geology and ground-water resources of the Jordan Valley, Utah: Utah Geological and Mineral survey Water-Resources Bulletin 7, 63 p.

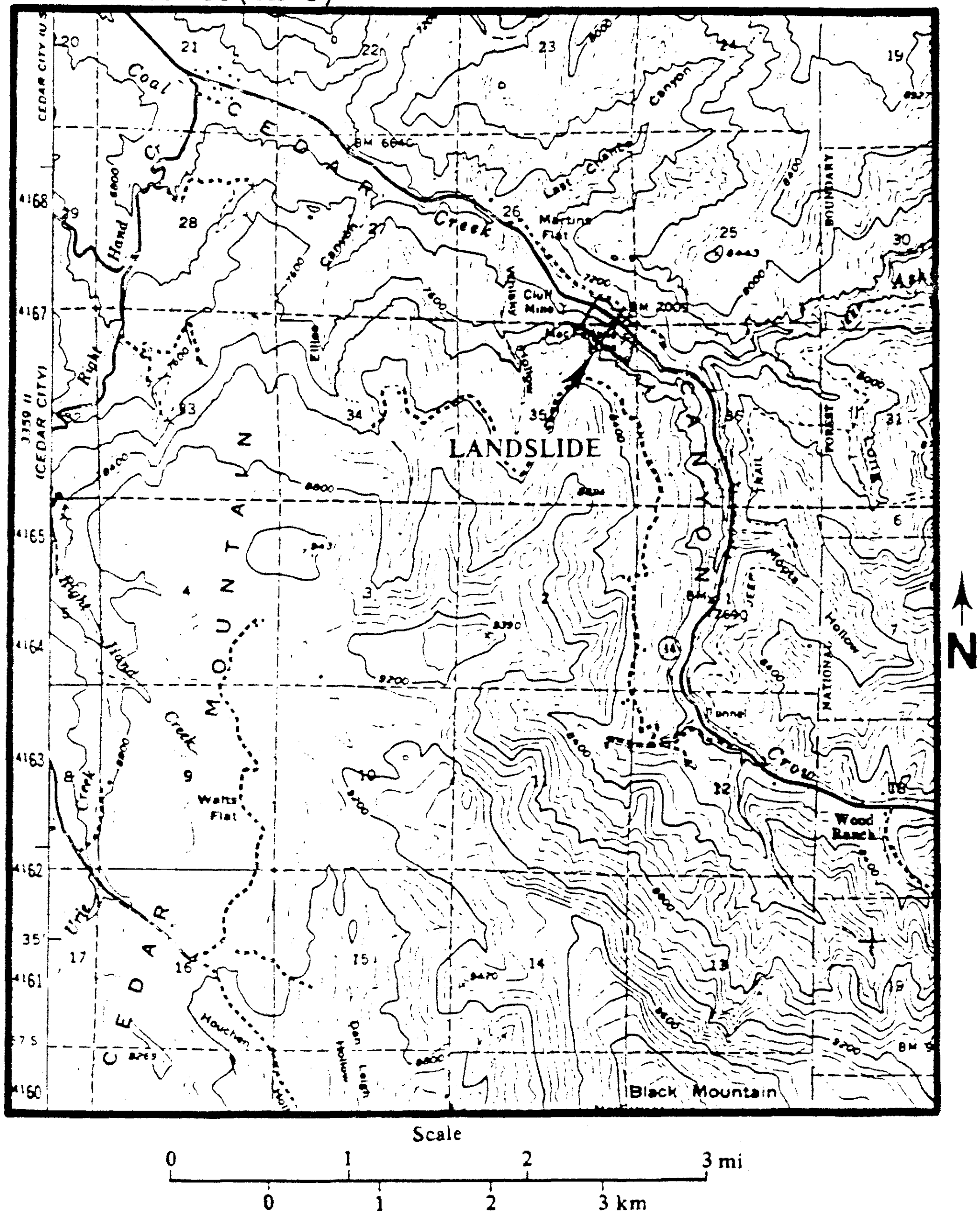
Project:			Requesting Agency:
Cedar Canyon landslide reconnaissance, Iron County, Utah.			Utah Division Comprehensive Emergency Management
By: Kimm M. Harty Gary E. Christenson	Date: 4-11-89	County: Iron	Job No.: (GH-3) 89-05
USGS Quadrangle: Flanigan Arch (237)			

INTRODUCTION

On March 27 1989, the Utah Geological and Mineral Survey (UGMS) was requested by Lorayne Frank, Director of the Utah Division of Comprehensive Emergency Management (CEM) to investigate a landslide in Cedar Canyon, about seven miles east of Cedar City, Utah. The landslide is in sections 26 and 35, T. 36 S., R. 10 W., Salt Lake Baseline and Meridian (fig. 1). It occurred sometime between midnight and 6:00 a.m. on March 27, 1989, and destroyed approximately one-third of a mile of Utah Highway 14. The purpose of the investigation was to provide CEM and Ira Schoppmann, sheriff of Iron County, advice and assistance regarding the hazard potential of the landslide and the likelihood for significant damming of Coal Creek by the slide. A field reconnaissance of the landslide was made between noon and 3:30 p.m. on March 28th, by Gary Christenson and Kimm Harty of the UGMS, and John Rokich of CEM. In addition to a field examination, the scope of work included a review of published and unpublished literature, data, and maps.

BEDROCK GEOLOGY

Field examination of the slide in addition to examination of geologic maps (Gregory, 1950; Doelling and Graham, 1972) and previously measured lithologic sections at and near the slide (UGMS unpublished data) suggest that the failure occurred in bedrock of the Cretaceous Tropic and Dakota Formations. In the slide area, the predominantly shale Tropic Formation grades into the underlying Dakota sandstone, and is referred to on geologic maps as the Tropic-Dakota Interval. The upper part of the interval resembles the Tropic shale, and is a gray shale containing thin layers of brown fine-grained sandstone (Doelling and Graham, 1972). The Tropic shale is a unit especially prone to landsliding in southern Utah. The lower part of the interval is a "...fine- to medium-grained sandstone alternating with gray shale, sandy shale, carbonaceous shale, and thick beds of coal..." (Doelling and Graham, 1972). Much of the landslide surface is covered by loose, unstable, buff-colored material ranging from clay and silt to car-sized boulders. This material is believed to be colluvium and broken rock of the Cretaceous Straight Cliffs Formation which forms the near-vertical main scarp of the landslide and a portion of the cliffs above the slide. This formation is described by Doelling and Graham (1972) as a "thick-bedded to massive cliff-forming sandstone with subordinate intervening gray shale, shaley sandstone, coal and carbonaceous shale..."



Contour Interval 80 feet

Figure 1. Location map showing Cedar Canyon landslide.

Three abandoned coal mines are present in the slide vicinity, one of which, the MacFarlane, was located on the failed slope and was sheared off by the landslide. All three mines were in the Tropic-Dakota Interval, and extracted a near-horizontal coal seam about 5-6 feet thick (Doelling and Graham, 1972). Mine spoil and concrete blocks from the MacFarlane mine protrude from the landslide along its eastern margin at about the level of the undisturbed portion of Highway 14. It is apparent from the topographic map (fig. 1) that the mine entrance moved downslope about 40 feet. The Cluff mine, west of the landslide (fig. 1), and the Koal Kreek mine, east of the slide, connect underground (Doelling and Graham, 1972). Presumably these mines also connected to the MacFarlane mine. Based on estimates of total coal production given by Doelling and Graham (1972), it is likely that the mine workings extend beneath the entire slide area. Doelling and Graham (1972) report that the MacFarlane mine extended 4000 feet into the hillside and that a fault constrained the southern limit of coal mining. This fault shows at least 24 feet of offset, but does not appear on available maps. Doelling and Graham (1972) report the mine was dry although local residents report the mine was wet and issuing water when sealed recently.

LANDSLIDE DESCRIPTION

The landslide is approximately 1700 feet wide by 1000 feet long. It covers approximately 40 acres and has a total relief of about 600 feet (fig.1). In addition to a portion of Highway 14, the portal of the abandoned and sealed MacFarlane coal mine was sheared off and also transported downslope by the landslide, and an old power line used when the mine was operating was destroyed. Utah Department of Transportation (UDOT) personnel reported that during the year or so prior to the March 27 landslide, the area had been a source of smaller landslides that necessitated constant maintenance of the highway (A. Scott Munson, District Engineer, oral commun., March 28, 1989). The morphology of the landslide suggests that the feature is a complex slump (rotational slide), with an earth flow at the toe as diagrammed in figure 2. Back-tilted minor scarps were identified throughout the body of the slide, and were particularly conspicuous near the head. The presence of numerous boulders scattered over the surface of the landslide indicate secondary failure by falling and rolling of material dislodged by the initial landslide movement. The head of the slide is at the base of a cliff, and now forms the lower part of the cliff. The main scarp of the slide is a maximum of about 150 feet high near the center. The height gradually decreases toward the flanks of the slide, giving an elongated half-moon appearance to the main scarp. We estimate the volume of the landslide to be approximately two million cubic yards.

Using a 1985 1:24,000 scale topographic map, it was determined that prior to the landslide, the slope of the ground surface from the crown of the slide to Utah Highway 14 was at least 30 degrees (58 percent), and may have been as high as 37 degrees (77 percent). From the highway down to the creek, the pre-slide slope was slightly less steep, averaging about 27 degrees (53 percent). It was apparent from the field inspection that the lower portion of the post-slide slope between the former location of the highway and the creek below is now in most places significantly steeper than the portion above the road. The lower portion of the landslide is oversteepened and the surficial

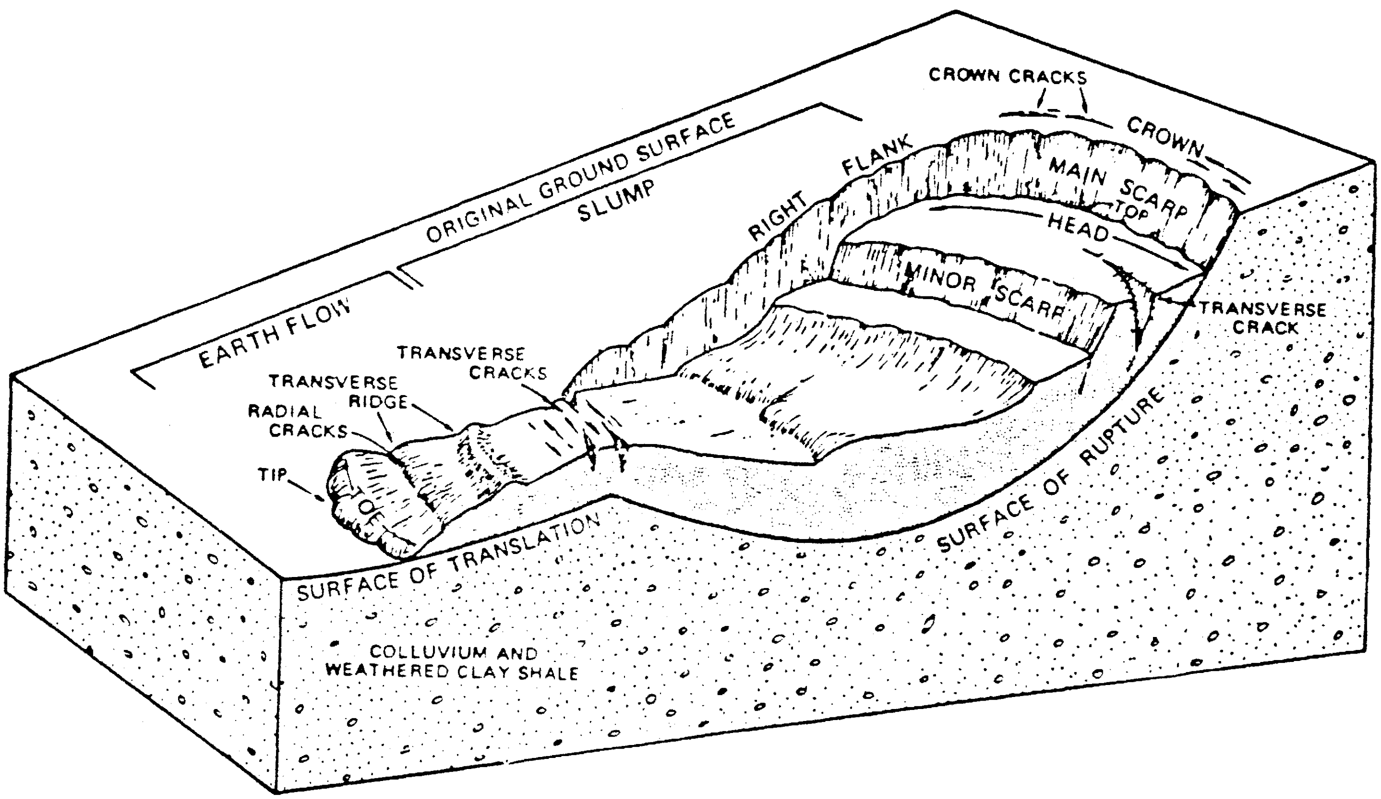


Figure 2. Schematic diagram of a landslide similar to the Cedar Canyon landslide, showing landslide nomenclature (modified from Varnes, 1978)

materials are very unstable and were actively sliding downslope during the reconnaissance.

The surface of rupture at the base of the slide appears to be complex, and the landslide moved downslope in a series of simultaneously-moving slumps and slides rather than as a single, intact, cohesive mass. In the western part of the slide, an intact but severely damaged portion of Highway 14 moved about 100 feet downslope but was not buried by landslide debris. The surface of rupture is thus below the present position of the highway here. Elsewhere, the road disappears beneath the landslide, with patches of crushed asphalt locally present on the landslide surface. The break in slope that roughly parallels the former location of the highway may indicate the location of the rupture surface of the landslide. No evidence of a daylighted rupture surface was observed in the field; it is likely that it was buried by debris.

It is unlikely that the surface of rupture is at or below the level of the creek. The toe of the landslide spilled into the canyon bottom and blocked portions of Coal Creek, but did not as a whole, slide into the creek. Although the creek was blocked in places, there is no evidence it was significantly shifted or uplifted by the slide. Blockage of the creek was probably produced by both tumbling rock material and by slumping and sliding within localized areas at the toe of the landslide. The creek cut through and breached the blockages before substantial ponding or flooding could occur. Aside from a noticeable instability of surficial soil and rocks, the landslide did not appear to be moving during the field investigation. Very little water was observed on the slide except where small isolated snow patches were preserved and melting.

POSSIBLE CAUSES

In addition to reports of the recent history of instability in this slope from UDOT personnel, there is geologic evidence for longer-term instability in the form of older (probably prehistoric) inactive landslide scarps and heads near the top of the slope. Evidence indicates a potentially unstable slope that may not have required a significant change in conditions to cause failure. Although it was not the purpose of this investigation to determine the cause of the failure, we did investigate several possible causes. No earthquakes were reported in the area near the time of the landslide (Sue Nava, University of Utah Seismograph Stations, oral commun., April 11, 1989), so ground shaking is not a likely cause.

Possible weather-related factors include both longer-term annual and seasonal precipitation trends, and shorter-term storm or snowmelt events. The National Weather Service (1989) reported that as of March 1, 1989, stream flow in Coal Creek was about 70 percent of normal. As of February 28, 1989, soil moisture indices for the south-central region of Utah, which includes Cedar City, indicate the area to be experiencing a "mild drought" (Office of the Utah State Climatologist, 1989a). In addition, precipitation received in the south-central region from February 24 to March 31 averaged only 76 percent of normal (Office of the Utah State Climatologist, 1989b). Most of the snow in the area had melted, with localized snow remaining mostly on north-facing slopes. Southern Utah is under below-average precipitation and moisture conditions for the current water year. Based on this information, it is difficult to attribute the landslide failure to longer-term weather-related causes.

Local precipitation records from a weather station located in Cedar Canyon about two miles west of the slide indicate that the area received nearly 0.4 inches of precipitation the day before the slide occurred. Previous to this rainfall event, no precipitation other than a trace amount was recorded since March 3, when 0.81 inches fell (Dudley Alger, Cedar City Water Department, written commun., April 10, 1989). It is possible that the rain that fell the day before the landslide occurred may have triggered the event, but significant instability already existed in the area prior to landslide movement.

Possible man-related factors which may have contributed to slope instability include highway- and mining-related alterations to the slope, drainage, and ground-water hydrology. The destroyed MacFarlane mine portal is located near the level of the hypothesized landslide rupture surface, at least along the east flank. It is possible that the landslide failed along a plane at the elevation of the mine workings, but further analysis is needed to verify or reject this possibility. It is unknown whether the hydrology of the mine or changes caused by sealing the portal contributed to the landslide.

HAZARD POTENTIAL AND RECOMMENDATIONS

The principal slide movement has occurred, but it is likely that minor slides, rock falls, and settlement will continue within the slide mass. In particular, rock falls may continue to occur along the landslide's cliff-forming main scarp. Cracks which connect with the main scarp extend along the base of the cliff west of the slide for several hundred feet. The slope below these cracks shows evidence of movement. These cracks probably formed contemporaneously with the main slide, and indicate that remaining slopes adjacent to the slide are potentially unstable.

The main purpose of this reconnaissance was to assess the potential for damming of Coal Creek by continued slide movement, posing a flood hazard downstream should the landslide dam fail. The rupture surface of the slide appears to be above the creek, and the damming that has occurred to date has been from material spilling over from the toe of the landslide into the creek. A certain amount of this will continue because slopes in the toe area are oversteepened and unstable. Coal Creek has been able to maintain its channel so far, and even if this type of movement continues, we believe the potential for damming with sufficient impoundment of water to pose a major flood hazard downstream is low. However, the possibility of renewed movement of the slide cannot be ruled out, and it was recommended that the toe area and downstream flow in Coal Creek be monitored regularly, and that the local government authorities prepare a plan for evacuation of low-lying areas along the creek, particularly in Cedar City, in case the slide does dam the creek. We estimate that it would take about an hour for flooding to reach Cedar City from the landslide area (W.F. Case, UGMS, oral commun., March 29, 1989). Because the channel of Coal Creek in Cedar City is relatively shallow with limited water-carrying capacity, and development has occurred adjacent to the creek in low-lying areas, it would not necessarily require failure of a large impoundment to cause damage. For this reason, it is important to monitor the landslide closely for continued movement, particularly in the toe area in the canyon bottom along Coal Creek.

Cited References

Doelling, H.H., and Graham, R.L., 1972, Southwestern Utah coal fields: Alton, Kaiparowits Plateau and Kolob-Harmony: Utah Geological and Mineral Survey Monograph Series No. 1, p. 302.

Gregory, H.E., 1950, Reconnaissance geologic map of eastern Iron County, Utah: Utah Geological and Mineral Survey Map 1, also Reprint no. 37, scale 63,360.

National Weather Service, 1989, Water supply outlook for Utah as of March 1, 1989: Colorado Basin River Forecast Center unpublished report, 10 p.

Office of the Utah State Climatologist, 1989a, Preliminary soil moisture and Palmer indices for the month ending February 28, 1989: Utah State University unpublished report, 2 p.

Office of the Utah State Climatologist, 1989b, Precipitation update for the weeks ending March 3, March 10, March 17, March 24, and March 31, 1989: Utah State University unpublished reports, 2 p. each.

Varnes, D.J., 1978, Slope movement types and processes, in Schuster, R.L., and Krizek, R.J., eds., Landslides - analysis and control: National Academy of Sciences Transportation and Research Board Report 176, p. 12-33.

Project: Geologic Investigation of a landslide in Hoytsville, Summit County, Utah			Requesting Agency: Rep. Glen E. Brown Utah State House of Representatives
By: Kimm M. Harty	Date: 6-9-89	County: Summit	Job No.: (GH-4) 89-08
USGS Quadrangle: Wanship (1250), Coalville (1291)			

INTRODUCTION

In response to a request by Representative Glen E. Brown of the Utah State House of Representatives, the Utah Geological and Mineral Survey (UGMS) investigated a landslide in Hoytsville, three miles south of Coalville in Summit County (SE 1/4, section 28, T. 2 N., R. 5 E., Salt Lake Baseline and Meridian; fig 1). According to Roy Dixon, owner of the land on which the landslide was deposited, the slide occurred prior to 5:00 a.m. on Sunday, October 16, 1988. The purpose of the investigation was to assess the stability of the landslide, and to recommend measures to prevent future movement. The investigation took place from 11:00 a.m to 1:00 p.m. on Wednesday, May 17, 1989. Loren Rausher of the Utah Department of Transportation collaborated in the investigation, helped formulate recommendations, and reviewed this report. Also present during the field investigation were Gary Brown, son of Vera Brown, the owner of the land from which the slide was initiated, and Mr. Dixon. The scope of the investigation consisted of a review of current literature, maps, and aerial photography, and the field investigation.

GEOLOGY AND BACKGROUND HISTORY

The landslide is oriented almost due north on the north-facing slope of a borrow pit that was used during the 1960s as a source of fill material for nearby Interstate 80. The pit was excavated in alluvium in an abandoned terrace of the Weber River (Klauk and Harty, 1988). In the landslide area, the terrace is composed of alternating layers of predominantly fine-grained sediments (clay, silt, and sand), with occasional coarser-grained gravel layers. The terrace likely contains much sediment from Cottonwood Canyon (fig. 1), which, prior to development by early settlers, flowed westward through the borrow pit area to the Weber River. Water from Cottonwood Canyon is now diverted into irrigation canals.

The borrow pit has been the site of previous slope stability problems. In 1969 a landslide occurred on the south-facing slope of the pit, destroying a portion of Creamery Lane (fig. 2). The slope was back-filled and a perforated pipe underdrain was installed. In 1987, the UGMS investigated sinkholes or collapse pits that developed in an irrigated field just north of the 1969 landslide (Klauk and Harty, 1988) (fig. 2). The most likely cause of the 1969 landslide was wetting of the oversteepened slope of the pit. The formation of the collapse pits was caused by piping (subsurface channelized erosion) of the fine-grained alluvium, accelerated by flood irrigation of fields surrounding the borrow pit (Klauk and Harty, 1988). Geologic, topographic, and current hydrologic conditions on

Job No.89-08(GH-4)

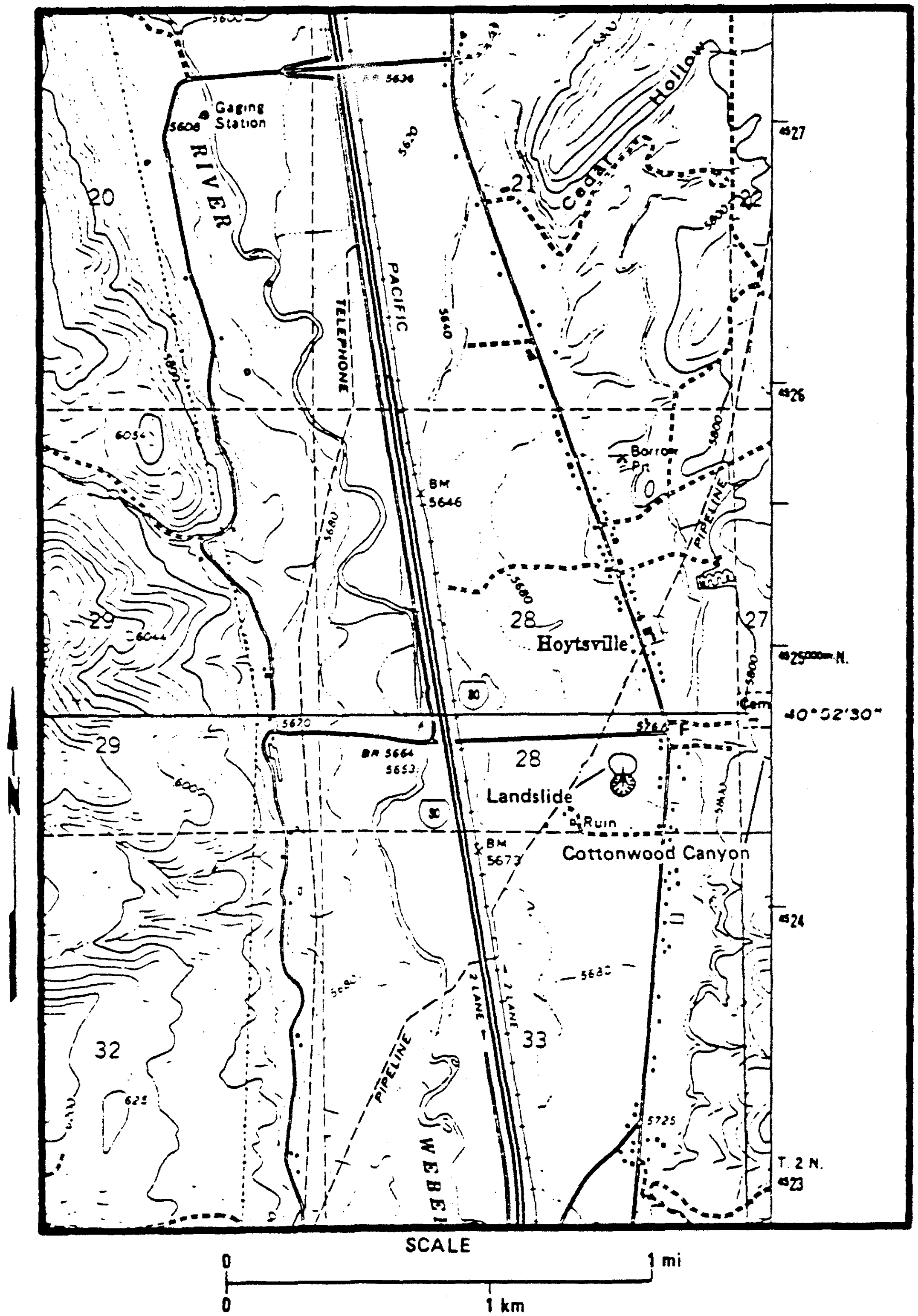


Figure 1. Location map of Hoytsville landslide (arrow shows direction of movement).

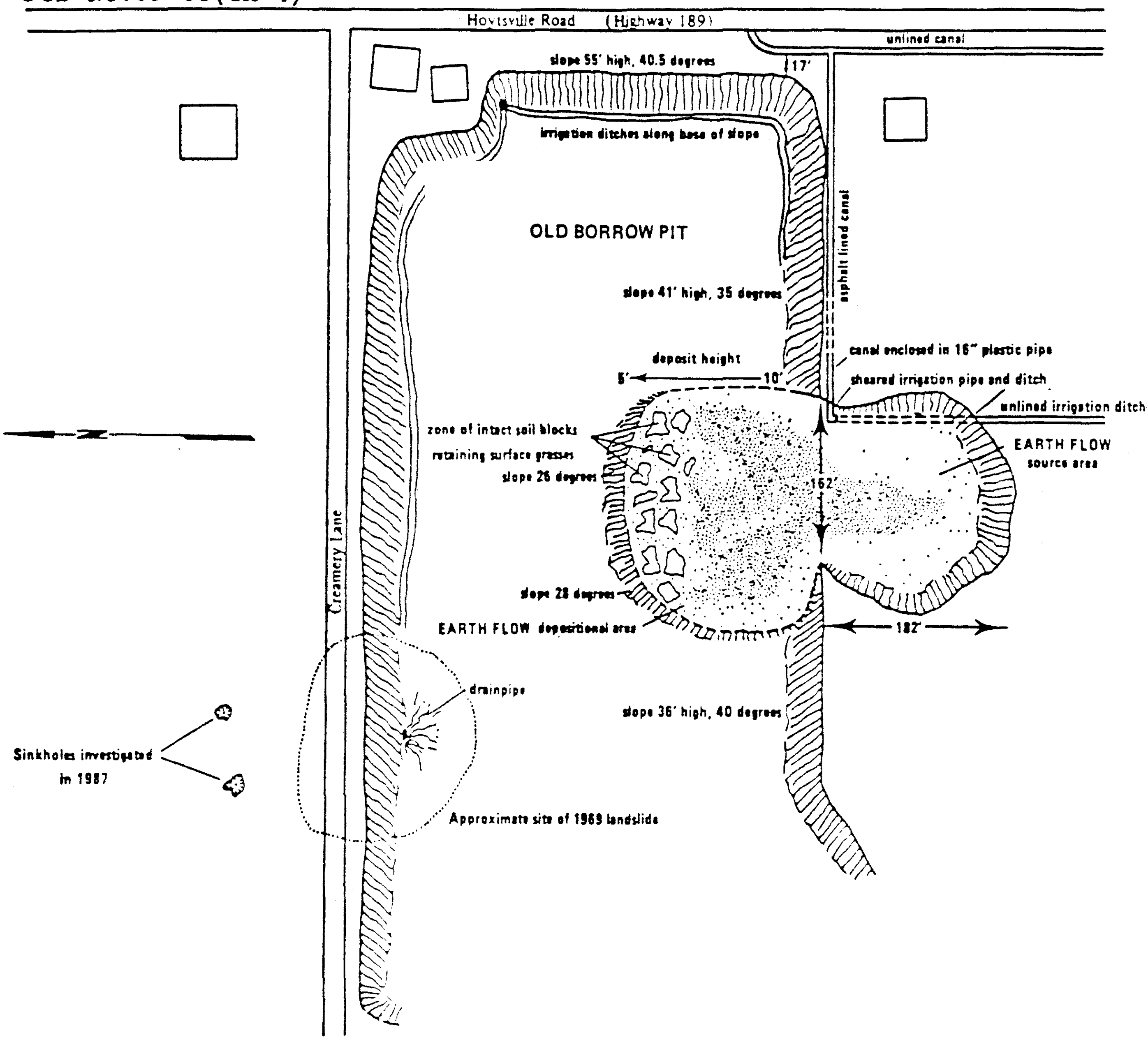


Figure 2. Sketch of landslide, borrow pit, and associated features (not drawn to scale).

the slopes of the borrow pit are conducive to erosion and instability; the fine-grained soils of the river terrace are very susceptible to erosion by piping, slopes along the sides of the borrow pit are steep, and the practice of flood irrigation provides a constant, saturating water source.

LANDSLIDE DESCRIPTION

The landslide is classified as an earth flow (fig. 3), and movement appears to have been at a moderate to rapid speed, under saturated conditions. The earth-flow deposit is relatively thin, ranging from five to ten feet in thickness, and extensive, suggesting ample water to spread the deposit over the flat floor of the borrow pit. The surface of the outermost portion of the earth-flow toe contains numerous intact soil blocks averaging about three to four feet in longest dimension, with most still retaining their original vegetal cover (fig. 2). These blocks comprised the grassy surface of the top of the slope before being "rafted" downslope in the earth flow.

The earth flow sheared off a 20-foot section of a 16-inch plastic irrigation pipe that fed into an unlined irrigation ditch, and destroyed about 0.6 acres of farmland above the borrow pit (fig. 2). A similar area of land at the bottom of the pit was covered by the earth-flow deposit. The flow is 182 feet long and 162 feet wide at the base of the borrow pit slope. The volume of material involved is estimated to be about 15,000-20,000 cubic yards, of which approximately 8,000 cubic yards was deposited on the borrow pit floor.

The slopes surrounding the borrow pit are steep, with the steepest being the west-facing slope (40.5 degrees) which parallels the Hoytsville road. Angles measured on the north-facing slope, east and west of the earth flow, were 35 and 40 degrees, respectively (fig. 2). The average pre-slide slope gradient in the area of the earth flow is estimated to be about 38 degrees, or close to 80 percent. The height of the slope was about 39 feet.

DISCUSSION

The earth flow most likely occurred as a result of a combination of conditions. The main factors causing the failure are believed to be the steep slope, fine-grained soils, and excess moisture applied through flood irrigation and possible canal seepage. As depicted in figure 2, an asphalt-lined canal carried water west along the south edge of the borrow pit. Water was channeled into a 16-inch diameter plastic pipe which then angled southward to divert flow into an open, unlined irrigation ditch (fig. 2). The position of the irrigation ditch closely follows the eastern flank of the earth flow, and it is possible that seepage from the ditch, or elsewhere near the main scarp, may have triggered the earth flow. Due to the seven-month period between the earth flow and this investigation, moisture conditions at the time of failure are unknown. The only moisture observed during the field visit was a small amount of water trickling from the sheared-off pipe onto the earth flow below, and a few areas of ponded water at the bottom of the borrow pit near the toe of the earth flow.

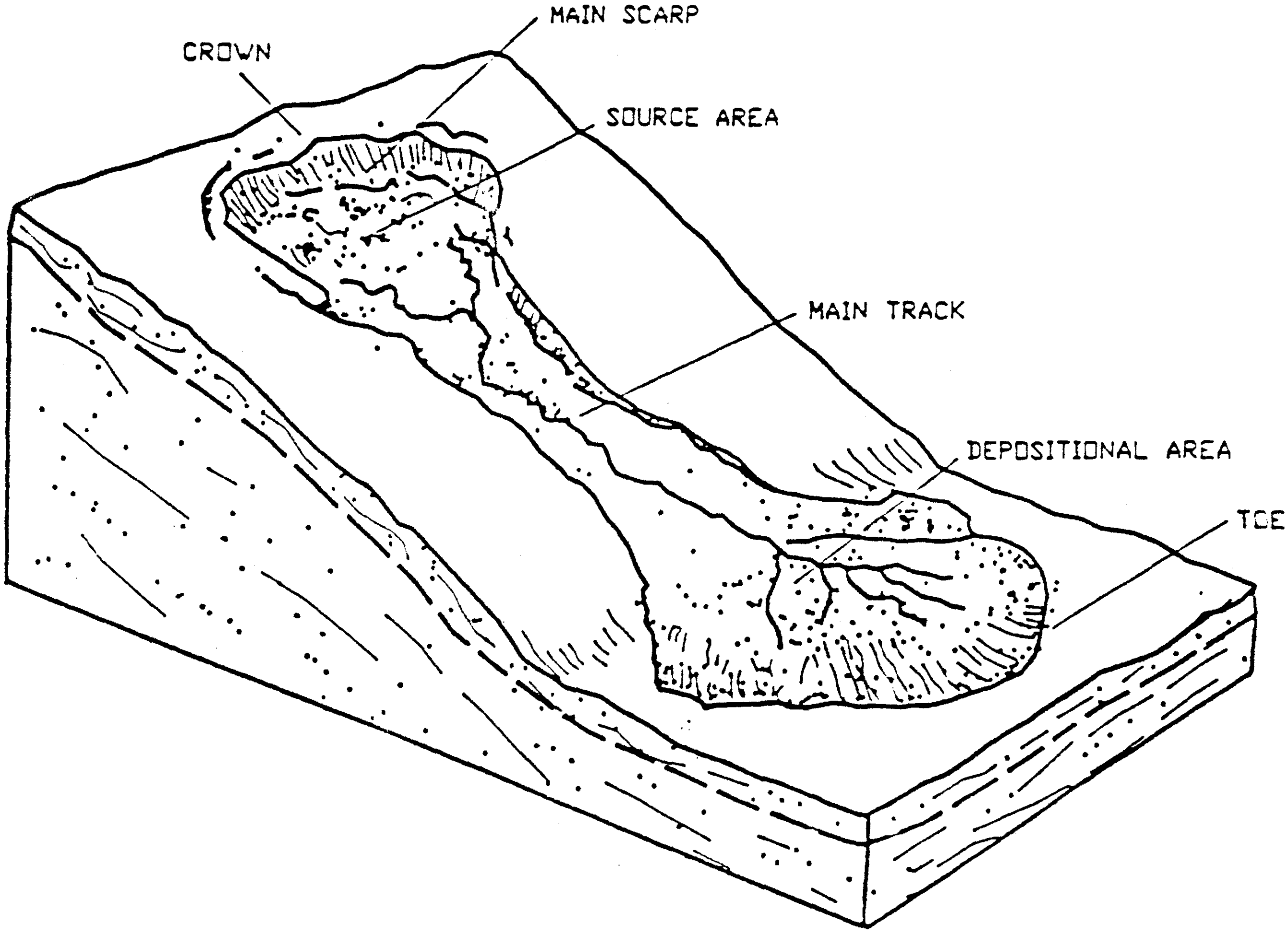


Figure 3. Diagram of a typical earth flow (modified from Zaruba & Mencle, 1969).

There was no indication that the landslide has moved since its failure last October. However, the main scarp is nearly vertical and reaches 15 feet in height along the northeastern portion of the earth-flow source area, beneath the sheared irrigation pipe. Shearing and toppling of soil blocks from the main scarp will probably occur until the scarp erodes naturally to form a more stable slope, or is graded.

Under current geologic conditions and irrigation practices, the slopes surrounding the entire borrow pit are considered to be susceptible to continued landslide activity. The slopes are high, steep, and composed of fine-grained alluvium. The west-facing slope face currently shows evidence of surface instability in the form of horizontal gaps that parallel the slope; tracts of vegetation have moved short distances downslope, exposing bare soil. This 40.5-degree slope stands about 55 feet high, and an unlined canal is only 17 feet from the southern portion of this slope (fig. 2). In addition, Roy Dixon reported that flood waters from Cottonwood Canyon occasionally flow into the pit over this slope. Added moisture, whether through precipitation, canal seepage, or surface runoff, could create a reduction in the internal strength of this slope, which already appears to be in an unstable state. Should a landslide of similar magnitude to the recent earth flow form on this west-facing slope, the Hoytsville Road, 27 feet behind the borrow pit, and residential areas across the road would be impacted.

RECOMMENDATIONS

The two principal factors responsible for the slope failure are believed to be the addition of water to the slope through irrigation, and the extreme height and steepness of the slope. To ensure stability of existing slopes, these factors must be controlled. A reduction in flood irrigation with lining of canals, or a change to sprinkler irrigation, with care taken to avoid watering near the earth flow, will reduce the amount of water added to the slope. This course of action has thus far been successful in halting enlargement and reappearance of collapse pits in the field above the 1969 landslide. Grading of the earth flow, especially near the main scarp, will reduce the potential hazard from soil block failures. A maximum stable slope angle for these materials is about 2:1 (26 degrees). To fully evaluate the stability of borrow pit slopes, potential for future landslides, and measures needed to ensure stable slopes, a thorough soils and slope stability investigation by a qualified geotechnical firm would be required.

CITED REFERENCES

Klauk, R.H., and Harty, K.M., 1988, Sinkhole and landslide investigation in Summit County, Utah, in Black, B.D., (comp.), Technical Reports for 1987, Site Investigation Section: Utah Geological and Mineral Survey Report of Investigation 216, p. 99-103.

Zaruba, Q., and Mencle, V., 1969, Landslides and their control: Elsevier, Amsterdam, 205 p.

Project: Freeze Canyon debris flood, Salt Lake County, Utah			Requesting Agency: Utah Division of Comprehensive Emergency Management
By: Kimm M. Harty	Date: 6-14-89	County: Salt Lake	Job No.: (GH-5) 89-09
USGS Quadrangle: Mountain Dell (1252)		Ft. Douglas (1253)	

On Monday, June 12, 1989, an interdisciplinary team of specialists (table 1) visited the site of a debris flood in a tributary of Emigration Canyon, Salt Lake County, Utah. The purpose of the visit was to observe the relationship between a burned area and the flood, and the effectiveness of flood control structures placed immediately after the fire. Two hazard mitigation plans concerning the relationship between forest fires and flash floods are currently being prepared for other areas of Utah by Fred May of the Utah Division of Comprehensive Emergency Management who coordinated this effort, and organized this survey team to lend some insight into hazard mitigation in Emigration Canyon. A second visit to the canyon was made on June 16, 1989, with Gary Christenson of the Utah Geological and Mineral Survey, to investigate the source area of the flood.

In early September, 1988, a wildfire burned over 5600 acres of woodland in a portion of Emigration Canyon (Nelson and Rasely, 1989) (fig. 1). The fire burned approximately 90 percent of Freeze Canyon, and 80 percent of the adjacent Brigham Fork watershed. These areas experienced a damaging flood nine months later, on the evening of June 9, 1989, as a result of an intense thunderstorm. More than 1 inch of water fell over these small watersheds between 9:30 and 11:30 p.m. Hydrologists from the U.S. Soil Conservation Service estimate that floodwaters seven-feet deep surged down Freeze Canyon toward Emigration Canyon and residences below. No lives were lost, but damage in residential areas included flooding and sediment deposition in yards, basements, garages, driveways, and access roads. Other damage included culvert wash-outs and blockages, undercutting and partial collapse of roads by stream erosion, and shearing of underground utility lines.

Although flooding occurred in Brigham Fork as well as Freeze Canyon, only the latter was visited. In the middle portion of the canyon, grasses, small herbaceous plants, and some small (< 6 inches high) woody-stemmed plants such as chokecherry have re-established since the fire. Tall trees still stand, but many are dead with very little forest canopy.

Freeze Canyon has an east and west fork in the headwaters area, and the confluence is at approximately 6400 feet elevation. Farther downstream, at about 6200 feet elevation, the channel gradient becomes more gentle and the canyon widens (fig. 2). The lower portion of Freeze Canyon is underlain by the Cretaceous Kelvin Formation, consisting of reddish sandstone and pale-gray limestone (Van Horn and Crittenden, 1987). Most of middle portion of the canyon is underlain by Jurassic-age Twin Creek Limestone which is predominantly gray colored. The upper part of the canyon, above the confluence of the two

Table 1. Emigration Canyon Flash Flood Hazard Mitigation Survey Team, June 12, 1989.

Fred May, Hazard Mitigation Planner
Utah Division of Comprehensive Emergency Management

Dave Dalrymple, Wildfire Suppression Specialist
Utah Division of State Lands and Forestry

Kimm Harty, Hazards Geologist
Utah Geological and Mineral Survey

Frank Roberts, P.E.
Utah Division of State Parks and Recreation

Michael Treshow, Ph.D., Botanist, Professor
University of Utah, Biology Department

Alex Morris, Resource Coordinator
Salt Lake Soil Conservation Service

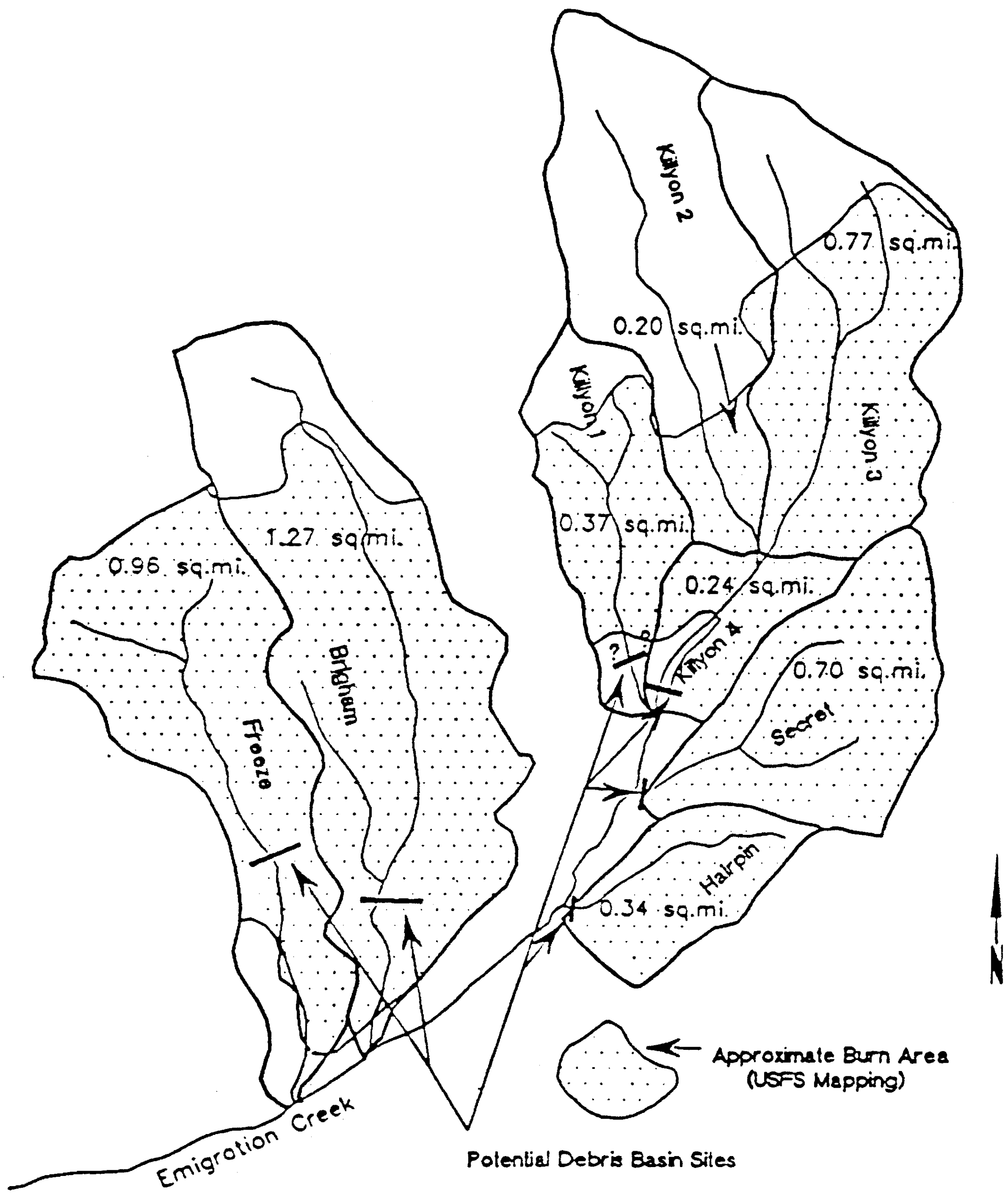
Greg Smith, Hydrologist and Meteorologist
National Weather Service
Colorado River Basin Forecast Center

Scott Williams, Flood Mitigation Planner
Davis County Public Works and Flood Control

Mike Lowe, County Geologist
Davis County Public Works and Flood Control

Ken Short, P.E.
Utah Division of Water Resources

Job No. 89-09
(GH-5)



Compiled by: Craig Nelson (S.L.County) and Bob Rasely (S.C.S.)

Figure 1. Major watershed burned areas, 1988 Emigration Canyon fire (Nelson and Rasely, 1988).

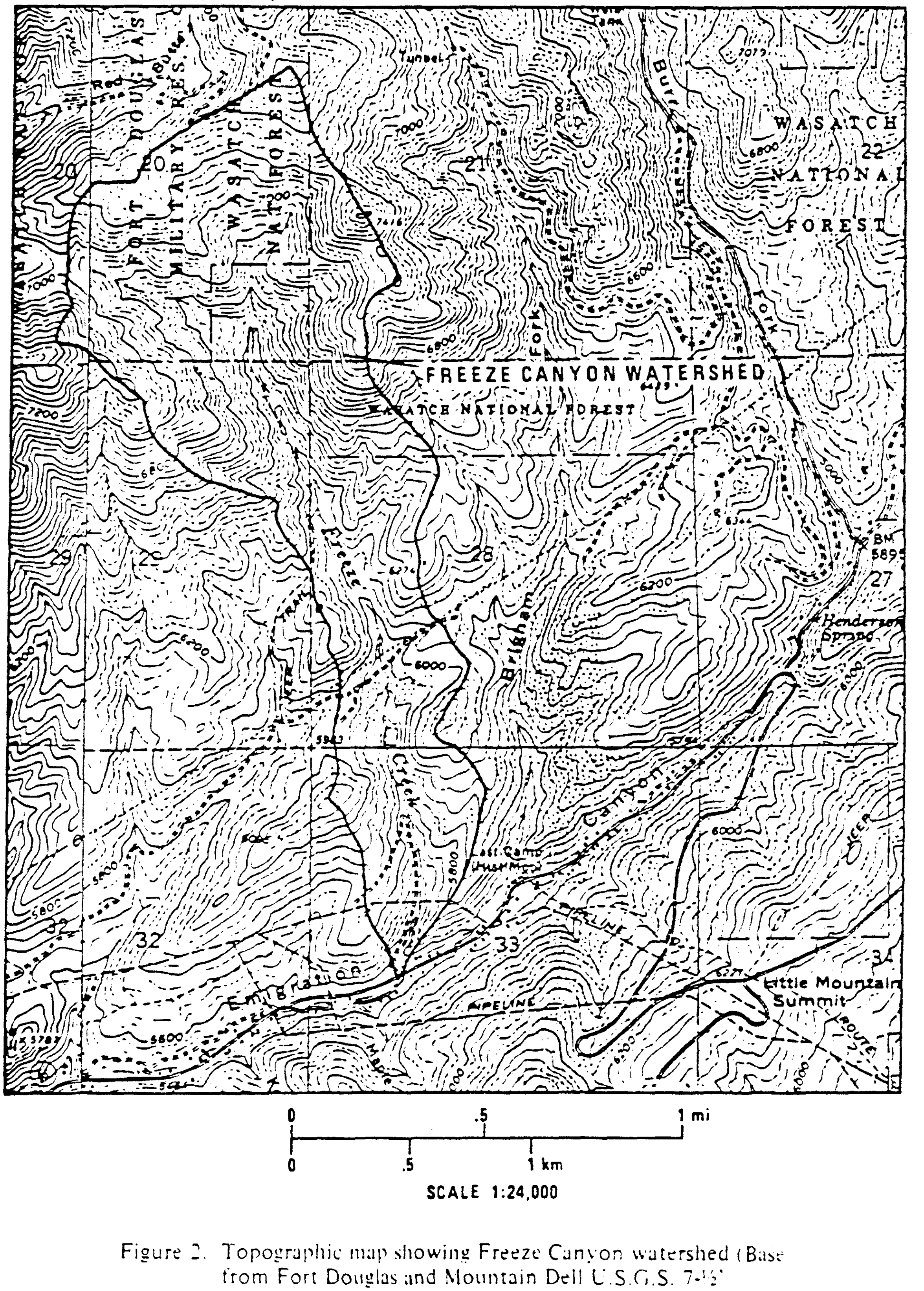


Figure 2. Topographic map showing Freeze Canyon watershed (Base from Fort Douglas and Mountain Dell U.S.G.S. 7-½' topographic quadrangles).

drainage channels is underlain by pink to light orange-colored Nugget Sandstone.

Recognizing the potential for flooding and erosion on the denuded watershed, the U.S. Soil Conservation Service working with Salt Lake County installed about five gabion structures and numerous short wire fences in the channel of Freeze Creek within 30 days after the September wildfire. These structures are designed to alter the channel gradient, causing deposition of sediment, and to retard floodwater velocity, thereby reducing the potential for catastrophic flooding. Field observations showed that many of the fences, although heavily damaged during the flood, were effective in trapping debris, including cobble to boulder-sized rocks, that otherwise could have washed farther downstream toward residential areas.

Examination of the confluence area of Freeze Creek showed that flood damage (channel erosion and overbank flooding) was more severe in the east than in the west fork. The head of the east fork is a bowl-shaped amphitheater with severe fire damage to vegetation. Just downstream from this amphitheater is a relatively unburned area along the bottom of the drainage. The head of the east fork is mantled by a deep, loose, friable organic soil. Before the fire, this area had supported mostly shrubs and grass, with trees only at the bottom of the hollow along the channel. With little post-fire vegetation remaining to retard overland flow, the amphitheater funneled runoff into the narrow channel, causing floodwaters to rise quickly. Most of the coarse debris (cobbles, boulders) entrained by floodwaters was scoured from the channel below this area. Floodwater and finer-grained debris were also contributed from other hillsides and small ephemeral drainages and gullies in middle Freeze Canyon as evidenced by channel scour and hillside rilling and erosion.

Much of the larger material transported in the channel was deposited in the middle and lower reaches of the watershed, where the channel gradient decreases, and flood-control structures were emplaced. Damage to downstream residences could have been greater had not the gabions and fences been installed in Freeze Creek. The floodwaters that damaged residences in lower Freeze and Emigration Canyons carried finer sediment such as silt, sand, and gravel which was deposited in basements and garages of homes and buildings near the mouth of Freeze Creek. U.S. Soil Conservation hydrologists estimate the depth of the floodwaters could have reached at least 14 feet instead of 7 feet had not the flood control structures been emplaced (R.C. Rasely, U.S.S.C.S Geologist, oral commun., June 13, 1989).

At present, the head region of the watershed is subject to continued erosion and possible flooding. The lower and middle portions of the stream bed of Freeze and Brigham Fork Creeks now contain sediment and debris deposited behind flood-control structures. In the event of another severe flood, this material could become entrained in a debris flood or flow and again cause damage in downstream areas. Re-establishment of the vegetation to a pre-fire state, especially at the head of the watershed, and/or repair of some of the flood-control structures would help lessen the impact of such an event.

CITED REFERENCES

Nelson, C.V., and Rasely, R.C., 1988, Affleck Park fire sediment yield analysis: Salt Lake County Public Works Department unpublished memorandum, 5 p.

Nelson, C.V., and Rasely, R.C., 1989, Evaluating the debris flow potential after a wildfire; rapid response using the PSIAC method, Salt Lake County, Utah: Geological Society of America Abstracts with Programs, v. 21, no. 5, p. 121.

Van Horn, Richard, and Crittenden, M.D., Jr., 1987, Map showing surficial units and bedrock geology of the Fort Douglas Quadrangle and parts of the Mountain Dell and Salt Lake City North Quadrangles, Davis, Salt Lake, and Morgan Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1762, Scale 1:24,000.

Project:			Requesting Agency:
Field Reconnaissance of the effects of the July 31, 1989 storm and flood on Cedar City and the Cedar Canyon Landslide, Iron County, Utah.			Utah Division of Comprehensive Emergency Management
By: Kimm M. Harty	Date: 8-17-90	County: Iron County	Job No.: (GH-6) 89-12
USGS Quadrangle: Cedar City (238)			

INTRODUCTION

On August 3, 1989, the Utah Geological and Mineral Survey (UGMS) investigated the northern portion of Cedar City which was impacted by a flood on July 31, four days earlier. The purpose of the investigation was to document the nature and extent of the flooding, and to provide the Utah Division of Comprehensive Emergency Management (CEM) with information to aid their investigation of the flood. We also visited the site of the March 27, 1989 Cedar Canyon landslide, to observe the current state of the slide, and to assess whether the recent rainfall and flooding had affected the landslide. Suzanne Hecker of the UGMS was present during the field reconnaissance, and contact was made with John R. Williams of the Iron County Sheriff's Office in Cedar City.

THE CEDAR CITY FLOOD

Approximately 0.75 inches of water fell in 30 minutes in an intense thunderstorm that moved rapidly through the northern part of Cedar City on Monday afternoon, July 31, 1989. A resulting flash flood caused damage primarily to residences, vehicles, and property in several subdivisions. No lives were lost, but floodwaters filled basements; deposited mud and debris in streets, yards, and fields; and damaged automobiles parked on city streets. The floodwaters that impacted residences came primarily from two unnamed ephemeral stream channels that drain west from the Hurricane Cliffs. For this report, the channels are designated "A" and "B", and are shown in figure 1 along with the approximate area that experienced the worst flooding (sections 35 and 36 of T. 35 S., R. 11 W., Salt Lake Baseline and Meridian). New residential development has occurred at the base of the Hurricane Cliffs between White Mountain on the south and the unpaved road leading up Fiddlers Canyon on the north (fig. 1). Development has modified the drainages of channels A and B, and channel A was in part paved for a subdivision road. Channel B is now blocked by a debris basin (fig. 1).

Although the flooding caused damage to many homes, much floodwater was channeled along the streets away from homes. The effects of the flood were particularly evident in areas downstream from the point where channel A floodwaters met those of channel B. This occurred at the approximate location of the midpoint of the section line between sections 35 and 36. Numerous partially buried automobiles were observed downstream, to the southwest of this area.

Examination of the debris basin constructed on channel B indicated that the volume of water entering the basin exceeded its capacity, such that floodwaters flowed through the spillway at the northeast end of the basin's embankment. Floodwaters did not appear to overtop the embankment in any other area. Water exiting the spillway appeared to flow west onto subdivision properties and open fields, and southwest along the upper road of the subdivision. On August 3, the debris basin was still filled with water to about the spillway elevation. A large, fresh-looking debris-slide scar is visible on the cliff above channel B (fig. 1), and the slide may have occurred during the rainstorm. It was not investigated during the reconnaissance, and due to the large amount of water in the basin, it is not known if any material from this slide entered the basin.

John R. Williams (oral commun., Aug. 3, 1989) indicated that only minor flooding and little damage occurred to the north or south of the area depicted in figure 1. Mr. Williams reported that Coal Creek, the stream that drains Cedar Canyon about 3 miles to the south, did not overflow its channel although it reached bankfull stage. Field inspection of the main and distributary channels of Fiddlers Creek showed that floodwaters generally remained within their banks. However, evidence for overland flow from direct precipitation on the surface of the alluvial fan was observed. No structures except a farm house were on the alluvial fan in the vicinity of the main channel of Fiddlers Canyon. A debris basin that receives flow from Fiddlers Canyon (sections 26 and 35, fig. 1) via two underground pipes showed evidence of recent use in the form of ponded water and flattened grass in areas immediately upstream. The debris basin contained only a small volume of water. However, it is not known what percentage of the runoff from Fiddlers Canyon was channeled to the basin.

THE CEDAR CANYON LANDSLIDE

After the investigation of the flooding in northern Cedar City, we visited the site of the March 27, 1989 Cedar Canyon landslide. Since the initial visit by the UGMS on March 28th (see Harty and Christenson, 1989 for detailed information), the Utah Department of Transportation (UDOT) established survey points on the slide to measure movement, and a temporary road was paved across the slide and opened to traffic on May 1, 1989. According to Scott Munson (UDOT-Cedar City, oral commun., Aug. 8, 1989), the landslide has not shown evidence of movement since its initial failure. Coal Creek now flows virtually unobstructed near the toe area of the slide at the bottom of Cedar Canyon, whereas in March, it was partially obstructed and formed a series of small ponds. Visual inspection of the road crossing the slide revealed no indications of movement resulting from the recent rainstorm. However, a tension crack about 15-20 feet in length was discovered atop the graded north (outer) shoulder of the road, near the middle of the landslide. The crack travels oblique to the road and disappears into the roadbed. The crack has a horizontal displacement of approximately one inch, and a maximum vertical displacement of between one half to one inch where the crack meets the road. Subsidence features or small "sinkholes", some more than one foot deep, are aligned along the crack.

The crack appeared to have formed recently, an assessment supported by Scott Munson (oral commun., Aug. 8, 1989). The formation of tension cracks is usually a sign of slope instability, and is often the first warning sign of an impending slope failure. Should a failure occur along the tension crack, it is likely that the road would be damaged. It would be wise to monitor the crack regularly for signs of additional widening or downslope movement, and to devise a method for warning motorists of possible road damage in the area.

REFERENCE CITED

Harty, K.M., and Christenson, G.E., 1989, Cedar Canyon landslide reconnaissance, Iron County, Utah: Utah Geological and Mineral Survey unpublished report, 7 p.

Job No.89-12(GH-6)

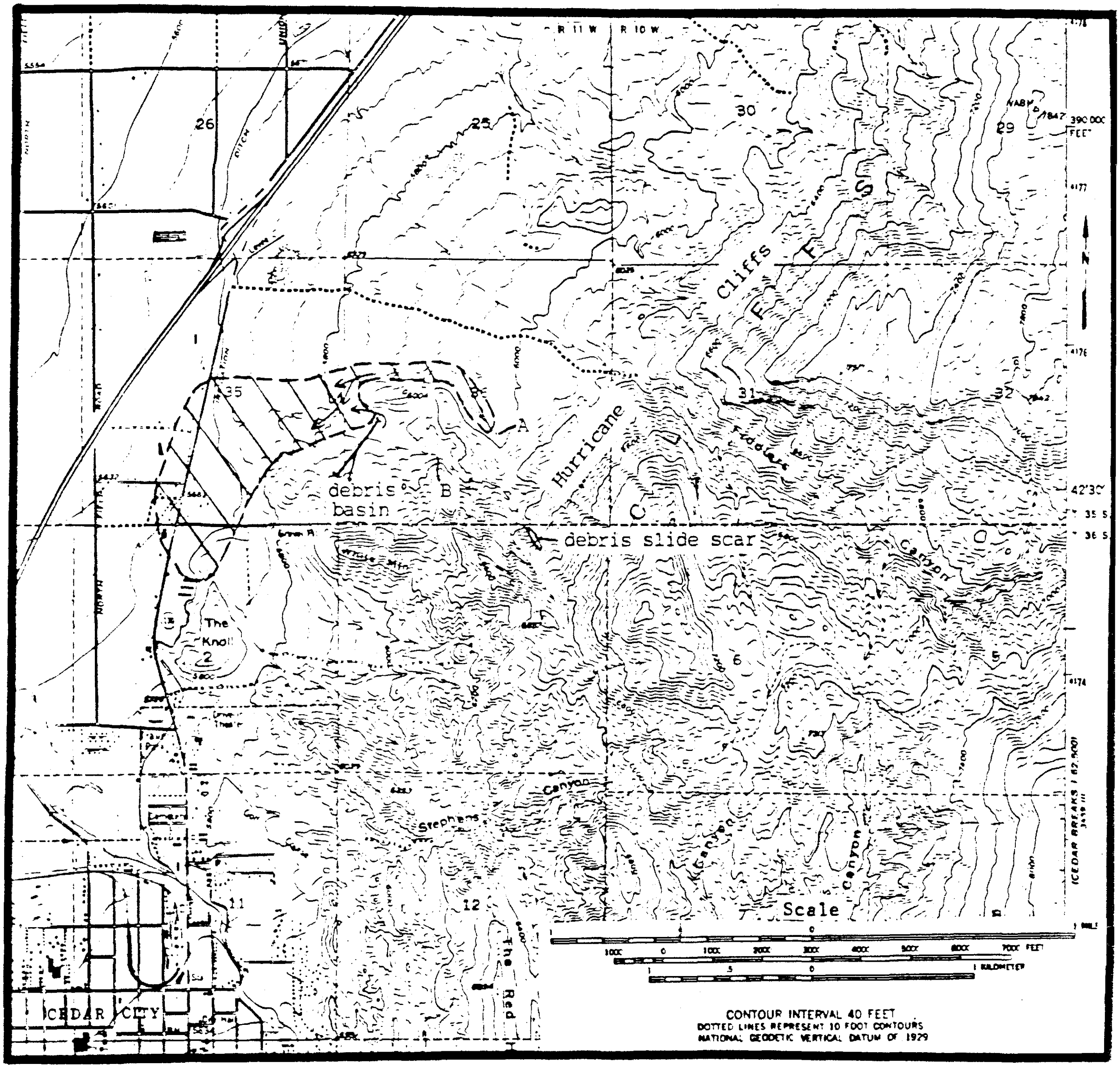


Figure 1. Location map showing approximate boundary (hachured pattern) of the July 31, 1989 northern Cedar City flood. Arrows indicate direction of flow from channels A and B.

Project: Geology, Geologic Hazards, And Recommendations For Land-Use Planning, Marriott-Slaterville Area Master Plan, Weber County, Utah			Requesting Agency: Weber County Planning Dept.
By: Mike Lowe	Date: 11/2/89	County: Weber	Job No.: (GH-7) 89-15
USGS Quadrangle: North Ogden (1370), Plain City (1371), Ogden (1345), and Roy (1346)			

INTRODUCTION

The purpose of this report, requested by Ed Reed (Weber County Planning Department), is to provide information concerning the geology and geologic hazards of the Marriott-Slaterville area of Weber County, Utah, to be incorporated into their master plan. The Marriott-Slaterville area is located in unincorporated Weber County immediately west of Ogden (figure 1). The scope of work consisted chiefly of a literature review and report preparation. Geologic investigations and map compilation were completed during my tenure as Weber County Geologist from 1985-1988, and that information has been excerpted and included in this report.

GENERAL GEOLOGY

Introduction

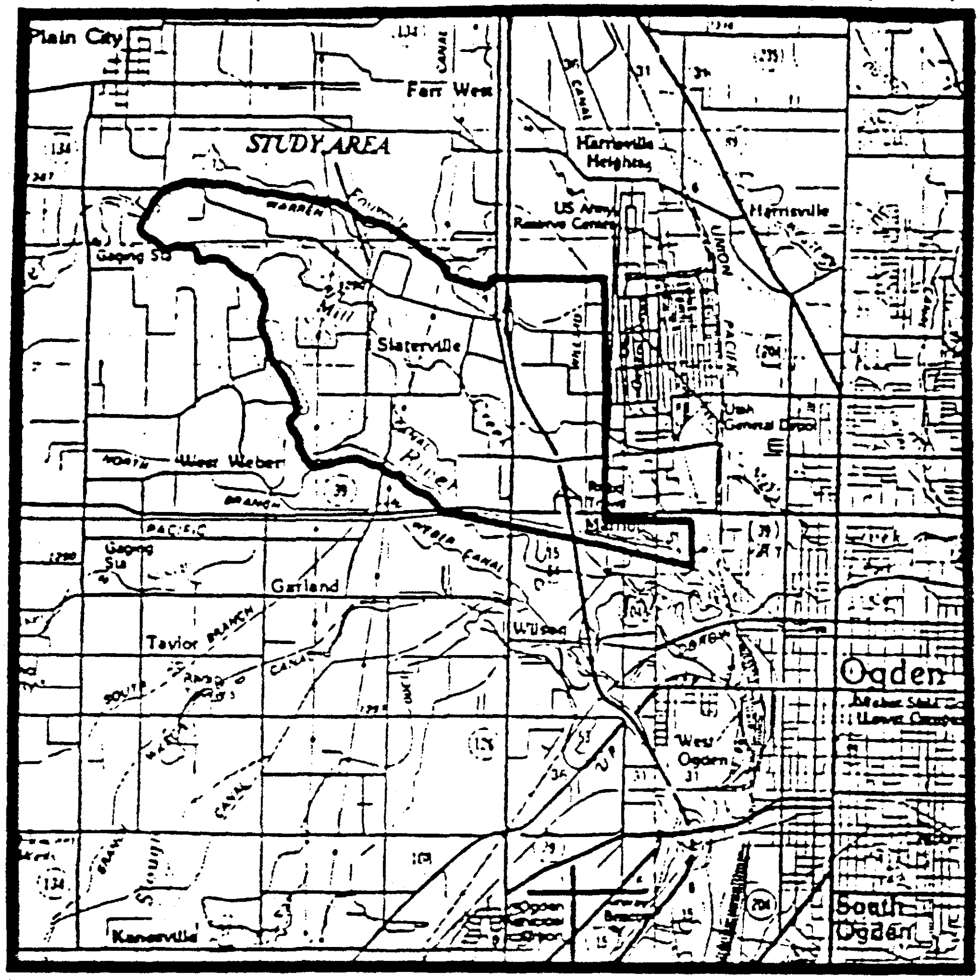
The Marriott-Slaterville area is located in the Ogden Valley Segment of the Wasatch Front Valleys Section of the Basin and Range Physiographic Province (Stokes, 1977). The Ogden Valley Segment is a north-south trending structural trough which has been the site of accumulation of great thicknesses of sediment since the advent of Basin and Range normal faulting approximately 15 million years ago (Hintze, 1988). The Wasatch Range and the west-dipping Wasatch fault bound the trough to the east, and geophysical data indicates that Little Mountain may be part of a horst which bounds the trough to the west (Feth and others, 1966). The sediments filling the trough are predominantly of fluvial, lacustrine, and deltaic origin. Geophysical data indicates that, in some areas, these sediments may be as much as 6,000 to 9,000 feet thick (Feth and others, 1966).

Quaternary Geologic History

The Marriott-Slaterville area is located in a closed hydrologic basin, called the Lake Bonneville basin, and water flowing into this basin generally leaves only by evapotranspiration. The Lake Bonneville basin has been an area of internal drainage for much of the last 15 million years, and lakes of varying sizes likely existed in the area during all or most of that time (Currey and others, 1984). Figure 2 is a schematic

Job No. 89-15(GH-7

Base Map from OGDEN and PROMONTORY POINT
U.S.G.S. 1:100,000 topographic maps.

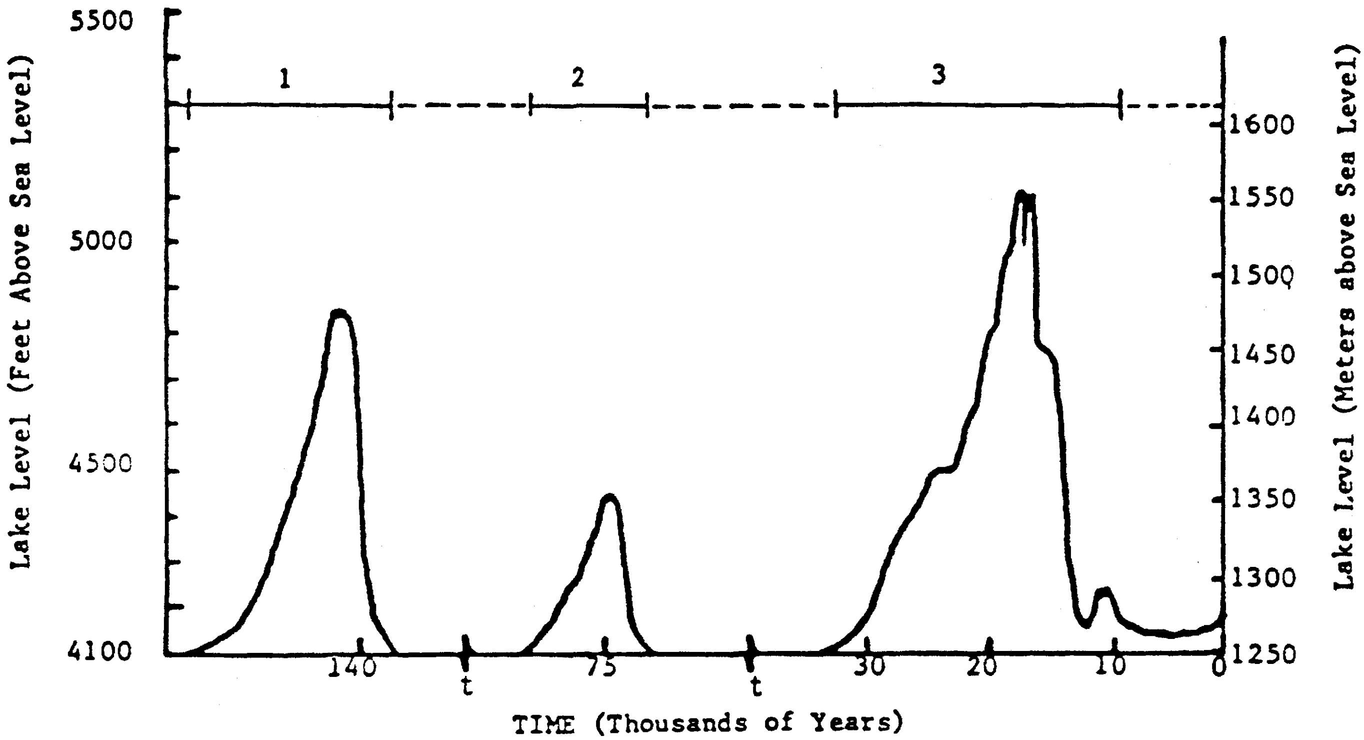


SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS

KILOMETERS 1 0 1 2 3 4 5 6 7 8
MILES 1 0 1 2 3 4 5

N

Figure 1. Location map of Marriott-Slaterville showing study area.



Explanation

1 - Little Valley lake cycle.
2 - Cutler Dam lake cycle.
3 - Bonneville lake cycle.
t - Splice point on graph. Periods of time during interlacustrine phases have been removed to condense graph.

Figure 2. Schematic diagram showing a hydrograph of probable lake levels in the Lake Bonneville basin for the past 150,000 years. Numbered solid lines above lake level curves represent time periods of lake cycles described in this report. Dashed lines represent interlacustrine periods when lakes in the Lake Bonneville basin stood at relatively low levels or were nonexistent. (Hydrograph modified from Currey and Oviatt, 1985, and extended past 35,000 years before present on the basis of recent statigraphic studies of pre-Lake Bonneville deposits by Machette and others, 1986, with additional modifications for this report).

diagram showing the approximate time periods of, and the approximate elevations reached, during the last three lake cycles in the Lake Bonneville basin.

The first lake cycle shown on figure 2, which inundated the Marriott-Slaterville area, is called the Little Valley lake cycle. This lake cycle occurred sometime between about 150,000 years ago and 90,000 years ago and rose to a level of at least 4,983 feet in elevation (Scott and others, 1983). It is likely that during the Little Valley lake cycle, the Marriott-Slaterville area was the site of accumulation of sediments deposited into the lake by the Weber River, and that part of the sediment mass below the ground surface is made up of sediments of this age. No sediments of Little Valley lake cycle age, however, are exposed at the surface to verify this.

The next to the last lake cycle in the Lake Bonneville basin, the Cutler Dam lake cycle, occurred sometime around 75,000 years ago and rose to an elevation of at least 4,400 feet in elevation (Oviatt and others, 1985). Work on this lake cycle is in preliminary stages, but is likely that the Marriott-Slaterville area was inundated during the Cutler Dam lake cycle and that lacustrine sediments of this age are found beneath the present-day ground surface.

In the latter part of Pleistocene time, from about 32,000 years before present to about 10,000 years before present, a lake with a maximum depth of at least 1,000 feet covered an area of about 20,000 square miles in what is now northwestern Utah, northeastern Nevada, and southeastern Idaho (Currey and others, 1984). This lake was named Lake Bonneville, and the period of time occupied by the rise and fall of this lake is called the Bonneville lake cycle (Scott and others, 1983). Many of the landforms found in Weber County are the result of erosion and deposition during Lake Bonneville time, including the Bonneville Shoreline (approximately 5,200 feet in elevation), the Provo Shoreline (approximately 4,800 feet in elevation,) and deltas graded to the Provo Shoreline at the mouth of Ogden Canyon and Weber Canyon. Figure 3 is a hydrograph of Lake Bonneville which illustrates the terminology used in describing Quaternary deposits and Bonneville lake-cycle events in this report.

At the end of the Bonneville lake cycle, water levels receded to those of Great Salt Lake. Geologic evidence indicates that Great Salt Lake reached a post-Gilbert Shoreline high of approximately 4,221 feet about 2,000 years before present (Murchison, 1989). Archeological evidence indicates that Great Salt Lake reached an elevation of approximately 4,217 feet sometime during the 1600s (Utah Division of Comprehensive Emergency Management, 1985). Above average precipitation during the recent wet cycle caused the Great Salt Lake to reach a historical high of 4,211.85 feet in June of 1986 and April of 1987 (U. S. Geological Survey records).

During the last 10,000 years (post-Lake Bonneville time), fluvial erosion and deposition have been the dominant geologic processes in the Marriott-Slaterville area. Fluvial sands and gravels were deposited over Lake Bonneville sediments by the Weber River, Mill Creek, and Fourmile Creek.

1- Bonneville lake cycle transgressive phase.
2- Bonneville lake cycle regressive phase.
3- Stansbury deposits.
4- Bonneville deposits.
5- Provo deposits.
6- Gilbert deposits.
7- Stansbury Shoreline stage.
8- Bonneville Shoreline stage.
9- Provo Shoreline stage.
10- Gilbert Shoreline stage.

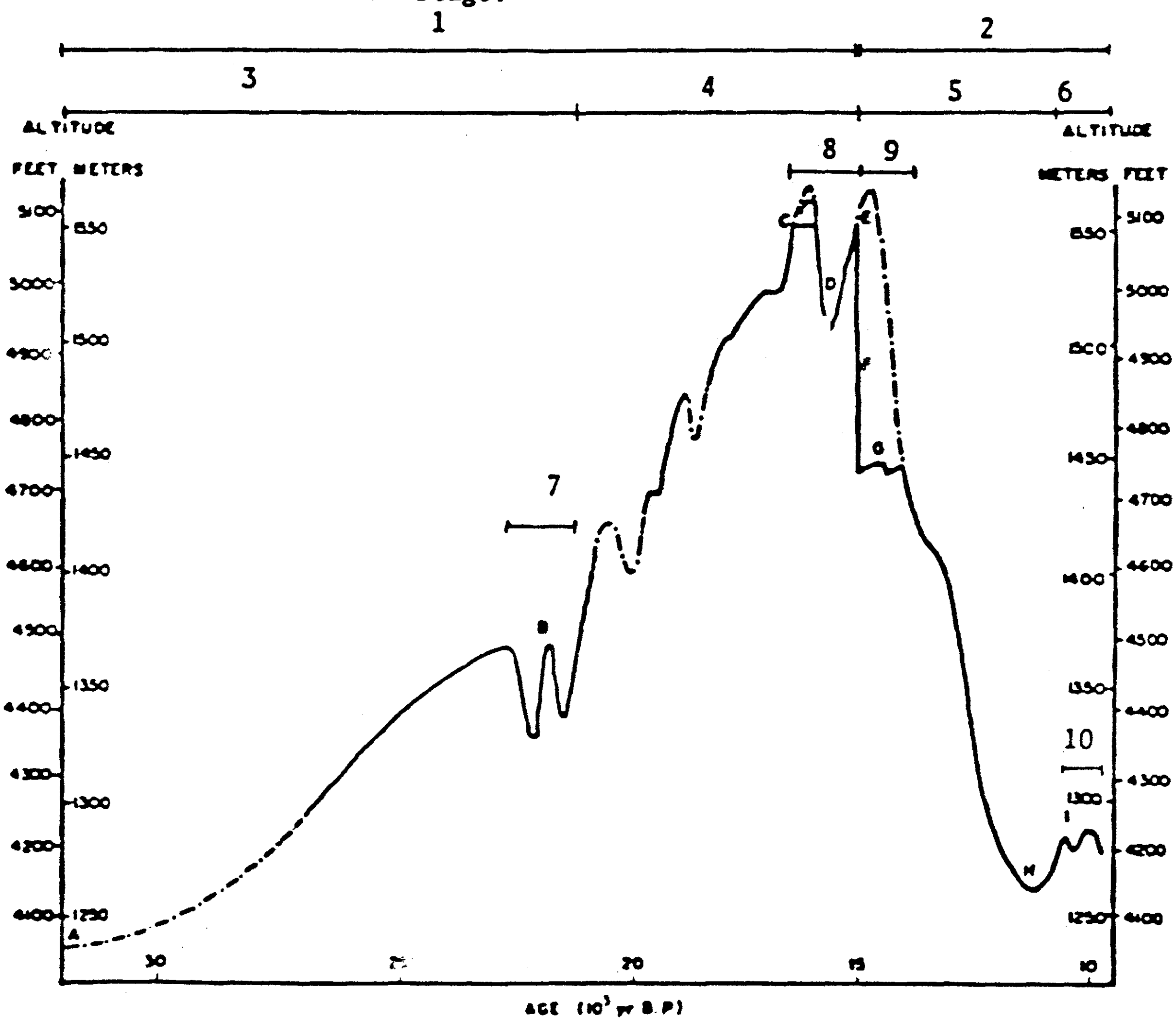


Figure 3. Hydrograph of Lake Bonneville (adapted from Currey and Oviatt, 1985). Numbers show time periods of terminology, and letters show time and altitude of events discussed in this report.

Surficial Geology

Figure 4 is a geologic map of Marriott-Slaterville area, Weber County. This map is from a 1:100,000 scale map by Davis (1985). Surficial deposits in the Marriott-Slaterville area include two types: Bonneville lake-cycle offshore lacustrine sediment (primarily Provo deposits), and post-Lake Bonneville fluvial sediments.

The oldest sediments exposed in the Marriott-Slaterville study area are Bonneville lake-cycle offshore deposits (figure 4, Qlop and Qlob). These are predominately silt, clay, and sand which settled to the lake bottom in offshore quiet water. These offshore deposits are well stratified and sorted. At the ground surface in most areas these offshore sediments were deposited when the lake was at the Provo Shoreline level, but at depth were deposited when the lake was at the Bonneville Shoreline level. Bonneville-level offshore deposits occur at the ground surface south of the Mill Creek Youth Center.

Post-Lake Bonneville fluvial deposits (figure 3, Qfp) are found along the drainages of Mill Creek, Fourmile Creek, and the Weber River. These sediments consist primarily of sands and gravels deposited in the stream channels, and silt and clay overbank sediments deposited during flood stages. These drainages have eroded into and deposited fluvial sediments over the Bonneville lake-cycle offshore deposits.

GEOLOGIC HAZARDS

Introduction

Potential geologic hazards in the Wasatch Front area include earthquake hazards (ground shaking, surface fault rupture, tectonic subsidence, liquefaction, seismically-induced slope failure and/or flooding), slope failures, problem soils, flooding, and shallow ground water. This report presents a preliminary evaluation of potential geologic hazards affecting the Marriott-Slaterville area and identifies areas in which site-specific studies should be completed prior to development.

Earthquake Hazards

The study area is in an active earthquake zone called the Intermountain seismic belt which extends from northwestern Montana to southwestern Utah (Smith and Sbar, 1974). In the Weber County area, the largest magnitude earthquake during historical time occurred in 1914 near Ogden and was an estimated Richter magnitude 5.5 (Arabasz and others, 1979). Numerous smaller earthquakes have occurred in the Weber County area within the last 120 years. Many of these earthquakes cannot be attributed to known active faults, although faults capable of generating earthquakes are present in the area. The Wasatch fault, which trends north-south along the mountain front east of the Marriott-Slaterville area, is the one of most concern because of its recency of movement, potential for generating large earthquakes, and proximity to the study area. It consists of a zone of faults and crustal deformation, sometimes

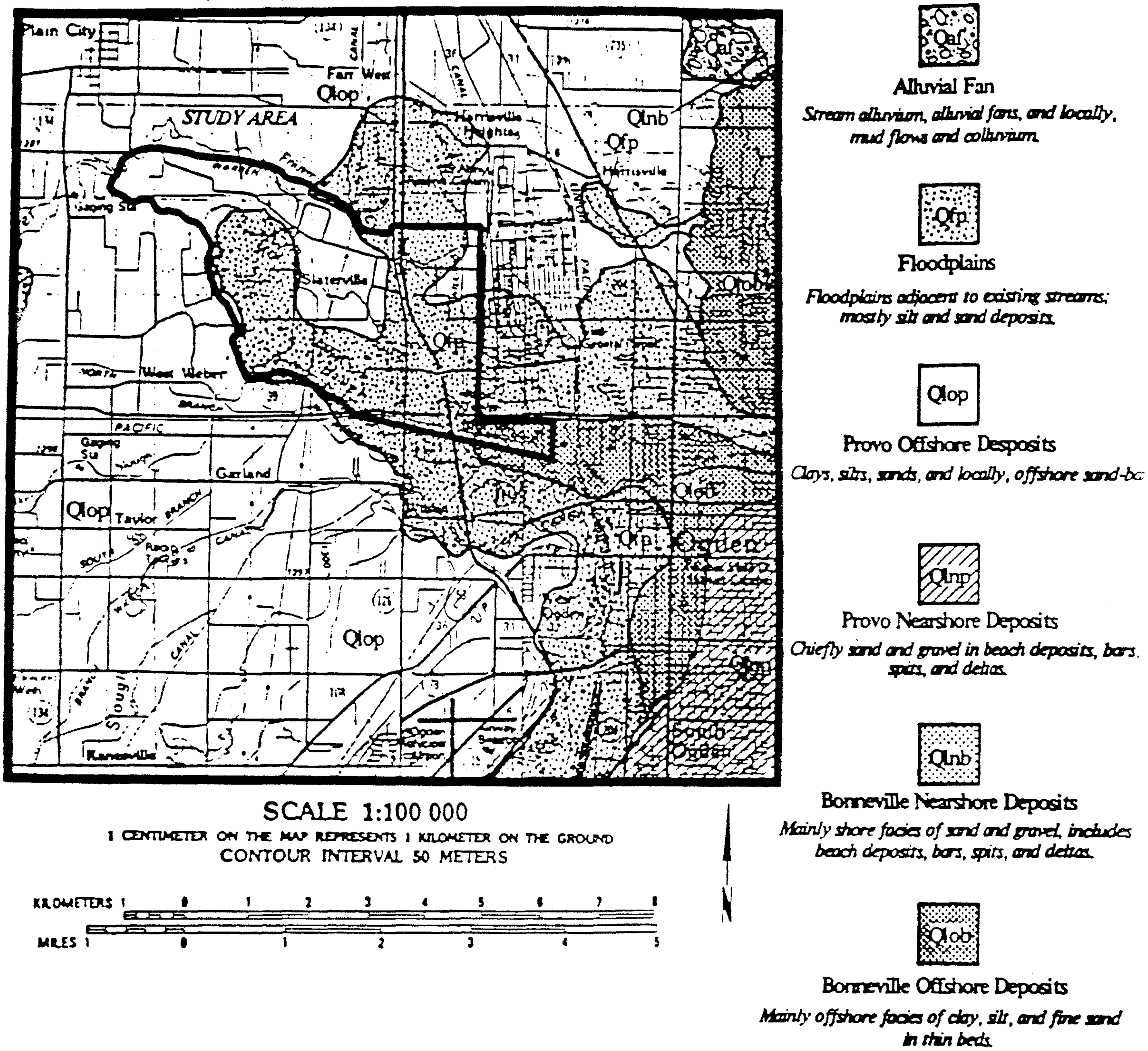


Figure 4. Geology of the Marriott-Slaterville area (modified from Davis, 1985).

as much as several thousand feet wide, and is considered capable of generating earthquakes up to magnitude 7.0-7.5 (Schwartz and Coppersmith, 1984). Other fault zones, such as the Hansel Valley or East Cache fault zones, are capable of generating earthquakes which could cause ground shaking damage in the Marriott-Slaterville area.

Ground Shaking

Ground shaking is the most widespread and frequently occurring earthquake hazard and is responsible for the majority of earthquake-caused damage. The extent of property damage and loss of life in an earthquake due to ground shaking are determined by several factors including: 1) strength of seismic waves reaching the surface (horizontal accelerations are the most damaging), 2) frequency, amplitude, and duration of ground shaking, 3) proximity to fault zones or epicenters, 4) foundation materials, and 5) building design (Costa and Baker, 1981). Foundation materials are important because ground shaking can be amplified by local site conditions, and the site response is influenced by the nature and thickness of underlying unconsolidated deposits (Hays and King, 1982).

The severity of ground shaking is chiefly dependent on the magnitude of the earthquake. Based on expected shaking levels at bedrock sites, the Uniform Building Code (UBC) places the Marriott-Slaterville area in seismic zone 3 and gives minimum specifications for earthquake-resistant design and construction. The Utah Seismic Safety Advisory Council (USSAC) places the Marriott-Slaterville area in seismic zone U-4 and recommends application of UBC zone 3 specifications with more stringent review and inspection to insure compliance.

Both the UBC and USSAC seismic zonations are based on expected ground shaking in bedrock. It is important to understand that when the fundamental mode of response of a building has the same period as the seismic waves, the potential for high damage levels increases. Short period waves (0.1-0.2 seconds) are most destructive to 1-2 story buildings, whereas waves with 0.2-0.7 second periods are most destructive to 3-7 story buildings. Longer period waves may cause damage to taller buildings with relatively little effect on other structures. Figure 5 shows ground accelerations that are expected to occur along the Wasatch Front, including the Marriott-Slaterville area, for various exposure periods. In the Marriott-Slaterville area, peak horizontal ground accelerations with a 10 percent probability of exceedance in 50 years could be as high as 30 percent the force of gravity. Peak horizontal ground accelerations with a 10 percent probability of exceedance in 250 years could be as high 60 percent the force of gravity in the Marriott-Slaterville area. Maximum Modified Mercalli intensities (table 1) associated with these ground accelerations could be as high as XIII and X, respectively (Bolt, 1978). Donovan (1981) has determined that ground shaking generated by earthquakes with epicenters within a 10-mile radius of the study area could be even greater.

Significant damage due to ground shaking could occur in the Marriott-Slaterville area in the future. It is therefore recommended that all construction conform to Uniform Building Code standards for seismic zone 3 with monitoring by Weber County Building Inspectors as recommended by the Utah Seismic Safety Advisory Council for their seismic zone U-4.

Job No. 89-15
(GH-7)

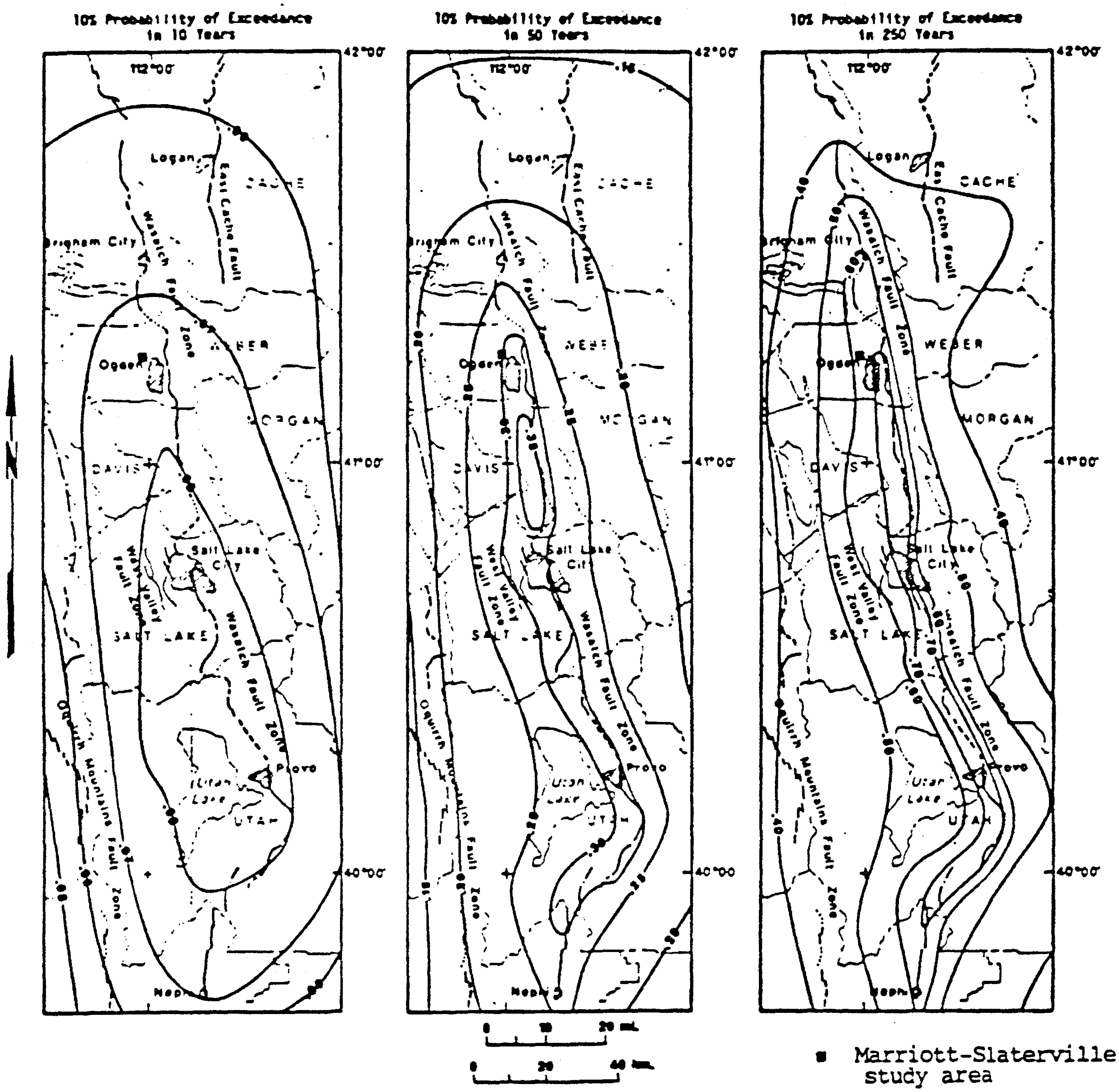


Figure 5. Contours of Peak ground accelerations on soil sites with 10 percent probability of being exceeded in 10 years, 50 years, and 250 years (Youngs and others, 1987)

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building; standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse, great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Table 1. Modified Mercalli intensity scale of 1931 (abridged) (Earthquake Information Bulletin, 1974).

Surface Fault Rupture

Studies along the Wasatch fault zone (Schwartz and Coppersmith, 1984) and elsewhere indicate that the most likely areas for surface fault rupture are along areas of previous (prehistoric) rupture. These areas are identified by mapping fault scarps, and the nearest scarps are along the Weber segment of the Wasatch fault, about 3 1/2 miles east of the study area. There is no evidence of surface fault rupture hazard in the Marriott-Slaterville study area.

Tectonic Subsidence

Large-scale tectonic subsidence may accompany surface faulting during large earthquakes as the downthrown block undergoes regional downdropping and tilting toward the fault (Keaton, 1987). This subsidence may occur over tens of miles from surface faults. Tectonic deformation maps (figure 6) for the Wasatch fault indicate that predicted subsidence due to the "characteristic" Wasatch fault earthquake (Richter magnitude 7.0-7.5) is less than 5 feet in the Marriott-Slaterville area (Keaton, 1987). Tilting of the ground surface to the east may be as much as 0.5 feet/mile, however (Keaton, 1987). These maps also indicate that flooding caused by tectonic subsidence could occur due to ponded shallow ground water in the eastern portion of the Marriott-Slaterville area. Tectonic subsidence is most likely to affect lake shorelines, tall buildings, and gravity-flow systems such as sanitary sewers, storm sewers, and canals.

Liquefaction

Liquefaction is a phenomenon which may occur during earthquakes of magnitude 5.0 and larger (Kuribayashi and Tatsuoka, 1975, 1977; Youd, 1977). Liquefaction occurs when loose, saturated, fine-sand deposits are subjected to earthquake shaking, causing the loss of essentially all shear strength as pressures are rapidly transferred from the granular structure of the soil to pore water (Anderson and others, 1982). Depending on slope, four types of ground failure are commonly associated with liquefaction (Tinsley and others, 1985; Anderson and others, 1982): 1) flow landslides (slopes steeper than about 5.0 percent), 2) lateral spread landslides (slopes between about 0.5 percent and 5.0 percent), 3) ground oscillation (slopes less than about 0.5 percent, liquefaction at depth) and 4) bearing-capacity failures (slopes less than about 0.5 percent, liquefaction at the ground surface). Clays in excess of 15 percent may preclude liquefaction (Anderson and others, 1982), as do confining pressures at depths below about 30 feet (Youd, T. L., oral commun., May 19, 1986).

Liquefaction potential maps by Bay (1987) indicate that the Marriott-Slaterville area is in a high liquefaction potential zone. The "high" rating means that the probability of the earthquake-generated critical acceleration needed to induce liquefaction in susceptible soils has a greater than 50 percent chance of being exceeded during the next 100 years. The ground-surface slope in the Marriott-Slaterville area is generally gentler than 0.5 percent, so ground oscillation and bearing

Base Map from OGDEN and PROMONTORY POINT
U.S G.S. 1:100,000 topographic maps.

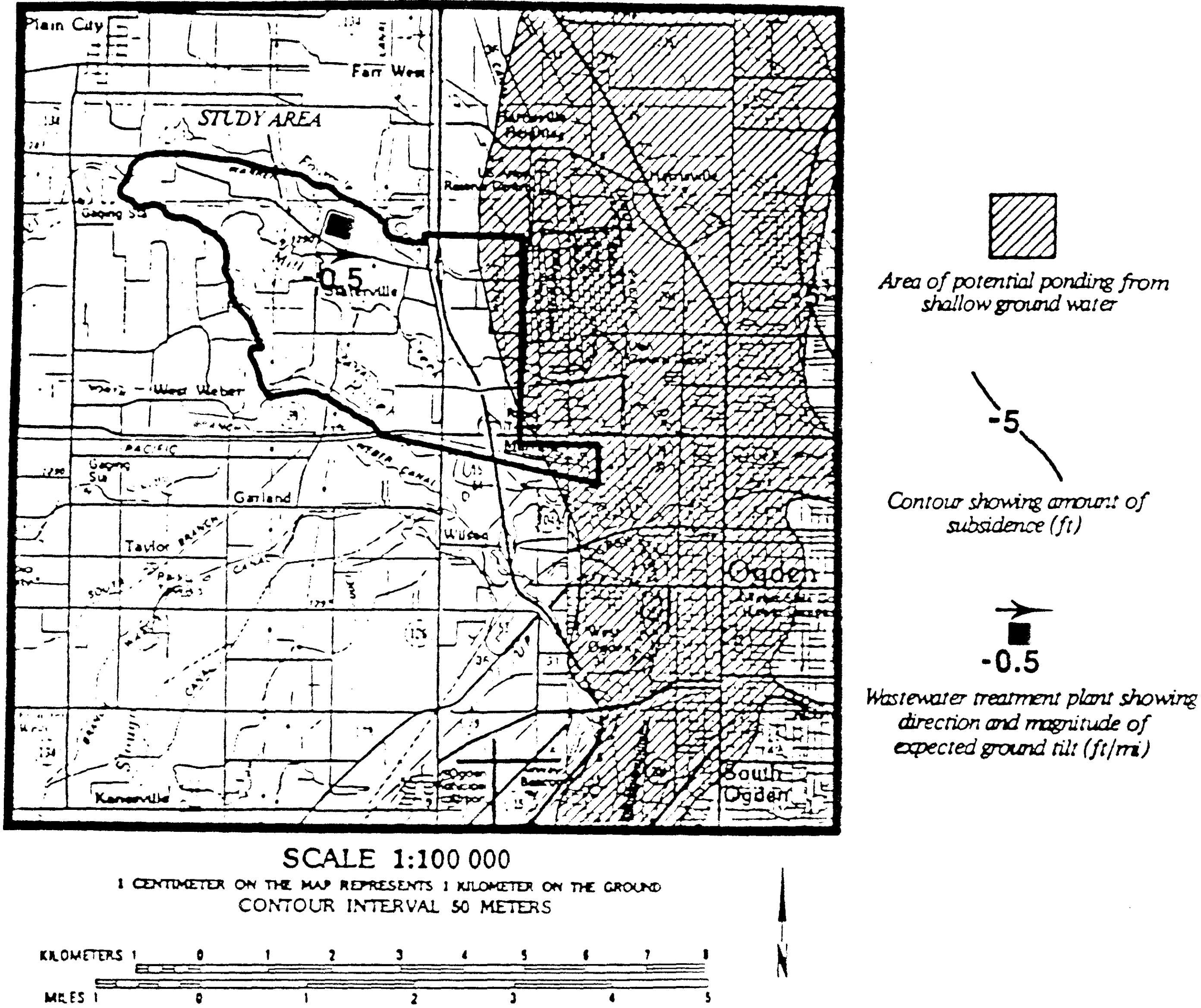


Figure 6. Map showing possible effects of tectonic deformation associated with Weber segment of Wasatch fault zone 'characteristic' earthquakes (modified from Keaton, 1987).

capacity failures are the most likely types of ground failure to accompany liquefaction. Slopes are locally steeper along the banks of streams and the Weber River, and liquefaction-induced lateral spreads and landslides could occur in those areas. Site-specific studies to evaluate the liquefaction potential and, if necessary, recommend mitigative measures, should be performed prior to construction.

Earthquake-Induced Slope Failure And/Or Flooding

Earthquakes of magnitude 4.0 or greater are generally required to induce slope failure (Keefer, 1984). The role of earthquake ground shaking in initiating slope failures is not well understood and no studies assessing seismic slope stability in the Marriott-Slaterville area have been completed. Those slopes most susceptible to non-seismically induced landsliding are most likely to fail during an earthquake, and it is recommended that all slope-stability studies (see next section) include analyses under seismic conditions during both moderate and large earthquakes.

Flooding due to earthquake events may result from dam failure, tectonic subsidence, discharge of ground water, and diversion of surface drainage. Earthquake-induced flooding in the Marriott-Slaterville area is most likely to occur along the Weber River due to dam failure upstream on either the Ogden or Weber River (U. S. Bureau of Reclamation, 1983; Harty and Christenson, 1988), or ponding of shallow ground water due to tectonic subsidence (Keaton, 1987).

Slope Failure

No slope failures have been identified in the Marriott-Slaterville area. Slope failures could occur along drainages where stream erosion has created steep bluffs. Development, where possible, should be set back from those bluffs where slopes are steeper than 2.5 horizontal to 1 vertical. Prudent setback distances can be determined on a site-specific basis by projecting a plane at a 2.5 (horizontal) to 1 (vertical) slope (40 percent) through the center of the steep slopes, and not building closer than where this plane intersects the present ground surface. These setback distances would generally not be large in the Marriott-Slaterville area because the bluffs are not high, and would also serve to protect development from being undermined by stream erosion. Should development within this setback distance be necessary, site-specific slope-stability and erosion-potential studies should be performed prior to approval of the proposed development.

Problem Soils

Potential problem soils include collapsible (hydrocompactable) soils, compressible organic soils, and soils with a high shrink-swell potential. Problems with soils can also occur due to differential compaction when construction occurs on sediments with different characteristics. Erickson and others (1968) mapped the soils in the Marriott-Slaterville area. Soils in the study area mostly have only low to moderate shrink-swell potential, but soils of the Kirkham series also occur and these soils have a high shrink-swell potential (Erickson and others, 1968). Compressible organic soils may occur in areas of former swamps or shallow lakes. Standard soil and foundation investigations should be conducted prior to development so that problem soils may be identified and, if necessary, mitigative measures may be suggested.

Shallow Ground Water

Depth to shallow ground-water maps have not been produced for the Marriott-Slaterville area. Regional maps indicate that depth to ground water may be less than 10 feet, however (Hecker and Harty, 1988). It is likely that perched ground water is present in some areas, especially in the vicinity of the drainages. The presence of shallow ground water and potential problems may be identified and, if necessary, mitigative measures suggested by conducting standard soil and foundation investigations prior to development.

Flooding

Floods are most likely to occur in response to cloudburst storms or rapid spring snowmelt and runoff, with the most serious flooding usually occurring along the Weber River. The primary cause of flooding along the Weber River is rapidly melting snow from late April to early July (Federal Emergency Management Agency, 1982a). The largest snowmelt floods of record on the Weber River occurred in 1896, 1907, 1909, 1920, 1922, and 1952 (Federal Emergency Management Agency, 1982a).

The potential 100-year flood plains in the Marriott-Slaterville area are shown in National Flood Insurance Program Flood Insurance Rate Maps for unincorporated Weber County (Federal Emergency Management Agency, 1982b). Flood hazards in the Marriott-Slaterville area occur principally along the Weber River. Figure 7 is a floodway schematic showing terms associated with the 100-year flood. The 100-year flood is divided into a floodway and a floodway fringe. Development should not be permitted in floodway areas. Development may take place in floodway fringe areas by raising the ground elevation. Care must be taken when allowing development in the floodway fringe because encroachment on floodplains reduces the flood-carrying capacity, increases the flood heights of streams and rivers, and increases flood hazards in areas beyond the encroachment itself (Federal Emergency Management Agency, 1982a). Weber County has adopted the National Flood Insurance Program and Federal Emergency Management Agency guidelines for development in flood hazard areas should be followed.

RECOMMENDATIONS

Geologic hazards affecting the Marriott-Slaterville area have been identified in this report. Potential loss of life and property due to these hazards can be lessened if the proper site-specific studies are completed prior to development and, if necessary, mitigative measures are taken. Site-specific liquefaction studies are recommended prior to construction because the entire area is in a high liquefaction potential

Job No.89-15(GH-7)

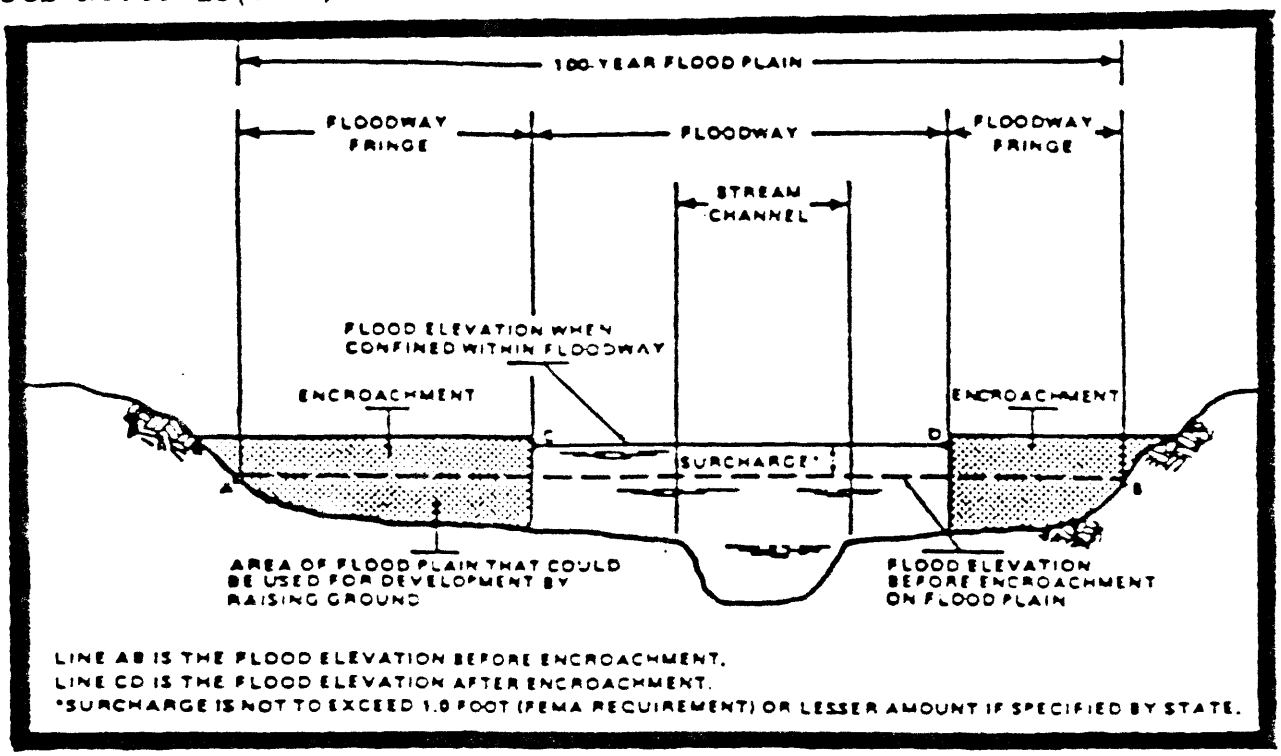


Figure 7. Floodway schematic showing terms associated with the 100-year flood (Federal Emergency Management Agency, 1982a).

zone. Standard soil and foundation studies to identify problem soils and shallow ground water are recommended prior to the construction of all permanent structures throughout the study area. Slope-stability studies including factor of safety analysis under both static and earthquake ground-shaking conditions (using both moderate and large magnitude earthquake parameters) should be completed prior to any development in close proximity to erosional bluffs exceeding slopes of 2.5 horizontal to 1 vertical. No permanent structures should be placed in the 100-year floodway, and development in floodway fringe areas should follow Federal Emergency Management Agency guidelines. Approval of proposed development should be contingent upon review and acceptance of completed engineering geologic and soil foundation reports by a qualified engineering geologist and the Weber County Engineer.

Maps in this report were excerpted from hazard maps available at the Weber County Planning Department. Maps depicting other geologic hazards not present in the Marriott-Slaterville area (surface fault rupture, landslides, debris flows, and rock fall) are also available at the Weber County Planning Department.

REFERENCES CITED

Anderson, L. R., Keaton, J. R., Aubry, Kevin, and Ellis, S. J., 1982, Liquefaction potential map for Davis County, Utah: Department of Civil and Environmental Engineering, Utah State University, Logan, Utah, and Dames & Moore Consulting Engineers, Salt Lake City, Utah, 50 p.

Arabasz, W. J., Smith, R. B., and Richins, W. D., editors, 1979, Earthquake studies in Utah, 1850-1978: University of Utah Seismograph Stations, Department of Geology and Geophysics, Salt Lake City, Utah, 548 p.

Bay, J. A., 1987, Liquefaction potential mapping of Weber, Box Elder, and Cache Counties, Utah (M. S. thesis): Utah State University, Logan, Utah, 140 p.

Bolt, B. A., 1978, Earthquakes; A Primer: San Francisco, W. H. Freeman and Company, 241 p.

Costa, J. E., and Baker, V. R., 1981, Surficial Geology; Building with the Earth: New York, John Wiley and Sons, 498 p.

Currey, D. R., Atwood, Genevieve, and Mabey, D. R., 1984, Major levels of Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73, 1:750,000 scale.

Currey, D. R., and Oviatt, C. G., 1985, Durations, average rates, and probable causes of Lake Bonneville expansions, stillstands, and contractions during the last deep-lake cycle, 32,000 to 10,000 years ago, in Kay, P. A., and Diaz, H. F., eds., Problems of and prospects for predicting Great Salt Lake levels: Conference proceedings, Center for Public Affairs and Administration, University of Utah, Salt Lake City, Utah, p. 9-24.

Davis, F. D., 1985, The geology of the northern Wasatch Front: Utah Geological and Mineral Survey Map 53-A, 1:100,000 scale.

Donovan, Neville, 1986, Ground motion issues for base isolation: National Science Foundation, Applied Technology Council, Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation, March 12-14, 1986, p. 343-353.

Erickson, A. J., Wilson, Lemoyne, Hughie, V. K., Nielson, Woodrow, and Chadwick, R. S., 1968, Soil survey of Davis-Weber area, Utah: U. S. Department of Agriculture, Soil Conservation Service, in cooperation with Utah Agricultural Experiment Station, 149 p.

Federal Emergency Management Agency, 1982a, Flood insurance study, Weber County, Utah, unincorporated areas: Federal Emergency Management Agency Community Number 490187, Washington D. C., 25 p.

----1982b, Flood Insurance Rate Map, Weber County, Utah, unincorporated areas: Federal Emergency Management Agency Panel Numbers 490187 0001 0600, Washington D. C., 1:6,000 scale.

Feth, J. H., Barker, D. A., Moore, L. G., Brown, R. J., and Veirs, C. E., 1966, Lake Bonneville: geology and hydrology of the Weber Delta District, including Ogden, Utah: U. S. Geological Survey Professional Paper 518, 76 p.

Harty, K. M., 1988, Flood hazard from lakes and failure of dams in Utah: Utah Geological and Mineral Survey Map 111, 1:750,000 scale.

Hays, W. W., and King, K. W., 1982, Zoning of earthquake ground shaking hazard along the Wasatch fault zone, Utah: Seattle, Third International Earthquake Microzonation Conference, v. 3, p. 1307-1318.

Hecker, Suzanne, and Harty, K. M., 1988, Shallow ground water and related hazards in Utah: Utah Geological and Mineral Survey Map 110, 1:750,000 scale.

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

Keaton, J. R., 1987, Potential earthquake-induced tectonic subsidence along the Wasatch Front, north-central Utah, in McCalpin, James, ed., Proceedings of the 23rd Symposium on Engineering Geology and Soils Engineering: Utah State University, Logan, Utah, p. 19-34.

Keefer, D. K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, p. 402-421.

Kuribayashi, Eiichi, and Tatsuoka, Fumio, 1975, Brief review of liquefaction during earthquakes in Japan: Soils and Foundations, v. 15, no 4, p. 81-92.

----1977, History of earthquake-induced liquefaction in Japan: Japan Ministry of Construction, Public Works Research Institute Bulletin, v. 31, 26 p.

Machette, M. N., Personius, S. F., and Nelson, A. R., 1987, Quaternary geology along the Wasatch fault zone: segmentation, recent investigations, and preliminary conclusions, in Gori, P. L., and Hays, W. W., eds., Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, v. I: U. S. Geological Survey Open-File Report 87-585, p. A-1-72.

Murchison, S.B., 1989, Fluctuation history of Great Satl Lake, Utah, during the last 13,000 years (M.S. thesis): University of Utah, Salt Lake City, Utah, 137 p.

Oviatt, C. G., McCoy, W. D., and Reider, R. G., Quaternary lacustrine stratigraphy along the lower Bear River, Utah; evidence for a shallow early Wisconsin lake in the Bonneville basin: Geological Society of America Abstracts with Programs, v. 17, no. 4, p. 260.

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

Scott, W. E., McCoy, W. D., Shroba, R. R., and Rubin, Meyer, 1983, Reinterpretation of the exposed record of the last two cycles of Lake Bonneville, western United States: Quaternary Research, v. 20, p. 261-285.

Smith, R. B., and Sbar, M. L., 1974, Contemporary tectonics and seismicity of the western United States with emphasis on the Intermountain Seismic Belt: Geologic Society of America Bulletin, v. 85, p. 1205-1218.

U.S. Bureau of Reclamation, 1983, Technical report on dam failure inundation study, Echo Dam (Weber River Project, Utah): Unpublished report, 9 p.

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

Utah State Division of Comprehensive Emergency Management, 1985, Hazard mitigation plan - executive summary, Great Salt Lake Beneficial Development Area - Utah, 1985: Utah Department of Public Safety, 21 p.

Tinsley, J. C., Youd, T. L., Perkins, D. M., and Chen, A. T. F., 1985, Evaluating earthquake potential, in Ziony, J. I., ed., Evaluating earthquake hazards in the Los Angeles region; an earth science perspective: U. S. Geological Survey Professional Paper 1360, p. 263-315.

Youd, T. L., 1977, Discussion of "Brief review of liquefaction during earthquakes in Japan" by Kuribayashi, Eiichi, and Tatsuoka, Fumio, 1975: Soils and Foundations, v. 17, no. 1, p. 82-85.

Youngs, R. R., Swan, F. H., Power, M. S., Schwartz, D. P., and Green, R. K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, in Hays, W. W., and Gori, P. L., eds., Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, v. II: U. S. Geological Survey Open-File Report 87-585, p. M-1-110.

REVIEWS

Project:			Requesting Agency:
Review of report "Notice of intent to construct gold processing facilities, Barneys Canyon Project"			Environmental Health Bureau of Water Pollution Control
By: G.E. Christenson W.F. Case	Date:	County: Salt Lake	Job No.: (R-1) 88-02
USGS Quadrangle: Lark #1173			

In response to a request from Charlie Dietz, Bureau of Water Pollution Control, a review of the seismic hazards section of the "Notice of Intent (NOI) to Construct Gold Processing Facilities, Barneys Canyon Project" (JBR Consultants Group, 1988) was completed. The scope of work for this review included a study of the geotechnical reports for the site by Sergent, Hauskins, and Beckwith (1988a, 1988b) on which the NOI was based. No field investigation or air photo interpretation was made for the review and only seismic hazards were considered. The site geologic conditions and potential for environmental contamination under static conditions have been reviewed by Bureau of Water Pollution Control geologists and engineers.

The proposed project involves development of a heap leach system consisting of lined leach pads and ponds. The system is designed to contain all solutions so that the potential for environmental contamination is low. In evaluating earthquake hazards at a site such as this, the principal consideration is to minimize the possibility of rupturing pond or pad liners or causing failure of embankments allowing escape of solutions to the environment. The earthquake hazards which could potentially do this include: 1) surface fault rupture, 2) ground shaking, 3) liquefaction-induced ground failure, and 4) seismically-induced slope failure.

The report adequately addresses surface fault rupture hazards by stating the location of the nearest faults and indicating a lack of evidence for surface faulting at the site. The West Valley fault zone in West Valley City is omitted from their analysis, but it is about 15 miles to the northwest and does not traverse the site.

Ground shaking is addressed in the report by calculating the peak horizontal ground acceleration for the site corresponding to a 500 yr recurrence interval. This is the recurrence commonly used in building and site design, and the value of 0.18 g obtained in this analysis corresponds well with recent generalized probabilistic studies which yielded values ranging from slightly less than 0.2 g (Algermissen and others, 1982) to slightly greater than 0.20 g (Youngs and others, 1987). Ground shaking itself is unlikely to directly effect liners or embankments, but is important because it may induce liquefaction or slope failure.

Liquefaction potential is not addressed in the NOI report, but is implied in the geotechnical report (Sergent, Hauskins, and Beckwith, 1988a, p. 54) to be low and was eliminated as a failure mode in the seismic slope stability analysis. Local perched water tables occur at depths of between 23 and 47 feet (p. 28), and site soils are poorly sorted with much clay and gravel. These conditions indicate a low liquefaction potential. Also, generalized liquefaction potential maps for Salt Lake County (1:48,000 scale) do not show a liquefaction hazard here, although the area is at the edge of the map and perhaps outside the study area (Anderson and others, 1986).

The seismically induced slope failure potential as summarized in the NOI report is unclear, but is discussed in detail in the geotechnical reports (Sergent, Hauskins, and Beckwith, 1988a, 1988b) for both the waste dumps and leach heaps. The UGMS is not qualified to comment on the engineering aspects of the evaluation, but assuming the calculated factors of safety are correct, it is indicated that leach heaps at the proposed slope of 1:1.38 may experience failure under the design acceleration of 0.18 g with displacement of less than 6 inches (Sergent, Hauskins, and Beckwith, 1988a, p. 55-56). This is considered to be within safe limits by Sergent, Hauskins, and Beckwith. Although the usage of the term "safe" is unclear, it seems likely that such a displacement could rupture the pad liner allowing escape of leach fluids into underlying soils. Such a possibility is not discussed, but may cause environmental contamination and render the pad unusable until repaired.

In conclusion, the principal earthquake hazards have been adequately addressed and the site appears to be suitable for the proposed use, at least from the standpoint of earthquake hazards. One possibility not covered is that of rupture of the artificial liner resulting from a seismic slope failure, and the resulting potential for environmental contamination. If the Bureau of Water Pollution Control considers this to be a significant concern in view of their analysis of site soils, liner design, and potential for contamination, we suggest this issue be addressed prior to approval.

References Cited

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., and Bender, B.L., 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States: U.S. Geological Survey Open-File Report 82-1003, 99 p.

JBR Consultants Group, 1988, Notice of intent to construct gold processing facilities, Barneys Canyon Project, submitted to Utah Bureau of Water Pollution Control: Unpub. consultant's report for Kennecott Explorations (Australia) LTD, Salt Lake City, 75 p.

Sergent, Hauskins, and Beckwith, 1988a, Geotechnical investigations report, heap leach pads, Barneys Project, Salt Lake County, Utah: Unpub. consultant's report (SHB Job No. E87-2038A) for BP Minerals, Salt Lake City, 71 p.

---- 1988b, Geotechnical investigation report, waste rock dumps, Barneys Canyon Project, Salt Lake County, Utah: Unpub. consultant's report (SHB Job No. E87-2038B) for BP Minerals, Salt Lake City, 33 p.

Youngs, R.R., Swan, F.H., Power, M.S., Schwartz, D.P., and Green, R.K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, in Gori, P.L., and Hays, W.W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Open-File Report 87-585, p. M-1 - M-110.

Project:			Requesting Agency:
Review of report "Notice of intent to construct gold processing facilities for the Tenneco Goldstrike Project"			Environmental Health Bureau of Water Pollution Control
By: G.E. Christenson	Date: 7-6-88	County: Washington	Job No.: (R-2) 88-03
USGS Quadrangle: Goldstrike (163)			

In response to a request from Charlie Dietz, Bureau of Water Pollution Control, a review of the seismic hazards section of the "Notice of Intent (NOI) to Construct Gold Processing Facilities, for the Tenneco Goldstrike Project" (JBR Consultants Group, 1988) was completed. No field investigation or air photo interpretation was made for the review and only seismic hazards were considered. The site geologic conditions and potential for environmental contamination under static conditions have been reviewed by Bureau of Water Pollution Control geologists and engineers.

The proposed project involves development of a heap leach system consisting of lined leach pads and ponds. The system is designed to contain all solutions so that the potential for environmental contamination is low. In evaluating earthquake hazards at a site such as this, the principal consideration is to minimize the possibility of rupturing pond or pad liners or causing failure of embankments allowing escape of solutions to the environment. The earthquake hazards which could potentially do this include: 1) surface fault rupture, 2) ground shaking, 3) liquefaction-induced ground failure, and 4) seismically-induced slope failure.

The report discusses the probability of Quaternary-age surface fault rupture on the Gunlock fault, which is the nearest active fault. Because it does not traverse the site, the surface fault rupture hazard is low.

Ground shaking is addressed in the report by indicating that a lateral acceleration of 0.1 g is unlikely to be experienced during the operational life of the site (6-7 yrs). The peak horizontal ground acceleration for the site corresponding to a 500 year recurrence interval from recent generalized probabilistic studies ranges from 0.1 to 0.2 g (Algermissen and others, 1982). For a site with an operational life of 6-7 years, it may be more appropriate to use the 100-year recurrence (10% probability of exceedence in 10 years) values which are between 0.04 and 0.1 g, in general agreement with those in the report. Ground shaking itself is unlikely to directly effect liners or embankments, but is important because it may induce liquefaction or slope failure.

Liquefaction potential is not addressed in the NOI report, but can be considered very low because the leach pads will be on bedrock and granular fill in which a water table is unlikely to develop.

The seismic slope stability is discussed in the report in general terms based on a literature study only. Because leach heaps are granular material subject more to "angle of repose" ravelling and sloughing than rotational failures, and slopes will be held to 2:1, settlement of the heap and sloughing around the edges would be the most likely affect of ground shaking during an earthquake (as indicated on page 22). The greatest hazard would be due to a failure of the rock below the heaps. No landslides are shown in the geologic map or cross sections of the leach pad, and Brian Buck of JBR Consultants (oral commun., July 1, 1988) indicated that the rock is competent and over lying soils will be removed prior to construction of the pad. The heap will be set back from the edge of the pad, also reducing the likelihood of failure.

In conclusion, the principal earthquake hazards do not pose a threat to the site and it appears to be suitable for the proposed use, at least from the standpoint of earthquake hazards. The possibility of failure of natural materials beneath the pad is not addressed in the report, but is considered to be low by JBR Consultants and no evidence exists to indicate otherwise.

References Cited

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., and Bender, B.L., 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States: U.S. Geological Survey Open-File Report 82-1003, 99 p.

JBR Consultants Group, 1988, Notice of intent to construct gold processing facilities for the Goldstrike Tenneco Project, submitted to Utah Bureau of Water Pollution Control: Unpub. consultant's report for Tenneco Minerals Company, St. George, Utah, 60 p.

Project: Review of an Earthstore report, proposed water tank near Snake Creek Canyon, Wasatch County, Utah			Requesting Agency: Utah Division of Parks and Recreation
By: ~~Kimm M. Harty~~ Gary E. Christenson	Date: 9-19-88	County: Wasatch	Job No.: 88-05(R-3)
USGS Quadrangle: Brighton (1169)			

At the request of Frank L. Roberts of the Utah Division of Parks and Recreation, the Utah Geological and Mineral Survey (UGMS) reviewed an Earthstore engineering geology/geotechnical engineering report (Job no. 17363-001-47) for a proposed 117,000-gallon water tank near Snake Creek Canyon, about 6 miles northwest of Heber City in Wasatch County. The proposed water tank site is in the SE 1/4 of section 18, T. E S., R. 4 E., Salt Lake Baseline and Meridian, and is to provide water to the nearby K & J Subdivision. The proposed site is on state land owned by the Utah Division of Parks and Recreation (UDPR), and the Earthstore report was prepared for the Snake Creek Property Owners Association in response to a request from UDPR. The scope of the review was limited to an evaluation of the Earthstore report, and other geologic literature available for the area surrounding the site. No field work was undertaken, and only the sections of the report relating to slope stability were reviewed. The UGMS does not maintain staff expertise needed to review the geotechnical engineering sections covering earth work and foundations.

The report satisfactorily explains the geologic conditions at the water tank site. Both the Earthstore report and one completed by the UGMS (Klauk and Mulvey, 1987) estimate the large landslide at the site to be old (early Holocene or Late Pleistocene). Based on the landslide's estimated age and the observation that the slide did not reactivate during the recent wet cycle (1982-1986), Earthstore classifies the landslide as stable. Although this evidence indicates that the large landslide is probably stable, it is not uncommon to have smaller parts of these old, large landslides move independently, particularly when disturbed by man. The best way to determine the stability at a particular site on a slide is to perform a factor of safety analysis based on soil, slope, and ground-water conditions at the site. Earthstore apparently did not consider it necessary to perform such a study, but makes several recommendations to reduce the risk of failure which should be closely followed. One of these is to install subdrains beneath the water tank (p. 12) and another is to drain discharge to an area well away and downslope from the site. Given the nature of the area, with its susceptibility to earth flows, debris slides, and debris flows, adequate drainage of surface runoff as well as any potential leaks from either the water tank or conveyance pipes is strongly recommended.

Examination of topographic maps indicates that should the water tank fail, by slope movement or other means, flood waters would likely drain downslope into an unnamed ephemeral creek which flows eastward through the K & J Subdivision. It would be prudent for the responsible party to consider the possibility that flood water from a failure of the tank may flow through the subdivision, and determine whether such flooding would present hazard to life or property.

In conclusion, the report adequately documents geologic conditions in the site area, and the assessment that the large landslide is presently stable and has been stable for at least the past few thousand years is reasonable. The report addresses the potential for local slope instability at the site caused by grading and disruption of drainage by making several recommendations, particularly with regard to drainage, that are very important. Care should be taken during construction to see that these are followed. Because a factor of safety analysis was not done, it is important to understand that the stability assessment is based on qualitative judgement and experience, and does not preclude the possibility that a failure affecting the site may occur.

REFERENCE CITED

Klauk, R.H., and Mulvey, W.E., 1987, Study of landslides west of the K & J Subdivision in Snake Creek Canyon, Wasatch County, Utah: Utah Geological and Mineral Survey Report of Investigation, no. 214, 28 p.

Project: Review of Radioactive Material License Application for Regional Low-Level Radioactive Waste Disposal Facility, Montrose County, Colorado			Requesting Agency: Utah Division of Environmental Health Bureau of Radiation Control
By: Barry J. Solomon	Date: 9-19-88	County: Montrose	Job No.: (R-4) 88-06
USGS Quadrangle: Uravan, Montrose County, Colorado			

In response to a request from Larry Anderson, Director, Bureau of Radiation Control, a review of the geotechnical portion of the Radioactive Material License Application for the proposed Regional Low-Level Radioactive Waste Disposal Facility, Montrose County, Colorado, was performed. No field investigation or detailed literature search was conducted for this review. The license application was prepared by Umetco Minerals Corporation. Included with the application as Appendix A were extracted sections from an environmental report prepared by Gibbs & Hill, Inc. The Gibbs & Hill report summarizes geotechnical investigations performed by Chen & Associates, Inc. The original Gibbs & Hill and Chen & Associates documents, however, were not reviewed. An earlier review of the license application was conducted by The MARK Group Engineers and Geologists, Inc. (1988). Draft comments by The MARK Group indicate serious shortcomings of the Umetco license application, and many of their comments are corroborated in this review.

The proposed facility lies on the southwestern edge of Spring Creek Mesa, approximately 20 mi (32 km) east of the Utah border. The site lies within the San Miguel River Sub-Basin, a portion of the Dolores River Drainage Basin. The Dolores River, in turn, flows northwestward into Utah and joins the Colorado River about 15 mi (24 km) northeast of Arches National Park. If a release of contaminants from the facility occurred, a significant potential for degradation of water quality in southeastern Utah would exist. The purpose for review of this license application in Colorado is to safeguard the health and safety of the people downstream in southeastern Utah.

The most obvious and serious deficiency of the Umetco application is the lack of site-specific geotechnical information. A two-phased approach is proposed by Umetco for development of the facility: 1) Phase I includes the design, construction, operation, monitoring, and closure of a surface facility for disposal of radium-contaminated soils and debris, and 2) Phase II includes development of a deep underground site for disposal of low-level radioactive wastes generated in the Rocky Mountain Low-Level Radioactive Waste Compact. The geotechnical information Umetco relies upon, however, was not collected from either Phase I or Phase II sites. The information, in fact, was not even generated for this project. The Gibbs & Hill report (Appendix A) and the Chen & Associates geotechnical study were prepared for an earlier Union Carbide proposal for a tailings and effluent impoundment project associated with nearby mining. The tailings project was proposed for the flat mesa top, whereas the radioactive waste disposal project is proposed to the southwest on the steeper flanks of the mesa. The project areas are not the same, and site-specific data collected at one cannot be used at the other. In addition, the tailings project did not encompass any aspect of deep underground burial, which is a very important part of Phase II of the license application for the radioactive waste disposal project. The Umetco application states that "The license application is not for final approval" of the Phase II (underground) site, "but is intended to present a basic design and disposal concept along with the appropriate environmental information so that public comments can be obtained" (final paragraph, Executive Summary). Non-site-specific environmental information, though, is not "appropriate" for a license application. Such information may be suitable for a site selection and screening process, but a license application should be well beyond the conceptual design phase. Detailed site characterization should be undertaken prior to application submittal, and site-specific characterization data should be an integral part of the license application. Comments from interested parties should arise from an adequate data base. That the data is inadequate is evident from comments of The MARK Group, some of which are paraphrased below.

The MARK Group draft review contains several comments on the adequacy of both natural and engineered barriers to contain leachate. Of primary importance to Utah is the potential for transport of leachate into ground and surface water and ultimate migration of contaminants into the state. The host rock is not a good natural barrier, with significant potential for migration of leachate through the natural system by flow in a well-developed joint system noted by Gibbs & Hill, and in fault zones, some of which are present in the area. As stated in the license application, several faults in the region are considered potentially active (Kirkham and Rogers, 1981). The potential for rupture of engineered barriers at both surface and subsurface facilities by fault movement has not been addressed in the report, but such rupture could damage ring dikes and clayey liners in the surface facility and waste packages in the subsurface facility.

The MARK Group has indicated that the integrity of the site may be further compromised by at least two other geologic factors: coarse-grained, permeable fluvial channel deposits in the host rock, and failure of slopes. Gravel channels may be present in the host rock, and their presence and significance as pathways for contaminant movement must be considered. Slope failures could contribute to loss of radioactive waste material from the surface disposal facilities and containment structures, resulting in downstream transport of wastes.

In their more detailed review, The MARK Group also makes some quantitative estimates of several factors which the applicant must respond to prior to project development. The estimates relate to ground-water geochemistry, design of clay liners and cover, and seismic analysis. In addition, adequate programs to monitor ground water movement and soil and rock movement at the site must be developed and instituted prior to resubmittal of the license application. Finally, the potential effects of historical mining and minerals exploration activity has not been investigated, or a thorough borehole search and characterization program conducted to ensure that previous activities have not created pathways between the waste and water-bearing units.

The license application submitted by Umetco Minerals Corporation is inadequate to support development of a regional low-level radioactive waste disposal facility in Montrose County, Colorado. The Utah Geological and Mineral Survey, while not endorsing each specific review comment of the MARK Group, agrees with their conclusion that "...the application and proposed action have serious technical shortcomings, most of which will require additional data collection and analysis...". The lack of site-specific data, and the extrapolation of data from an adjacent area, is not responsive to concerns over potential ground and surface water contamination which may affect southeastern Utah. We recommend that the state of Utah follow the progress of this license application and continue to comment where necessary to ensure that all prudent precautions are taken prior to development.

REFERENCES

Kirkham, R.M., and Rogers, W.P., 1981, Earthquake potential in Colorado, a preliminary evaluation: Colorado Geological Survey Bulletin 43.

The MARK Group, 1988, Draft review, regional low level radioactive waste disposal facility, Uravan, Colorado, 38 p.

Project:			Requesting Agency:
Review of soil foundation report, J. W. Powell Museum, Green River, Utah.			Community Impact Board
By: William E. Mulvey	Date: 2-22-89	County: Emery County	Job No.: (R-5) 89-02
USGS Quadrangle: Green River (625)			

As a part of the Utah Geological and Mineral Survey (UGMS) contract with the Department of Community and Economic Development, the UGMS has reviewed the Soil and Foundation Investigation conducted by Rollins, Brown and Gunnell, Inc. for the J. W. Powell Museum in Green River, Utah. The purpose of the review was to evaluate whether geologic hazards at the site were adequately addressed. We realize that the building is now under construction, and our comments are given to make the owners aware of possible hazards and to consider remedial actions that may be taken.

The building is in the 100-year flood plain of the Green River, as designated by the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map for the City of Green River. Although we have not evaluated the FEMA study for accuracy, the presence of the site in the flood plain indicates a hazard may exist and that the site is covered under the federal flood insurance program (if adopted by the city). Engineers for the building should be made aware that the building is in a designated flood plain, and contact FEMA to decide an appropriate action.

A concern regarding foundation stability is the presence of the Mancos Shale beneath coarse alluvial gravels ten feet below the surface in test holes 1 and 4. The Mancos Shale is known to have a high shrink-swell potential and has damaged improperly designed structures in Green River and elsewhere. The coarse alluvium overlying the shale may allow surface water to percolate downward and reach the shale, causing shrink-swell problems. Although we cannot assess the adequacy of the foundation design to account for shrinking and swelling in the shale, we recommend that precautions be taken in landscape design to avoid changes in moisture content in the Mancos Shale. Such precautions include collecting runoff from the roof and ground and diverting it away from the building. Attention should also be paid to water requirements of vegetation planted near the building foundation; it is advisable not to apply water to soils around the foundation or to let the water table rise beneath the building if it can be avoided.

Project: Review of Colorado Department of Health Hearing Exhibits Related to a Proposed Low-Radioactive Waste Disposal Facility, Montrose County, Colorado			Requesting Agency: Utah Division of Environmental Level Health, Bureau of Radiation Control
By: Barry J. Solomon	Date: 3-1-89	County: Montrose (Colorado)	Job No.: (R-6) 89-03
USGS Quadrangle: Uravan 7-1/2 minute			

Introduction

In response to a request from Larry Anderson, Director, Bureau of Radiation Control, a review was performed of the geotechnical portions of exhibits presented to a hearing before the Colorado Department of Health on November 17 and 18, 1988. The hearing was in regard to the application of Umetco Minerals Corporation for a Specific Radioactive Material License for a Regional Low-Level Radioactive Waste Disposal Facility. Particular emphasis of the review was placed on the: 1) Ground Water Investigation Report, prepared for Umetco by Bishop-Brogden Associates, Inc., September, 1988; 2) Geotechnical Study, prepared for Umetco by Western Engineers, Inc., September, 1988; 3) Hydrology Study, prepared for Umetco by Western Engineers, Inc., September, 1988; and 4) reporter's transcript of proceedings. This material reflected the results of field and laboratory investigations conducted after the preparation of the License Application by Umetco, which was reviewed by UGMS on September 19, 1988.

The proposed facility lies on the southwestern edge of Spring Creek Mesa, approximately 20 mi (32 km) east of the Utah border. The site is on the San Miguel River in the Dolores River Drainage Basin. The Dolores River flows northwestward into Utah and joins the Colorado River about 15 mi (24 km) northeast of Arches National Park. If a release of contaminants from the facility occurred, a potential for degradation of water quality in southeastern Utah would exist. The purpose for this review is to help safeguard the health and safety of the people in southeastern Utah downstream of the proposed facility by determining the likelihood of contamination of the San Miguel River.

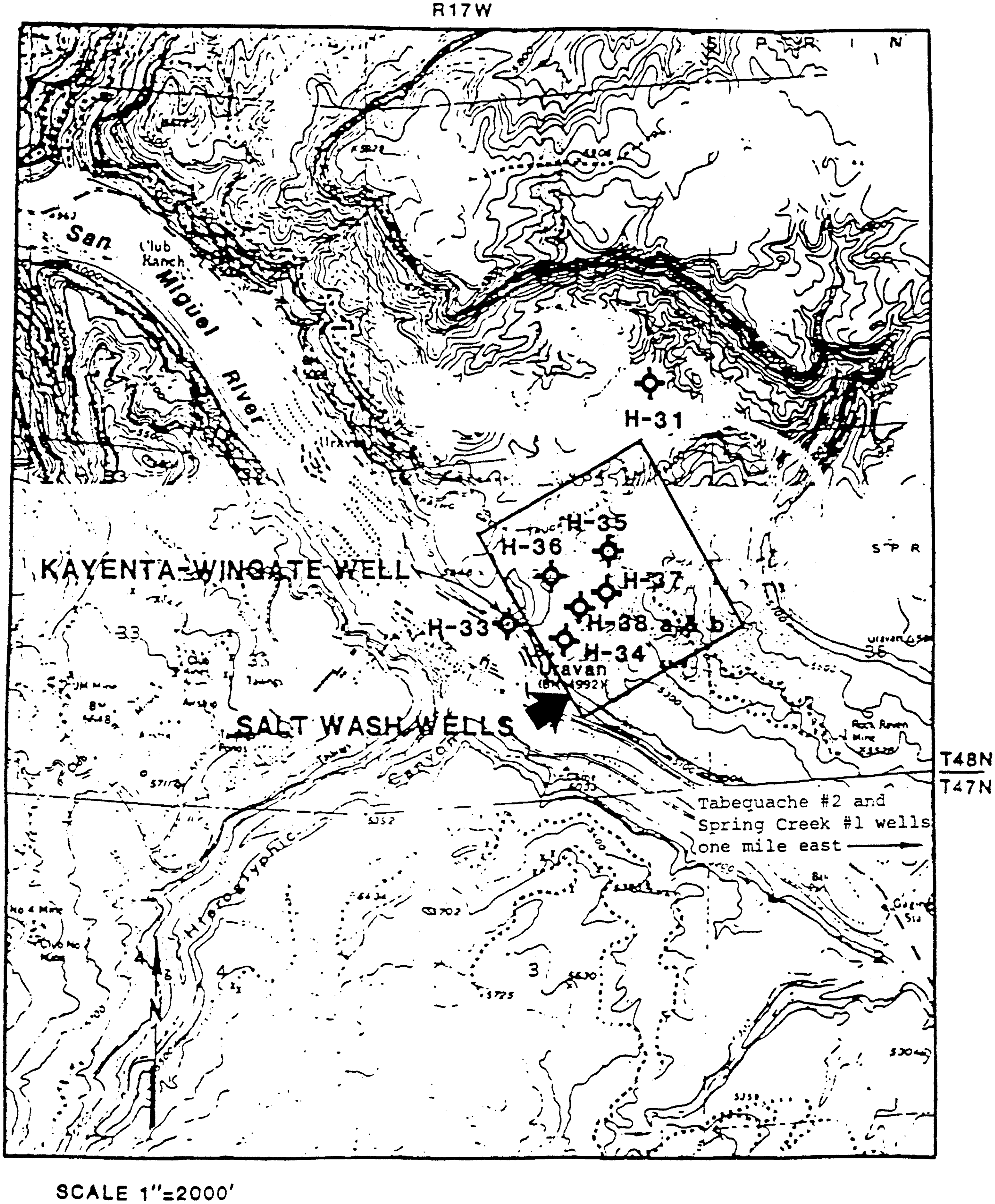
The integrity of the facility will depend upon a combination of engineered and natural barriers. Engineered barriers include a clay cap, clay liner, ring dike, and grouting and sealing of fractures. The cap and ring dike are to retard infiltration of surface water into the facility and to protect it from erosion. The liner, grouting and sealing are to prevent any possible transport of contaminants from the facility into aquifers. The Umetco proposal presumes that there are no "fatal flaws" to the site, and that the only geologic limitation to the site is its "low to moderate fracturing." This premise appears correct because no "fatal flaws" are positively identified; however, there are indications of possible geohydrologic shortcomings. Also, the dependence of site integrity upon engineered barriers is not sound practice. Engineered barriers for such a critical facility should only serve as backup to natural barriers.

Geohydrology

Two aquifers exist in the site vicinity: 1) the Kayenta-Wingate aquifer of Triassic age, which occurs about 360 feet below the surface at the proposed site, and 2) the Salt Wash Member of the Morrison Formation of Jurassic age, which occurs at the site beneath a thin veneer of Quaternary alluvial deposits (Bishop-Brogden Groundwater Investigation Report, 1988). Rocks at the site strike northwest and dip gently to the northeast.

The Kayenta-Wingate system is the principal ground-water aquifer beneath the site. Infiltration through overlying, relatively impermeable beds of the Morrison and Summerville Formations occurs at a very low rate, according to the Bishop-Brogden Ground Water Investigation Report. The construction of engineered barriers for the repository will slow the rate of infiltration even further, with a travel time of 1800 years for water to infiltrate to the Kayenta-Wingate from the surface as calculated by Bishop-Brogden. Should ground water reach this aquifer by flow through fractures in overlying beds, however, contaminants might be discharged into the San Miguel River through outcrops of the Kayenta near the base of Spring Creek Mesa; this would be of particular concern to Utah. A review of the grouting and sealing program to inhibit fracture flow, and a review of input into the hydrologic models and methods of analysis, should be performed to confirm study conclusions, but are beyond the scope of this review.

The presence of saturated flow within the Salt Wash Member beneath the site, and a mechanism for recharge, are points of contention that may require further study. Umetco believes the Salt Wash Member is essentially dry at the site and that whatever ground water exists in the Salt Wash Member offsite is not recharged by infiltration onsite. Several wells have been drilled in the vicinity of the proposed site (figure 1). Well H-31, 2900 feet northeast of the site down dip, contains free water immediately below the Salt Wash Member in the Summerville Formation. The Tabequache #2 and Spring Creek #1 wells, about 2 miles southeast of the site along strike, yield 120 gpm from the Salt Wash Member. Well H-35, located 560 feet east of the site, encountered water from depths of 123 to 127 feet in the upper part of the Salt Wash Member, but did not test the lower part; the well was pumped dry within 75 minutes, with an estimated production of less than 0.2 gallons per minute. Six other wells on or near the site did not encounter water in the Salt Wash Member. Wells H-31, Tabequache #2, and Spring Creek #1 were drilled prior to 1988 for purposes unrelated to the present study. Well H-35 and the six other wells were drilled in August, 1988 for characterization of the Umetco site.



Well Locations

FIGURE 1

BISHOP-BROGDEN ASSOC., INC.

Umetco believes that the Salt Wash Member receives no significant recharge from drainage into, and infiltration through, the site because of the small size of the area. The hydrology study (Western Engineers, Inc., 1988, p. 1) states that "The total area tributary to the developed site is approximately 47 acres inclusive of the site." However, it was not proven that no recharge occurs and it is possible that during the course of a year, drainage from 47 acres may infiltrate the site, enter the Salt Wash Member, and travel down dip toward potentially potable ground water northeast of the site. Production that was encountered in H-35 was tested for only one day in a dry season (August, 1988), and was not monitored over a period of time to account for differences in precipitation and infiltration.

To clarify the potential for infiltration and recharge of the Salt Wash Member onsite, well H-35 should be deepened to the base of the Salt Wash Member and monitored during the spring to determine water levels in the period of maximum potential infiltration. Should significant water be encountered, additional wells should be drilled and tested 1) updip, toward the site to trace the extent of water-bearing strata; and 2) along strike to determine the hydraulic connection, if any, between well H-35 and other wells with known production from the Salt Wash Member. Because sandstone in the Salt Wash Member was deposited in fluvial channels, these discontinuous channel deposits may not have been accurately detected by the initial drilling program; water-bearing strata in H-35 may not have been encountered on-site due to lateral variations in lithology.

Contamination of the Salt Wash aquifer, though, is of less concern to Utah than to Colorado because ground water flow in the Salt Wash Member is to the northeast, away from the San Miguel River. The Salt Wash Member occurs below the level of adjacent creeks north and east of the site, and would not likely contaminate surface water flowing from the San Miguel River into Utah.

<u>Geologic Hazards</u>

Geologic hazards may reduce the effectiveness of engineered barriers. The liner, grout, and seals might be broken by surface faulting, and cap material and protective ring dikes may be destroyed through mass movement from adjacent slopes in the overlying, slide-prone Brushy Basin Member of the Morrison Formation. Existing information suggests that these events are unlikely during operation and post-closure monitoring of the facility, but opportunity should be taken prior to licensing to assess these potential impacts. Active faulting might create a hazard for Utah by rupturing liners and other engineered protection and providing a direct pathway for contaminants to enter the Kayenta-Wingate aquifer and ultimately the San Miguel River. Mass movement may create a hazard by damaging the cap, liner, or ring dike, disrupting drainage and exposing the material to erosion by surface water with eventual flow into the San Miguel River.

Three faults have been identified in the vicinity of the site (Cater and others, 1955; McKay, 1955), the closest lying 1.5 miles to the northwest and trending southeast toward the slope at the northeast edge of the site. No minimum age of movement has been placed upon these faults, but the site lies between potentially active faulting of the Uncompahgre Plateau and the Paradox Valley (Kirkham and Rogers, 1981). Although no active faults have been identified onsite, there is no indication that Umetco has undertaken a detailed study of air photo lineaments and Quaternary surficial materials to address this possibility. Additional studies of this type are recommended for complete assurance of site integrity.

Landslide potential is a particular threat in the Brushy Basin Member which underlies the slopes one-quarter mile north and east of the site. During periods of increased rainfall, and along fracture or fault planes, the bentonitic shales are particularly susceptible to failure, similar to occurrences in the Brushy Basin elsewhere in Colorado and Utah. No discussion was presented by Umetco regarding the presence or absence of landslides on slopes adjacent to the proposed site, or the hazard they may pose.

Conclusions and Recommendations

No "fatal flaws" have been identified at the proposed site of a low-level radioactive waste disposal facility in Montrose County, Colorado. The existence of such flaws appears unlikely, but minimal effort would contribute to confidence in the suitability of the site. Ground-water recharge through the site, rupture of the site and engineered barriers by active faulting, and disruption of engineered barriers by landslides from adjacent slopes are all possibilities whose potential could be accurately determined with a more complete site characterization program. This program may include geophysical surveys, additional drilling and ground-water monitoring as required, and detailed study of Quaternary deposits and geologic structures. Studies directed toward potential faulting and landslides are of more concern to Utah because these hazards may introduce contaminants into the San Miguel River. Although the geohydrologic studies are important to Colorado because they address the possibility of contamination of the Salt Wash Member aquifer, they are of less concern to Utah because this aquifer near the site does not discharge to the San Miguel River, and its contamination would likely have no downstream effect in Utah.

Review of engineered barrier design and of hydrologic modeling, which is beyond the scope of this review, should be conducted by the state of Utah. Dependence upon engineered barriers as the primary protection against potential site failure is not sound engineering practice; the natural environment should be capable of waste containment for such a critical facility.

References

Cater, F. W., 1970, Geology of the Salt Anticline Region in Southwestern Colorado: U.S. Geological Survey Professional Paper 637, 80 p.

Cater, F. W., Butler, A. P., Jr., and McKay, E. J., 1955, Geologic map of the Uravan Quadrangle, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-78, scale 1:24,000.

Kirkham, R. M., and Rogers, W. P., 1981, Earthquake potential in Colorado, a preliminary evaluation: Colorado Geological Survey Bulletin 43, 171 p.

McKay, E. J., 1955, Geologic map of the Atkinson Creek Quadrangle, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-57, scale 1:24,000.

Appendix

1988-89 Publications of the Applied Geology Program

MAPS

Hecker, Suzanne, Harty, K.M., and Christenson, G.E., compilers, 1988, Shallow ground water and related hazards in Utah: Utah Geological and Mineral Survey Map 110, scale 1:750,000.

Harty, K.M., and Christenson, G.E., 1988, Flood hazards from lakes and failures of dams in Utah: Utah Geological and Mineral Survey Map 111, scale 1:750,000.

CIRCULARS

Christenson, G.E., 1987 (reprint), Suggested approach to geologic hazards ordinances in Utah: Utah Geological and Mineral Survey Circular 79, 16 p.

MISCELLANEOUS PUBLICATIONS

Kaliser, B.N., and Slossen, J.E., 1988, Geologic consequences of the 1983 wet year in Utah: Utah Geological and Mineral Survey Miscellaneous Publication 88-3, 109 p.

Kaliser, B.N., 1989, Water-related geologic problems of 1983 - Utah occurrences by county: Utah Geological and Mineral Survey Miscellaneous Publication 89-4, 24 p.

Anderson, R.E., and Christenson, G.E., 1989, Quaternary faults, folds, and selected volcanic features in the Cedar City 1° x 2° quadrangle, Utah: Utah Geological and Mineral Survey Miscellaneous Publication 89-6, scale 1:250,000.

REPORTS OF INVESTIGATION

Black, B.D., compiler, 1988, Technical reports for 1987 - Site Investigation Section: Utah Geological and Mineral Survey Report of Investigation 216, 115 p.

Black, B.D., and Christenson, G.E., compilers, 1988, Technical reports of the Wasatch Front county geologists, June 1985 - June 1988: Utah Geological and Mineral Survey Report of Investigation 218, 154 p.

OPEN-FILE REPORTS

Sprinkel, D.A., 1987 (revised 1988), Potential radon hazard map of Utah: Utah Geological and Mineral Survey Open-File Report 108, scale 1:1,000,000.

Atwood, Genevieve, Noonan, Mary, Case, W.F., and Mabey, Don, 1988, Earthquake response strategies for UGMS and the earth-science community: Utah Geological and Mineral Survey Open-File Report 115, 33 p.

Case, W.F., 1988, Maximum extent of potential flooding due to simultaneous failure of dams in Salt Lake County, Utah: Utah Geological and Mineral Survey Open-File Report 127, approximate scale 1:79,200.

Klauk, R.H., 1988, Causes of shallow ground-water problems in part of Spanish Valley, Grand County, Utah: Utah Geological and Mineral Survey Open-File Report 129, 46 p.

Case, W.F., 1988, Acid neutralizing capacity map of Utah: Utah Geological and Mineral Survey Open-File Report 132, scale 1:500,000.

Kaliser, B.N., 1988, Thematic mapping applied to hazards reduction, Davis County, Utah: Utah Geological and Mineral Survey Open-File Report 135, 18 p.