Report of Investigation

No. 198

TECHNICAL REPORTS FOR 1984
SITE INVESTIGATION SECTION

Compiled by Kimm M. Harty

1985

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ILLUSTRATIONS

PREFACE

The Site Investigation Section is part of the Utah Geological and Mineral Survey Applied Geology program. The section is charged with providing assistance to tax-supported entities (cities, towns, counties, state agencies, school districts) on matters where geologic factors are of concern. As a consequence, the Site Investigation Section undertakes a broad spectrum of projects that vary in length and complexity. Emphasis is placed on site evaluations for critical public facilities (police and fire stations, hospitals, water treatment plants) and schools. The section also conducts investigations to answer specific geologic or hydrologic questions from state and local governments. Examples include evaluation of protective zones required for culinary springs for local health departments, and investigating slope stability or soil problems in developing areas for county planning departments. Such projects are usually of short duration (a month or less) and are performed at no cost to the requesting agency. At times, however, the Site Investigation Section conducts studies of a longer and more detailed nature. These investigations are also designed to meet a specific need, and are generally performed under a cost-sharing contract with the public entity requesting the study.

Information dissemination is a major goal of the UGMS, and Site Investigation Section studies considered of general interest to the public are published in one of several UGMS formats (Report of Investigation, Special Studies, Bulletin) that allow for wide distribution and long-term availability. They are included on the UGMS publication list. Special Studies and Bulletins can be purchased from the UGMS and are placed in libraries throughout the state. Reports of Investigations can be obtained for the cost of reproduction at the UGMS publications sales desk. However, most Site Investigation Section special-purpose projects address specific problems of interest to a limited audience. The results of these studies are commonly presented in a technical report and are distributed on a need-to know basis. Copies of the reports are maintained in the Site Investigation Section files, but a list of projects and their locations have not until recently been available for public inspection.

The intent of this Report of Investigation is to present in a single document the forty-nine special-purpose technical studies done by the Site Investigation Section in 1984 (fig. 1) which received only limited distribution. The reports are grouped by topic, and the author(s) and requesting agency are indicated. Minor editing has been performed for clarity and conformity, but no attempt was made to upgrade the original graphics, most of which were produced using a copying machine. This report represents the second of an annual compilation of such studies, and is intended to make the results of all Site Investigation Section projects more easily available to the public.

Kimm M. Harty
May, 1985

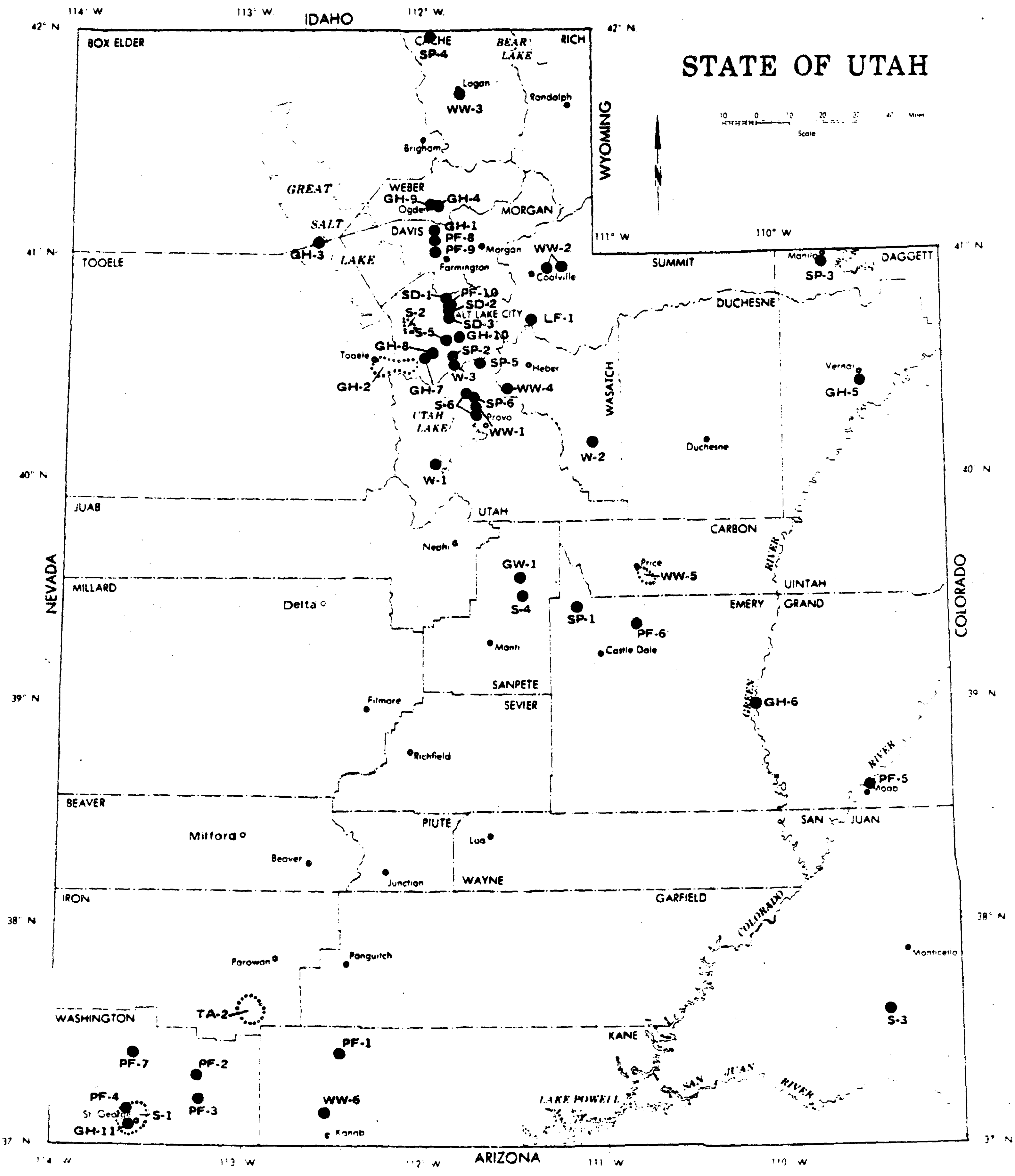


FIGURE 1. Location map.

SITE INVESTIGATIONS

Public Facilities

Schools

Subdivisions

Terrain Analysis

PUBLIC FACILITIES

Project: Alton Firehouse			Requesting Agency: Town of Alton
By: G. E. Christenson	Date: 8/13/84	County: Kane	Job No.: PF-1
USGS Quadrangle: Alton (151)			

A geologic inspection was performed to determine whether a proposed Alton firehouse project will "be adversely affected by geological features, or phenomenon," or will "adversely affect any unique geological features in the area." The site was visited on August 1, 1984, and the project was discussed with Orval Palmer, Alton Town Board member and Town Clerk. An abandoned school presently occupies the site, and the firehouse project consists of remodeling the school building to house emergency vehicles with construction of a driveway from the main road to the east.

No test pits were excavated, so details of foundation conditions (soil types, depth to ground water) are not known. The soils at the surface are granular (sand, gravel) and of a type that usually provides stable foundations. In any case, no new buildings are proposed for the project and the existing building does not appear to have sustained any serious foundation-related damage. Slopes at the site are gentle and stable and flood hazard is generally low. However, Alton is just east of the Sevier fault zone on which Quaternary displacement has been demonstrated. Because of the potential for ground shaking from earthquakes centered on this or other more distant fault zones, the area has been placed in Uniform Building Code seismic zone 2, a zone with potential for moderate earthquake damage. Although no structures for human occupancy are planned, the town may wish to upgrade the existing structure to meet modern seismic codes to insure that emergency vehicles will be in service following an earthquake.

In conclusion, the proposed project will not adversely affect any known unique geological features in the area. It will also not be adversely affected by geologic features or phenomena provided adequate precautions are taken.

Project:			Requesting Agency:
Pintura water tank inspection			Pintura City, Utah
By: H. E. Gill	Date: 8/24/84	County: Washington	Job No.: PF-2
USGS Quadrangle: New Harmony (117)			

In response to a request from Rulon Larsen, Environmental Certifying Officer, Pintura, Utah, a geologic investigation was undertaken to determine if the proposed rehabilitation of Pintura's culinary water tanks will "be adversely affected by any geological features or phenomenon" or will "adversely affect any unique geological features in the area." A field reconnaissance was conducted on July 26, 1984, at which time the Pintura water system, consisting of distribution lines and two metal water tanks (attachment 1) each of approximately ten thousand gallon capacity, was examined. The water tank foundations consist of 8-inch thick concrete slabs approximately 10 feet square placed on soil mounds and supported in places along their edges by rock and wood beams.

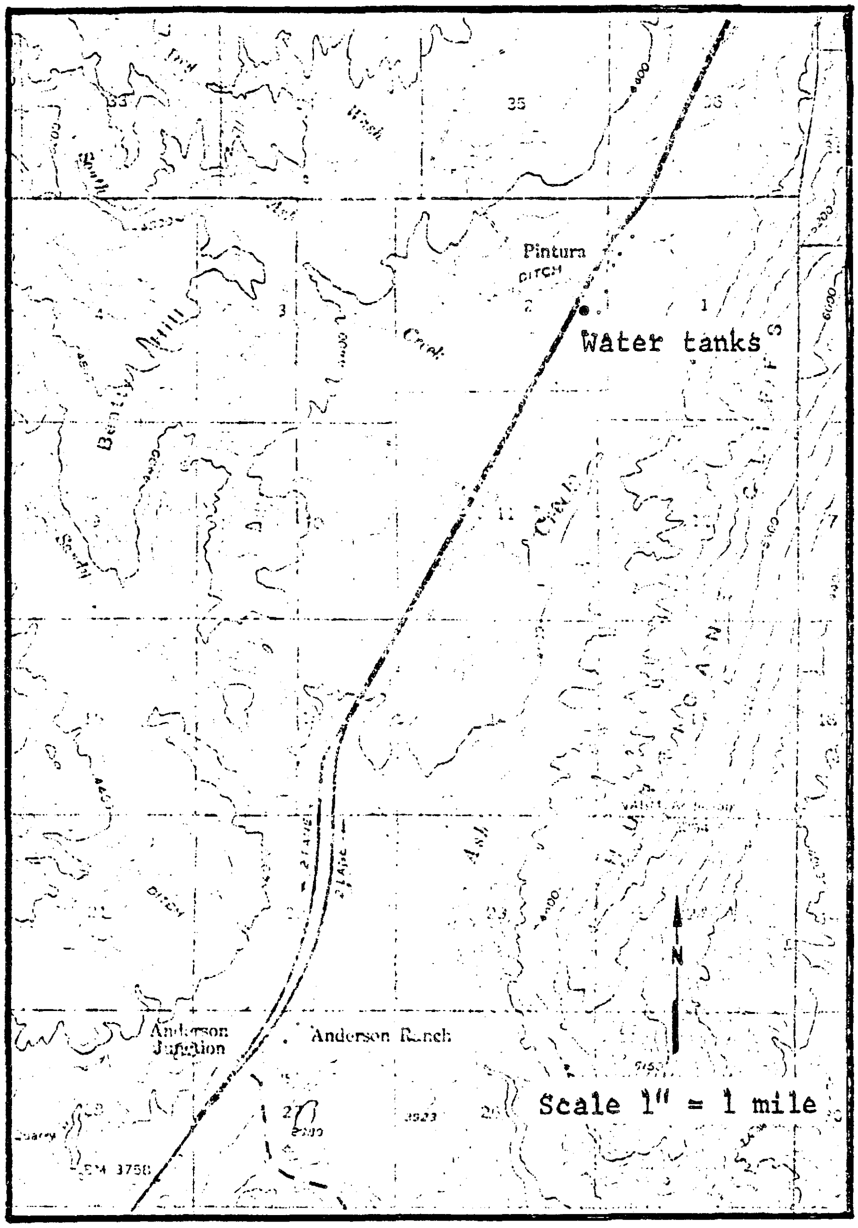
No test pits were excavated, so details of foundation conditions (soil types, depth to ground water) are not known. The soils at the surface are granular and bedrock outcrops are common. Slopes at the site are gentle and stable and flood hazard is low. The Hurricane fault trends north-south through the area, and at its closest point is approximately one half mile east of Pintura. Quaternary displacement has been demonstrated on this fault. A Quaternary basalt flow and alluvial fan (1 mile and 1.5 miles respectively northeast of Pintura) are offset by the fault (Earth Sciences Associates, 1982). Because of the potential for ground shaking from earthquakes associated with this fault, the area is in Uniform Building Code seismic zone 2, a zone of potential moderate earthquake damage. Ground shaking could cause damage to the water lines or failure of the water tank foundations, depending upon the magnitude and location of the earthquake epicenter.

In summary, the proposed project will not adversely affect any known unique geological features in the area (Earth Sciences Associates, 1982; Christenson, 1983). In addition, the water tanks will not be adversely affected by geologic features or phenomenon at the site, however adequate precautions should be taken to protect against strong ground shaking from an earthquake along the Hurricane fault. It is recommended that an engineer familiar with earthquake-resistant design inspect and provide recommendations for seismic resistant foundations.

Selected References

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

Earth Sciences Associates Inc., 1982, Seismic safety investigation of eight SCS dams in southwestern Utah: Phase I report, prepared for U.S. Department of Agriculture Soil Conservation Service, Palo Alto, California, 48 p.



General Location Map
Pintura culinary water tanks

Project:			Requesting Agency:
La Verkin firehouse site inspection			La Verkin City
By: H. E. Gill	Date: 8/31/84	County: Washington	Job No.: PF-3
USGS Quadrangle: Hurricane NE (76)			

In response to a request from O. Burt Pace, Environmental Certifying Officer, La Verkin, Utah, a geologic investigation was undertaken to determine if the proposed La Verkin firehouse project will "be adversely affected by any geological features or phenomenon" or will "adversely affect any unique geologic features in the area". The site was visited on July 25, 1984, and the project was discussed with Edward Cambell, La Verkin Fire Chief. The new firehouse will be a single story structure of concrete block construction. The property is located on the east side of La Verkin (attachment 1), on the site of a former single family dwelling. Only a large concrete slab remains from the original structure. There was no basement and the subsurface soils were not disturbed. The site was graded prior to construction of the home and is relatively flat.

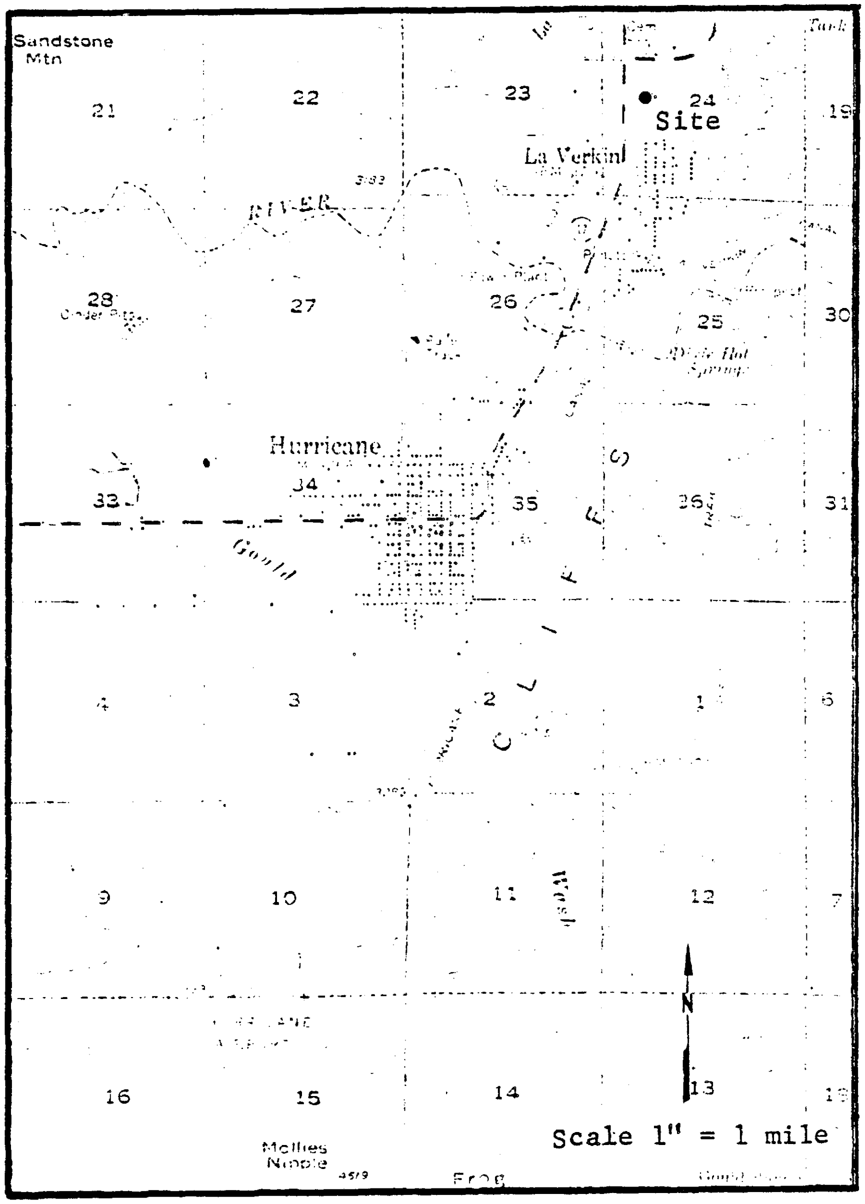
No test pits were excavated, so details of foundation conditions beneath the site (soil types, depth to ground water) are not known. However, an excavation north of the site and a three foot deep unlined irrigation ditch approximately 30 feet to the south were examined. At both locations the soils have a high clay content and are overbank deposits of the Virgin River. A thin veneer of windblown sediments occurs locally. The clay soils are moderately plastic and may possess some shrink-swell potential. No flood and slope stability hazards are present at the site. La Verkin is located approximately a half mile west of the Hurricane fault on which Quaternary faulting has been demonstrated. Alluvial fans are offset at several locations between the Hurricane Airport and Taylor Creek, approximately 6 miles south of La Verkin (Earth Sciences Associates, 1982). Because of the potential for ground shaking from earthquakes centered on this fault, La Verkin is in Uniform Building Code seismic zone 2, a zone of potential moderate earthquake damage.

In summary, the proposed project will not adversely affect any known unique geological features in the area (Earth Sciences Associates, 1982; Christenson, 1983). However, site soils may be expansive and should be accounted for in the buildings foundation design. The proximity of the fire station to the Hurricane fault and the likelyhood that it will be subject to ground shaking indicates that at a minimum all construction should conform to specifications listed in the Uniform Building Code for structures in Seismic Zone 2.

Selected References

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

Earth Sciences Associates Inc., 1982, Seismic safety investigation of eight SCS dams in southwestern Utah: Phase I report, prepared for U.S. Department of Agriculture Soil Conservation Service, Palo Alto, California, 48 p.



General Location Map

LaVerkin Firestation Site

Project:			Requesting Agency:
Santa Clara waterline improvements			Santa Clara City, Utah
By: H. E. Gill	Date: 8/31/84	County: Washington	Job No.: PF-4
USGS Quadrangle: St. George NW (79)			

In response to a request from Parley G. Hassell, Environmental Certifying Officer, Santa Clara, Utah, a geologic investigation was undertaken to determine if proposed water line improvements for the Santa Clara culinary water system will "be adversely affected by geological features, or phenonemon," or will "adversely affect any unique geological features in the area." A field reconnaisance was conducted on July 26, 1984 at which time four locations (attachment 1) were examined: 1)a new water line at Chapel Street, 2) new valves along Park View Drive, 3)a new water line from the east end of Canyon View Drive to its junction with Santa Clara Drive, and 4) a new water line on Vineyard Road near North Lava Flow Drive.

No test pits were excavated, however, Utah Geological and Mineral Survey Special Studies no. 58, "Engineering Geology of the St. George Area, Washington County, Utah", presents information on ground water, slope stability, soils, and flooding in Santa Clara that was utilized to evaluate the four sites. Flood and slope failure hazards at all four locations are generally low; however, site 1 is near the toe of an existing landslide. Christenson (1980) examined the landslide for Santa Clara City and determined that it was caused by saturation of subsurface soils. A drain has been installed to dewater the landslide, and no movement has been reported for over a year (Parley Hassell, oral commun., Environmental Certifying Officer, Santa Clara, Utah). However, if water were to again enter the slide mass, renewed movement may occur and possibly damage the proposed water line. Soils with high shrink-swell characteristics (Chinle Formation) were observed in the vicinity of sites 1 and 3. It is not known if they occur immediately beneath the water line corridors. If present, the soils could if saturated swell and cause breaks in the water lines. Santa Clara is 7 miles east of the Grand Wash fault and 8 miles west of the Washington fault. Quaternary displacement has been demonstrated on the Washington fault approximately 10 miles east-southeast of Santa Clara (Earth Sciences Associates, 1982). Because of the potential for ground shaking from eathquakes centered on these faults, the area is in Uniform Building Code seismic zone 2, a zone of potential moderate earthquake damage. Line breaks may occur due to ground shaking, depending on the magnitude and location of an earthquake.

In summary, the proposed project will not adversely affect any known unique geological features in the area (Earth Sciences Associates, 1982; Christenson, 1983). Renewed movement of the landslide at site 1 could result in damage to the new water line at this location. The presence of expansive soils at sites 1 and 3 could, if they become saturated, result in damage to the water lines. All sites are within 10 miles of the active Washington fault and damage to the water lines may occur from ground shaking during an earthquake. At all locations it is advisable that the proposed water line corridors be inspected and recommendations made by an engineer familiar with landslides, expansive soil, and earthquake hazards.

Selected References

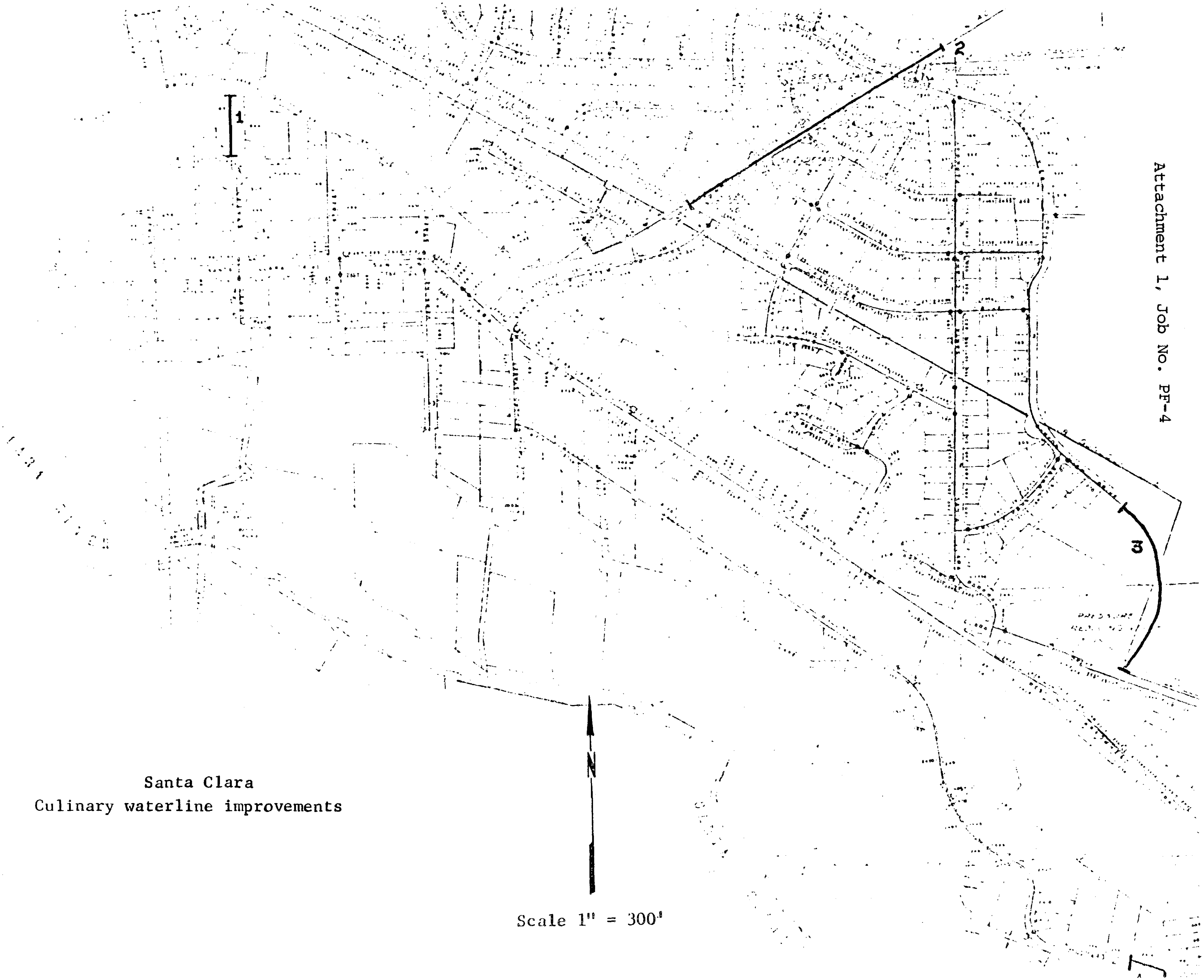
Christenson, G. E., 1983, Engineering geology of the St. George area, Washington County, Utah: Utah Geological and Mineral Survey Special Studies 58, 32 p.

Earth Sciences Associates Inc., 1982, Seismic safety investigation of eight SCS dams in southwestern Utah: Phase I report, prepared for U.S. Department of Agriculture Soil Conservation Service, Palo Alto, California, 48 p.

Utah Geological and Mineral Survey

Site Investigation Section

Attachment 1, Job No. PF-4



Santa Clara
Culinary waterline improvements

Scale 1" = 300'

Project: Examination of a water tank site in Moab, Utah			Requesting Agency: Moab City
By: W. R. Lund	Date: 6/10/84	County: Grand	Job No.: PF-5
USGS Quadrangle: Moab (497)			

A trip to southeastern Utah was made between June 4-6, 1984. The purpose of the trip was three fold:

1. (WW-5) To examine exposures of the Mancos Shale in the vicinity of Price and Wellington, Utah with representatives of the State Health Department and the Southeastern Utah District Health Department (S. Thiriot and G. Storey respectively). Problems have developed with a number of septic tank/drainfield systems installed in the Mancos Shale in Carbon and Emery Counties. Other systems, also installed in the shale appear to be working satisfactorily. New health department regulations prohibit installation of drainfields in bedrock, a fact which has created considerable controversy in the Price area. This examination was to determine what if any modifications in the regulations should be made for the Mancos Shale and/or what kinds of alternate disposal systems might be appropriate for Mancos terrain. It was determined that additional information regarding the number of failing vs. functioning systems is required. G. Storey (Southeastern Utah Health District agreed to examine their files and contact individual owners as necessary to obtain that information.

2. (GH-6) Investigation of an underground gasoline leak in Green River, Utah. Considerable quantities of gasoline have been discovered in portions of the Green River sewer system. The suspected source is a leak in an underground storage tank at one of two nearby gas stations. The UGMS gas detection device was used to measure the concentration of gasoline fumes at the manhole where the gasoline occurs and also at a nearby sewer pump station. Readings of 9 and 2 percent were obtained respectively. A number of other manholes within a two-block area were also checked, none showed evidence of gasoline. It appears that the gasoline is coming from the stations as suspected. A sample of the gasoline will now be analyzed to identify the chemical tracer present. Each major oil company (in this case Husky and Shell) use a distinctive tracer in their product to allow its identification in cases such as this. Further UGMS involvement is likely only if the source of the gasoline cannot be identified by its tracer.

3. (PF-5) Examination of a million gallon water tank in Moab, Utah the foundation of which has begun to crack and settle. The water tank is approximately three years old and is located on a norrow ridge top northwest of Moab. The city engineer (Mr. Keogh) claims that he saw cracks in the top of the ridge paralleling those in the tank foundation and is concerned that a landslide may be developing adjacent to and beneath the water tank. A careful examination of the site and both sides of the ridge showed no evidence of slope movement (the cracks reported by the city engineer were no longer visable). A foundation investigation was

not performed for the tank nor is there any documentation of the materials exposed in the foundation excavation at finished grade. Bedrock is exposed on the ridge top and on the south ridge slope, the north slope is underlain by colluvium of variable thickness. It is not known if the bedrock-colluvium contact lies beneath the water tank, but it is the colluvium side of the tank that is settling. It was suggested to the city engineer that a series of monitoring points be established on the slope and their evaluations surveyed periodically in an attempt to detect any evidence of slope movement. He agreed to establish the monitoring net and will contact UGMS when he has some data.

Project: Water tank site inspection, Elmo, Utah			Requesting Agency: Castle Valley Special Service District
By: H. E. Gill	Date: 9/6/84	County: Emery	Job No.: PF-6
USGS Quadrangle: Elmo, Utah (794)			

In response to a request from Darrell V. Leamaster, District Manager, Castle Valley Special Service District, a geologic investigation was conducted on August 9, 1984 of the site proposed for a 500,000 gallon culinary water tank. The tank will be constructed of concrete, and will not be buried. Minimum grading will be required to level the foundation.

SCOPE OF WORK

The site investigation consisted of a review of available published and unpublished literature covering the area, a field reconnaissance of the site, and excavation of three backhoe test pits. The test pits were located outside the water tank peremeter to avoid disturbing foundation soils. I was accompanied in the field by Darrell Leamaster and Craig Johansen of Johansen and Tuttle Engineering.

SITE LOCATION AND DESCRIPTION

The site is approximately two miles north of Cleveland, Utah on top of Poison Spring Bench (attachment 1). The bench slopes less than one degree to the northeast, while slopes bounding the bench are steep (approximately 16 degrees to the northeast, southeast, and southwest). Deep gullies are cut into the bench on the southwest and north sides of the site. Evidence of minor sheet erosion was observed on the steeper slopes. Sparse, low grasses provide the major vegetative cover at the site. Access is by ungraded dirt road, however, a new roadway has been surveyed.

GEOLOGY, SOILS, AND HYDROLOGY

Poison Spring Bench is a flat-topped erosional remnant of Mancos Shale capped with stream gravels and cobbles derived from the Wasatch Plateau to the west. The Mancos Shale, which is upper Cretaceous in age, consists of blue-black to gray marine shale, with several prominent sandstone members (Spieker, 1931). In the study area, the Mancos Shale is primarily a blue-gray shale that weathers to a highly expansive clay. From observations made along the bench, the gravel unit capping the Mancos Shale ranges in thickness from 4 feet to greater than 25 feet. Beneath the water tank site the gravel cap appears to be at least 25 feet thick. In the drainage immediately north of the site, a coarse pebble-cobble conglomerate was observed, underlying the gravel unit, approximately 25 feet below ground surface. The conglomerate was one to three feet thick and was found only in drainages north of the site. This unit may represent a basal conglomerate of the Mesa Verde Sandstone that overlies the Mancos Shale.

The soils encountered beneath the site were continuous between the three test pits (attachment 2). They consist primarily of a thin silty sand topsoil layer overlying a medium-dense, nonplastic, moderately-indurated well graded sand with gravel/well graded gravel with sand. A clean sand lens approximately one foot thick was encountered in all test pits from 3.5 to 5.5 feet below the ground surface (attachment 2). Stage II caliche was encountered in all soil horizons but was most prominent from about two to three feet beneath the ground surface. The soils contained approximately five percent cobbles and a trace of boulders, and the degree of induration made excavation below 10 feet immpossible.

Annual precipitation in the study area is approximately 8.5 inches (Mundorff, 1972). There was no evidence of ground water in the test pits or in the gullies near the site. The valley floor below Poison Spring Bench is approximately 100 feet lower than the water tank site, and depth to ground water in the site area is expected to be greater than 100 feet. The North Branch Cleveland Canal is approximately 1500 feet east and 100 feet lower than the water tank site and poses no threat to the facility.

GEOLOGIC HAZARDS

The Mancos Shale weathers to a highly expansive clay that, when saturated, could cause structural damage to foundations placed on them. Rapid erosion of the shale can cause undercutting of the bench slopes, making them unsafe for structures placed near the edge. Under wet conditions, slope failures could occur in the Mancos Shale. However, there was no indication of slope failure observed at the site or on the slopes in the immediate vicinity. The study area is in zone 2 of both the Uniform Building Code and the Utah Seismic Safety Advisory Council statewide seismic zonation. Earthquake hazard in the vicinity of the site is considered moderate. In 1968, a magnitude 4 earthquake occurred approximately 15 miles northwest of the site (Arabasz and others, 1979).

SUMMARY

The water tank will be on Poison Spring Bench an erosional remnant of Mancos Shale capped by a gravel unit. The gravel cap at the site is at least 25 feet thick. This should provide adequate seperation from the Mancos Shale to protect against foundation problems. Further erosion of the shale could cause undercutting of the bench slopes. It is recommended that the water tank have an adequate set back distance from the edge of the bench to account for this possibility. Because of the low annual precipitation and the depth to ground water, saturation of the Mancos Shale should not present a problem. A pebble-cobble conglomerate exists between the shale unit of the Mancos Shale and the gravel unit capping the bench. If the conglomerate is continuous it would form an impermeable layer between the shale and overlying material. The site is within Uniform Building Code Seismic Zone 2 (Seismic Safety Advisory Council Seismic Zone U-2) and all structures should be designed to at least those minimum standards.

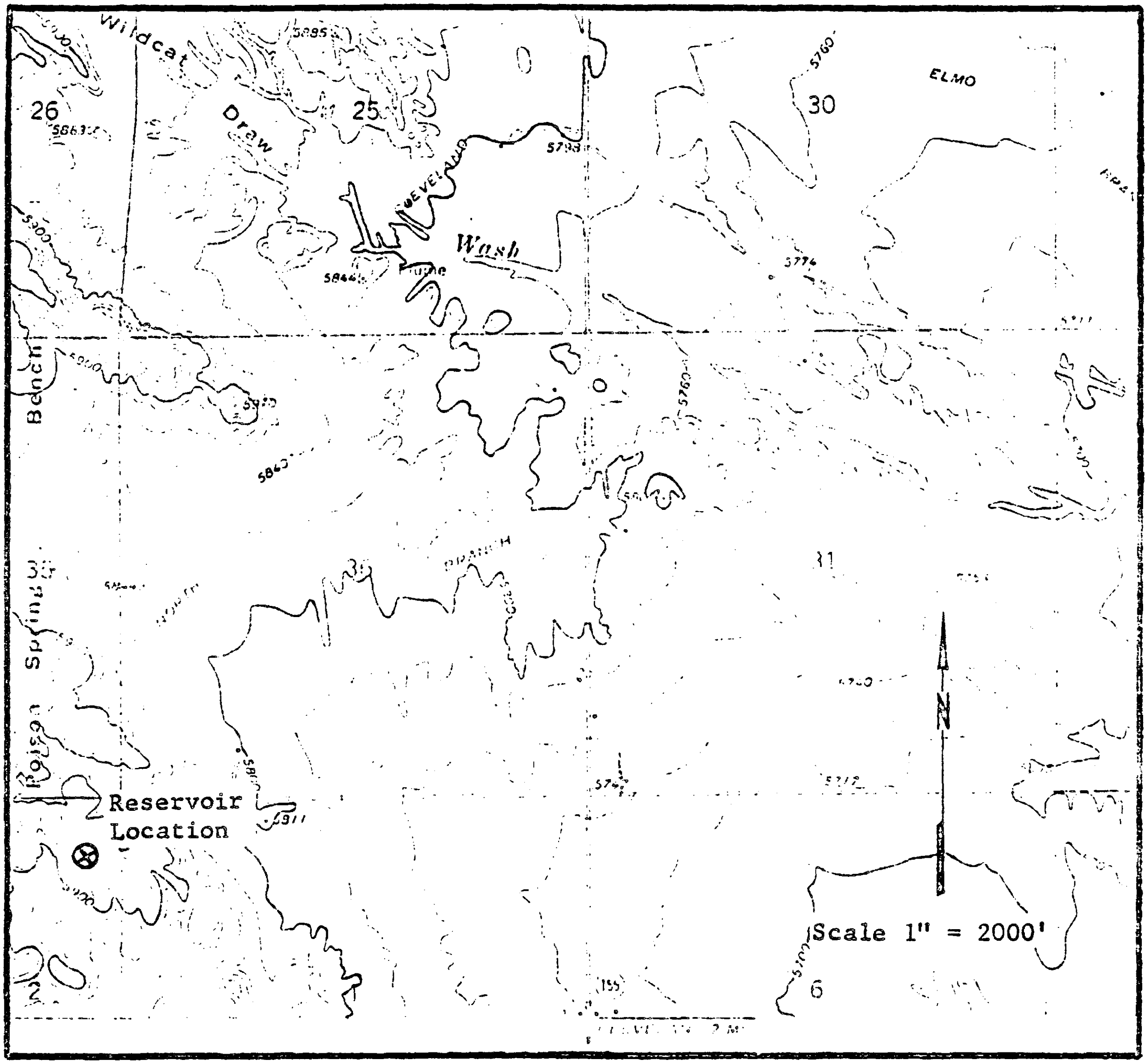
References

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

Mundorff, J. C., 1972, Reconnaissance of chemical quality of surface water and fluvial sediment in the Price River Basin, Utah: Utah Department of Natural Resources Technical Publication 39, 55 p.

Speiker, E, M., 1931, The Wasatch Plateau coal field Utah: U.S. Geological Survey Bulletin 819, 210 p.

Attachment 1, Job No. PF-6



General Location Map
500,000 Gallon Culinary Water Storage Tank
Castle Valley Special Service District

Attachment 2 Job No. PF-6

Logs of Test Pits*
Castle Valley Special Service District Culinary Water Tank

Test Pit 1

0.0' - 1.0' Silty sand (SM); topsoil, brown, low density, nonplastic, weakly indurated, dry.

1.0' - 10.0' Well graded sand with gravel/well graded gravel with sand (SW/GW); brown, medium dense, nonplastic, moderately indurated, dry; stage II caliche from 2 to 3 feet, medium-grained, moderately indurated sand (SP) lens from 5.5 to 6.5 feet.

Test Pit 2

0.0' - 1.0' Silty sand (SM); topsoil, brown, low density, nonplastic, weakly indurated, dry.

1.0' - 10.0' Well graded sand with gravel/well graded gravel with sand (SW/GW); brown, medium dense, nonplastic, moderately indurated, dry; stage II caliche from 2 to 3 feet, medium-grained, moderately indurated sand (SP) lens from 5.0 to 6.0 feet.

Test Pit 3

0.0' - 1.0' Silty sand (SM); topsoil, brown, low density, nonplastic, weakly indurated, dry.

1.0' - 10.0' Well graded sand with gravel/well graded gravel with sand (SW/GW); brown, medium dense, nonplastic, moderately indurated, dry; stage II caliche from 2 to 3 feet, medium-grained, moderately indurated sand (SP) lens from 3.0 to 4.0 feet.

Note: Ground water not encountered in any of the test pits.

*Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (revised 1975), Description of Soils (Visual Manual procedure), and (draft) Classification of Soils for Engineering Purposes D2487-83.

Project:	Requesting Agency:
Central water tank investigation	Washington County

By:	Date:	County:	Job No.:
G. E Christenson	9/14/84	Washington	PF-7

USGS Quadrangle: Central East (160) Central West (161)

PURPOSE AND SCOPE

The purpose of this investigation was to evaluate geologic conditions at two water tank sites near Central, Utah, in sections 2 and 3, T. 39 S., R. 16 W., SLB&M (attachment 1). Both sites are on steep hillsides at an elevation of 5500 feet, and tanks will be placed on benches cut into the hillsides. A 400,000 gallon metal tank will be placed at site 1 and construction is planned to begin immediately. The exact location of site 2 has not been finalized and no immediate plans for construction have been made.

The scope of work for this study included a literature review with a field reconnaissance on September 5, 1984. I was accompanied on the investigation by Harold Anderson of McDonald Engineering (Washington County engineers).

GENERAL GEOLOGY

Central is in the Pine Valley Mountains of north-central Washington County. Bedrock in the area is generally flat lying and consists of the Tertiary-age Claron Formation and overlying volcanic rocks of the Quichapa Formation (Cook, 1957, 1960). Site 1 is entirely within the Quichapa Formation, whereas site 2 is near the contact and includes the upper Claron and lower Quichapa Formations.

The Claron Formation is a sequence of limestones with minor calcareous sandstone, limestone pebble conglomerate, and shale above a basal sandstone and quartzite cobble conglomerate (Cook, 1957, 1960). The upper part of the Claron exposed in the site 2 vicinity consists predominantly of laminated white limestone with thin sandstone and conglomerate interbeds. Beds are nearly flat lying with local dips of 5 to 10 degrees to the north, west, and south.

The Quichapa Formation conformably overlies the Claron and includes three ignimbrites (welded tuffs) and a breccia unit (Cook, 1960). The lowermost ignimbrite, the Leach Canyon tuff, is exposed at site 2 and consists of a red to pink, rhyolitic crystal to crystal-vitric tuff. In most sections, this tuff includes an underlying layer of black glass or vitric tuff (Cook, 1960). At site 2, this black vitric tuff is present overlying the Claron Formation and underlying the pink crystal tuff of the upper part of the Leach Canyon tuff. At site 1, rock types vary from south to north from a red-brown crystal tuff at the site to a red-brown vitric tuff at the top of the hill. It is not known which unit within the Quichapa Formation this represents, although it is probably the Leach Canyon tuff. No bedding is visible at site 1, and fractures are closely spaced with no predominant directions.

No known active faults are present at either site. The nearest suspected Quaternary faults are about 4 miles northwest and southwest of Central and consist of groups of several short fault segments (Anderson and Miller, 1979). During historic time, two large earthquakes have been recorded in the area (Arabasz and others, 1979; Christenson and Deen, 1983). A magnitude 6.3 (modified Mercalli intensity VIII; attachment 2) earthquake struck Pine Valley about 6 miles east of Central on November 17, 1902. This is the largest earthquake in Washington County since the beginning of the record around 1850. On December 5, 1902, a magnitude 5.0 (intensity VI) earthquake occurred, also centered near Pine Valley. Although the locations and magnitudes of the events are approximate because they predate instrumental recordings, they indicate that events of these magnitudes occur in the area and are not necessarily associated with known active faults.

SITE CONDITIONS

Site 1

The volcanic rocks at site 1 are lithologically homogeneous, lack visible bedding, and are highly fractured. Predominant fracture sets indicative of preferred planes of weakness were not observed, and the fresh rock will probably provide an adequate foundation for a water tank. However, exposures in road cuts indicate that near surface rock is highly weathered to depths of at least several feet. Weathering is by granular disintegration as the rock breaks down into individual sand-size grains (originally crystals in the tuff). This material may be subject to settlement or slope failure when subjected to heavy loads.

Hillsides are covered with cobble- to boulder-size colluvium less than 1 foot thick in most places. Although slopes at site 1 are protected by this layer of colluvium, the underlying weathered rock is readily eroded by flowing water and subject to ravelling. Thus, the weathered rock is probably not capable of maintaining slopes greater than the angle of repose of dry sand, which is about 30 degrees. Natural slopes are approximately 24 degrees and less (about 2:1). The tank is to be placed on a bench cut into an already steep hillside with an expected vertical backwall cut of about 20 feet. If weathered rock extends to this depth, laying back of this slope to assure stability would require a massive excavation extending a great distance up the slope. If fresh rock is encountered, a less extensive excavation will be required.

No well-defined channels or slope-wash rills are present and flood hazard is considered low at site 1. However, exposure of weathered rock in cut slopes may result in a severe erosion problem. Runoff must be directed around any such exposed slopes, and compensation made for material dislodged by gravity or water falling directly on the slope.

Site 2

Although a site location has not been chosen, it appears that the Claron Formation is exposed at elevation 5500 feet throughout the area. The limestone and minor sandstone and conglomerate comprising the Claron Formation are competent rocks which should provide good foundation conditions. However, interbeds of less competent rock such as shale or weathered sandstone may be locally present. If volcanic rocks of the Quichapa Formation are found at the chosen site, conditions similar to those described at site 1 are anticipated.

Slopes at site 2 range from about 13 degrees to greater than 25 degrees. Although the limestone occurs in more gentle slopes near the base of the hill, it should be competent to support near vertical cuts. Bedding is generally flat with maximum down-slope dips of about 10 degrees. The degree of weathering in the subsurface is not known, but limestone is not subject to granular disintegration and should not pose the problems found in volcanic rocks of the Quichapa Formation at site 1. However, volcanic rocks similar to those at site 1 occur in upper slopes in the site 2 area, and slope conditions will be similar.

Several gullies with natural levees composed of large boulders are present in the site 2 area. Although drainage areas are small, substantial stream power due to the steepness of slopes and rate of flow is indicated by the size of debris in these levees. Active talus slopes including gravel- to boulder-size debris are also present which pose a rock-fall hazard, particularly during large storms or earthquake ground shaking.

CONCLUSIONS AND RECOMMENDATIONS

Both sites are on bedrock and involve a bench cut into a relatively steep slope. Fresh rock at either site should provide good foundation conditions. Care should be taken to avoid placing the foundation partially on fill or weathered rock at the front edge of the excavation because of possible problems with differential settlement. Natural slopes at both sites are stable, but steep cut slopes behind the tanks may be unstable, particularly at site 1. Close attention should be paid to rock conditions in these areas and mitigation measures such as drainage diversions, gunnite or shotcrete covering, or rock bolts may be required to stabilize slopes. An attempt should be made to avoid steep areas in siting the water tanks to minimize the excavation necessary for laying back cut slopes. Drainages should be avoided, and drainage diversions placed to protect tanks and cut slopes from erosion. A low to moderate rock-fall hazard is present at both sites, and drainage diversions could be engineered to provide some protection from falling rock.

Earthquake hazard is moderate in the area, and tanks should be designed to withstand ground shaking accompanying earthquakes of magnitude 6 to 7, which generally correspond to modified Mercalli intensities of VIII or greater (attachment 2). The area is in Uniform Building Code (UBC) and Utah Seismic Safety Advisory Council (USSAC) seismic zone 2 which requires construction to withstand intensities up to VII. However, because water tanks are critical facilities which must be functional following an earthquake, and in view of the 1902 intensity VIII event in Pine Valley and other recent data from geological studies (Earth Science Associates, 1982; Thenhaus and Wentworth, 1982), we would recommend earthquake resistant design to meet intensities of VIII or greater (UBC and USSAC seismic zone 3).

REFERENCES

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

Arabasz, W.S., 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, 548 p.

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

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

------- 1960, Geologic atlas of Utah, Washington County: Utah Geological and Mineral Survey Bulletin 70, 124 p.

Earth Science Associates, 1982, Seismic safety investigation of eight SCS dams in southwestern Utah: Palo Alto, California, consultants report to the U.S. Soil Conservation Service, Portland, Oregon.

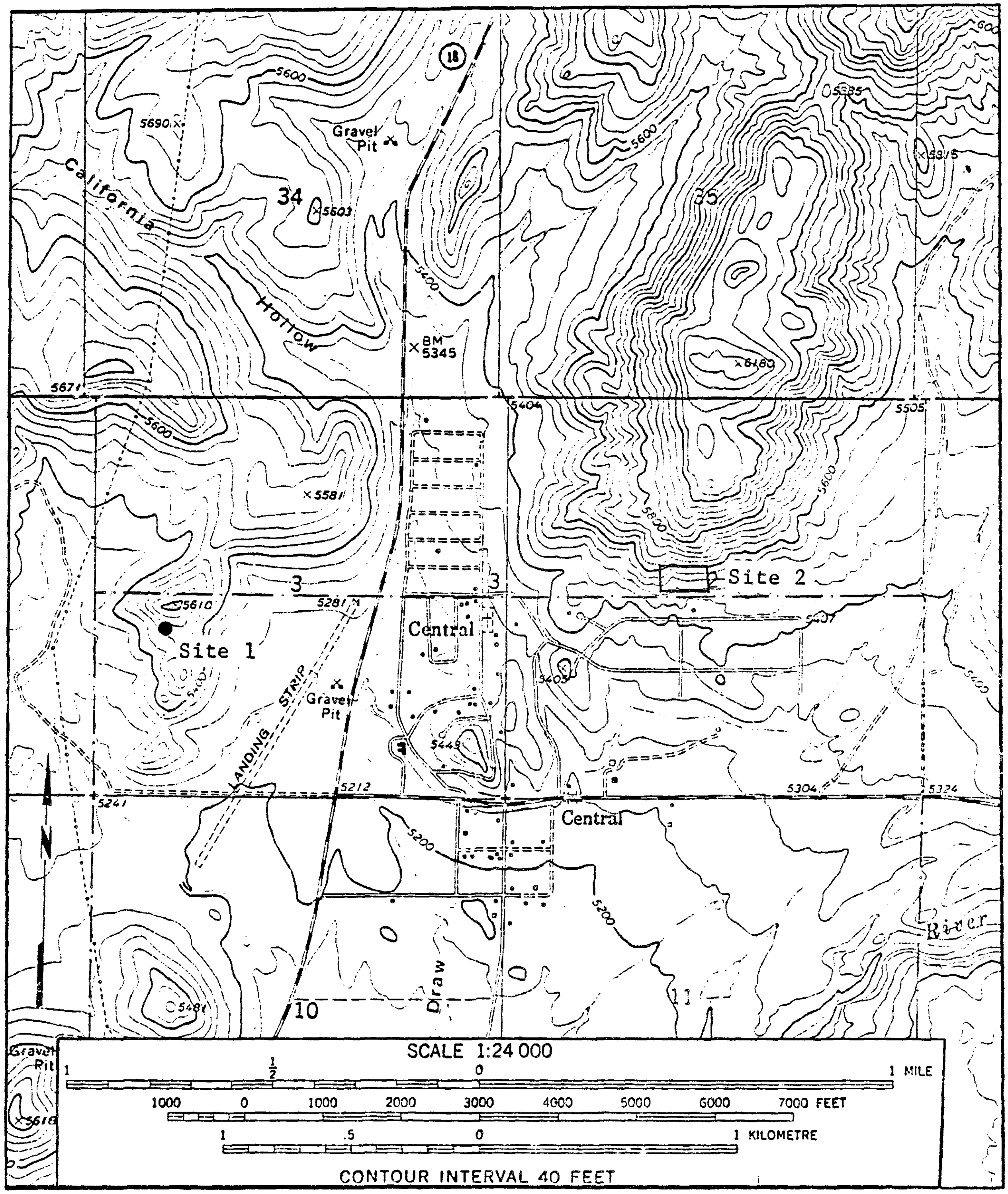
Mortensen, V.L., and others, 1977, Soil survey of Washington County area, Utah: U.S. Soil Conservation Service, U.S. Bureau of Land Management, National Park Service, and Utah Agricultural Experiment Station, 140 p.

Thenhaus, P.C., and Wentworth, C.M., compilers, 1982, Zones of similar ages of surface faulting and estimated maximum earthquake size in the Basin and Range province and selected adjacent areas: U.S. Geological Survey Open-File Report 82-742, scale 1:2,500,000.

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

Base map from: USGS 7½ topo quads
Central East, Utah
Central West, Utah

Attachment 1, Job No. PF-7



Location map

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.

Project:			Requesting Agency:
Davis Co. solid waste management project facility			Davis Co. Health Dept.
By: H. E. Gill	Date: 12/5/84	County: Davis	Job No.: PF-8
USGS Quadrangle: Kaysville (1320)			

In response to a request from Mr. Louis K. Cooper, Davis County Health Department Environmental Health and Laboratory Division, an engineering geologic investigation was made of the site proposed for the Davis County Solid Waste Management Project Facility. The plant will produce steam by burning refuse. A portion of the structure will lie below the ground surface, and hydrologic and soils information were obtained to a depth of 30 feet.

SITE LOCATION AND DESCRIPTION

The proposed site is adjacent to the eastern boundry of Hill Air Force Base in T. 5 N., R. 1 W., E1/2 NW1/4 SE1/4 sec. 4, SLB&M (attachment 1). Slopes in the study area range from an approximately 2 percent to the southwest in the southern portion of the property, to about 10 percent to the west-southwest in the northern portion. The property is a cultivated field and no natural surface drainage remains at the site. However, topographic maps indicate that two shallow surface drainages, one to the southwest and the other to the northeast, did exist on the southern end of the property prior to cultivation. Access is from Hill Field Road approximately 1500 feet to the south. The climate is temperate and semiarid with precipitation averaging about 14 inches anually (Feth and others, 1966).

SITE INVESTIGATION

The site investigation included a review of available published and unpublished maps and reports on the study area, a field reconnaissance of the property performed on October 24, 1984, and drilling five auger borings from 30 to 34 feet deep (attachment 2). Although the property encompasses approximately 25 acres, the borings were clustered where the plant will actually be built. No other subsurface investigations were undertaken. Detailed soils logs of the borings are presented in attachment 3 of this report.

SITE GEOLOGY

The property is on the southern part of the Weber River delta (Feth and others, 1966). The delta was deposited in Lake Bonneville during late Pleistocene time. The Provo level bench crosses the site, accounting for the change in slope from 2 to 10 percent from south to north across the property (Curry, 1980).

The soil sequence beneath the site contains varying degrees of sand, silty sand, silty clay, and clay (attachment 3). The upper soil horizons were predominantly sand and silty sand. However, 4 to 13 feet of silty clay, and clay were found at depth in borings 1,2, and 3 (attachment 3). Based on drill response, sand horizons were medium dense and silty-clay and clay lenses were stiff. Depth to ground water ranges from approximately 13 to 20 feet below ground surface (attachment 3).

GEOLOGIC HAZARDS

The property is in Uniform Building Code (UBC) seismic zone 3, and Utah Seismic Safety Advisory Council (USSAC) zone U-4, indicating that major damage corresponding to intensity VIII or higher of the modified Mercalli scale may occur (attachment 4). The main trace of the Wasatch fault is approximately 2.5 miles east of the site at the base of the Wasatch Range. Although surface rupture on the site during an earthquake is unlikely, the site could be subjected to strong ground shaking. Ground shaking is considered to be the greatest geologic hazard to the site. The presence of medium- to fine-grained clean sands below the water table indicates that a potential for liquifaction exists at the site.

The Washington Terrace landslide complex is approximately 1.5 miles northeast of the property. The soils there are similiar to those at the site (Shroder, 1967). During the site reconnaissance no evidence of slope instability was observed, however, the natural surface expression has been altered by cultivation and shallow surface failures may have been obscured. The low density, noncohesive, granular soils beneath the site could result in sloughing of temporary construction slopes. The hazard from erosion is not considered to be great, however, precautions should be taken to allow for adequate surface drainage.

CONCLUSIONS AND RECOMMENDATIONS

From a geologic standpoint, the proposed site is suitable for construction of the plant. However, the following recommendations are made:

1) Ground water is within 20 feet of the surface and a portion of the building is to be below the ground surface. It is recommended that the site be dewatered and a subsurface drainage system installed prior to construction, if excavations extend below the water table.

2) The site is in UBC seismic zone 3 and USSAC zone U-4. In the event of a major earthquake the site can expect strong ground shaking. It is recommended that the facility be designed at a minimum to meet UBC requirements for zone 3 construction.

3) A potential exists for liquifaction of saturated fine sand and silt lenses beneath the site. It is recommended that a detailed soils investigation be performed with borings to a depth of at least 50 feet below ground surface to examine this possibility.

4) The Washington Terrace landslide complex is near the site and the soils are similiar in the two areas. No indication of slope instability was observed during the site reconnaissance. A possibility exists for sloughing of temporary construction slopes in the loose, granular soils. It is recommended that construction excavations remain open for the minimum time necessary, and that permanent construction slopes be revegetated as soon as possible. Revegetation of slopes, and establishment of adequate surface drainage would also help prevent surface erosion at the site.

SELECTED REFERENCES

Cluff, L. S., Brogan, G. C., and Glass, C. E., 1970, Wasatch fault northern portion, earthquake fault investigation and evaluation: Woodward-Clyde and Associates, Oakland, California, 24 p.

Curry, D. R., 1980, Coastal geomorphology of Great Salt Lake and vicinity, in Gwynn, J. W., ed., Great Salt Lake, a scientific, historical, and economic overview: Utah Geological and Mineral Survey Bulletin 116, p. 69-82.

Erickson, A. J., and others, 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.

Feth, J. H., 1955, Sedimentary features in the Lake Bonneville Group in the East Shore area, near Ogden, Utah, in Eardley, A. J., ed., Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geological Society Guide Book to the Geology of Utah, number 10, p. 45-69.

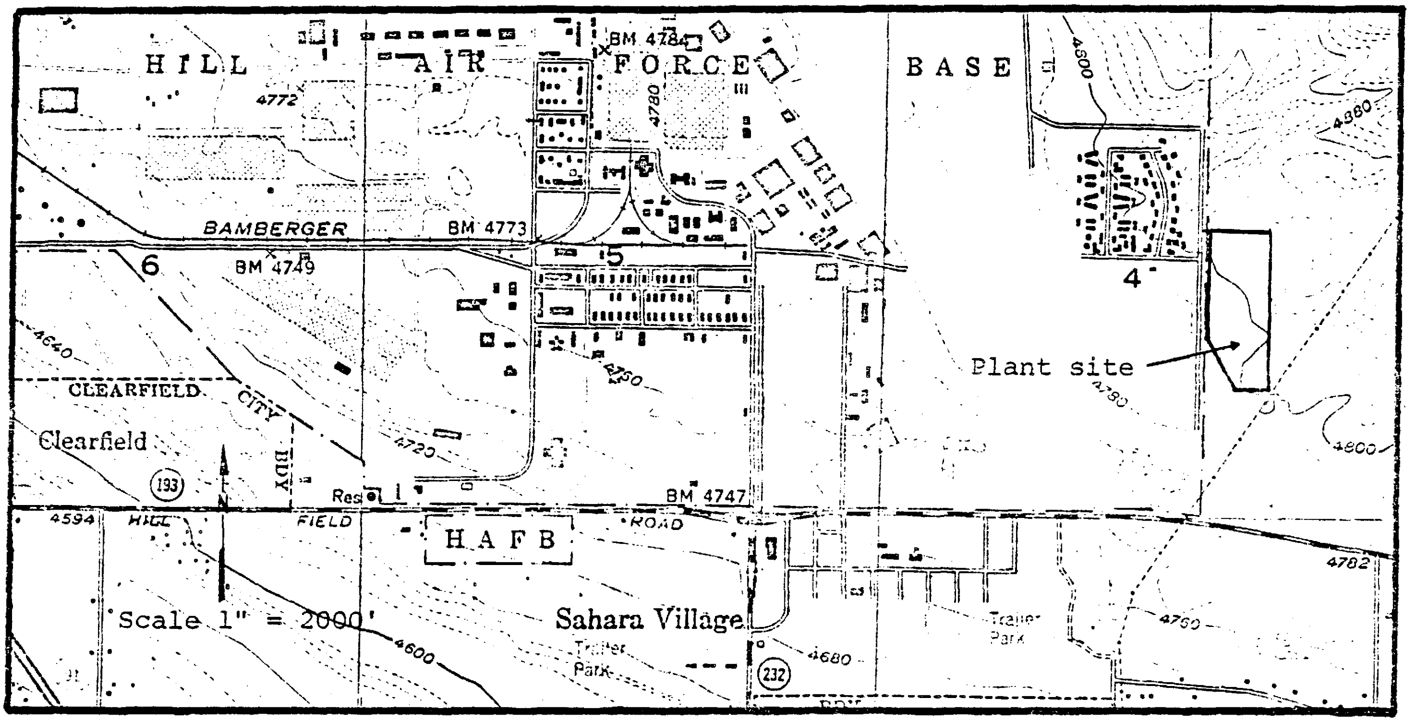
Gill, H. E., 1981, Geologic investigation of a major slope failure in the Washington Terrace landslide complex near the mouth of Weber Canyon, Weber County, Utah: Utah Geological and Mineral Survey Report of Investigation 163, 18 p.

Miller, R. D., 1980, Surficial geologic map along part of the Wasatch Front, Salt Lake Valley, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1198, central part, scale 1:100,000.

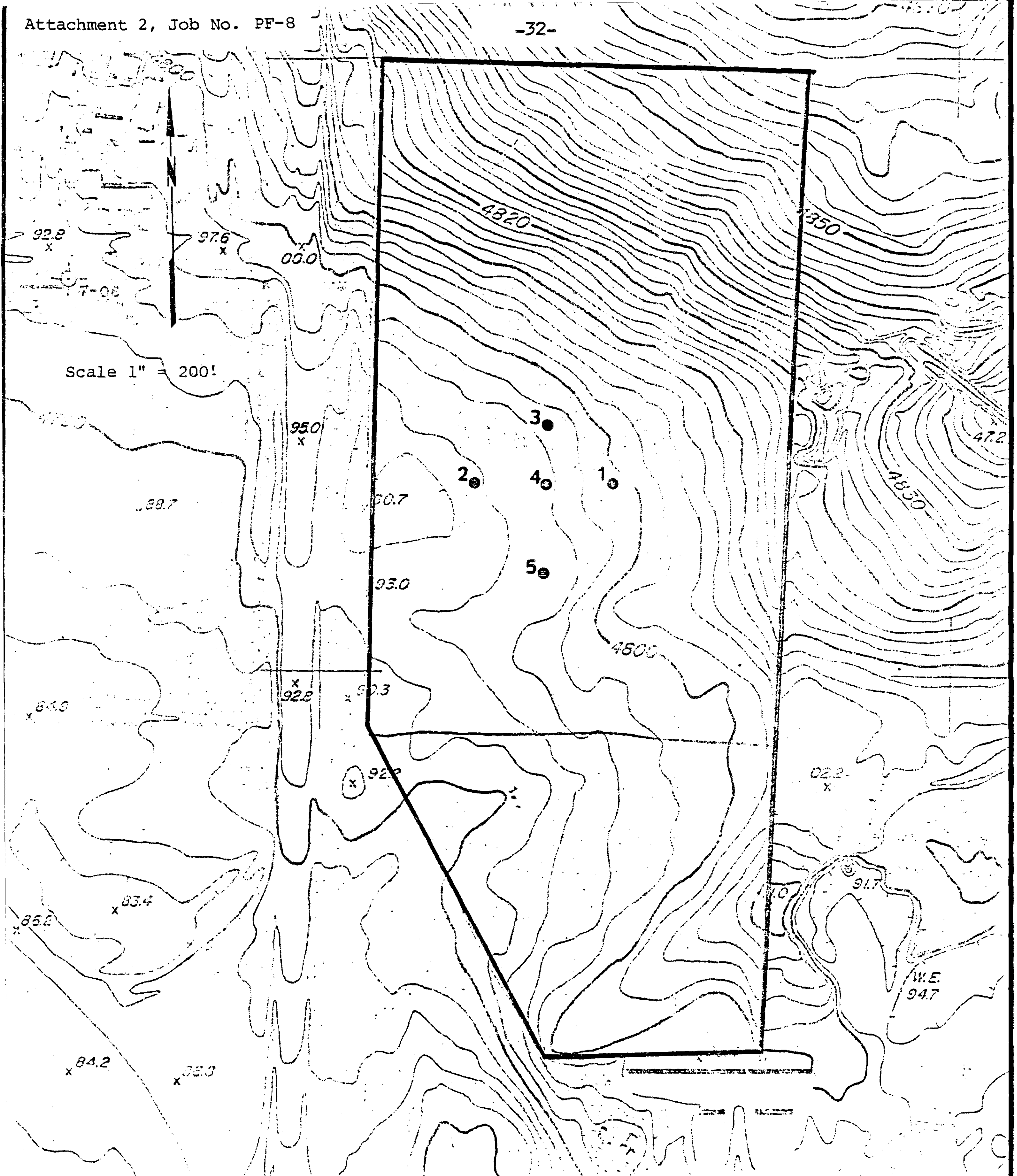
Pashley, E. F., Jr., and Wittins, R. A., 1972, Landslides of the northern Wasatch Front, in Hilpert, L. S., ed., Environmental geology of the Wasatch Front: Utah Geological Association Publication 1, p. K1-K16.

Shroder, J. F., Jr., 1967, Landslides of Utah: University of Utah doctoral dissertation, p. A5-A11.

Attachment 1, Job No. PF-8



General Location Map, Davis County Solid Waste Management Project Facility.



Study Area with Boring Locations

Attachment 3, Job No. PF-8

Logs of Auger Borings*

Boring 1

0.0' - 2.0'	Silty sand (SM); topsoil, dark brown, low density, nonplastic, nonindurated, moist.
2.0' - 7.0'	Silty sand (SM); brown, medium dense, low plasticity, nonindurated, moist.
7.0' - 12.0'	Silty clay/clayey silt (CL/ML); brown, stiff, medium plasticity, nonindurated, dry.
12.0' - 17.0'	Gravelly sand (SM); brown, loose, nonplastic, nonindurated, dry; contains 15 percent gravel.
17.0' - 20.0'	Clayey sand/sandy clay (SC/CL); brown, low density, none to medium plasticity, nonindurated, saturated.
20.0' - 29.0'	Silty clay (CL); brown, firm, medium plasticity, nonindurated, saturated.

Note: Ground water encountered at 19.8 feet.

Boring 2

0.0' - 3.0'	Silty sand (SM); topsoil, dark brown, low density, nonplastic, nonindurated, moist.
3.0' - 7.0'	Silty sand (SM); brown, medium dense, none to low plasticity, nonindurated, dry.
7.0' - 9.0'	Silty clay (CL); brown, stiff to very stiff, medium plasticity, nonindurated, dry.
9.0' - 14.0'	Gravelly sand (SP); brown, loose, nonplastic, nonindurated, dry; contains 25 percent gravel.
14.0' - 20.0'	Sand (SP); brown, loose, nonplastic, nonindurated, moist to wet.
20.0' - 30.0'	Gravelly sand (SP); brown, loose, nonplastic, nonindurated, wet; contains 25 percent gravel.
30.0' - 34.0'	Silty clay/clay (CL/CH); black, firm, high plasticity, nonindurated, saturated.

Note: Ground water encountered at approximately 13 feet. Caving in gravel lenses may have caused erroneous reading.

* Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (revised 1975), Description of Soils (Visual Manual Procedure). Percentages recorded for various size fractions are field estimates. Density and induration were based on drill response.

Attachment 3, Job No. PF-8

Boring 3

0.0' - 2.0'	Silty sand (SM); topsoil, dark brown, low density, nonplastic, nonindurated, moist.
2.0' - 5.0'	Silty sand (SM); brown, medium dense, low plasticity, nonindurated, dry.
5.0' - 11.0'	Silty clay (CL); brown, stiff, medium plasticity, nonindurated, moist.
11.0' - 16.0'	Silty sand (SM); brown, loose, nonplastic, nonindurated, saturated.
16.0' - 21.0'	Silty clay (CL); brown, stiff, medium plasticity, nonindurated, saturated.
21.0' - 29.0'	Clay (CH); light brown, stiff, high plasticity, nonindurated, saturated.

Note: Ground water encountered at 13.8 feet.

Boring 4

0.0' - 3.0'	Silty sand (SM); topsoil, dark brown, low density, nonplastic, nonindurated, moist.
3.0' - 8.0'	Silty clay (CL); brown, stiff, medium plasticity, nonindurated, dry.
8.0' - 10.0'	Sandy clay (CL); firm, low to medium plasticity, nonindurated, dry.
10.0' - 13.0'	Sand (SP); light brown, loose, nonplastic, nonindurated, dry.
13.0' - 18.0'	Gravelly sand (SP); brown, loose, nonplastic, nonindurated, moist; contains 25 percent gravel.
18.0' - 29.0'	Sand (SP); brown, loose, nonplastic, nonindurated, saturated.

Note: Ground water encountered at approximately 15 feet. Caving in gravel and sand lenses may have caused erroneous reading.

Attachment 3 cont.

Boring 5

0.0' - 3.0'	Silty sand (SM); topsoil, dark brown, low density, nonplastic, nonindurated, moist.
3.0' - 10.0'	Silty sand (SM); brown, low density, low to medium plasticity, nonindurated, dry.
10.0' - 15.0'	Gravelly sand (SP); brown, loose, nonplastic, nonindurated, dry; contains 25 percent gravel.
15.0' - 29.0'	Sand (SP); brown, loose, nonplastic, nonindurated, wet to saturated.

Note: Ground water encountered at approximately 14 feet. Caving in gravel lense may have caused erroneous reading.

Project: Kaysville block 19 hazards evaluation			Requesting Agency: Kaysville City Corp.
By: H. Gill & K. Harty	Date: 1/15/85	County: Davis	Job No.: PF-9
USGS Quadrangle: Kaysville (1320)			

In response to a request from John W. Thacker, City Administrator for Kaysville City Corporation, a geologic hazards evaluation was made of city block 19 in Kaysville, Utah. Redevelopment of the block is planned with construction of a new city hall, police station, and senior citizens center. It is our understanding that the new city hall will have a slab-on-grade foundation with no basement, and that the police station will be either a new structure or an addition to the existing combination police and fire station. The senior citizens center will be constructed at a later date. Design details for the structures were not available at the time of the investigation.

SITE LOCATION AND DESCRIPTION

Kaysville lies along the Wasatch Front in Davis County approximately 15 miles south of Ogden, Utah, between the Great Salt Lake to the west, and the Wasatch Mountains to the east (attachment 1). With the exception of one lot, Kaysville City Corporation has acquired all of block 19 encompassing an area of approximately 20 acres. Block 19 has a mean elevation of about 4,300 feet above sea level and a slope of approximately 3 percent to the southwest. The property is bounded on the north by 100 North Street, on the south by Center Street, on the east by 100 East Street, and on the west by Main Street. At the present time, there are six structures on block 19: two private residences facing Center Street, a senior citizens center on 100 North, a combination police and fire station facing 100 East, and a combination city hall and library on Main Street (attachment 2).

The U.S. Geological Survey 7 1/2' Kaysville topographic quadrangle map shows an intermittant stream stopping just north of the city limits (attachment 1). Residents stated that at one time the drainage ran north of block 19 and possibly crossed the northwest corner of the property. The stream channel has been filled and the flow piped into the city's storm drain system.

SITE INVESTIGATION

The site evaluation included a review of available maps, aerial photos, and reports on the study area, and a field investigation on December 13, 1984. In addition to a general site reconnaissance, the field investigation included excavation of an 87.8 foot long, east-west trending trench from 6 to 10 feet deep, and a test pit 10 feet deep (attachment 2). The trench was excavated at the site of the new city hall and the test pit was in an open area between the present police/fire station and the senior citizens center (attachment 2). Although the exact location of the new police station has not been determined, the test pit is in the general area planned for that facility and provides sufficient data for the soil/hazard investigation. Present during the field investigation was Mr. Vance Garfield, Parks and Recreation Director for Kaysville City.

SITE GEOLOGY AND SOILS

Kaysville is underlain by Lake Bonneville sediments of Pleistocene age. Fine silt and clay deposited during Provo and Bonneville lake stages are found beneath the site (Feth and others, 1966). These off-shore, lake-bottom sediments predominate in the Kaysville area and may attain a thickness of several tens of feet (Feth and others, 1966).

The soil sequence beneath the site consists of silty clay and clay with a minor clayey sand lens, approximately 1.3 feet thick, in the north test pit (attachment 3). The fine-grained sediments are firm to stiff with medium to high plasticity, and the clayey sand lens is medium dense with low to medium plasticity (attachment 3). There was no bedrock encountered at the site. The nearest rock outcrops are approximately 2 miles to the east and bedrock is probably at least several hundred feet below the surface at the site.

GEOLOGIC HAZARDS

The Quaternary age Wasatch fault, is at the base of the Wasatch Range approximately 2 miles east of Kaysville. Block 19 lies 1.1 miles west of the nearest mapped fault trace, and 1.3 miles east of a concealed NW-SE trending fault (Cluff, and others, 1970; Van Horn, 1975a). Kaysville is in Uniform Building Code (UBC) seismic zone 3 and Utah Seismic Safety Advisory Council (USSAC) seismic zone U-4. There was no evidence of faulting observed at the ground surface or in the test pit or trench excavated at the site.

Considerable landslide activity has taken place along the Wasatch Front near Kaysville during the past several thousand years. Van Horn (1975a) has mapped a number of prehistoric slope failures, the closest being approximately 1/2 mile to the northwest of block 19. Evidence of previous landslide activity can be found on hillslopes near the mouth of Webb Canyon, approximately 1.5 miles northeast of Kaysville (Van Horn, 1975a). A liquefaction, or lateral spread feature occurs along the Wasatch fault zone approximately 2.0 miles southeast of Kaysville (Van Horn, 1975a). Van Horn (1975a) stated that slope failure caused by liquefaction is believed to be a prevalent landslide mechanism in silt and silty clay Lake Bonneville sediments. Van Horn (1975b) documented the occurrence of two major prehistoric liquefaction-induced landslides, one 2,000-5,000 years old and the other probably less that 2,000 years old, south of Kaysville near Farmington, Utah. Both are believed to have been triggered by seismic activity.

The potential for landslides, debris flows, and debris floods in canyons along the Wasatch Front must be considered in a hazard evaluation of Kaysville. Webb and Baer Creek Canyons, situated close to Kaysville (approximately 1.5 miles east), possess moderate and very high potential respectively for generating debris flows which may reach the canyon mouths. The canyons rate high and very high respectively, for generation of debris floods which may reach the canyon mouths (Wieczoreck and others, 1983). Despite the hazard posed by these landslide-prone areas, it is unlikely that Kaysville and block 19 would be threatened by slope failure generated within the canyons. The distance from the canyon mouths to the city is approximately 1.5 miles and it is doubtful that a debris flow would extend that far from the mountain front. However, as the U.S. Department of Housing and Urban

Development (HUD) flood hazard maps for the City of Kaysville (1974; 1976) show, the northwest corner of block 19 may be subject to a debris flood eminating from the canyons. The present senior citizens center is in this area and the new one will also be built at this site. Because of the elevation difference across block 19, other portions of the property are unlikely to be affected by flooding. A debris flood was recorded in 1917 in Webb Canyon. However, the flood was of limited extent and only deposited debris on farms near the mouth of the canyon.

Ground water was encountered in both the trench and the test pit. The water table in the trench was measured at three locations, the west end, middle, and east end (attachment 2; locations a, b, and c,). Measurements were taken immediately after the excavation was completed and again approximately one hour later. The water level at location "a" rose from 6.7 to 6.3 feet below ground surface during the hour. Location "b" rose from 6.5 to 6.0 feet, and location "c" remained at 6.1 feet below the ground surface (attachment 3). Because the trench was deeper at the west end (approximately 10 feet on the west as compared to about 6 feet on the east), it took longer for the water level to stabilize. The clayey soils were saturated from approximately 4.5 feet below ground surface to the bottom of the trench. In time, the water level would probably rise to this level. The water level in the test pit was 9 feet below the surface after the excavation was completed and rose to 8.3 feet an hour later. The soils were saturated from 7.3 below the ground surface.

The clayey sand lens observed in the north test pit indicates that additional saturated sand or silt lenses may occur at depth beneath block 19. If that is the case, there is a potential for liquefaction. Anderson and others (1982) have placed the entire City of Kaysville in a moderate liquefaction potential zone. Due to the extensive fine-grained lake bottom sediments beneath block 19, the potential also exists for shrinking and swelling clays.

CONCLUSIONS AND RECOMMENDATIONS

From a geologic standpoint, block 19 is suitable for the proposed construction, however, the following recommendations are made:

1) Ground water is within 6 to 7 feet of the ground surface. The measurements were taken during December when the water table is near its lowest level. During the spring and summer water levels may rise much higher depending upon precipitation and irrigation practices. Therefore, it is recommended that all facilities be constructed without basements.

2) A flood hazard zone exists in the northwest corner of block 19. It is recommended that prior to construction in this area, steps be taken to mitigate the potential for flooding.

3) A potential hazard exists from shrinking and swelling clays and liquefaction of saturated fine sand lenses beneath block 19. It is recommended that a detailed soils/foundation investigation be performed for each new building, and that at least three borings, to a minimum depth of 50 feet, be drilled across block 19 to investigate for liquefiable sand and silt lenses at depth.

4) The site is in UBC seismic zone 3 and USSAC zone U-4. In the event of a major earthquake block 19 can expect to experience strong ground shaking. It is recommended that all facilities be designed at a minimum to meet UBC requirements for zone 3 construction.

5) Numerous earth failures (landslides, debris flows, and debris floods) are mapped near the study area. There was no indication of instability observed at the site, either at the surface or in the trench and test pit, it is felt that the possibility of earth failure on the property is low. However, Webb Canyon does possess the potential for debris floods, and a major event (100 or 200 year flood) could possibly reach Kaysville.

SELECTED REFERENCES

Anderson, L. R., and others, 1982, Liquefaction potential map for Davis County, Utah: Department of Civil and Environmental Engineering Utah State University, and Dames and Moore Consulting Engineers, for U.S. Geological Survey, contract no. 14-08-0001-19127, 49 p.

Butler, Elmer, and Marsell, R. E., 1972, Developing a state water plan, cloudburst floods in Utah, 1939-69: U.S. Geological Survey in cooperation with the Utah Department of Natural Resources Division of Water Resources Cooperative-Investigations Report Number 11, 103 p.

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

Davis, F.D., 1983, Geologic map of the central Wasatch Front, Utah: Utah Geological and Mineral Survey Map 54-A, scale 1:100,000.

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.

Feth, J.H., 1955, Sedimentary features in the Lake Bonneville Group in the East Shore area, near Ogden, Utah, in Eardley, A.J., ed., Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geological Society Guide Book to the Geology of Utah, number 10, p. 45-69.

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.

Jones, D.J., and Marsell, R.E., 1955, Pleistocene sediments of lower Jordan Valley, Utah, in Eardley, A.J., ed., Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geological Society Guide Book to the Geology of Utah, number 10, p. 85-112.

U.S. Department of Housing and Urban Development Federal Insurance Administration, 1974, Flood hazard boundary map, City of Kaysville, Utah: Map no. H-01 and H-02, scale 1:12,000.

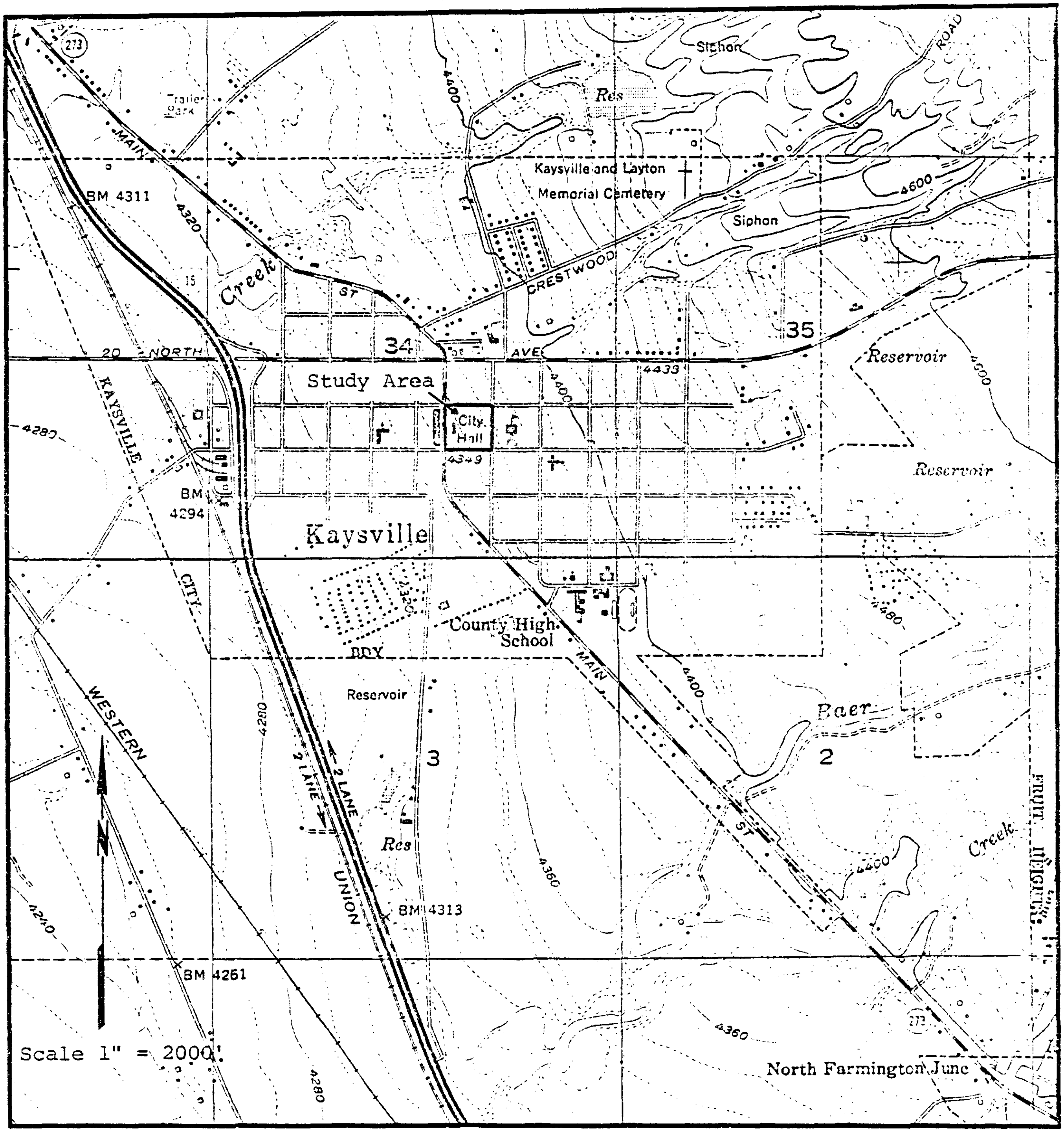
U.S. Department of Housing and Urban Development Federal Insurance Administration, 1976, Flood hazard boundary map, City of Kaysville, Utah: Map no. H-01 and H-02, scale 1:12,000.

Van Horn, Richard, 1975a, Unevaluated reconnaissance geologic maps of Salt Lake and Davis Counties west of the Wasatch Front, Utah: U.S. Geological Survey Open-File Report 75-616, p. 14.

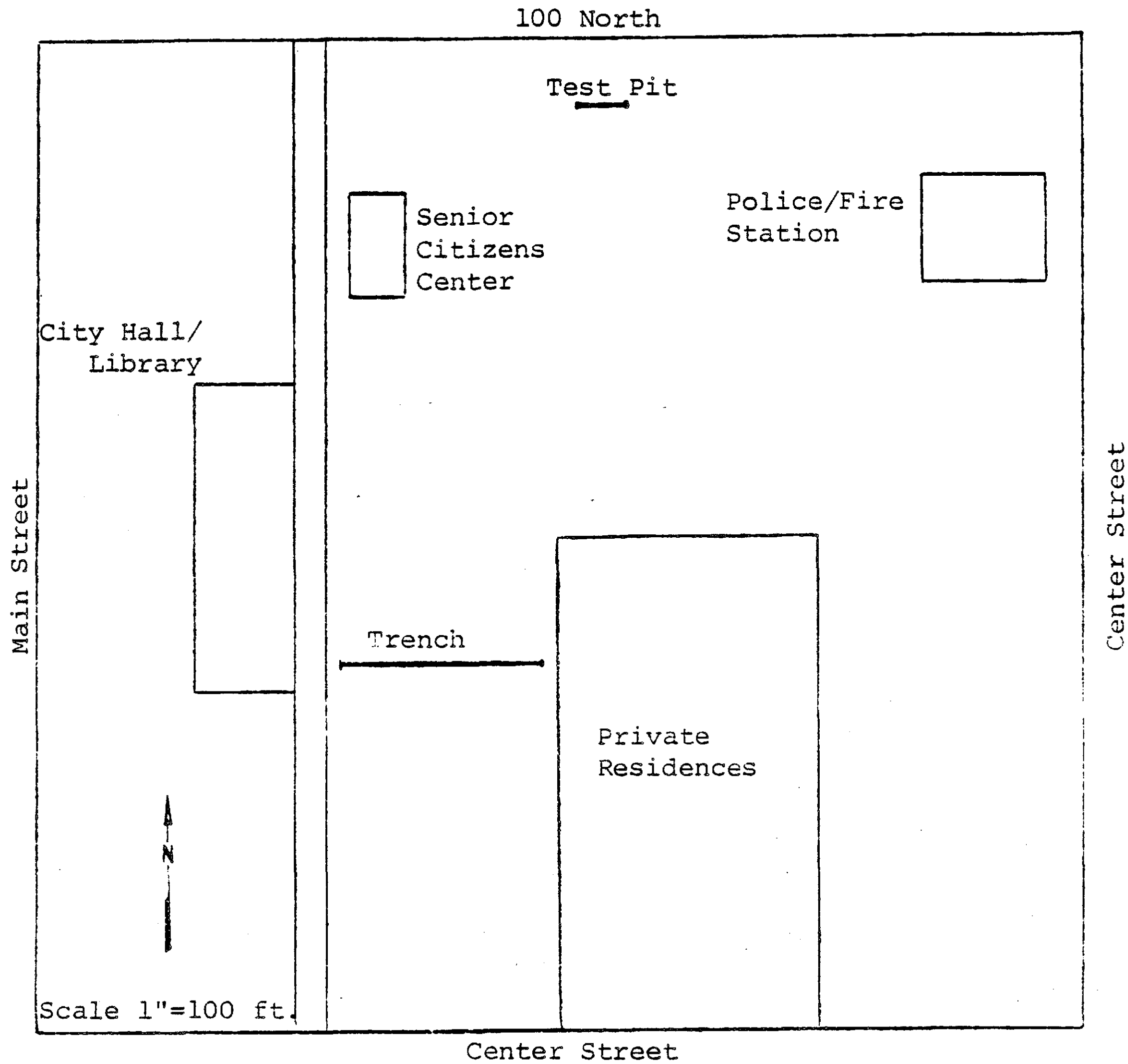
-------- 1975b, Largest known landslide of its type in the United States - a failure by lateral spreading in Davis County, Utah: Utah Geology, V. 2, no. 1, p. 83-87.

Wieczorek, G.F., Ellen, Stephen, Lips, E.W., Cannon, S.H., and Short, D.N., 1983, Potential for debris flow and debris flood along the Wasatch Front between Salt Lake City and Willard, Utah, and measures for their mitigation: U.S. Geological Survey Open-File Report 83-635, 45 p.

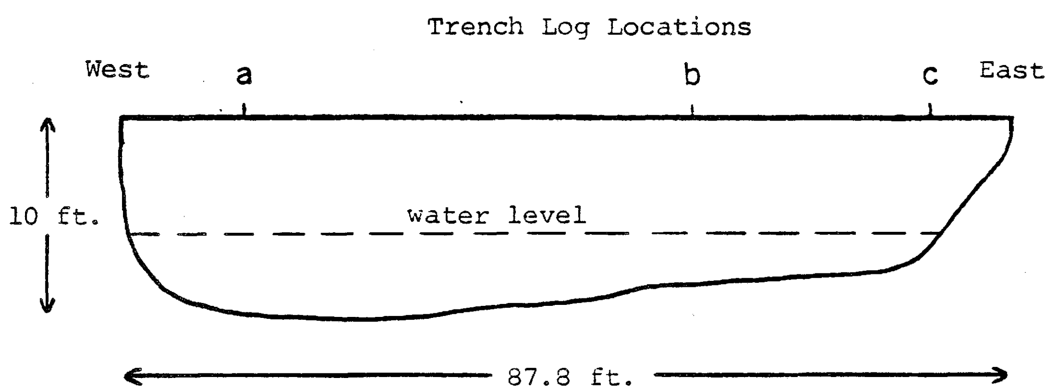
Wooley, R. R., 1946, Cloudburst floods in Utah 1850-1938: U.S. Geological Survey Water-Supply Paper 994, 128 p.



General Location Map, Kaysville City Block 19.



Trench and Test Pit Locations



Attachment 3, Job No. PF-9

Trench Logs*

Location a

0.0' - 1.1'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonindurated, moist.
1.1' - 2.6'	Silty clay (CL); light brown/brown, stiff, high plasticity, weakly indurated, dry.
2.6' - 10.0'	Clay (CH); light brown, firm, high plasticity, weakly indurated, dry to saturated.

NOTE: Soil saturated 4.5 feet below ground surface. Ground water encountered at 6.7 feet, rising to 6.3 feet after 1 hour.

Location b

0.0' - 1.5'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, noninudrated, moist.
1.5' - 3.5'	Silty clay (CL); light brown/brown, stiff, high plasticity, weakly indurated, dry.
3.5' - 5.8'	Clay (CH); light brown, firm, high plasticity, weakly indurated, dry to saturated.

NOTE: Soil saturated 5.4 feet below ground surface. Ground water encountered at 6.5 feet, rising to 6.0 feet after 1 hour.

Location c

0.0' - 1.1'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonindurated, moist.
1.1' - 3.0'	Silty clay (CL); light brown/brown, stiff, high plasticity, weakly indurated, dry.
3.0' - 6.0'	Clay (CH); light brown, firm, high plasticity, weakly indurated, dry to saturated.

NOTE: Soil saturated 4.4 feet below ground surface. Ground water encountered at 6.1 feet, remaining at this level after 1 hour.

*Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (revised 1975), Description of Soils (Visual Manual Procedure). Percentages recorded for various size fractions are field estimates.

Attachment 3, Job No. PF-9 cont.

Test Pit Log*

0.0' - 0.8'	Gravelly clay (CL); topsoil, dark brown, firm, medium plasticity, nonindurated, moist to wet; contains 25 percent gravel.
0.8' - 2.4'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonindurated, moist.
2.4' - 5.3'	Silty clay (CL); light brown/brown, stiff, medium plasticity, weakly indurated, dry.
5.3' - 6.0'	Sandy clay (CL); brown, stiff, medium plasticity, weakly indurated, moist.
6.0' - 7.3'	Clayey sand (SC); brown, medium density, low to medium plasticity, nonindurated, moist.
7.3' - 10.0'	Clay (CH); light brown, firm, high plasticity, weakly indurated, saturated.

NOTE: Soil saturated 7.3 feet below ground surface. Ground water encountered at 9.0 feet, rising to 8.3 feet after 1 hour.

*Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (revised 1975), Description of Soils (Visual Manual Procedure). Percentages recorded for various size fractions are field estimates.

Project:			Requesting Agency:
Salt Lake City water tank study			Salt Lake City Dept. of Public Utilities
By: R. H. Klauk	Date: 1/21/85	County: Salt Lake	Job No.: PF-10
USGS Quadrangle: Fort Douglas (1253)			

BACKGROUND AND SCOPE OF WORK

In response to a request from LeRoy W. Hooton, Jr., Director, Salt Lake City Corporation, Department of Public Utilities, an investigation has been conducted for a proposed 1.5 million gallon water tank at the mouth of Red Butte Canyon. The purpose of the investigation was to identify any geologic hazards and adverse soil conditions that may be present at the site.

The scope of work included the following:

1. a review of existing geologic and hydrologic literature, and;
2. a field reconnaissance of the site on November 5, 1984.

LOCATION AND DESCRIPTION

The site is in the S1/2 sec. 34, T. 1 N., R. 1 E., Salt Lake Baseline and Meridian (attachment 1). The water tank would be located on a bedrock knob on the northwest side of the mouth of Red Butte Canyon, approximately 300 feet above the creek. The site is sparsely vegetated with scrub oak and native grasses. According to George Jorgensen (personal communication, November 5, 1984), chief engineer for the project, a portion of the top of the knob will be removed to provide a foundation for the tank.

GEOLOGY AND SOILS

The bedrock knob is primarily composed of the Mahogany Member of the Ankareh Formation, which consists of brown to reddish-purple shale, mudstone, and fine-grained sandstone. The Mahogany Member makes contact with the Thaynes Formation in the northern part of the site. The Thaynes Formation consists of a silty, medium-gray limestone. Bedrock in the knob strikes east-northeast and dips 40 to 50^{o} south. Where bedrock is not exposed, the site is covered by in situ soil mostly weathered from the Mahogany Member. This soil, primarily composed of silt and clay, is less than 3 feet thick.

The Mahogany Member of the Ankareh Formation contains relatively soft (less resistant) shale and mudstone interbedded with more resistant sandstone. The steeply dipping, less resistant shale and mudstone beds are lower in shear strength along which planes of weakness may develop resulting in slope failure at the site. In addition, these shale and mudstone beds are potentially moisture sensitive and may swell upon wetting producing fractures in the foundation.

No springs were observed during the reconnaissance and perched water is not present beneath the site.

SEISMICITY AND FAULTING

Van Horn (1969) has mapped a fault in bedrock bordering the site to the northeast (attachment 1). He joined this fault with a fault displacing Lake Bonneville sediments in Research Park (attachment 1). No evidence of the bedrock fault, (breccia, slickensides, offset beds) was observed in the field during the reconnaissance. Furthermore, the left-lateral displacement shown between the Thaynes and Ankareh formations is not consistant with the normal faulting characteristic of the Wasatch fault zone. However the displacement observed in the Lake Bonneville sediments in Research Park is typical of the Wasatch fault zone. If the bedrock fault does exist, it is inactive and is not a continuation of the Quaternary fault. The seismic event that caused displacement on the Quaternary fault in Research Park may also have produced the faulting discovered by Everitt (1980) in the excavation for the addition to the University of Utah Medical Center (attachment 1).

The site is located in Uniform Building Code (UBC) seismic zone 3 and Utah Seismic Safety Advisory Council (USSAC) seismic zone 4. This indicates the site is within an area where an earthquake can produce modified Mercalli intensities of V1l1 or greater (attachment 2). An intensity greater than V1l1 were associated with the earthquake that caused the ground rupture visible in Research Park. A recurrence of such an event would cause severe ground shaking at the tank site.

CONCLUSIONS AND RECOMMENDATIONS

The Mahogany Member of the Ankareh Formation consists of less reisstant shale and mudstone interbedded with more resistant sandstone. These softer beds produce planes of weakness in the rock which, when combined with the steep bedding, could produce slope failure in cuts at the site. These beds could also be moisture sensitive and swell upon being exposed to moisture.

No evidence of the bedrock fault mapped as bordering the site to the northeast was found during this investigation. If the bedrock fault does exist, it is not continuous with the the Quaternary fault located in Research Park 3000 feet south of the site. Quaternary faulting was also observed at the University of Utah Medical Center approximately 3200 feet to the west. Recurrence of movement along these faults would produce severe ground shaking at the water tank site.

Based on these conditions, the following recommendations are made:

1. The engineering study being conducted for the site should take into account possible slope failure and moisture sensitivity of the Mahogony Member of the Ankareh Formation.

2. The site should be reinspected by a geotechnical engineer or engineering geologist when excavations are to grade to determine if adverse conditions exist with the foundation that were not previously identified.

3. The structure should be designed and constructed in accordance with UBC seismic requirements for zone 3, including design review and field inspection to insure compliance as required for USSAC seimic zone 4.

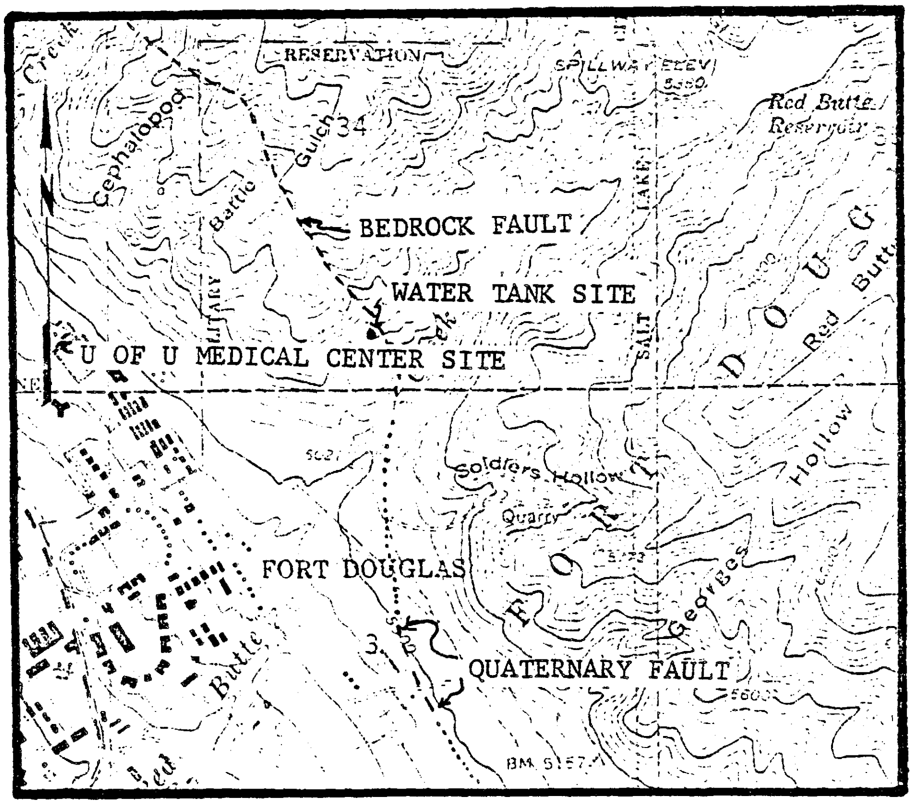
REFERENCES CITED

Everitt, B. L., 1980, Geology of some foundation excavations in northeastern Salt Lake City: Utah Geological and Mineral Survey Report of Investigation no. 149, 24 p.

Gill, H. G., and Lund, W. R., 1984, Engineering geology of Park City, Summit County, Utah: Utah Geological and Mineral Survey Special Studies 66, 42 p.

Van Horn, Richard, 1969, Preliminary geologic map of the southern half of Fort Douglas quadrangle, Salt Lake County, Utah: U.S. Geological Survey Open-File Report 69-308, scale 1:24,000.

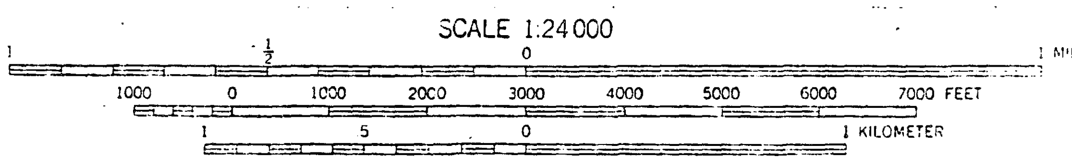
R. 1 E.



T. 1 N.

T. 1 S.

Base map from: U.S.G.S. 7 1/2'
topographic quadrangle Fort Douglas,
Utah.



CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

FAULT--long dashed where approximately located; short dashed where inferred; dotted where concealed.

LOCATION MAP OF WATER TANK SITE

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), 1974, p. 28.

SCHOOLS

Project:			Requesting Agency:
Investigation of seven school sites in Washington County, Utah			Washington County School District
By: G. E. Christenson	Date: 1/17/84	County: Washington	Job No.: S-1
USGS Quadrangle: St. George SE (37), St. George NE (78), St. George NW (79)			

PURPOSE AND SCOPE

The purpose of this study is to assess geologic hazards and soil conditions for construction at seven proposed school sites in Washington County. All sites are in the St. George area and have been designated A through G for this report (attachment 1). Site A is on the South Black Rocks lava flow near Santa Clara, site B is at 540 North and 1450 West, and site C is in Green Valley. Site D is between Bloomington and Green Valley, and the remaining three are in Bloomington (site E), Bloomington Hills (site F), and Panorama Park (site G).

The scope of work included a literature review and air photo analysis with a field investigation performed on December 6-7, 1983. Detailed investigations were performed at sites A, B, E, F, and G, including excavation of test pits at four of the sites. No test pits were excavated at site A near Santa Clara because it is on the South Black Rocks lava flow. Only a preliminary field investigation was requested for sites C and D. This investigation consisted of a surface reconnaissance and inspection of existing cuts at site C and a site viewing at site D. I was accompanied during the field investigation by Keith Empey of the Washington County School District.

SITE CONDITIONS AND HAZARDS ASSESSMENT

Site A - South Black Rocks

Site A is on the generally flat surface of the South Black Rocks lava flow and is bordered to the east and west by washes incised 15-30 feet below the top of the flow. The lava is geologically young (several thousand years old) and retains a barren, rugged surface that is free of vegetation and soil in the southern part of the site. To the north, it is partially covered by eolian sand and the surface is smoother with patchy vegetation. The lava flow consists of an upper layer of basaltic cinders and blocks ranging in diameter from several inches to several feet overlying the main body of dense, jointed basalt. The thickness of the upper cinder layer is variable and test pits in the layer were not attempted for this study. About 1/4 mile to the south, across State Highway 91 in the Arrowhead Trail section of Santa Clara, the layer was found to be about 8 feet thick above dense lava (Lund, 1980). The flow is underlain by alluvial sand and gravel of ancestral Sand Hollow Wash, down which the lava flowed. Sand Hollow Wash was subsequently diverted eastward along the eastern edge of the flow. Beneath the deposits of both the modern and ancestral Sand Hollow Wash are bentonitic shales of the Triassic-age Petrified Forest Member of the Chinle Formation. Foundation excavations, however, will be entirely in the lava flow.

Shallow ground water is not expected at the site and the water table is probably near or below the level of the washes on either side of the site. The Santa Clara Reservoir along the west side of the site may produce locally high water table conditions in that area when the reservoir is full. However, basalt flows are typically highly permeable and well-drained because of extensive joint systems in the rock. Also, their strength is not greatly affected by unconfined ground-water conditions in the jointed rock. The U.S. Department of Housing and Urban Development Federal Insurance Administration (1980) has included much of the site in a flood hazard zone. The spillway of the Santa Clara Reservoir discharges onto the site and, if ever used, could flood much of the southern part. The land is flat except for slopes along washes east and west of the site. No evidence for instability was observed in these slopes which are underlain by basalt and weakly to moderately indurated sand. The underlying bentonitic shales of the Chinle Formation which is characteristically unstable in slopes is buried sufficiently deep to present no slope stability problems.

Site B - 540 N., 1450 W.

Site B is on a southwest-sloping alluvial lowland south of State Highway 91 and west of West Black Ridge (attachment 1). It is traversed from northeast to southwest by a wash cut about 10 feet below the upper alluvial surface. Soil types in the upper surface consist of about 2.5 feet of red, silty sand underlain by a thick (6.5 feet) layer of moderately indurated, white gypsum and gypsiferous sand (test pit 1, attachment 2). At depths below 9.0 feet, the gypsum layer is underlain by a calcium carbonate-cemented sand which is strongly indurated and known locally as "water rock." In the major wash areas it is expected that much of the gypsum layer has been removed and soils consist principally of silty sand. Sandstone, siltstone, and shale of the Moenave Formation underlie the area but will probably not be encountered at depths of less than 10 feet except in wash areas. Foundation materials will thus consist principally of gypsum and gypsiferous sands covered by a variable thickness of silty sand.

No ground water was encountered in test pit 1 to a depth of 9.5 feet. Ground water reportedly is present below the "water rock" in a subdivision east of the site and elsewhere throughout the St. George area. It is thus possible that excavations which penetrate this layer may encounter water. Also, ground water may be present in modern sandy alluvium in dry washes from seepage where the "water rock" layer has been partially removed by stream erosion and is draining into the alluvium. The U.S. Department of Housing and Urban Development Federal Insurance Administration (1980) has mapped a flood-hazard zone along the wash which traverses the property from northeast to southwest. Drainage from parts of the subdivision to the east is diverted into the wash and recent flow was evident. No problems with stability of natural slopes are expected at the site due to low slope gradients and the degree of induration of soil materials.

Site C - Green Valley

Most of site C is on the northeast-facing slope of a gravel-capped bench south of the Santa Clara River (attachment 1). The northeastern corner of the site extends beyond the slope onto the southern edge of the Santa Clara River flood plain. The sloping areas of the site are underlain by shale and sandstone of the Petrified Forest Member of the Chinle Formation. These rocks are buried beneath a thin layer of gravelly colluvium but are exposed in road cuts. A small terrace capped by remnant stream gravels about 3 feet thick occurs near the center of the site. Shales beneath these thin gravels are generally weathered to a highly expansive clay. The northeastern corner is underlain by fine-grained flood-plain deposits of the Santa Clara River. Foundation materials may include sandstone bedrock, stream terrace and colluvial gravels, and silty and clayey alluvium but will principally consist of highly expansive clay and weathered shale.

Although no test pits were excavated for the preliminary evaluation at this site, it is probable that ground water is at depths exceeding 10 feet throughout the site. Flood hazard is low except in the northeastern corner which is at the edge of the 100-year flood plain of the Santa Clara River as defined by the U.S. Department of Housing and Urban Development Federal Insurance Administration (1978, 1980). The presence of the Petrified Forest Member of the Chinle Formation generally indicates highly expansive soils and potentially unstable slopes. No existing slope failures were observed and natural slopes appear stable under present conditions, although alterations to slopes during and after construction may induce failure in these materials.

Site D - Between Green Valley and Bloomington

Site D is in the bottom of a broad, shallow, east-trending tributary valley of the Santa Clara River between the river and Bloomington Hill (attachment 1). The site is chiefly in sandy alluvium and eolian deposits. Several small flood retention structures are present along the wash at or near the site. Sand in the valley bottom and surrounding slopes is underlain by shale of the Petrified Forest Member of Chinle Formation. The preliminary investigation at this site did not include test pits to determine the thickness of sand, but it is probable that both sand and the underlying shale (generally weathered to a highly expansive clay) will be encountered in foundation excavations.

Permanent shallow ground-water conditions are not expected at the site, although local, temporary water tables may develop when impoundments along the wash contain water. Flood hazard is high along the wash and behind impoundments. Slopes are sufficiently gentle that the potential for instability is low even in areas where the Petrified Forest Member of the Chinle Formation is found.

Site E - Bloomington

Site E is along Man-of-War Road east of the Virgin River near the center of Bloomington (attachment 1). Two distinct levels are present at the site; the western part is on the flood-plain and the eastern part is on a lower terrace of the Virgin River. The western part is lower in elevation and has been the site of a water-retention pond and rodeo grounds at various times in the past. Test pit 2 (attachment 2) in the western part indicated bedded clayey soils to a depth of 11 feet, perhaps representing sediment trapped in the pond. The upper 3 feet of soil consists of sandy fill, probably from the old rodeo arena. The eastern part of the site is underlain by very uniform, fine, sandy alluvium to a depth of at least 10 feet (test pit 3, attachment 2). Foundation materials will thus vary from fine sand to clay from east to west across the site.

Ground water was encountered in the test pits, and is probably below foundation depths throughout the site. The east edge of the 100-year flood plain of the Virgin River as defined by the U.S. Army Corps of Engineers (1973) is along the western property line. Thus, floods of larger magnitude may affect the lower, western part of the site. Flooding of the eastern part is very unlikely. The only slopes present on the site surround the lower western part and are underlain by sand similar to that in test pit 3 (attachment 2). Although erosion is active on these slopes, they are not subject to slope failure.

Site F - Bloomington Hills

Site F is in a bedrock lowland traversed by east-west trending ridges and swales between Webb Hill and the Price City Hills (attachment 1). The lowland is underlain by rocks of the Shnabkaib and Upper Red Members of the Moenkopi Formation which strike from N. 75° W. to N. 75° E. and dip about 20 degrees to the north. The Upper Red Member consists of sandstone and shale and is found only along the northern edge of the site. The majority of the site is underlain by shale and gypsum of the Shnabkaib Member and by locally-derived alluvium. The low, linear ridges traversing the site are formed by more resistant layers in the bedrock while swales are underlain by less-resistant layers usually buried beneath about 5 feet of alluvium (test pits 4 and 5, attachment 2). Alluvium over most of the site is silty and gypsiferous, but sandy alluvium is found along the northern edge between ridges of the Upper Red Member. Foundation materials will vary from gypsum, shale, and sandstone bedrock to sandy, silty, and gypsiferous alluvium. Structures may be particularly subject to differential settlement at the site because a single foundation may encounter several of these material types.

No ground water was encountered in test pits to depths of 9-10 feet; and it is expected to be much deeper. Flood hazard is greatest along the wash which follows the road diagonally across the site from southwest to northeast (attachment 1). Evidence for recent flow in this and other washes at the site was present. No slopes occur which would present problems for construction. A rock-fall hazard is present to the north at the base of Webb Hill. Although the northern boundary of the site is not marked, it appears that falling boulders have not reached it in the past and at present a wash at the base of the hill prevents falling rocks from reaching the site.

Site G - Panorama Park

Site G is south of Middleton on a south-sloping alluvial plain traversed by broad, incised drainages 10-20 feet deep forming a gently rolling terrain. The plain is underlain by alluvial and eolian sand which extends to depths of more than 9.5 feet (test pit 6, attachment 2). A moderately indurated caliche (calcium carbonate) zone is present from 1.5-2.5 feet, grading downward into weakly indurated calcareous and gypsiferous sand. Basalt boulders and cobbles up to 3 feet in diameter are scattered across the surface. Access for test pit excavation could only be gained along the western edge of the site, but it is reported that elsewhere in the Panorama Park area, particularly at the new high school site about a mile to the east, a hard calcium carbonate-cemented layer ("water rock") is present which requires blasting to excavate. Such conditions may exist locally at the site, but in general foundations will probably be in silty sand containing minor amounts of calcium carbonate and gypsum.

No ground water was encountered, although water is reported within and beneath "water rock" layers to the east. At the high school, drains were required beneath the football stadium to remove water encountered during excavation of the "water rock." At site G, however, drainages are sufficiently deep to drain the soils naturally and maintain ground-water levels below probable foundation depths. Flood hazard and slope stability are not problems due to the lack of drainage area for modern washes and lack of steep slopes or unstable soil materials.

CONCLUSIONS AND RECOMMENDATIONS

A summary of construction conditions including foundation conditions and geologic hazards at each site along with general recommendations regarding suitability for construction and precautions to be taken are given in Table 1. A more detailed explanation of foundation conditions and hazards listed on the table is given below.

Soil conditions found in the area which may adversely affect foundations are: 1) gypsum and gypsum-rich soil, 2) expansive clays, 3) bedrock and indurated soil, and 4) loose cinder layers. Gypsum is water-soluble, and gypsiferous soils and bedrock commonly contain open voids where gypsum has dissolved. Collapse of these voids when a load (such as a building) is applied and possible accelerated dissolution of gypsum due to wetter conditions induced by lawn watering or water-sewer pipe leakage may result in ground subsidence. In addition to being a poor foundation material, gypsum contains sulfate which is deleterious to concrete. Special sulfate-resistant concrete must be used wherever concrete may come in contact wth gypsiferous soil. Large quantities of gypsum are found at sites B and F, and gypsum is present in lesser amounts at site G. Trace amounts of disseminated gypsum not detectable in the field are probably present at all sites. The presence of gypsum need not preclude construction, but necessitates that precautions such as strict drainage control and special foundation designs be used.

Expansive soils such as at site C and perhaps beneath surficial sands at site D present a serious foundation problem. While dissolution of gypsum occurs over longer periods of time, expansion of clays can occur very rapidly upon wetting. Alternate wetting and drying of these soils causes volume changes which may crack foundations. Problems of this nature in similar expansive soils have occurred in the Santa Clara Bench and Green Valley areas. Local problems with expansive soils may also be present at sites E (western part) and F. Strict control over moisture content of expansive soils and special foundation designs are required for construction in these areas.

Bedrock and indurated soils generally provide firm foundations but may cause excavation difficulties. Shallow bedrock consisting of basalt or containing sandstone beds requiring blasting or heavy ripping equipment is present at sites A, C, F (particularly the north end), and possibly D. Indurated soils were found at site B, although excavation was possible with a backhoe at least to a depth of 9.5 feet where the impenetrable "water rock" layer was encountered.

Construction on the South Black Rocks lava flow (site A) may encounter problems in addition to difficulty of excavation. Void spaces between loose cinders in the upper layer have not been completely filled with eolian sand or

TABLE 1.- Construction conditions, Washington County school sites

Location	Flood Hazard	Potential for Slope Failure	Depth to Ground Water	Soil Conditions for Foundations	Construction Conditions and Recommendations
Site A - South Black Rocks	Moderate to high	Low	Probably>10'	Poor to good - loose cinders in upper layers	Strict control over use of cinders in foundations and fill; flood hazard locally high requiring possible alterations to the Santa Clara Reservoir spillway.
Site B - 540 North, 1450 West	Moderate to high	Low	>9.5'	Poor - gypsum abundant	Special foundation design and drainage control to accomodate gypsum in soils; use of sulfate-resistant concrete; flood hazard locally high requiring drainage diversion or impoundment
Site C - Green Valley	Low to moderate	Moderate to high	Probably>10'	Poor - expansive soils	Special foundation design and drainage control to accomodate expansive soils; potentially unstable slopes requiring careful control of grading; local sand-stone layers difficult to excavate; construction not recommended except in northeastern corner
Site D - between Green Valley and Bloomington	High	Low	Probably>10'	Good - locally poor if expansive clays beneath sand are encountered in excavations	Flood control measures needed; extremely poor soil conditions may exist locally requiring removal and replacement with compacted fill
Site E - Bloomington	Low	Low	>11'	Moderate to good - clayey soils on west side	Conditions favorable on east side, acceptable but less favorable on west side; no major problems
Site F - Bloomington Hills	Moderate to high	Low	>10.5'	Poor - gypsum abundant	Special foundation design and drainage control to accomodate gypsum; use of sulfate-resistent concrete; flood hazard locally high requiring drainage diversion or impoundment; local sandstone layers difficult to excavate in northern part
Site G - Panorama Park	Low	Low	9.5'	Moderate to good-gypsum present	Conditions favorable, minor gypsum in in sandy soils

weathered rock material. The cinder layers may thus be subject to compaction and settlement when disturbed or loaded. Where large diameter cinders are found, proportionately large void spaces may exist beneath the surface. A similar settlement problem may arise if on-site materials are used for fill and oversized clasts are not removed or sufficient fine-grained matrix material not added to achieve proper gradation for use in compacted fill.

Problems with shallow ground water (less than 10 feet) are not anticipated at any of the sites except perhaps when water is present in nearby impoundments (sites A and D). The most significant flood hazards are present at sites A, B, D, and F along washes or impoundments that border and traverse the sites. Flood control measures and/or close attention to placement of structures at these sites will be required to mitigate or avoid flood hazard areas. No modern slope failures are present at any of the sites, and a significant potential for slope stability problems is present only at site C. Care will be required in any construction at site C to control undercutting, wetting, loading of slopes, or other activities which may induce failure.

The nearest known active fault in the area is the Washington fault which trends north-south through the city of Washington. Site G lies about 2 miles to the west, and other sites range from 4 to 7 miles from the fault. Because of these distances, the hazard from surface fault rupture at all sites is low. However, all are in Uniform Building Code seismic zone 2, a zone of moderate earthquake hazard with a maximum expected Modified Mercalli earthquake intensity of VII (attachment 3). Structures at all sites should be designed and constructed in accordance with UBC seismic requirements for zone 2. Because of the lack of shallow ground water, liquefaction potential (loss of shear strength in soils, generally saturated clean sands, during earthquake ground shaking) is considered to be low at all sites.

In summary, conditions for construction are most favorable at sites E and G where few soil problems and geologic hazards exist. Less favorable conditions are present at sites A, B, D, and F where care will be required to mitigate flood hazards and potential soil/foundation problems. Structures may still be built safely at all of these sites if geologic hazards and soil conditions are taken into account in design and construction. However, construction on potentially unstable slopes underlain by highly expansive soils at site C is not recommended. Structures should be placed on the flat northeastern corner of the site where more favorable soil and slope conditions exist. At all sites, standard soil foundation investigations should be performed which include an assessment of liquefaction potential and special attention to the effects of expansive and gypsiferous soils.

REFERENCES

Christenson, G. E., and Deen, R. D., 1983, Engineering geology of the St. George area, Washington County, Utah: Utah Geological and Mineral Survey Special Studies 58, 25 p.

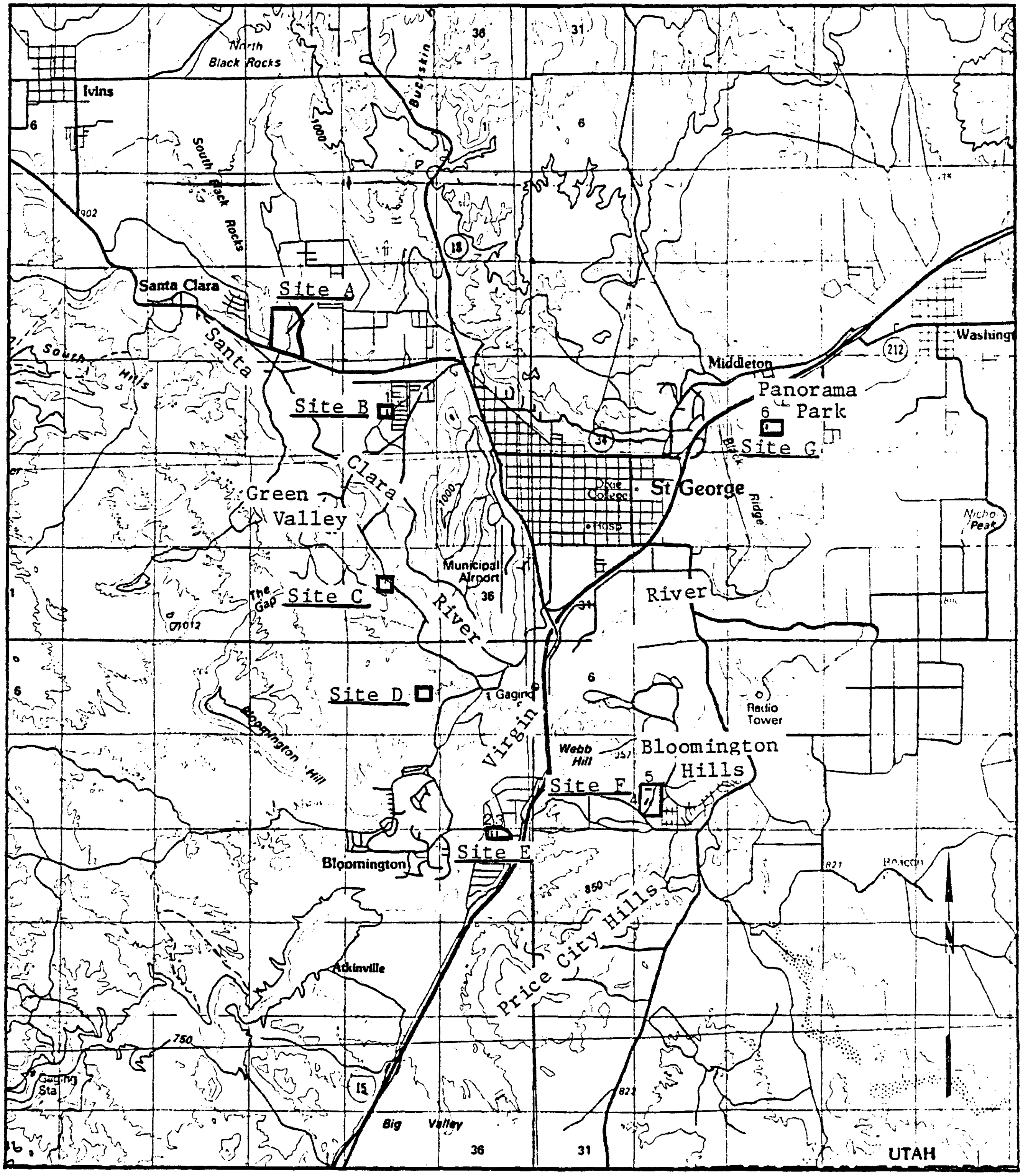
Lund, W. R., 1980, Inspection of Arrowhead Trail section of Santa Clara City for the southwestern Utah District Health Department: Utah Geological and Mineral Survey, memorandum to B. N. Kaliser, October 3, 1980, 5 p.

U.S. Army Corps of Engineers, 1973, Flood plain information, Virgin River and Fort Pierce Wash, vicinity of St. George, Washington County, Utah: Report for Washington County Commission, 31 p.

U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978, Flood hazard boundary map, Unincorporated area, Washington County.

------1980, Flood hazard boundary map, City of St. George, Utah.

Base Map from: USGS 30'x60' Topo Quad
St. George, Utah - Arizona



0 1 2 miles

Scale 1:100,000

Explanation

1 Test Pit

Approximate location of school sites and test pits, Washington County School District

Attachment 2, report of 1/17/84 to Jack F. Burr

Logs of Test Pits
Washington County School Sites

Soil Description*

Site B - 540 N., 1450 W.

Test Pit No. 1

0' - 2.5'	Silty sand (SM); red, low to medium density, nonplastic, dry, nonindurated.
2.5' - 9.0'	Gypsum and gypsiferous sand (SP); white to green, high density, nonplastic, moist, moderately indurated; contains calcium carbonate in lower part.
9.0' - 9.5'	Sand (SP); white to green, high density, nonplastic, moist, strongly indurated; calcium carbonate-cemented "water rock," contains gypsum.

Site E - Bloomington

Test Pit No. 2

0' - 3'	Silty sand (SM); red, medium dense, low plasticity, dry, non-indurated; artificial fill and disturbed soil on old rodeo ground.
3' - 11'	Silty clay (CL); red to green, firm to stiff, medium plasticity, moist, nonindurated.

Test Pit No. 3

0' - 2'	Silty sand (SM); red, medium density, nonplastic, dry, nonindurated; fine sand.
2' - 10'	Silty sand (SM); red, medium density, nonplastic, moist, non-indurated; fine sand.

*Soils classified according to procedures in ASTM standard D2488-69 (revised 1975), Description of Soils (visual Manual Procedure).

Site F - Bloomington Hills

Test Pit No. 4

0' - 4.5'	Sandy silt (ML); white to pale green, firm, low plasticity, dry, nonindurated; alluvium.
4.5' - 6.5'	Brecciated, weathered shale and gypsum; Shnabkaib Member of the Moenkopi Formation.
6.5' - 10.5'	Bedded shale and gypsum, locally brecciated; Shnabkaib Member of of the Moenkopi Formation.

Test Pit No. 5

0' - 5'	Silty sand (SM); red, medium dense, nonplastic, dry, nonindurated; alluvium.
5' - 8'	Gypsiferous sand and weathered shale; Upper Red Member of the Moenkopi Formation.
8' - 9'	Red shale and gypsum; Upper Red Member of the Moenkopi Formation.

Site G - Panorama Park

Test Pit No. 6

0' - 1.5'	Silty sand (SM); red, loose, nonplastic, dry, nonindurated; includes basalt boulders at surface up to 3 feet in diameter.
1.5' - 2.5'	Silty sand (SM); white, medium to high density, nonplastic, dry, moderately indurated; pedogenic caliche (calcium carbonate-cemented) horizon.
2.5' - 9.5'	Silty sand (SM); red, medium dense, nonplastic, dry, weakly indurated; carbonate nodules and gypsum stringers present locally.

Note: No ground water encountered in any test pits.

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), 1974, p. 28.

Project: Granite School District site investigations			Requesting Agency: Granite School District
By: H. E. Gill	Date: 5/29/84	County: Salt Lake	Job No.: S-2
USGS Quadrangle: Magna (1214) Salt Lake City South (1213)			

In response to a request from Mr. Brent Hilton, Director New School Facilities Granite School District, an engineering geologic investigation was conducted on May 1st and 3rd, 1984, of the proposed sites for two elementary schools and one junior high school. It is understood that the buildings will be single story structures of cement block and masonary construction, without basements. The site investigations consisted of a review of applicable published and unpublished maps, memos, and reports available for the areas, a field reconnaissance, and excavation of test holes at each site. Mr. Ed Lamborn, field supervisor for Granite School District, was present during the field reconnaissance. A tire mounted backhoe was provided by Granite School District.

Site location and description

Site 1 is located at 6200 South and 3400 West (attachment 1). Abandoned unlined irrigation ditches border the property on the north, east and south. The 10-acre property was formerly a cultivated field and no natural drainage is evident. The topography is relatively flat with a gentle 1.5 degree slope to the south.

Site 2, the junior high school, is located at 5900 South and 5600 West (attachment 1). The 20-acre property is bounded on the south and west by houses. The eastern half of the property is a topographic depression and is approximately 10 feet lower in elevation than the western half which has a 2.5 degree slope to the east. The site was previously cultivated and natural drainage has been altered, however, surface water flows toward the depression.

Site 3 is a 10 acre parcel located at 3100 South and 5400 West (attachment 1). The property is bounded on the south and west by unlined irrigation canals, which are part of the North Jordan canal system. The canals are approximately 10 feet wide and six to seven feet deep, and carry water throughout the year. The Greenbriar mobile home subdivision is immediately east of the site. The overall topography is flat (less than 1 degree slope to the north) but the microrelief is irregular because several areas have been graded for new roads.

Site conditions

At site 1 four test holes were excavated on the northern end of the property adjacent to but not on the actual building site (attachment 2). This was to avoid disturbing the soils beneath the foundation. The excavation depths were from 10 to 10.5 feet deep, and Lake Bonneville shoreline deposits, on which a thin layer of topsoil has formed, were found at all locations (attachment 3). A fine-grained, medium- to low-density, silty sand was encountered in all test holes. The sand was nonplastic, nonindurated, and moist, becoming dry with depth. In test hole 2 thin silty clay lenses are interbedded with the sand from 7 feet to the bottom of the test hole. In test hole 4 interbedded silty clay lenses extend from 3.4 to 7.2 feet. Beyond this point a homogeneous silty clay unit was encountered. The clay is low to moderately plastic, nonindurated, and dry. In all excavations the silty sand exhibited medium to low density and the consistency of the silty clay was firm to stiff. The fine-grained sediments increase toward the south and southwest part of the site. Ground water was not encountered in any of the excavations and it is estimated that the depth to the unconfined water table is greater than 40 feet (Seiler and Waddell, 1984).

Four test holes were excavated at site 2 to depths ranging from 5.5 to 10.5 feet below the surface (attachment 4). Test holes 1 and 4 were located on the east half of the site, which is a topographic depression, while test holes 2 and 3 were on the west half of the property which is on the slope below the Provo Bench. The excavations were located adjacent to the building site rather than beneath the foundation. In all four test holes a thin layer of clayey sand topsoil, which has been disturbed by cultivation, overlies Lake Bonneville shoreline deposits (attachment 3). The lake deposits in test holes 1 and 4 were silty sand to approximately 2.5 feet below the surface and clean gravel and sand lenses from there to the bottom of both excavations (approximately 10 feet). These coarse-grained deposits have a low to very low density, no plasticity, and are nonindurated. Excavation of test holes 2 and 3 was difficult due to the presence of cobbles and boulders, and the indurated nature of the deposits. Test hole 2 reached 6.5 feet and test hole 3 only 5.5 feet before the backhoe could not continue. After approximately one foot of clayey sand topsoil, a layer of firm, nonindurated, medium plasticity, sandy clay was found to a depth of from 2 to 3 feet below the surface. From this point to the bottom of both excavations a strongly indurated silty gravel, with cobbles and boulders, was encountered. This horizon may be a tufa deposit. In all excavations the upper 2 to 3 feet were wet but deeper soils were only moist. The coarse-grained nature of the deposits on the property allow water to infiltrate rapidly to depth and no ground water was encountered in the excavations. The depth to the unconfined aquifer is probably greater than 40 feet (Seiler and Waddell, 1984). Due to the dissimilar characteristics of the soils on the east and west halves of the property, a potential for differential settlement exists for structures constructed across this contact. Based on soil type, depth to water, and the probability of a moderate to severe earthquake in the area, the site is classified as having a high liquifaction potential (J. Keaton, oral commun., 1984). Therefore, soil types and water table levels should be investigated to a depth of at least 50 feet.

At Site 3, 4 test holes were excavated to approximately 10 feet below ground surface (attachment 5). The exact proposed position of the building on the site is unknown (E. Lamborn, oral commun., 1984), however, an attempt was made to locate the test holes in what was thought to be the general area of the structure. The site is underlain by Lake Bonneville lake bottom deposits on which a thin layer of topsoil has formed (attachment 3). Lake sediments in the excavations were soft- to very-stiff, medium- to high-plasticity, nonindurated, silty clay and clay. The sand content ranged from 10-20 percent and the soils were wet to saturated. Ground water was observed in all test holes at depths from 7.5 to 10 feet below the surface. In test hole 1 an horizon of gravel with cobbles was ecnountered at approximately 9.5 feet. However, it could not be examined because of the shallow water table. The gravel indicates that the clays are not continuous at depth. The site is in an area classified as having moderate liquifaction potential (J. Keaton, oral commun., 1984) therefore, soil types should be investigated to a depth of at least 50 feet.

Seismicity

All three sites lie within Uniform Building Code (UBC) seismic zone 3, and Utah Seismic Safety Advisary Council (USSAC) seismic zone U-4 (major damage corresponds to intensity VIII and higher of the Modified Mercalli Scale) (Attachment 6). Jordan Valley has experienced a number of earthquakes in the past. Fresh scarps along the Wasatch Front attest to the occurrance of prehistoric earthquakes. The largest historic event occurred in 1910 and had an estimated Richter magnitude of 5.5 M/L and a Modified Mercalli Intensity of VI (Arabasz and others, 1979). A swarm of small events occurred in the Magna area in 1978 and the most recent earthquake (epicenter very near the 1978 events) occurred in October 1983 and had a Richter magnitude of 4.3 M/L (University of Utah Seismograph Stations, oral commun., 1984). Several Quaternary faults were mapped near the three sites. There is a mapped fault 1500 feet northeast of site 1 (Van Horn, 1979). The site is approximately 2 miles southwest of the Jordan Valley Fault Zone (Dames & Moore, 1979). Mapped faults are located approximately 2 3/4 miles east and 2 miles west of site 2 (Tooker and Roberts, 1971, Van Horn, 1979). The Jordan Valley Fault Zone is about 2 1/2 miles east of site 3 and the epicentral area for the 1978 and 1983 earthquakes is approximately 2 1/2 miles to the northeast. Renewed movement along these faults, or any others within the Jordan Valley could produce strong ground shaking at all the proposed sites, the intensity of which would depend upon the magnitude of the earthquake, the location of the epicenter, and the local geologic conditions.

Conclusions and recommendations

1. All three sites lie within UBC seismic zone 3 and USSAC seismic zone U-4 and in the event of a moderate to severe earthquake in Salt Lake County the sites could encounter strong ground shaking. All structures should be designed accordingly.

2. Shallow ground water was observed only at site 3 and leakage from unlined canals on the south and west of the property contribute to the high water level. Lining the canals where they border the property, or installing an underground drainage system may alleviate future problems with shallow ground water.

3. Test holes at site 2 indicate two soil types with very dissimilar characteristics across the site, loose sand and gravel to the east and strongly indurated gravel with cobbles and boulders to the west. A structure built across the soil change may encounter differential settling, therefore, this situation should be avoided if possible.

4. Site 2 and 3 are in areas classified as having high and moderate liquifaction potential respectively. It is recommended that borings to a depth of at least 50 feet be drilled to investigate the ground-water level and the possibility of liquifiable soils beneath the sites.

Selected References

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

Dames & Moore, 1979, Report of fault study UDOT/UDPS complex, Salt Lake County, Utah: Utah State Building Board, 8 p.

Everitt, B. L., 1980, Depth to wet season water table Jordan Valley, Utah: unpublished map, Utah Geological and Mineral Survey, scale 1:60,000.

International Conference Of Building Officials, 1976, Uniform building code: Whittier, California, p. 132-140.

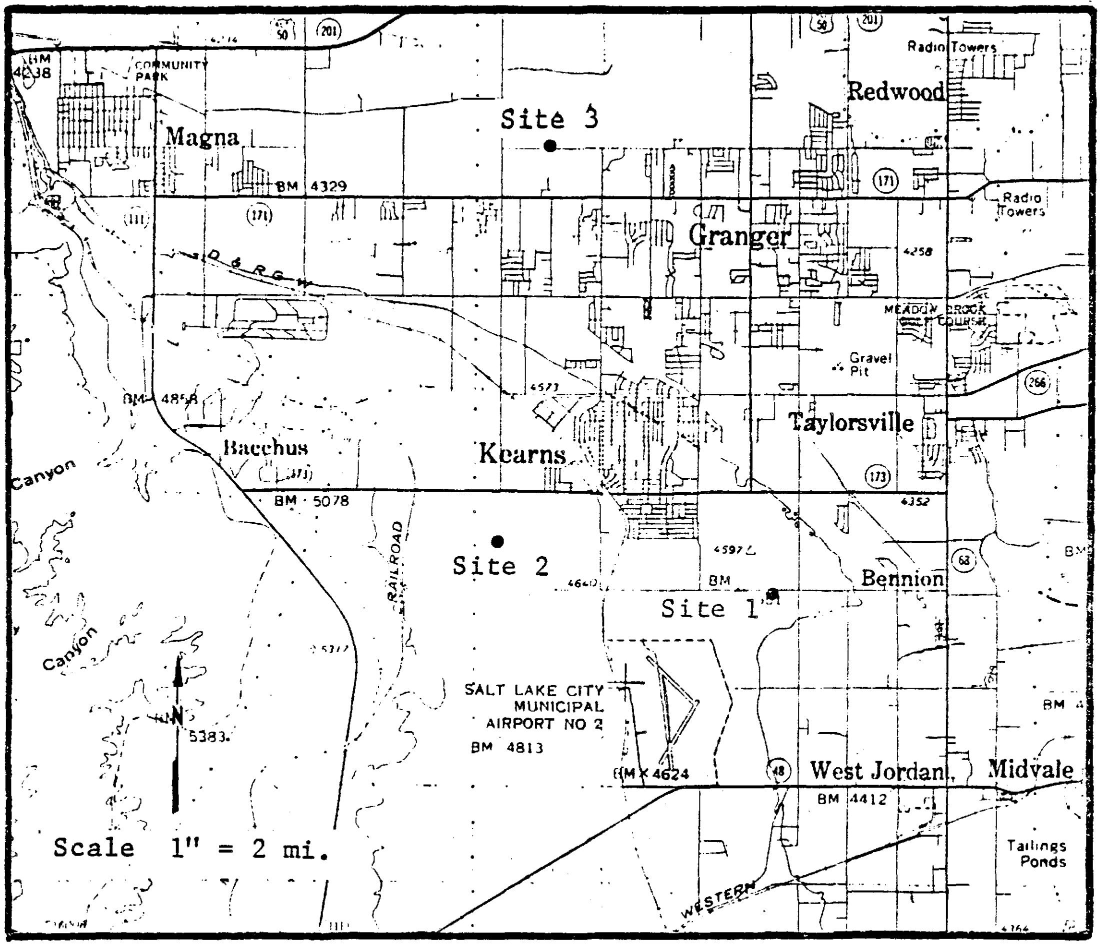
Marsell, R.E., and Threet, R.L., 1960, Geologic map of Salt Lake County, Utah: Utah Geological and Mineral Survey Bulletin 69, scale 1:125.000.

Seiler, R.L. and Waddell, K.M., 1983, Reconnaissance of the shallow-unconfined aquifer in Salt Lake Valley, Utah: U.S. Geological Survey Water-Resources Report 83-4272.

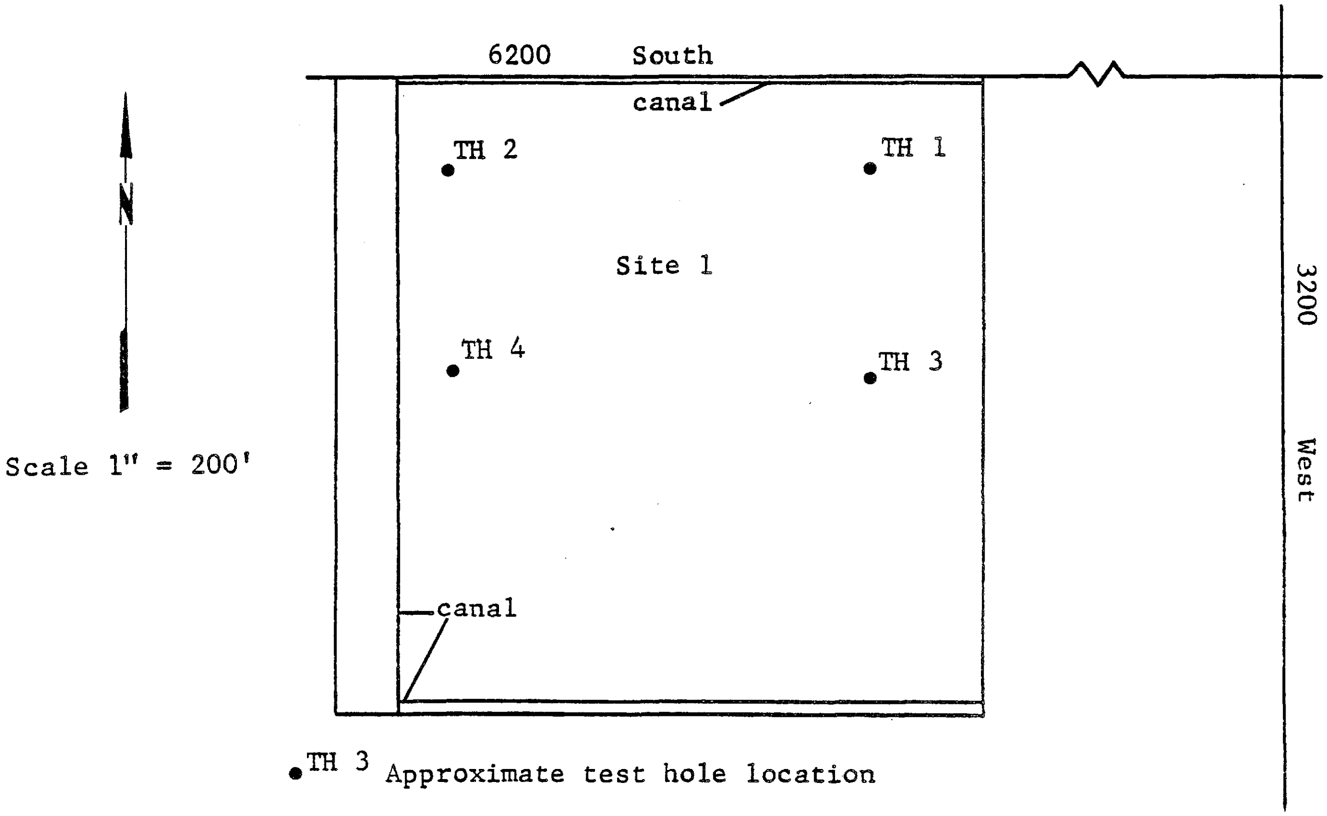
Tooker, E.W., and Roberts, R.J., 1971, Geologic map of the Magna quadrangle, Salt Lake County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ 923, scale 1:24,000.

Van Horn, Richard, 1979, Surficial geologic map of the Salt Lake City South Quadrangle, Salt Lake County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1173, scale 1:24,000.

Ward, D. B., 1979, Seismic zones for construction in Utah: Seismic Safety Advisory Council, Salt Lake City, 13 p.



Location Map Granite School District School Sites



Site Plan Property No. 1

Attachment 3 Job No. S-2

Logs of Test Holes Site 1*

Test Hole 1

0.0' - 0.9'	Silty sand (SM); topsoil, brown, low density, nonplastic, nonindurated, moist; moderate root development.
0.9' - 10.0'	Silty sand (SM); yellow brown, medium to low density, nonplastic, nonindurated, dry.

Test Hole 2

0.0' - 1.0'	Silty sand (SM); topsoil, brown, low density, nonplastic, nonindurated, moist; moderate root development.
1.0' - 2.0'	Silty sand (SM); brown, low density, nonplastic, nonindurated, slightly moist.
2.0' - 7.0'	Silty sand (SM); yellow brown, medium to low density, nonplastic, nonindurated, dry.
7.0' - 10.0'	Silty sand (SM); yellow brown, medium to low density, nonplastic, nonindurated, dry; thin lenses of silty clay (CL) interbedded with sand, firm, medium to low plasticity, weakly indurated, dry.

Test Hole 3

0.0' - 1.0'	Silty sand (SM); topsoil, brown, low density, nonplastic, nonindurated, moist; moderate root development.
1.0' - 4.5'	Silty sand (SM); brown, low density, nonplastic, nonindurated, slightly moist.
4.5' - 10.0'	Silty sand (SM); yellow brown, medium to low density, nonplastic, nonindurated, dry.

Test Hole 4

0.0' - 1.0'	Silty sand (SM); topsoil, brown, low density, nonplastic, nonindurated, moist; moderate root development.
1.0' - 3.4'	Silty sand (SM); yellow brown, low density, nonplastic, nonindurated, dry.
3.4' - 7.2'	Silty sand (SM); yellow brown, medium to low density, nonplastic, nonindurated, dry; thin lenses of silty clay (CL) interbedded with sand, firm, medium to low plasticity, nonindurated, dry.
7.2' - 10.0'	Silty clay (CL); yellow brown, stiff, medium to low plasticity, weakly indurated, dry.

*Soil descriptions conform to ASTM Standard D 2488-69

Attachment 3 cont. Job No. S-2

Logs of Test Holes Site 2*

Test Hole 1

0.0' - 1.0'	Clayey sand (SC); topsoil, dark brown, low density, low plasticity, nonindurated, wet.
1.0' - 2.5'	Silty sand (SM); brown, low density, nonplastic, nonindurated, wet.
2.5' - 10.0'	Sandy gravel (GP); yellow brown, loose, nonplastic, nonindurated, wet.

Test Hole 2

0.0' - 0.8'	Clayey sand (SC); topsoil, dark brown, low density, low plasticity, nonindurated, wet.
0.8' - 2.1'	Sandy clay (CL); yellow brown, firm, medium plasticity, nonindurated, wet.
2.1' - 6.5'	Silty gravel with cobbles (GM); light brown, highly dense, slight plasticity, moderately indurated, moist; 15 percent cobbles.

Test Hole 3

0.0' - 0.9'	Clayey sand (SC); topsoil, dark brown, low density, low plasticity, nonindurated, wet.
0.9' - 3.2'	Sandy clay (CL); yellow brown, firm, low plasticity, nonindurated, wet.
3.2' - 5.5'	Silty gravel with cobbles (GM); light brown, highly dense, slight plasticity, strongly indurated, moist; 15 percent cobbles.

Test Hole 4

0.0' - 1.0'	Clayey sand (SC); topsoil, dark brown, low density, low plasticity, nonindurated, wet.
1.0' - 2.5'	Silty sand (SM); brown, low density, nonplastic, nonindurated, wet.
2.5' - 10.5'	Sandy gravel (GP); light brown, loose, nonplastic, nonindurated, wet.

*Soil descriptions conform to ASTM Standard D 2488-69

Attachment 3 cont. Job No. S-2

Logs of Test Holes Site 3*

Test Hole 1

0.0' - 0.8'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonindurated, moist.
0.8' - 2.8'	Silty clay (CL); light gray, stiff, highly plastic, nonindurated, wet.
2.8' - 10.0'	Silty clay/clay (CL/CH); gray, stiff to very stiff, highly plastic, nonindurated, saturated below 4.5'; gravel and cobble horizon was encountered at 9.5'.

Note: Water table at 8.5'

Test Hole 2

0.0' - 0.7'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonidurated, moist.
0.7' - 1.5'	Silty clay (CL); dark brown, soft to firm, medium plasticity, nonindurated, moist.
1.5' - 10.0'	Silty clay/clay (CL/CH); gray, stiff to very stiff, highly plastic, nonindurated, saturated.

Note: Water table at 7.5'

Test Hole 3

0.0' - 0.7'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonindurated, moist.
0.7' - 1.7'	Silty clay (CL); brown, soft to firm, medium plasticity, nonindurated, moist.
1.7' - 10.0'	Silty clay/clay (CL/CH); gray, firm to very stiff, medium plasticity, nonindurated, saturated.

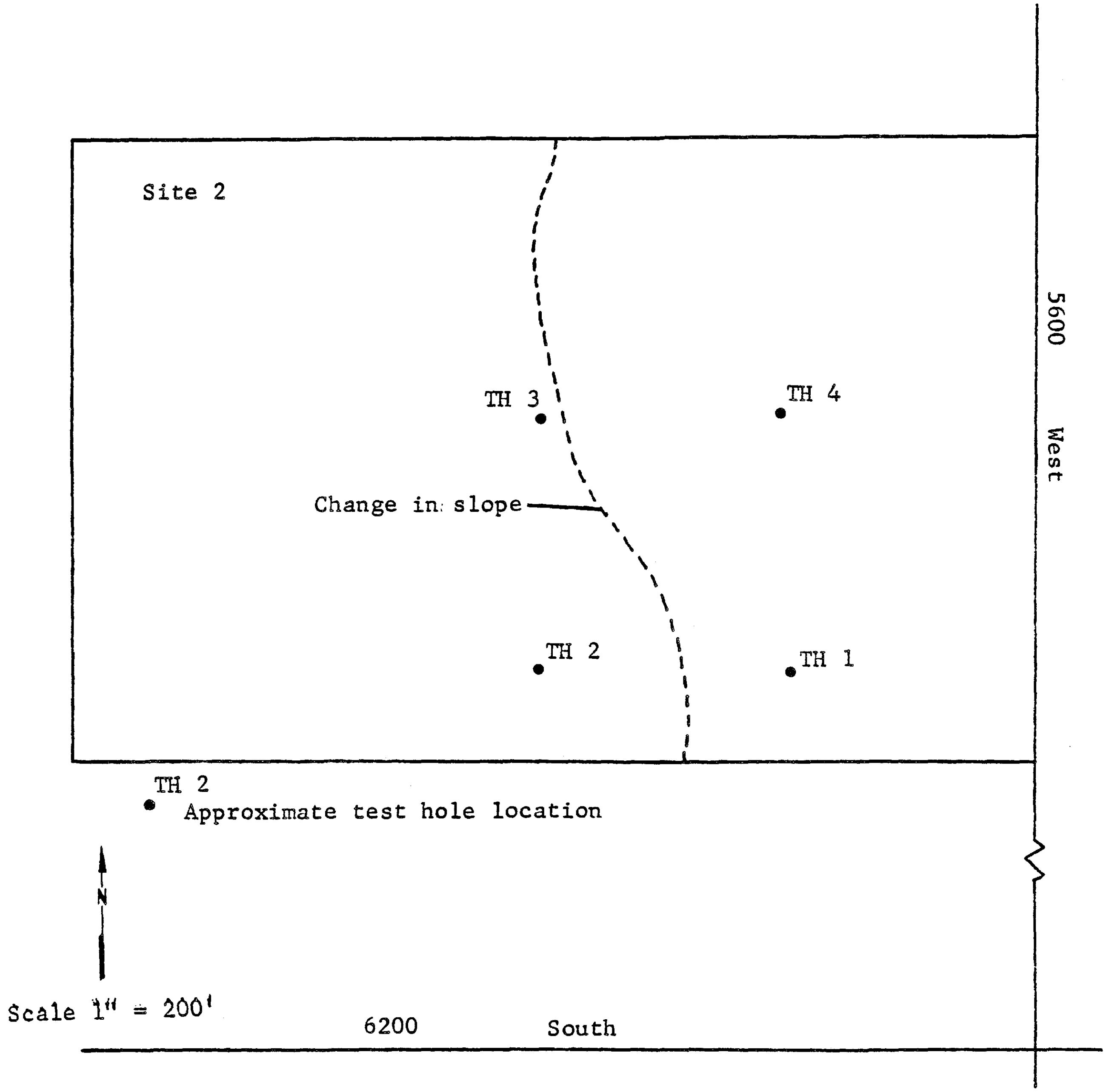
Note: Water table at 9.5'

Test Hole 4

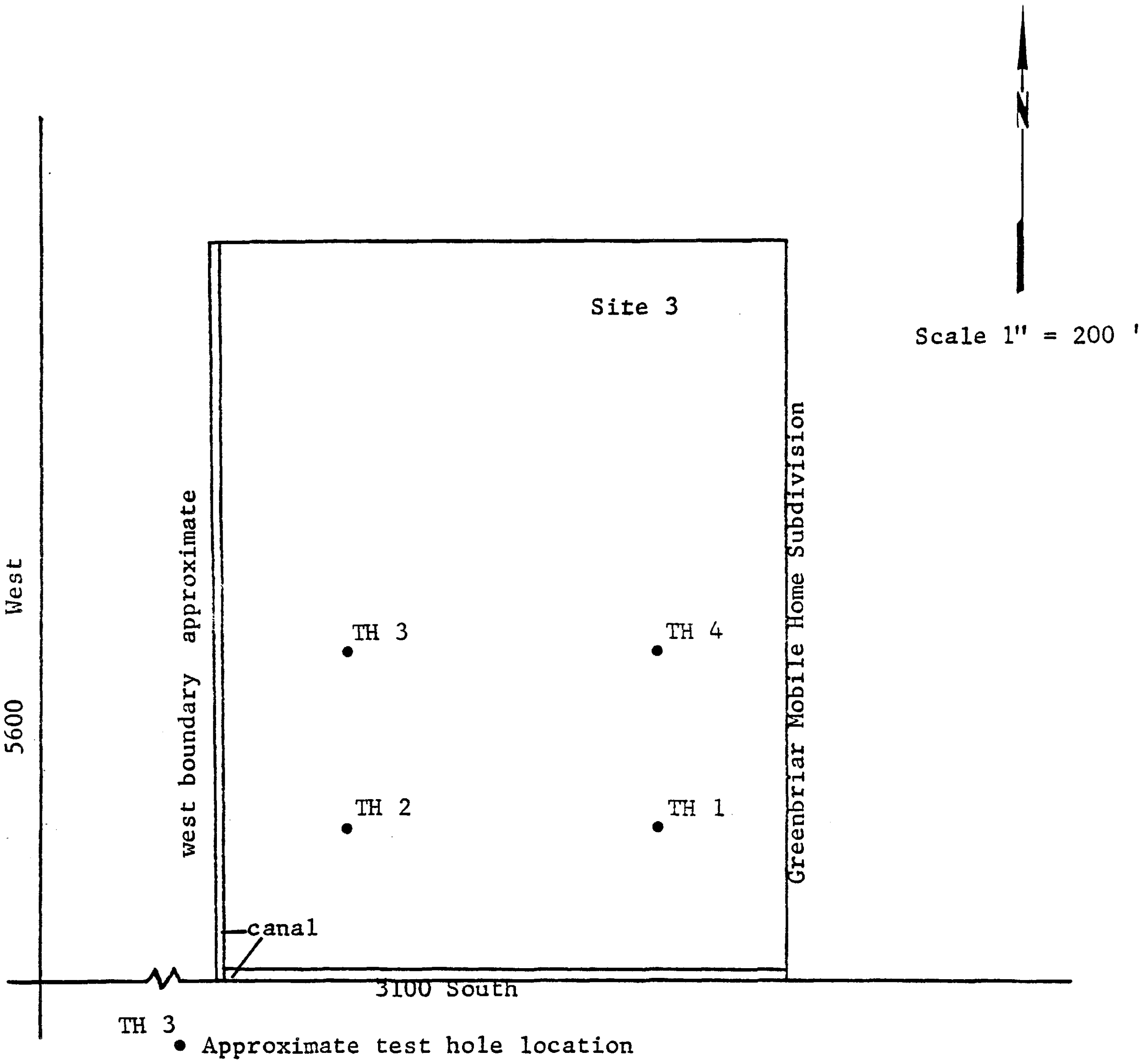
0.0' - 0.7'	Silty clay (CL); topsoil, dark brown, soft, medium plasticity, nonidurated, moist.
0.7' - 1.5'	Silty clay (CL); brown, soft to firm, medium plasticity, nonindurated, wet.
1.5' - 10.0'	Silty clay/clay (CL/CH); gray, firm to very stiff, medium to high plasticity, nonindurated, saturated.

Note: Water table at 10'

*Soil descriptions conform to ASTM Standard D 2488-69



Site Plan Property No. 2



Site Plan Property No. 3

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.*

Project:			Requesting Agency:
Blanding Middle School site			San Juan School District
By: G. E. Christenson	Date: 8/22/84	County: San Juan	Job No.: S-3
USGS Quadrangle: Blanding NW (209)			

PURPOSE AND SCOPE

The purpose of this investigation was to evaluate foundation conditions and geologic hazards at a proposed middle school site in Blanding, Utah. The site is in north Blanding between 600 and 800 North and 100 and 300 West Streets (attachments 1 and 2). Concern regarding foundation conditions in the area has arisen because of damage to a relatively new (1-1.5 year old) Mormon stake center one block northeast of the site (attachment 1). The foundation of this building reportedly consists of a slab-on-grade placed directly on clay shale with little or no compacted fill. Cracking of walls and sidewalks has occurred, necessitating remedial measures such as removal of lawns that require watering from around the building and installation of a subsurface drainage system to keep the foundation dry.

The scope of work for this study included a literature review, field reconnaissance, and excavation of five test pits (attachments 2 and 3). A road cut along 800 North Street in the northwest corner of the property and a cut for a retention basin in the northeast corner were also inspected. A brief survey of damage to the nearby stake center was also performed. I was accompanied in the investigation by Donald V. Jack, San Juan School District Superintendent.

SITE CONDITIONS

Description

The site covers an area of roughly four city blocks, and is traversed from northwest to southeast by a low, rounded ridge between two shallow drainages. Test pits 1, 3, and 4 were excavated along the crest of the ridge (attachment 2). Test pit 2 was excavated on the west side of the ridge on the bank of the drainage which trends along the west edge of the site. An abandoned, breached impoundment structure on this drainage is in the southwest corner of the property. At maximum capacity, the reservoir behind the structure would have extended back to the vicinity of test pit 2. Along the east edge of the site, a flood retention pond has been constructed by the city of Blanding. The pond has been excavated into the low ridge at the north end, with the excavated material used to construct the embankment around the remainder of the pond. An abandoned farm field is south of the pond in the southeast corner of the property at test pit 5.

Geology and Hydrology

Bedrock occurs at shallow depth (generally less than 10 feet) throughout the site. In the northern part, it is a yellow-green clay shale which weathers to an expansive, high plasticity clay. This shale was found in test pits 1, 2, and 3 and in the 800 North road cut and the retention pond cut. In the southern part, sandstone and a variety of other rock types (sandy claystone, carbonaceous claystone, and black shale) were encountered in test pits 4 and 5. Haynes and others (1972) indicate the local rock type to be the Dakota Sandstone, which in its upper part intertongues with the overlying Mancos Shale. The site is probably near the contact between these two units, because the shales in the topographically (and stratigraphically) higher northern part are typical of the Mancos Shale, while rocks in the southern part are typical of the upper Dakota Sandstone.

Overlying the bedrock in much of the area is a thin layer of Quaternary-age gravel derived from the Abajo Mountains to the north. These gravels are cemented with calcium carbonate and mixed to varying degrees with the overlying eolian sand and loess which forms the surficial layer throughout the site (attachment 3). This eolian material consists of silty sand which is cemented with calcium carbonate in its lower part. This sand ranges from less than a foot to over 6 feet thick.

All soils were dry and no ground water was encountered in any test pits. Logs of wells in the north Blanding area record static water levels ranging from 40 to 120 feet below ground surface, with many dry holes drilled to similar depths. Several dry holes have been drilled near the site to depths greater than 100 feet.

CONCLUSIONS AND RECOMMENDATIONS

The site is relatively free from most geologic hazards. Slopes are gentle and stable. Ground water is well below foundation depths. Flood hazard is low except in washes, and the restricted drainage basin areas and existing retention ponds and dams reduce the hazard significantly. No known active faults are present and the area is in both the Uniform Building Code and Utah Seismic Safety Advisory Council seismic zone 1, the zone of lowest seismic risk in the state corresponding to earthquakes with maximum modified Mercalli intensities of V to VI (attachment 4).

Surficial materials found throughout the site generally provide suitable foundation conditions. However, the underlying bedrock units are less favorable, and expansive materials believed to be responsible for damage to the nearby stake center are present at least in the northern part of the site. The same clay shale occurs at depths ranging from 6 inches on the slope at test pit 2 to 3-9 feet along the crest of the low ridge (test pits 1 and 3). Any construction in this part of the site would be founded at least partially on weathered shale and clay, and special foundation designs utilizing compacted fill with strict drainage control would be required. Conditions in the southern part of the site are more favorable, with sandstone and less highly weathered and expansive shales providing more stable foundation materials. However, it is possible that the clay shales may occur in this area as well and it would be advisable to pay close attention to foundation materials during excavation to evaluate conditions and alter foundation designs as necessary.

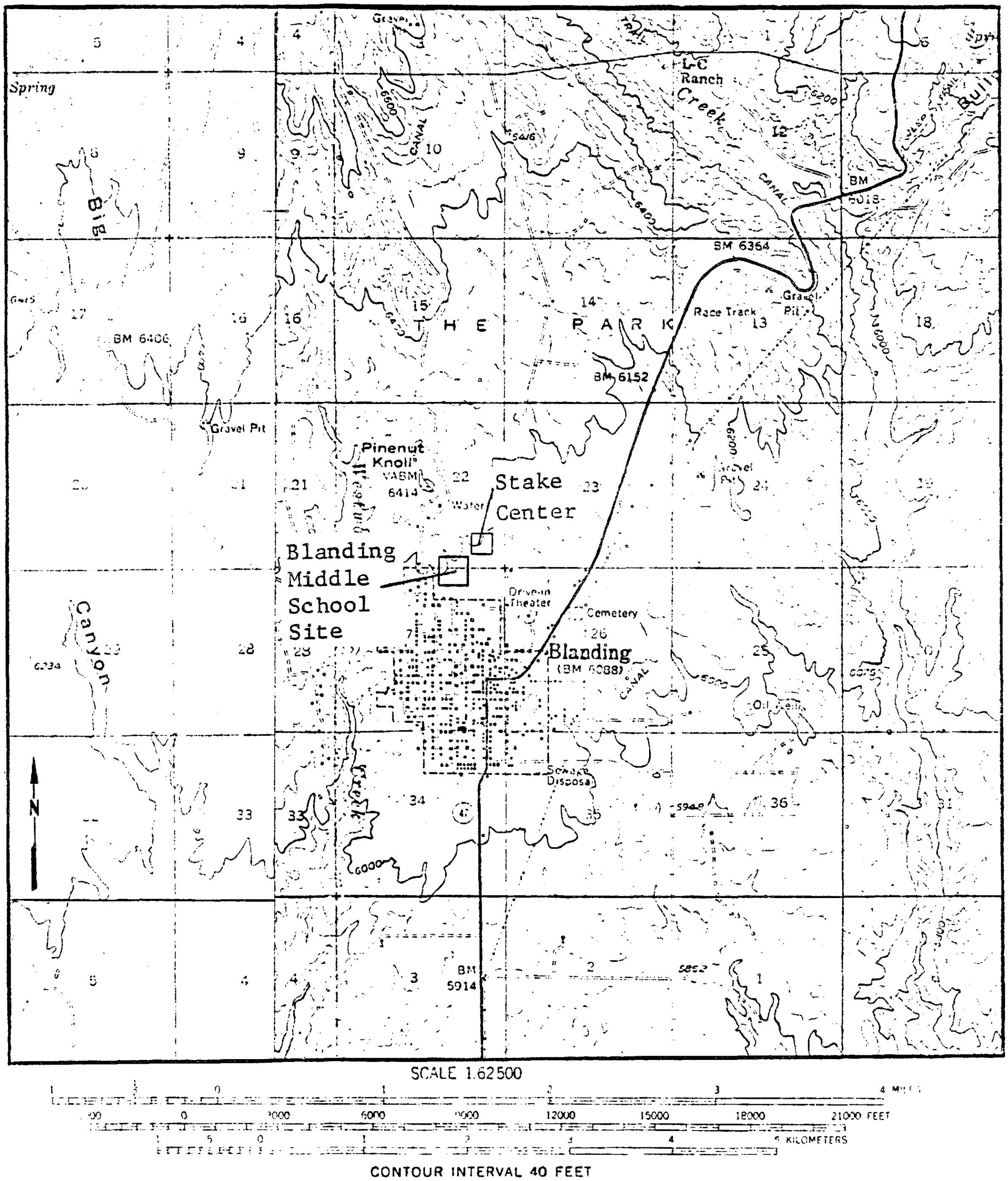
In conclusion, the southern part of the site is more favorable for construction from the standpoint of foundation conditions. In view of the history of foundation problems in the area, we recommend a thorough soil foundation investigation by a qualified soil engineering firm prior to construction regardless of where the building is to be placed on the site.

REFERENCES

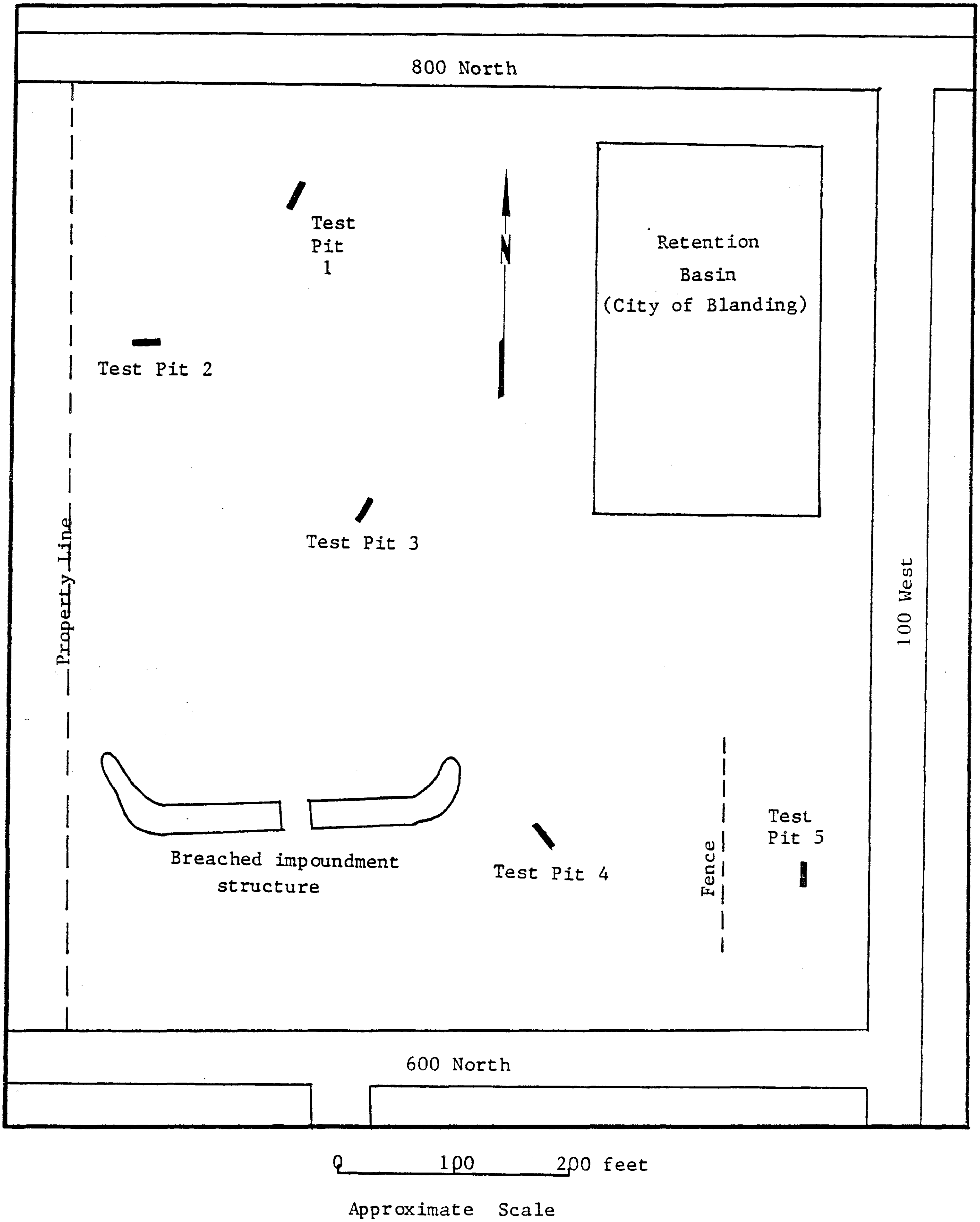
Haynes, D.D., Vogel, J.D., and Wyant, D.G., 1972, Geology, structure, and uranium deposits of the Cortez Quadrangle, Colorado and Utah: U.S. Geological Survey Miscellaneous Investigations Map I-629, scale 1:250,000.

Olsen, M.E., Wilson, LeMoyne, Metcalf, J.W., and Hutchings, T.B., 1962, Soil survey of the San Juan area, Utah: USDA Soil Conservation Service and Utah Agricultural Experiment Station, 49 p.

Base Map from: USGS 15' Topo Quads
Blanding, Utah
Brushy Basin Wash, UT



Location map



Location of test pits, Blanding Middle School site

Attachment 3, Job No. S-3

Blanding Middle School Site
Logs of test pits

Soil Description*

Test Pit No. 1

0' - 1'	Silty sand (SM); red, medium dense, nonplastic, dry, nonindurated; eolian.
1' - 5'	Silty sand (SM); red to white, high density, nonplastic, dry, weakly to moderately indurated; eolian.
5' - 6'	Silty sand (SM); white, high density, nonplastic, dry, moderately indurated; stage II-III pedogenic carbonate, eolian.
6' - 9'	Silty gravel with sand and cobbles (GM); white, high density, nonplastic, dry, moderately indurated; stage III pedogenic carbonate, Abajo Mountain alluvial fan and pediment gravel.
9' - 11'	Fat clay (CH); green, very stiff, moderate to high plasticity, weakly indurated, moist; weathered shale, Mancos Shale (?).

Test Pit No. 2

0' - 0.5'	Clayey sand (SC); red-green, low density, low to medium plasticity, nonindurated, dry; mixed colluvium of shale and eolian sand.
0.5 - 10'	Lean to fat clay (CL/CH); yellow-green, very stiff to hard, high plasticity, nonindurated, dry; weathered shale at 0.5', grading downward into fresher shale (Mancos Shale?) at depth.

Test Pit No. 3

0' - 2'	Silty sand (SM); red, medium dense, nonplastic, nonindurated, dry; eolian.
2' - 3'	Silty sand with gravel (SM); white, high density, nonplastic, weakly to moderately indurated, dry; mixed eolian sand and Abajo Mountain alluvial fan and pediment gravels.
3' - 10'	Lean to fat clay (CL/CH); yellow-green, very stiff to hard, moderate to high plasticity, weakly indurated, dry; calcium carbonate-impregnated Mancos Shale (?).

*Soils classified according to procedures in ASTM Standard D2488-69 (Revised 1975), Description of Soils (Visual Manual Procedure) and D2487-83 (draft), Classification of Soils for Engineering Purposes.

Test Pit No. 4

0' - 5'	Silty sand (SM); red, medium dense, nonplastic, nonindurated, dry; eolian, argillic (clay-rich) soil B horizon in lower part.
5' - 10'	Silty sand with gravel (SM); white, high density, nonplastic, moderately indurated, dry; mixed eolian sand and Abajo Mountains alluvial fan and pediment gravel.
10' - 12'	Sandstone; green, weathered, medium-grained, carbonate-rich (Dakota Sandstone?).

Test Pit No. 5

0' - 1.5'	Silty sand (SM); red, medium dense, nonplastic, nonindurated, dry; eolian.
1.5' - 3'	Sandy lean clay (CL); red, very stiff, moderate plasticity, nonindurated, dry; argillic horizon, clay skins.
3' - 8'	Interbedded shale, carbonaceous claystone, sandy claystone, sandstone.

Note: No ground water encountered in any test pits, all test pit walls stable.

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.*

Project:			Requesting Agency:
Spring City elementary school site			North Sanpete School District
By: R. H. Klauk	Date: 10/10/84	County: Sanpete	Job No.: S-4
USGS Quadrangle: Spring City (799)			

BACKGROUND

In response to a request from Dr. Harold R. Johnson, Superintendent of the North Sanpete School District, an investigation has been conducted at a proposed elementary school site in Spring City. The site is located at the west end of town between 100 and 200 North Streets, immediately east of 500 East Street (SW 1/4 sec. 28 and SE 1/4 sec. 29, T. 15 S., R. 4 E., Salt Lake Baseline and Meridian) and encompasses approximately 8.5 acres (attachment 1). The purpose of the investigation was to identify geologic hazards and/or adverse soil conditions at the site.

SCOPE OF WORK

The scope of work included:

1. a review of existing geologic and hydrologic literature;

2. a field reconnaissance of the site on September 24, 1984;

3. the excavation and logging of 2 test pits;

4. and review of a soils and foundation report of the site by Rollins (1982).

GEOLOGY AND HYDROLOGY

Spring City is located in Sanpete Valley at the western edge of the Wasatch Plateau. The city is situated on coalescing alluvial fans formed by Oak and Canal Creeks. Rocks exposed in the drainage basins of the two creeks include limestone, sandstone, shale, and conglomerate of the Tertiary Flagstaff Limestone, the Tertiary/Cretaceous North Horn Formation, and the Cretaceous Price River and Blackhawk Formations (Robinson, 1971). In the valley alluvium derived from these rocks varies from coarse-grained, bouldery, cobbley gravel near the valley margin to finer-grained silty and clayey deposits near the valley axis.

Ground water in the unconsolidated sediments in Sanpete Valley occurs under both unconfined (water table) and confined (artesian) conditions. In the Spring City area, ground water is found only under water table conditions. East of Spring City, at the edge of the valley, depth to the water table is from 60 to 100 feet. Depths decrease to the west; the water table rises to levels above the land surface west of the city (Robinson, 1971).

Sanpete Valley is located in Unified Building Code (UBC) seismic zone 3 and Utah Seismic Safety Advisory Council (USSAC) seismic zone 4. This indicates the site is within an area where an earthquake of modified Mercalli intensity Vlll or greater are expected. See attachment 2 for an explanation of the intensity scale. Many earthquakes have occurred in or near the valley, with several being Richter magnitude 4 or greater (Arabasz and others, 1979). Holocene faults (movement within the last 10,000 years) are located in Sage Valley adjacent to the west flank of the San Pitch Mountains (Anderson and Miller, 1979). Anderson and Miller (1979) also report late Pleistocene faults (movement from 10,000 to 500,000 years ago), west of Wales, adjacent to the east flank of the San Pitch Mountains, approximately 11 miles west of Spring City (attachment 3). No Pleistocene or younger fault movement is known to be closer to the site.

SITE CONDITIONS

The proposed Spring City elementary school site is located on the Oak Creek alluvial fan (attachment 1). The site slopes generally from east to west, with approximately 40 feet of total relief. A small drainage crosses the property from east to west.

Soils on the site consist of silty or clayey topsoil underlain by sand with up to 80 percent cobbles and boulders (attachment 4). These coarse deposits extend to a depth of at least 7 feet and presumably much deeper. Difficulty in excavating with a tractor mounted backhoe precluded extending the test pits below 7 feet. These coarse-grained soils generally provide good foundation materials, but, due to the high percentage of oversized material (greater than 6 inches), are not suitable for structural fill. The soil and foundation report for the site by Rollins (1982) does not discuss the presence of boulders or cobbles. However, the high blow counts recorded on the logs for the 3 borings made at the site may be indicative of large-size material. No evidence of moisture-sensitive soils was noted by visual inspection of the test pits. Furthermore, laboratory testing by Rollins (1982) indicates these soils have no expansive characteristics.

No ground water was present in either test pit and Rollins (1982) reports no ground water encountered in the borings to the depth drilled (16 feet). Robinson (1971) indicates depth to ground water beneath the site to be from 30 to 60 feet. Due to the coarse-grained soil types, it is unlikely a perched water table is present in this area.

The site is within 1500 feet of the flood hazard area (flood plain of Oak Creek) delineated by the 1978 U.S. Department of Housing and Urban Development Federal Insurance Administration flood map. The possibility does exist that construction on the site will block the small drainage crossing the property. Surface runoff concentration in this drainage during high intensity rain storms could create flooding problems.

COCLUSIUONS AND RECOMMENDATIONS

The Spring City elementary school site is located in UBC seismic zone 3 and USSAC seismic zone 4. Several earthquakes of Richter magnitude 4 and greater have occurred in this area and potentially active Quaternary faults are on the west edge of the valley adjacent to the San Pitch Mountains. Subsurface soils at the site are generally suitable for foundations and shallow ground water is absent. Possible difficulty exists, however, with excavating these soils to desireable depths. Furthermore, much of the site may contain soils unsuitable for structural fill Flood hazard is low, but localized runoff may be a problem. Based on these conditions, the following recommendations are made:

1. Structures should be designed and constructed, at a minimum, in accordance with UBC seismic requirements for zone 3, including design review and field inspection to insure compliance for USSAC seismic zone 4.

2. Mitigating measures are needed to reduce the potential local flooding hazard that may result from blockage of the small drainage.

3. A detailed foundation investigation should be conducted once the exact size and location of the building has been determined, to identify foundation characteristics below the structure and to determine the extent of material unacceptable as structural fill.

REFERENCES CITED

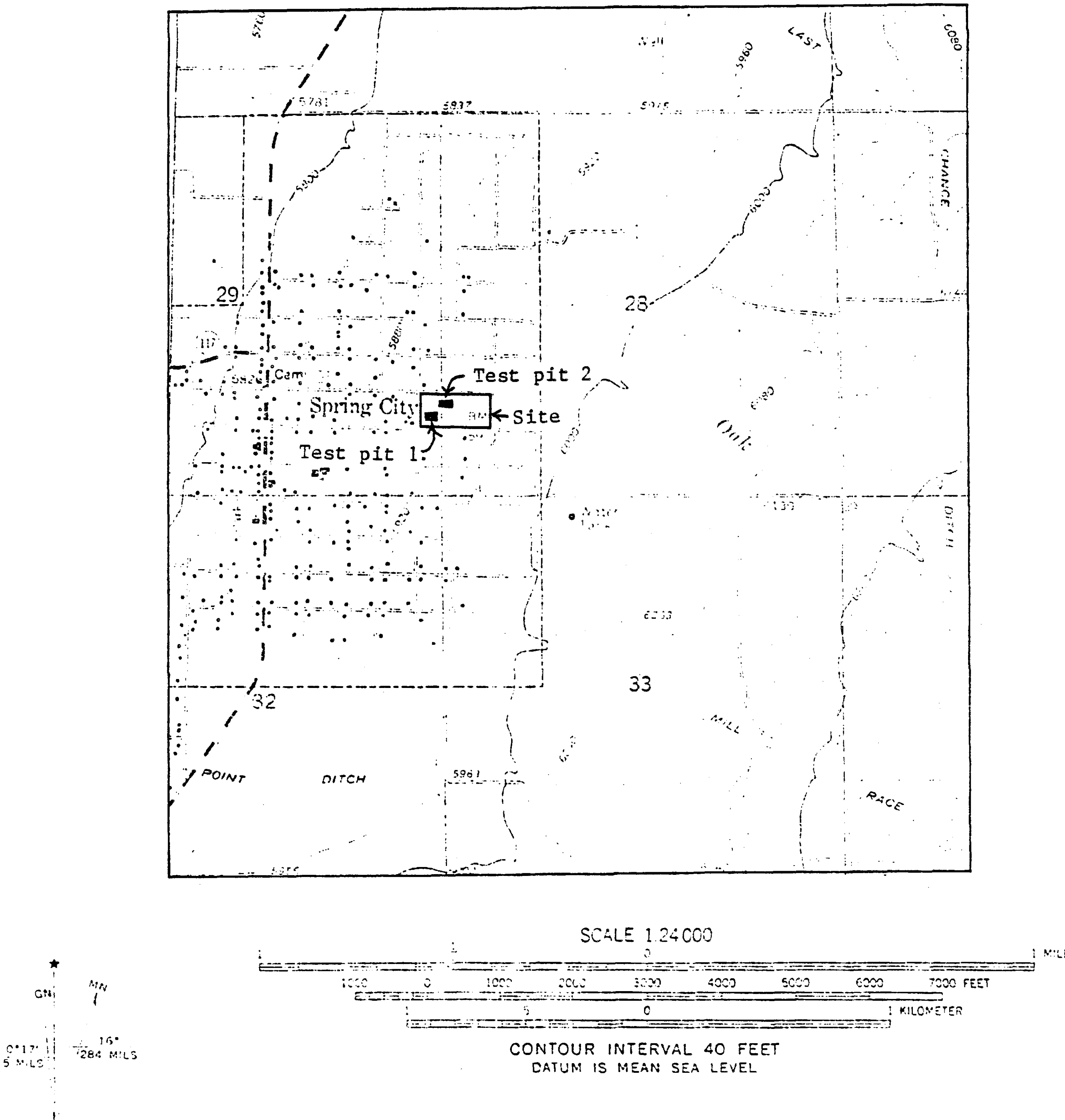
Anderson, L.W., and Miller, D.G., 1979, Quaternary fault map of Utah: Fugro, Inc., Long Beach, California, 35 p., scale 1:500,000.

Arabasz, W.J., Smith, R.B., and Richins, W.D., (editors), 1979, Earthquake studies in Utah, 1850 to 1979: University of Utah, Department of Geology and Geophysics, 548 p.

Robinson, G.B., Jr., 1971, Ground-water hydrology of the San Pitch River drainage basin, Sanpete County, Utah: U.S. Geological Survey Water-Supply Paper 1896, 80 p.

Rollins, R.L., 1982, Soil and foundation investigation Spring City elementary school Spring City, Utah: Rollins, Brown and Gunnell, Inc., Provo, Utah, 8 p.

U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978, Flood hazard boundary map - unincorporated area, Sanpete County, Utah: Community-Panel No. 490111 0007A, scale 1:24,000.



Base map from: U.S.G.S. 7½' topographic quadrangle Spring City, Utah

Location of Spring City elementary school site

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.

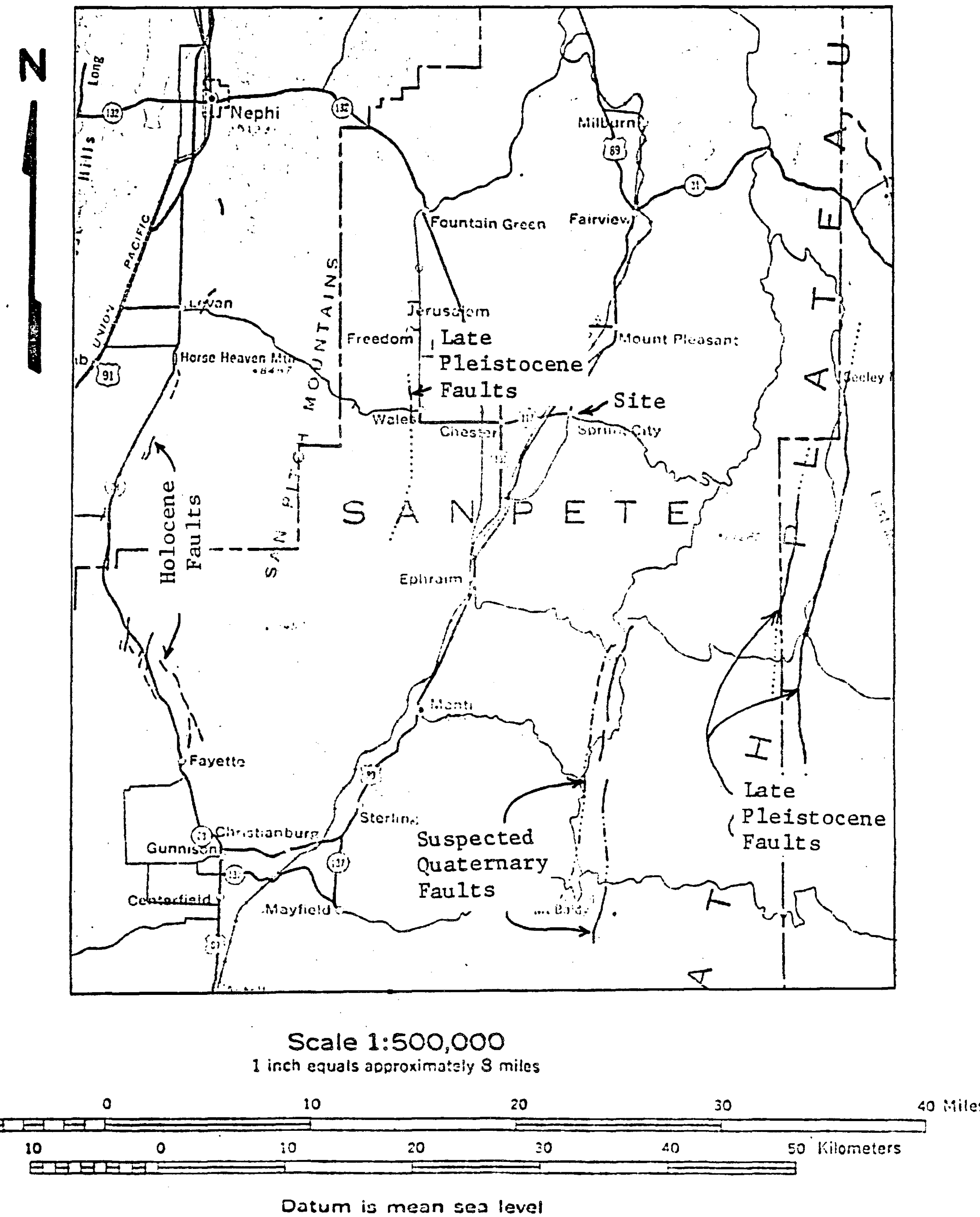
IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

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.*



Location of Holocene, late Pleistocene and suspected Quaternary (Present to 1,600,000 years before present) faults in the Spring City area, Utah.

(Map modified from Miller and Anderson, 1979)

Attachment 4, Job No. S-4

Logs of Test Pits *

Soil Descriptions

Test Pit 1

0.0' - 1.0'	Silty clay - clayey silt (CL-ML); brown, firm, low to medium plasticity, moist, nonindurated; 20-30 percent sand; isolated subrounded cobbles, maximum particle size 12 inches; fine roots throughout.
1.0' - 7.0'	Silty sand - clayey sand (SM-SC); tan, medium to high density, subrounded, nonindurated, moist; 20 percent cobbles and 60 percent boulders, maximun particle size 2.0 feet; secondary calcium carbonate accumulation.

Test Pit 2

0.0' - 1.0'	Silty clay - clayey silt (CL-ML); brown, firm, low to medium plasticity, moist, nonindurated, 10 percent sand; isolated subrounded cobbles, maximum particle size 8 inches; fine roots throughout.
1.5' - 6.0'	Silty sand - clayey sand (SM-SC); tan, medium to high density, subrounded, moist, nonindurated; 20 percent cobbles and 50 percent boulders, maximum particle size 2.0 feet; secondary calcium carbonate accumulation.

Note: No ground water encountered.

* Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (Revised 1975), Description of Soils (Visual Manual Procedure). Percentages recorded for various size fractions are field estimates.S-5

Project:			Requesting Agency:
Lone Peak elementary school			Jordan School District
By: H.E. Gill	Date: 11/19/84	County: Salt Lake	Job No.: S-5
USGS Quadrangle: Draper (1171)			

In response to a request from Clement Bishop, Administrator Auxiliary Services Jordan School District, a geologic hazards investigation of the Lone Peak Elementary School site was undertaken. The site is at 11580 south and High Mesa Drive in Sandy, Utah. The investigation included review of a geotechnical report prepared by Delta Geotechnical Consultants Inc., examination of applicable geologic reports and maps covering the study area, air photo analysis, and a brief field reconnaisance performed on November 7, 1984.

REVIEW OF DELTA GEOTECHNICAL REPORT

Earthquake/slope stability analysis: In general, we concur with Delta Geotechnical's slope stability analysis using 0.20g as the earthquake ground acceleration factor. Delta Geotechnical did not cite a reference for their value for horizontal ground acceleration, however, it corresponds well with the value used by Algermissen and Perkins (1976), and the Utah Seismic Safety Advisory Council (1979). Therefore, we recommend compliance with the suggestions and recommendations set forth in the Delta Geotechnical report for cuts and fills on site.

We concur that a potential exists for shallow slope failures on saturated slopes at the site. We recommend permanent slopes be revegetated as soon as possible, and that temporary excavations remain open for only the minimum time required.

Soils/erosion hazard: The U.S. Department of Agriculture Soil Conservation Service (1974) has mapped site soils as sand or loamy fine sand having high permeability and low shrink-swell potential. As stated in the Delta Geotechnical report, surface drainage should be good. We concur with recommendations for adequate surface drainage during and after construction, and with recommendations for subsurface drains behind retaining walls.

Erosion of the loose sandy soil may be a problem. Heavy rainstorms could cause gullying if precautions are not taken. Revegetation of slopes, and rapid establishment of a surface drainage system are extremely important.

UGMS SITE INVESTIGATION

Earthquake/slope stability analysis: Woodward-Clyde and Associates (1970), mapped a class III lineament (possible fault or rupture) 300 feet southwest of the site (not addressed in the Delta Geotechnial report). The field reconnaissance and photo examination showed that the lineament is a Lake Bonneville erosional feature created by longshore currents eroding Little Cottonwood Creek delta deposits, and older Lake Bonneville sediments.

The site is in Uniform Building Code (UBC) seismic zone 3, and Utah Seismic Safety Advisary Council (USSAC) seismic zone U-4, indicating that major damage corresponding to intensity VIII and higher of the Modified Mercalli Scale may be expected (attachment 1).

Examination of pre-1970 aerial photographs indicates a small debris flow has occurred in the major drainage crossing the site (not addresed in the Delta Geotechnical report). During the site reconnaisance it was observed that site grading had removed all evidence of the debris flow. It is anticipated that additional site grading (slopes will be leveled and the major drainage in which the flow occurred will be eliminated) will completely alter site topography thus alleviating any future debris flow problems.

CONCLUSIONS

1) We generally concur with Delta Geotechnical's earthquake and slope stability analyses, and with their recommendations for adequate surface and subsurface drainage.

2) A possible fault mapped approximately 300 feet southwest of the property was found to be a Lake Bonneville erosional feature associated with long shore currents.

3) The site is in UBC zone 3 and USSAC zone U-4 and the school should be designed at a minimum to meet UBC recommendations for zone 3 construction.

4) Examination of aerial photos showed a small debris flow on site. Site grading has removed all evidence of the failure, and future grading and construction should alleviate any future problems.

Selected References

Algermissen, W. T., and Perkins, D. M., 1976, A probabilistic estimate of maximum acceleration in rock in the contiguous United States: U.S. Geological Survey Open-File Report 76-416, 45p.

Cluff, L. S., and others, 1970, Wasatch fault northern portion, earthquake fault investigation and evaluation: Woodward-Clyde and Associates, Oakland, California, 24p.

Crittenden, M. D., Jr., 1965, Geology of the Draper quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-377, Scale 1:24,000.

International Conference Of Building Officials, 1976, Uniform building code: Whittier, California, 728 p.

Ward, D. B., 1979, Seismic zones for construction in Utah: Seismic Safety Advisory Council State of Utah, Salt Lake City, 13 p.

Woodward, Lowell, and others, 1974, Soil survey of Salt Lake area, Utah: U.S. Department of Agriculture Soil Conservation Service in cooperation with Utah Agriculture Experiment Station, 132 p.

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(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.

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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.*

Project: Alpine School District school sites			Requesting Agency: Alpine School District
By: H. E. Gill	Date: 12/5/84	County: Utah	Job No.: S-6
USGS Quadrangle: Orem (1088)			

In response to a request from Dr. Harold Jacklin, Division Manager of Physical Facilities, Alpine School District, a geologic hazards investigation was performed for two proposed school sites. The first site is for an elementary school at 700 West and 200 North in Orem, Utah. The second site is for a junior high school at 600 East Cedar Hollow Road in Lehi, Utah. The investigation included a review of soil and foundation reports prepared for each site by Rollins, Brown, and Gunnell, Inc., examination of applicable geologic reports and maps, and a field reconnaissance of each site on November 27, 1984.

The literature review and field reconnaissance did not reveal evidence of geologic hazards at either location. Both sites were relatively flat, and no faults are mapped near either property. The nearest Quaternary fault is the Wasatch fault at the base of the Wasatch Range several miles to the east. However, as mentioned in the soils reports, the sites are in Uniform Building Code (UBC) seismic zone 3 and Utah Seismic Safety Advisory Council (USSAC) zone U-4, indicating that major damage from ground shaking corresponding to intensity VIII or higher of the modified Mercalli scale may occur (attachment 1).

CONCLUSIONS ELEMENTARY SCHOOL SITE

1) In general, we concur with statements and recommendations made in the report concerning the absence of shallow ground water, liquefaction potential, and expandible or collapsible soils at the site.

2) The site is in UBC zone 3 and USSAC zone U-4 and the school should be designed at a minimum to meet UBC requirements for zone 3 construction.

CONCLUSIONS JUNIOR HIGH SCHOOL SITE

1) In general, we concur with statements and recommendations made in the report concerning the absence of shallow ground water, liquefaction potential, and expandible or collapsible soils at the site.

2) We concur with statements regarding differential settling across the site and suggest that recommendations made in the report to mitigate this problem be followed.

3) Unlined irrigation ditches were observed north and east of the property. If the ditches remain in use, irrigation water may leak into the subsurface soil. Depending on the location of the structure

this may present a problem. If the northern and eastern sections of the building are far enough from the ditches, the water may percolate deep into the subsurface before it reaches the foundation. However, if the building is near the ditches, water could reach the foundation before percolating to depth. Seepage problems can be mitigated by lining the irrigation ditches adjacent to the north and east sides of the structure.

4) The site is in UBC zone 3 and USSAC zone U-4 and the school should be designed at a minimum to meet UBC requirements for zone 3 construction.

SELECTED REFERENCES

Armstrong, R. M., 1975, Environmental geology of the Provo-Orem area, in Hamblin, W. K., ed., Brigham Young University geology studies, v. 22, part 1: Department of Geology Brigham Young University, p. 39-67.

Baker, A. A., 1964, Geologic map and sections of the Orem quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-241, scale 1:24,000.

Hunt, C. B., Varnes, H. D., and Thomas, H. E., 1953, Lake Bonneville: geology of northern Utah Valley, Utah: U.S. Geological Survey Professional Paper 257-A, 99 p.

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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.

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

Source: *Earthquake Information Bulletin* [illegible] (5), p. 28, 1974.

SUBDIVISIONS

Project:			Requesting Agency:
Review of Dames and Moore geotechnical report for residential development in Avenues area of Salt Lake City			S.L.C. Planning and Zoning Commission
By: G. E. Christenson	Date: 1/11/84	County: Salt Lake	Job No.: SD-1
USGS Quadrangle: Fort Douglas (1253)			

The geotechnical report reviewed is entitled "Soils, foundation, and engineering geology investigation, proposed residential development located north of North Bonneville Drive and east of Terrace Hills Drive, Salt Lake City, Utah", by Dames and Moore. The review consists of an assessment of the accuracy and completeness of the engineering geologic sections of the report. The scope of work included a literature survey and brief site reconnaissance on December 30, 1983. The ground surface was covered with snow at the time of the site visit.

The report appears to be accurate and complete with respect to engineering geologic considerations and outlines the precautions to be taken to accommodate existing conditions. Our principal comment regards the decision to forego all laboratory soil testing. Although coarse-grained soils such as those at the site do not lend themselves to laboratory testing, we feel that grain-size analysis should have been run to confirm field logs and to demonstrate suitable gradation for use of natural soils as structure fill.

Items from the report that should be stressed are: (1) positioning of structures away from the mouths of small drainage basins (p. 10) or possible diversion of drainages, (2) removal of sod, rubbish, and other deleterious materials including oversized particles from all soils to be used in structural fill (p. 13), and (3) use of design criteria in the Uniform Building Code for construction in seismic zone 3 for all structures (p. 21). In addition, the area is in Utah Seismic Safety Advisory Council (USSAC) seismic zone U-4. The USSAC recommends use of seismic design standards in UBC zone 3 for their zone U-4, but with more rigorous monitoring and review to ensure compliance.

Project:	Requesting Agency:
Review of Dames and Moore geotechnical report for residential development near Bonneville Drive - NE Salt Lake City	S.L.C. Planning and Zoning Commission

By:	Date:	County:	Job No.:
R. H. Klauk	6/15/84	Salt Lake	SD-2

USGS Quadrangle:
Fort Douglas (1253)

The geotechnical report reviewed is entitled "Soils foundation, and engineering geology investigation, proposed residential development located near Bonneville Drive, northeast Salt Lake City, Utah," by Dames and Moore. The review consisted of an assessment of the technical completeness of the engineering geology section of the report. The scope of work included a literature search and brief site reconnaissance on May 30, 1984.

The report seems to take into account all geologic conditions present on the site which could negatively affect the development. We do think, however, that grain size analyses should have been conducted to confirm field soil classifications and demonstrate suitable gradation for use of natural soils as structural fill. Please note also that Pavlis and Smith (1979) indicate displacement on the Virginia Street fault (located approximately 1/2 mile south of the site), although showing no signs of Quaternary movement, is related to movement on the Quaternary Warm Springs fault, a segment of the Wasatch fault zone, located approximately 2 miles to the west of the site. A final comment concerns Plate 2. The quality of the plate was poor, which made it very difficult to identify different geologic units.

Items from the report that should be stressed are:

(1) "Under no circumstances should buildings be established upon nonengineered fill which is currently present in certain portions of the site." (p. 16)

(2) "Care should be taken not to position the residential structures within the small drainage basins which pass through the site." (p. 16)

(3) "The use of excavated rock material as backfill should be limited to that meeting the general maximum particle size requirement for structural fill." (p. 20)

(4) In the event that foundations are established partially upon rock and partially upon soil, the rock should be overexcavated to a depth of four inches and replaced with compacted structural fill." (p. 24)

(5) "As a minimum, criteria stated within the Uniform Building Code for a Zone 3 Area should be incorporated into the design of the proposed structures." (p.30)

Reference Cited

Pavlis, T.L., and Smith, R.B., 1979, Slip vectors on faults near Salt Lake City from Quaternary displacements and seismicity: in Arabasz, W.J., Smith, R.B., and Richins, W.D., eds, Earthquake studies in Utah, 1850-1978: University of Utah Seismograph Station Special Publication, p. 375-381.

Project: Review of geotechnical report filed for proposed Valley Vista subdivision, Salt Lake City, Utah			**Requesting Agency:** Salt Lake City Corporation Planning and Zoning Commission
By: W. R. Lund	**Date:** 12/18/84	**County:** Salt Lake	**Job No.:** SD-3
USGS Quadrangle: Sugarhouse (1212)			

The Utah Geological and Mineral Survey has reviewed an engineering geology and geotechnical report prepared by Dames and Moore for the proposed Valley Vista five-lot subdivision at about 2000 South on Lakeline Drive (about 3000 East) in Salt Lake City, Utah. The review was concerned only with the engineering geologic aspects of the development. It is suggested that the city's engineering consultant review the foundation and grading portions of the report.

The scope of work presented in the report indicates that the investigation consisted of a review of available literature followed by a brief field reconnaissance. Since the investigation did not include original geologic mapping or excavation of test pits, it is assumed that most of the information presented on geology, soils, hydrology, and faulting comes from the literature. If that is the case, sources of information should be referenced in the report where appropriate.

Mapping of surficial deposits by Van Horn (1972a) shows that the site is underlain on the east by post-Bonneville shoreline alluvial-fan material and on the west by coarse-grained Lake Bonneville sediments. Mention of these two units is made in the report, but they are lumped together and few details are given. It is recommended that the distribution of these units be mapped on and geotechnical report prepared by Dames and Moore for the proposed Valley Vista five-lot subdivision at about 2000 South on Lakeline Drive (about 3000 East) in Salt Lake City, Utah. The review was concerned only with the engineering geologic aspects of the development. It is suggested that the city's engineering consultant review the foundation and grading portions of the report.

The scope of work presented in the report indicates that the investigation consisted of a review of available literature followed by a brief field reconnaissance. Since the investigation did not include original geologic mapping or excavation of test pits, it is assumed that most of the information presented on geology, soils, hydrology, and faulting comes from the literature. If that is the case, sources of information should be referenced in the report where appropriate.

Mapping of surficial deposits by Van Horn (1972a) shows that the site is underlain on the east by post-Bonneville shoreline alluvial-fan material and on the west by coarse-grained Lake Bonneville sediments. Mention of these two units is made in the report, but they are lumped together and few details are given. It is recommended that the distribution of these units be mapped on site and that test pits be excavated to determine their relative foundation characteristics. Crittenden (1965) shows that bedrock in the vicinity of the site is the Mahogany Member of the Ankareh Formation consisting chiefly of shale, mudstone, and sandstone. The report states that bedrock was observed in the drainage crossing the site and in nearby road cuts, but the rock type and formation were not identified. The report further indicates that shallow bedrock (3-5 feet) may exist beneath the northern-most lots making deep excavations difficult and costly in that area. The UGMS concurs with that evaluation, but further recommends that if permanent cut slopes in rock are planned, they be evaluated to determine the type and structural characteristics of the rock present and their effect on slope stability.

The location of the subdivision high on the side of Salt Lake Valley indicates that depth to the regional water table is several hundred feet or more. However, a spring shown southwest of the site on Crittenden's (1965) geologic map and Van Horn and Fields' (1974) flood and surface water information map implies that perched water-table conditions may exist in the area. The possible presence and potential effects of a perched water table on the site should be evaluated.

Evidence of recent fault activity is not present in the site vicinity (Van Horn, 1972b). The report discusses a concealed fault that may have experienced movement in the last 5,000 to 3 million years located about 1500 feet west of the proposed subdivision. No mention is made of bedrock faults mapped about 1000 feet to the northeast (Crittenden, 1972), however, Van Horn (1972b) indicates that they probably have not moved in the last 3 million years. It appears that during a major seismic event ground shaking and/or ground failure would be a greater hazard at the site than ground rupture. The UGMS concurs with the report recommendation that the criteria presented in the Uniform Building Code for construction in zone 3 seismic areas be used as a minimum design standard for the subdivision.

In summary, UGMS recommends that surficial deposits on site be mapped and test pits excavated to determine their foundation characteristics. The mapping should include bedrock where exposed to document rock types present and their structural characteristics. The possible presence of a shallow perched water table in the site vicinity needs to be investigated and if present its potential effect on the site evaluated. The subdivision is located in moderately steep terrain in a high earthquake hazard area, all construction should conform to UBC seismic zone 3 standards, and all permanent construction cuts should be carefully evaluated for slope stability.

SELECTED REFERENCES

Crittenden, M. D., Jr., 1965, Geology of the Sugar House Quadrangle Salt Lake County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-380, scale 1:24,000.

Mower, R. W., and Van Horn, Richard, 1973, Map showing minimum depth to water in shallow aquifers (1963-72) in the Sugar House Quadrangle, Salt Lake City, Utah: Miscellaneous Investigation Series Map I-766-I, scale 1:24,000.

Van Horn, Richard, 1972a, Surfical geologic map of the Sugar House Quadrangle, Salt Lake County, Utah: Miscellaneous Investigation Series Map I-766-A, scale 1:24,000.

---------------- 1972b, Map showing relative ages of faults in the Sugar House Quadrangle, Salt Lake County, Utah: Miscellaneous Investigation Series Map I-766-B, scale 1:24,000.

---------------- 1972c, Landslide and associated deposits map of the Sugar House Quadrangle, Salt Lake County, Utah: Miscellaneous Investigation Series Map I-766-D, scale 1:24,000.

---------------- 1972d, Relative slope stability map of the Sugar House Quadrangle, Salt Lake County, Utah: Miscellaneous Investigation Series Map I-766-E, scale 1:24,000.

Van Horn, Richard, and Fields, F. K., 1974, Map showing flood and surface water information in the Sugar House Quadrangle, Salt Lake County, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-766-N, scale 1:24,000.

TERRAIN ANALYSIS

Project:			Requesting Agency:
Bibliography of geology, soils, hydrology, and geologic hazards, Sevier and Sanpete Counties			Six-County Planning and Economic Development District
By: G. E. Christenson	Date: 1/17/84	County: Sevier and Sanpete	Job No.: TA-1
USGS Quadrangle: All quads in Sevier and Sanpete Counties			

SELECTED REFERENCES
Geology, Soils, Hydrology and Geologic Hazards
Sevier and Sanpete Counties

General Geology

Baer, J. L., and Callaghan, Eugene, eds., 1972, Plateau - basin and range transition zone, central Utah: Utah Geological Assoc. Publication 2, 123 p.

Blanchard, L. F., and Sanchez, J. D., 1982, Geologic map and coal sections of the Old Woman Plateau Quadrangle, Sevier County, Utah: U.S. Geological Survey Open-File Report 82-1093, 1:24,000.

Callaghan, Eugene, and Parker, R. L., 1961, Geology of the Monroe Quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-155, 1:62,500.

----- 1962, Geology of the Sevier Quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-156, 1:62,500.

Caskey, C. F., and Shuey, R. T., 1975, Mid-Tertiary volcanic stratigraphy, Sevier - Cove Fort area, central Utah: Utah Geology, v. 6, no. 1, p. 17-25.

Crosby, G. W., 1959, Geology of the south Pavant Range, Millard and Sevier Counties, Utah: Brigham Young University Geology Studies, v. 6, no. 3, 59 p.

Cunningham, C. G., and others, 1983, Geologic map of the Tushar Mountains and adjoining areas, Marysvale volcanic field, Utah, Piute, Beaver, Sevier, and Millard Counties: U.S. Geological Survey Miscellaneous Investigations Series Map I-1430-A, 1:50,000.

Cunningham, C. G., and Steven, T. A., 1979, Geologic map of the Monroe SW Quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1140, 1:24,000.

Doelling, H. H., 1972, Central Utah coal fields: Sevier - Sanpete, Wasatch Plateau, Book Cliffs and Emery: Utah Geological and Mineral Survey Monograph Series No. 3, 571 p.

Ellis, E. G., 1981, Geologic map and coal sections of the Ferron Canyon Quadrangle, Sanpete and Emery Counties, Utah: U.S. Geological Survey Open-File Report 81-319, 1:24,000.

Gilliland, W. N., 1951, Geology of the Gunnison Quadrangle, Utah: Nebraska University Studies, v. 5, no. 8, 1:62,500.

----- 1963, Sanpete - Sevier anticline of central Utah: Geological Society of America Bulletin, v. 74, p. 115-123.

Gregory, H. E., 1944, Geologic observations in the upper Sevier River valley, Utah: American Journal of Science, v. 242, p. 577-606.

Hardy, C. T., 1952, Eastern Sevier Valley, Sevier and Sanpete Counties, Utah with reference to formations of Jurassic age: Utah Geological and Mineral Survey Bulletin 43, 1:87,500, 1:62,500.

Hardy, C. T., and Zeller, H. D., 1953, Geology of the west-central part of the Gunnison Plateau: Geological Society of America Bulletin, v. 64, no. 11, p. 1261-1278, 1:93,750.

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 Coal Investigations Map C-82, 1:24,000.

Hawkes, R. L., 1979, The stratigraphy and structure of the Cedar Hills, Sanpete County, Utah: Brigham Young University Geology Studies, v. 27, pt. 1.

Hintze, L. F., ed., 1962, Geology of the southern Wasatch Mountains and vicinity, Utah - A symposium: Brigham Young University Geology Studies, v. 9, pt. 1, 1:125,000.

Hintze, L. F., compiler, 1980, Geologic map of Utah: Utah Geological and Mineral Survey, 1:500,000.

Kitzmiller, J. M., 1982, Preliminary geologic map of the Joes Valley Reservoir Quadrangle, Sanpete and Emery Counties, Utah: Utah Geological and Mineral Survey Map 67, 1:24,000.

Lipton, C. T., 1916, Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties: U.S. Geological Survey Bulletin 628, 1:62,500, 1:125,000.

Mabey, D. R., Crittenden, M. D., Jr., Morris, H. T., Roberts, R. J., and Tooker, E. W., 1964, Aeromagnetic and generalized geologic map of part of north-central Utah: U.S. Geological Survey Geophysical Investigations Map GP-422, 1:250,000.

Oberhansley, G. G., 1980, Geology of the Fairview Lakes Quadrangle, Sanpete County, Utah: Utah Geological and Mineral Survey Map 56, 1:24,000; also Brigham Young University Geology Studies, v. 27, pt. 3, p. 73-95.

Pratt, A. R., and Callaghan, Eugene, 1970, Land and mineral resources of Sanpete County, Utah: Utah Geological and Mineral Survey Bulletin 85, 69 p., 1:250,000.

Sanchez, J. D., and Hayes, P., 1977, Geologic map and coal resources of the Flagstaff Peak Quadrangle, Emery, Sanpete and Sevier Counties: U.S. Geological Survey Coal Investigations Map C-83, 1:24,000.

Schoff, S.L., 1951, Geology of the Cedar Hills, Utah: Geological Society of America Bulletin, v. 62, no. 6, 1:125,000.

Schneider, M. C., 1964, Geology of the Pavant Mountains west of Richfield, Sevier County, Utah: Brigham Young University Geology Studies, v. 11, p. 129-139.

Spieker, E. M., 1931, The Wasatch Plateau coal field, Utah: U.S. Geological Survey Bulletin 819, 1:62,500.

----- 1949, The transition between the Colorado plateaus and the Great Basin in central Utah: Utah Geological Society Guidebook 4.

Spieker, E. M., and Baker, A. A., 1928, Geology and coal resources of the Salina Canyon district, Sevier County, Utah: U.S. Geological Survey Bulletin 796-C, 1:62,500.

Spieker, E. M., and Billings, M. P., 1940, Glaciation in the Wasatch Plateau, Utah: Geological Society of America Bulletin, v. 51, no. 8, 1:125,000.

Steven, T. A., 1978, Geologic map of the Sevier SW Quadrangle: U.S. Geological Survey Miscellaneous Field Studies Map MF-962, 1:24,000.

----- 1979a, Geologic map of the Monroe NW Quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1107, 1:24,000.

----- 1979b, Geologic map of volcanic rocks in the Sevier NE Quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1108, 1:24,000.

Steven, T. A., and Cunningham, C. G., 1979, Geologic map of the Sevier SE Quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1109, 1:24,000.

Steven, T. A., and Morris, H. T., 1983, Geology of the Richfield Quadrangle, west-central, Utah: U.S. Geological Survey Open-File Report 83-0583, 1:250,000.

Stokes, W. L., Hintze, L. F., and Madsen, J. H., 1961-3, Geologic map of Utah: Utah State Land Board and Utah Geological and Mineral Survey, 1:250,000.

Williams, P. L., 1972, Map showing types of bedrock and surficial deposits, Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-H, 1:250,000.

Williams, P. L., and Hackman, R. J., 1971, Geology, structure, and uranium deposits of the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations I-591, 1:250,000.

Witkind, I. J., and others, 1982, Preliminary geologic map of the Manti 30' X 60' Quadrangle, Carbon, Emery, Juab, Sanpete, and Sevier Counties, Utah: U.S. Geological Survey Open-File Report 82-654, 1:100,000.

Slope Stability

Fleming, R. W., Schuster, R. L., John, R. B., and Robinson, S. L., 1977, Recent movement of the Manti, Utah, landslide: Engineering Geology, Soils Engineering Symposium, Proceedings no. 15, p. 161-178.

Shroder, J. F., Jr., 1971, Landslides of Utah: Utah Geological and Mineral Survey Bulletin 90, 51 p.

Wallace, R. G., 1977, Boulder terraces and debris flows in Sixmile and Manti Canyons, west edge of Wasatch Plateau, Utah: Geological Society of America, Abstracts with Programs, v. 9, no. 5, p. 663.

Williams, P. L., 1972, Map showing landslides and areas of potential landsliding in the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-L, 1:250,000.

Quaternary Faulting and Seismicity

Anderson, L. W., and Miller, D. G., 1979, Quaternary fault map of Utah: Long Beach, California, Fugro, Inc., 1:500,000.

Anderson, R. E., and Bucknam, R. C., 1979, Map of fault scarps in unconsolidated sediments, Richfield 1^{o} X 2^{o} Quadrangle, Utah: U.S. Geological Survey Open-File Report 79-1236, 1:250,000.

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

Pack, F. J., 1921, The Elsinore earthquakes in central Utah: Seismological Society of America Bulletin 11, p. 155-165.

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

Woodward-Lundgren and Associates, 1973, Wasatch fault, southern portion, earthquake fault investigation and evaluation: Consulting report for Utah Geological and Mineral Survey, 1:24,000.

Soils - Engineering Geology

Utah State Department of Highways, 1966, Materials inventory, Sanpete and Sevier Counties: Materials and Research Division, Materials Inventory Section, 22 p., 1:200,000.
U.S. Federal Highway Administration and Utah State Department of Highways, 1975, Draft environmental impact statement: Interstate 70 through Sevier Valley: U.S. Department of Transportation.
USDA Soil Conservation Service and others, 1981, Soil survey of Sanpete Valley area, Utah, parts of Utah and Sanpete Counties: 1:24,000.
Williams, P. L., 1972, Map showing relative ease of excavation in the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-J, 1:250,000.

Ground Water

Carpenter, C. H., Robinson, G. B., Jr., and Bjorklund, L. J., 1964, Selected hydrologic data, upper Sevier River basin, Utah: U.S. Geological Survey and Utah State Engineer Basic-Data Report 8.
----- 1967, Ground-water conditions and geologic reconnaissance of the upper Sevier River basin, Utah: U.S. Geological Survey Water-Supply Paper 1836, 1:250,000.
Carpenter, C. H., and Young, R. A., 1963, Ground-water data, central Sevier Valley, parts of Sanpete, Sevier, and Piute Counties, Utah: U.S. Geological Survey and Utah State Engineer Basic-Data Report 3, 34 p.
Covington, H. R., 1972, Map showing springs in the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-G, 1:250,000.
Cruff, R. W., 1977, Seepage study of the Sevier Valley - Piute Canal, Sevier County, Utah: U.S. Geological Survey and Utah Department of Natural Resources Technical Publication 58, 31 p.
Price, D., 1972a, Map showing general chemical quality of ground water in the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-K, 1:250,000.
----- 1972b, Map showing general availability of ground water in the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-M, 1:250,000.
Richardson, G. B., 1907, Underground water in Sanpete and central Sevier Valleys, Utah: U.S. Geological Survey Water-Supply Paper 199, 1:250,000.
Robinson, G. B., Jr., 1968, Selected hydrologic data, San Pitch River drainage basin, Utah: U.S. Geological Survey and Utah Department of Natural Resources Basic-Data Report 14.
----- 1971, Ground-water hydrology of the San Pitch River drainage basin, Sanpete County, Utah: U.S. Geological Survey Water-Supply Paper 1896, 80 p., 1:25,000.
Young, R. A., 1960, Ground-water areas and well logs, central Sevier Valley, Utah: U.S. Geological Survey and Utah State Engineer Information Bulletin No. 3.
Young, R. A., and Carpenter, C. H., 1961, Developing ground water in the central Sevier Valley, Utah: U.S. Geological Survey and Utah State Engineer Information Bulletin No. 5.
----- 1965, Ground-water conditions and storage in the central Sevier Valley, Utah: U.S. Geological Survey Water-Supply Paper 1789, 95 p., 1:125,000.

Land-Use

Narasimham, V. A., and Israelsen, E. K., 1975, A water - land use management model for the Sevier River basin, phase I and II: Utah Water Research Laboratory, Utah State University.

Flooding - Surface Water

Alter, J. C., 1930, Mud flows in Utah: Monthly Weather Review 58, p. 319-321.

Butler, E., and Marsell, R. E., 1972, Developing a state water plan - cloudburst floods in Utah, 1939-69: U.S. Geological Survey and Utah Department of Natural Resources Cooperative Investigations Report no. 11.

Covington, H. R., and Williams, P. L., 1972, Surface water map of the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-F, 1:250,000.

Hackman, R. J., and Williams, P. L., 1972, Map showing drainage basins and historic cloudburst floods in the Salina Quadrangle, Utah: U.S. Geological Survey Folio of the Salina Quadrangle, Utah Map I-591-N, 1:250,000.

Utah Division of Comprehensive Emergency Management, 1982, Utah's history of floods 1847-1981: Department of Public Safety, State of Utah, and Federal Emergency Management Agency, contract no. EMW-R-0223, Flood Plain Management Status Report.

Utah Water Research Laboratory, 1974, Planning for water quality in the Sevier River system in the state of Utah: Utah Water Research Laboratory Report PRWG 142-3.

U.S. Department of Housing and Urban Development, Federal Insurance Administration Flood Hazard Boundary Maps - Complete for much of the poputated area of Sevier and Sanpete Counties.

For copies of maps contact:

James Harvey, Division of Comprehensive Emergency Management, P.O. Box 8100, Salt Lake City, UT 84108, (801)533-5271.

U.S. Soil Conservation Service and others, 1977, Flood hazard analyses for local drainages in Richfield and vicinity, Sevier County, Utah: 8 p.

Waddell, K. M., Dodge, J. E., Darby, D. W., and Theobald, S. M., 1983, Hydrology of the Price River basin, Utah: U.S. Geological Survey Open-File Report 83-0208.

Wooley, R. R., 1946, Cloudburst floods in Utah 1850-1938: U.S. Geological Survey Water-Supply Paper 994, 128 p.

Utah Geological and Mineral Survey Site Investigations

Gill, H. E., 1981, Geologic investigation to locate a culinary water well for Gunnison City, Sanpete County, Utah: Utah Geological and Mineral Survey Report of Investigation No. 162, 18 p.

----- 1982, Geologic and hydrologic evaluation of Mt. Pleasant watershed, Sanpete County, Utah: Utah Geological and Mineral Survey Report of Investigation No. 169, 1:24,000.

Kaliser, B. N., 1974, Preliminary geologic reconnaissance of the Pleasant Creek Estates subdivision, Sanpete County, Utah: Utah Geological and Mineral Survey Report of Investigation No. 90, 2 p.

----- 1976, Geological reconnaissance of the site for the Sevier Valley Technical College with notes of archeological significance: Utah Geological and Mineral Survey Report of Investigation No. 107, 6 p.

UGMS Memos and letters - Sanpete County

Axtell Water Tank
Axtell - Michaelson Spring
Cottonwood Canyon slope failures
Fountain Green shallow ground water
Manti Canyon landslide
Moroni water storage reservoir
Palisade Lake trench cave-in
School sites in Manti and Ephraim
Sterling City springs
Wales culinary springs

UGMS Memos and letters - Sevier County

Monroe Hot Springs subdivision
Richfield City swimming pool
Salina Canyon - unnamed recreational subdivision
Salina City landfill

Project:	Requesting Agency:
Geologic evaluation of three parcels of land being considered for acquisition by State Lands and Forestry on Cedar Mountain, Iron County, Utah	Division of State Lands and Forestry

By:	Date:	County:	Job No.:
W. R. Lund	7/3/84	Iron	TA-2

USGS Quadrangle:
Cedar City (238) Cedar Mountain (197)

An investigation was conducted on June 19, 1984, of three parcels of land that the Utah Division of State Lands and Forestry proposes to acquire from the Bureau of Land Management under one of Utah State University's remaining quantity grant selections. The lands being considered are located on Cedar Mountain (attachment 1) and are described as follows: SE1/4 sec. 35, T. 36 S., R. 11 W.; NW1/4 SE1/4 sec. 36, T. 36 S., R. 11 W.; and NW1/4 SW1/4 sec. 1, T. 37 S., R. 11 W. The investigation consisted of a literature review and field reconnaissance for each parcel. The purpose of the investigation was to identify geologic hazards or conditions that may constrain future land use.

SE1/4 sec. 35, T. 36 S., R. 11 W.

This 160 acre parcel is located at the north end of Square Mountain (a subdivision of Cedar Mountain, attachment 1). Topographically, it consists of a gently sloping (6 to 8 degrees to the northwest) upland on the south and east, and steep slopes on the north and west. The upland area is underlain by a basalt flow of Quaternary age (Averitt, 1962). The steep slopes are covered by basalt talus that grades from blocks ranging in size from 5 to 10 feet in diameter at the tops of the slopes to 1 to 2 feet in diameter at the bases. The Triassic-age Moenave Formation (sandstone and siltstone) and the Jurassic-age Kayenta Formation (siltstone, mudstone, and sandstone) underlie the basalt but do not crop out on the parcel. Soil cover is very thin on the basalt flow (generally less than 1 foot), and nonexistant on talus slopes.

The principal geologic hazard on the property is from rock fall on the talus slopes below the basalt flow. The sedimentary rocks beneath the basalt are relatively soft. The talus is formed initially by erosion of the underlying beds and undercutting of the edges of the basalt (Averitt, 1962). This process yeilds large blocks of basalt often 3 to 5 feet wide and 20 feet long that break away from the flow and fall on the slopes below. As the blocks move down slope they break into successively smaller pieces. The hazard from rock fall is increased because of proximity to the seismically active Hurricane fault (1.5 miles west), portions of which may have been active during Holocene time (less than 10,000 Before Present) (Earth Science Associates, Inc., 1983).

Other considerations for future development of the parcel include; difficulty of excavating the basalt, potential instability of talus slopes, and an absence of suitable geologic conditions for onsite wastewater disposal. Basalt is normally a hard, dense rock, and it can be expected that any significant excavation in it will require blasting. The talus slopes on the property appear stable under natural conditions, and in some areas are covered by a heavy growth of tall brush and trees. However, the slopes are at or near their angle of repose and additional steepening either by grading for roads and buildings or by adding material to the slope may cause movement. Utah Health Department regulations require a minimum of 4 feet of suitable soil between the bottom of a wastewater soil absorption system and bedrock. It is doubtful that 4 feet of soil exists anywhere on the parcel underlain by the basalt flow, and talus is not considered suitable because it is too porous and provides no renovation for the sewage. Conditions are such (high altitude, and very shallow bedrock) that it may also be difficult to gain approval for alternate wastewater disposal systems recently approved for limited use by the Utah Wastewater Disposal Technical Review Committee.

NW1/4 SE1/4 sec. 36, T. 36 S., R. 11.W.

Located west of Lone Tree Mountain and south of Green Lake (attachment 1), this parcel encompasses 40 acres of very rugged terrain. An east-west ridge capped by a narrow basalt flow bisects the property. Slopes are steep and covered by coarse basalt talus. Individual blocks range in size from more than 10 feet to 1 to 2 feet in diameter. North of the ridge, the property extends onto a large, complex landslide of Quaternary age (Schroder, 1971; Averitt and Threet, 1973). The landslide is also covered by coarse (5 to 10 foot diameter) talus derived from basalt flows on Lone Tree Mountain, the west side of which is the headwall scarp for the landslide. Irregular troughs and linear depressions in the basalt rubble covering the landslide probably mark the upper part of individual slump blocks beneath the talus.

Geologic hazards present on the parcel include rock fall, which is active on the upper portion of most talus slopes, and a potential for renewed movement of the landslide at the north end of the property. Evidence of recent rock fall was observed on both the east-west ridge and on the west side of Lone Tree Mountain. Schroder (1971) considers the landslide to have occurred during late Pleistocene or early Holocene time (500,000 to 5,000 B. P.), possibly initiated by an abundance of moisture and/or ground shaking produced by movement on the Hurricane fault (2.5 miles west). He states that it has a recent appearance but lacks youthful features. Christenson (1981) found evidence for stability in soil pits excavated in the slide debris. Many of the test pits exhibited soil profiles, including Stage I to II caliche horizons (Gile and others, 1966), at an average depth of 2 feet. The soil horizons indicate stability of the land surface during the last few thousand years, because calichified soils with the observed level of development require at least that long to form. No surface evidence of recent instability was found on the parcel, and it is concluded that under existing conditions the landslide is stable. However, development on the landslide portion of the parcel, particularly oversteepening of slopes or addition of water, may result in renewed movement.

Other considerations for development on this parcel include problem foundation conditions caused by loose talus blocks and voids between the blocks, potential instability of talus slopes if disturbed, and the absence of suitable geologic conditions for onsite wastewater disposal.

NW1/4 SW1/4 sec. 1, T. 37 S., R. 11 W.

This 40 acre parcel is on the west side of Square Mountain (attachment 1). The northern half of the property is a gently sloping (4 to 6 degrees northwest) upland surface underlain by Quaternary-age basalt. The southern half is a steep talus slope. Jurassic-age sedimentary rocks (sandstone, siltstone, mudstone, limestone, and gypsum) of the Carmel Formation, Entrada

Sandstone, Curtis Formation and Windsor Formation underlie the basalt and the talus (Averitt, 1962), but do not crop out on the parcel. Soil cover on the basalt is very thin (generally less than 1 foot), and nonexistant on the talus slope.

The primary geologic hazard on the property is from rock fall onto the talus slope below the basalt flow. The degree of hazard is reduced due to a growth of tall brush and trees on the upper part of the slope. No evidence was observed of fresh rock falls. The rock fall hazard is increased due to possible seismic activity on the Hurricane fault (2 miles west). Recent debris avalanches and debris flows were seen on hillsides underlain by sedimentary rocks (principally the Tropic Formation) in the adjacent Shurtz Creek drainage, but similar failures have not occurred on the slope below the basalt flow.

Other considerations for development on the parcel include difficult excavation conditions in the basalt, potential instability of talus slopes if disturbed, unsuitable foundation conditions on talus slopes due to loose nature of the talus blocks and the voids between them, and the absence of suitable geologic conditions for onsite disposal of wastewater.

Conclusion

The three parcels of land being considered for acquisition by State Lands and Forestry are located in rugged terrain and include steep talus covered slopes. Because of the rock-fall hazard, potential for slope instability, and poor foundation conditions associated with talus, development on those slopes is not recommended. It is particularly important for rock-fall protection and slope stability that the vegetation established on the talus slopes not be removed.

A portion of the 40 acre parcel in sec. 36 includes part of a presently stable landslide. The landslide is covered by large talus blocks which would make development difficult in that area . If roads or utility lines must cross the landslide, their effect on slope stability should be carefully evaluated. Landslide stability is commonly sensitive to changes in moisture content. Wastewater disposal or any other activity which would result in a net addition of water to the landslide is not recommended.

Except for excavation difficulty, foundation conditions on those portions of the three parcels underlain by basalt flows should prove satisfactory. A foundation investigation is still recommended for large structures and housing developments. Adequate setback distances must be maintained from the edge of basalt flows above talus slopes. The distance required will depend on the type of structure to be built and the extent to which rock fall (i.e. undercutting of the basalt flow by erosion) is active at the site.

Geologic conditions on the three parcels are not suitable for wastewater disposal using septic tank and soil absorption systems. The depth of soil on all three parcels is minimal and does not meet State Health Department regulations for onsite disposal. The Wastewater Disposal Technical Review Committee, an advisory committee to the Bureau of General Sanitaiton, has recently approved certain alternative wastewater disposal systems (principally the Wisconsin Mound system) for limited use in Utah. The State Health Department should be contacted to determine if such systems are feasible on the parcels. If not, wastewater would have to be transported offsite to a suitable disposal area.

The parcels are located in 1979 Uniform Building Code (UBC) Seismic zone 3. The extent of damage to be expected in zone 3 corresponds to modified Mercalli intensity VIII or greater (attachment 2). It is recommended that any structures built on the properties conform to the latest UBC seismic design recommendations.

REFERENCES

Averitt, Paul, 1962, Geology and coal resources of the Cedar Mountain Quadrangle, Iron County, Utah: U.S. Geological Survey Professional Paper 389, 72 p.

Averitt, Paul, and Treet, R. L., 1973, Geologic map of the Cedar City Quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-1120, scale 1:24,000.

Christenson, G. E., 1981, Feasibility of Cedar Highlands subdivision, Iron County, Utah: Utah Geological and Mineral Survey memorandum to William Lund, 12 p.

Earth Science Associates, Inc., 1983, Phase II report seismic safety investigation of eight SCS dams in southwestern Utah: Soil Conservation Service West Technical Service Center, 511 NW Broadway, Room 510, Portland, Oregon, 38 p.

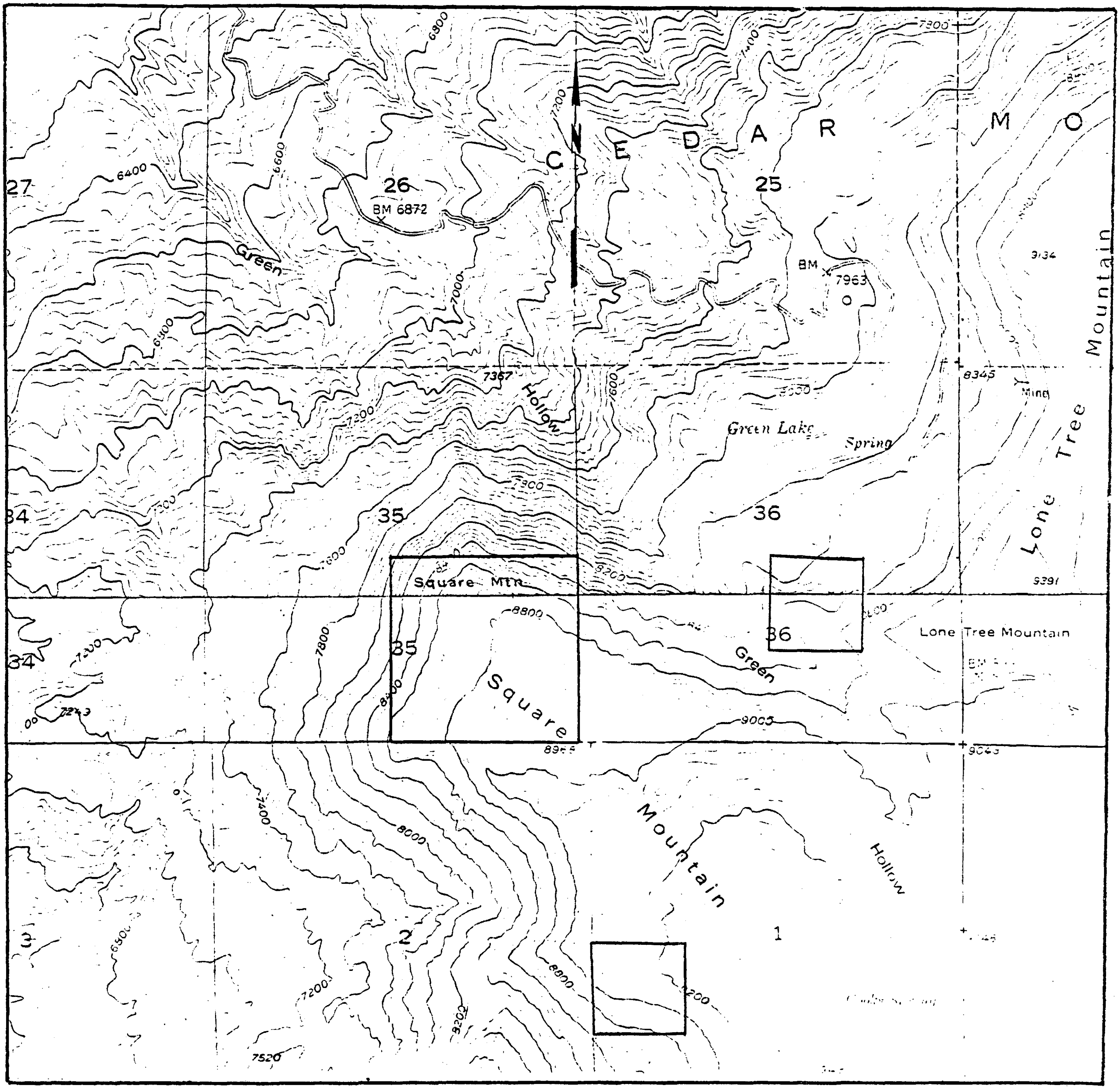
Gile, L. H., Peterson, F. F., and Grossman, R. B., 1966, Morphologic and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347-360.

Gregory, H. E., 1950, Geology of eastern Iron County, Utah: Utah Geological and Mineral Survey Bulletin 37, 153 p.

Schroder, J. F., 1971, Landslides of Utah: Utah Geological and Mineral Survey Bulletin 90, 51 p.

Ward, D. B., 1979, Seismic zones for construction in Utah: Salt Lake City, Seismic Safety Advisory Council State of Utah, 13 p.

Attachment 1, Job No. TA-2



Map showing the location of the three parcels being considered for acquisition by State Lands and Forestry. Scale 1:24,000.

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), 1974, p. 28.

PUBLIC HEALTH

Culinary Springs

Sanitary Landfills

Wastewater Disposal

Water Wells

Ground Water

Geologic Hazards

Culinary Springs

Project:			Requesting Agency:
Effects of coal mining at Huntington Canyon No. 4 Mine on Little Bear Spring, Emery County			Castle Valley Special Services District
By: G. E. Christenson	Date: 1/21/84	County: Emery	Job No.: SP-1
USGS Quadrangle: Rilda Canyon (797)			

PURPOSE AND SCOPE

The purpose of this study is to evaluate the possible effects of coal mining at Huntington Canyon No. 4 Mine on Little Bear Spring in Huntington Canyon. Beaver Creek Coal Company operates the mine in Mill Fork Canyon and is expanding it to the west and north in the direction of Little Bear Canyon (attachment 1). The impact of this mining on the quantity and quality of water discharging at Little Bear Spring was the subject of a report by Vaughn Hansen Associates (August, 1977) entitled "Water quality and hydrology study in the vicinity of Huntington Creek Mine No. 4 and Little Bear Spring." A review of this report and an independent assessment of geologic and hydrologic conditions of the area were performed for this study. The review of the Vaughn Hansen Associates report is given in attachment 2. In performing an independent assessment, UGMS reviewed the draft mining and reclamation plan submitted in mid-1983 by Beaver Creek Coal Company to the Utah Division of Oil, Gas and Mining (DOGM) for an Apparent Completeness Review. UGMS and DOGM then requested further clarification of geologic and hydrologic sections of the mine plan which related to Little Bear Spring, and received responses from Beaver Creek Coal Company in December, 1983. We have worked closely with Tom Munsen and John Whitehead of DOGM in evaluating these responses and the sections of the initial draft mine plan relating to the spring.

The scope of work included:

1. Literature search, including review and comment on the Vaughn Hansen Associates report and on the draft Mining and Reclamation Plan, Huntington Canyon No. 4 Mine Permit Application by Beaver Creek Coal Company
2. Air photo analysis
3. Brief site reconnaissance

The site reconnaissance was performed on November 8, 1982. Due to a moderately deep snow cover, only the immediate area of the spring was accessible.

GEOLOGY

Huntington Canyon No. 4 Mine is in the Wasatch Plateau coal field in central Utah (Doelling, 1972). It is on the highly dissected east edge of the Wasatch Plateau between Mill Fork and Little Bear Canyons, both of which are western tributaries of Huntington Canyon (attachment 1). Sedimentary rocks ranging in age from Late Cretaceous to Quaternary are exposed in the Huntington Canyon area. The oldest is the Mancos Shale which is overlain, in order of decreasing age, by the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone, Price River Formation, North Horn Formation, and Flagstaff Limestone. The Mancos Shale occurs in canyon bottoms with overlying units forming canyon walls. The North Horn Formation underlies the dissected plateau surface and caps most ridges with the overlying Tertiary-age Flagstaff Limestone occuring locally on the highest ridge crests. Quaternary-age alluvium and colluvium are found along streams and mantling slopes in the area. Characteristics of these geologic units are summarized in table 1.

The Upper Cretaceous Blackhawk Formation is the coal-bearing unit at Huntington Canyon No. 4 Mine and contains two prominent coal seams in the mine area. The Hiawatha seam is at the base of the Blackhawk Formation directly above the Star Point Sandstone. The Blind Canyon seam is about 100-130 feet above the Hiawatha seam, also in the lower part of the Blackhawk Formation (Beaver Creek Coal Company, 1983). Mining to date has been principally in the Blind Canyon seam and approximate limits of this mining as of October, 1981, are shown in attachment 1. Since that time, the mine has extended to the west approximately 1000 feet in the Blind Canyon seam and mining has recently begun in the Hiawatha seam near the mine entrance.

The regional dip of bedding is less than 5 degrees to the south, but several east-west-trending folds and north to northwest-trending high-angle normal faults interrupt this regional structure. Detailed geologic studies in the mine vicinity by Beaver Creek Coal Company (1983) indicate an east-plunging syncline in Little Bear Canyon with its axis roughly parallel to Little Bear Creek. The mine is south of this syncline along the east-plunging nose of the adjacent Flat Canyon anticline (Walton, 1954). Both are broad, gentle folds and bedding dips on the flanks are low.

The section of the plateau between Joe's Valley and Huntington Canyon in which the mine occurs is considered to be a horst, or upthrown block, between two major north-trending fault zones - the Joe's Valley fault zone to the west and the Pleasant Valley fault zone to the east. Within this block, several minor northwest-trending faults with maximum displacements of 30 feet are found in the mine area (attachment 1; Beaver Creek Coal Company, 1983).

GROUND WATER AND POSSIBLE IMPACTS OF MINING ON LITTLE BEAR SPRING

Little Bear Spring discharges from a lower sandstone bed of the Star Point Sandstone about 350 feet below the base of the Blackhawk Formation (Beaver Creek Coal Company, 1983). The Star Point Sandstone is a known aquifer and is the source of many of the largest springs in the Huntington Canyon - Cottonwood Canyon area (Danielson and others, 1981). Little Bear Spring is unique in that it is the largest spring and the only major spring discharging from the Star Point in the mine area, including Rilda, Mill Fork, Little Bear, and Crandell Canyons. The flow rate varies seasonally, and four recordings in 1978 ranged from 430 gallons per minute (gpm) in April to 190 gpm in November (Danielson and others, 1981). Maximum discharges from other springs in the Star Point and other formations in the mine area are less than 75 gpm and generally on the order of 30 gpm or less. Given the relatively small drainage area in Little Bear Canyon, it is apparent that the spring is not recharged from this drainage basin alone and is probably a discharge point for a regional aquifer. The large discharge and reported immediate increase in flow in response to spring snowmelt in Little Bear Spring indicates high permeabilities and rapid flow rates through the aquifer, probably controlled by fractures and faults rather than porosity or bedding in the sandstone.

Table 1.- Stratigraphic relationships, thicknesses, lithologies, and water-bearing characteristics of geologic units (adapted from Stokes, 1964 by Danielson and others, 1981)

System	Series	Formations and members	Thickness (feet)	Lithology and water-bearing characteristics
Quaternary	Holocene and Pleistocene		0-100	Alluvium and colluvium; clay, silt, sand, gravel, and boulders; yields water to springs that may cease to flow in late summer.
Tertiary	Eocene and Paleocene	Flagstaff Limestone	10-300	Light-gray, dense, cherty, lacustrine limestone with some interbedded thin gray and green-gray shale; light-red or pink calcareous siltstone at base in some places; yields water to springs in upland areas. (See table 9.)
	Paleocene	North Horn Formation	800±	Variegated shale and mudstone with interbeds of tan-to-gray sandstone; all of fluvial and lacustrine origin; yields water to springs. (See table 9.)
Cretaceous	Upper Cretaceous	Price River Formation	600-700	Gray-to-brown, fine-to-coarse, and conglomeratic fluvial sandstone with thin beds of gray shale; yields water to springs locally.
		Castlegate Sandstone	150-250	Tan-to-brown fluvial sandstone and conglomerate; forms cliffs in most exposures; yields water to springs locally.
		Blackhawk Formation	600-700	Tan-to-gray discontinuous sandstone and gray carbonaceous shales with coal beds; all of marginal marine and paludal origin; locally scour-and-fill deposits of fluvial sandstone within less permeable sediments; yields water to springs and coal mines, mainly where fractured or jointed.
		Star Point Sandstone	350-450	Light-gray, white, massive, and thin-bedded sandstone, grading downward from a massive cliff-forming unit at the top to thin interbedded sandstone and shale at the base; all of marginal marine and marine origin; yields water to springs and mines where fractured and jointed.
		Masuk Member Mancos Shale	600-800	Dark-gray marine shale with thin, discontinuous layers of gray limestone and sandstone; yields water to springs locally.

The source of recharge to the Star Point Sandstone aquifer has been shown to be snowmelt at higher elevations (Danielson and others, 1981). Hydro-Sciences, Inc. (1980) considers recharge to be principally from the west and northwest while Vaughn Hansen Associates (1977) consider the source to be principally from the north. The former is probably more correct (see attachment 2), with water infiltrating downward along fault and fracture zones from water-bearing units in overlying beds (Danielson and others, 1981). Once water reaches the Star Point Sandstone, further downward percolation is inhibited by the underlying less-permeable Mancos Shale and water moves laterally along fractures and faults to discharge points on hillsides such as Little Bear Spring.

A principal question with regard to the effect of the proposed coal mining on Little Bear Spring is whether or not the mine is in the spring recharge area. At this time, data are insufficient to answer this question, and a network of ground-water monitoring wells and perhaps a series of tracer dye tests would be required to make a conclusive determination. However, in view of the local geologic structure and location of the spring, it is highly likely that the mine and/or proposed mine extentions are in the recharge area or are between the principal recharge area and the spring and thus are in the zone through which ground water is travelling.

It is considered unlikely that a significant amount of recharge occurs from downward infiltration from the surface through the Blackhawk and overlying beds directly above the mine. Slopes are steep and underlain by low permeability materials of the North Horn, Price River, and Blackhawk Formations. Most rainfall and snowmelt would run off rapidly with little infiltration. This is supported by the reported lack of roof seepage and the dry nature of faults in the Blackhawk Formation in the mine (Hydro-Sciences, Inc., 1980; Beaver Creek Coal Company, 1983).

It is probable, however, that the mine is in a zone of ground-water movement between principal recharge areas to the west and northwest and the principal discharge point (Little Bear Spring). Most water is moving through the Star Point Sandstone, the major aquifer from which Little Bear Spring discharges. Possible ground-water conditions in the mine area are shown in attachment 3. Hydro-Sciences, Inc., (1980) and Beaver Creek Coal Company (1983) consider water in the Star Point to be either unconfined (attachment 3A) or confined (attachment 3B) beneath the Hiawatha seam . Danielson and others (1981) and Lines and others (1983) consider the Star Point and Blackhawk to act as a single aquifer in which unconfined water table conditions exist as shown in attachment 3C. If the conditions shown in either attachments 3B or 3C are present, flow of water into the mine will accompany extraction of the Hiawatha seam, particularly in areas of faulting. If an unconfined water table extends into the Blackhawk (attachment 3C), water may be intercepted in the Blind Canyon seam as well. The only pertinent data available regarding this question comes from an in-mine drill hole (MC-4-1, attachment 1) in which the water level was 38.2 feet below the top of the Star Point. The fact that the water level at the drill hole in this area of little or no recharge is so much higher than at the spring and so near the top of the Star Point indicates that levels in the proposed mine area in the direction of principal recharge (west of the spring) may be above the Star Point as depicted in Attachment 3B or 3C. Also, this drill hole is east of all faults in the mine area. If faults are acting as barriers to ground-water flow or conduits for flow in the Star Point, particularly high water levels may exist in and up-gradient (west) from fault zones as well and may be encountered during mining.

CONCLUSIONS

Given the existing data, it cannot be determined if mining will impact ground-water quality or quantity at Little Bear Spring. Information presented by Beaver Creek Coal Company (1983) in their mining and reclamation plan for Huntington Canyon No. 4 Mine and in their responses to questions posed by UGMS and DOGM in the Apparent Completeness Review are insufficient to ensure that no impact will occur. Water-level measurements in the Star Point Sandstone west of the present mine area, particularly in the northwestern-most parcel, will be required before a definite assessment can be made. Coal exploration holes presently exist in this area (HCD-1, HCD-2, DH-2-76a; attachment 1), but they are not monitored and water levels were not recorded during drilling. If levels are below the Hiawatha seam throughout the proposed mine area, interception of recharge waters to Little Bear Spring is unlikely. If water levels are above the Star Point Sandstone, whether confined beneath or extending into or above the Hiawatha seam, interception of flow (at least during mining of the Hiawatha seam) is likely. In any case, contamination of spring water is possible by washing of materials on the mine floor into fractures and ultimately into the Star Point aquifer. This will be particularly critical following extraction of the Hiawatha seam when the Star Point will be exposed on the mine floor. The potential for contamination and interception of flow during mining of the Blind Canyon seam is somewhat lower but still present. Injection of tracer dyes into fractures on the mine floor with monitoring at the spring may yield valuable information with regard to ground water flow paths and potential for contamination during mining.

In the mining and reclamation plan for Huntington Canyon No. 4 Mine, Beaver Creek Coal Company includes an agreement with the City of Huntington to replace any water intercepted and/or treat any water contaminated as a result of their mining operations. At present, the Division of Oil, Gas, and Mining plans to require Beaver Creek Coal Company to either bond to cover the cost of replacement and/or treatment of any spring water affected or to perform the necessary work to prove that mining will not affect the spring. We feel that this is an appropriate course of action and one that is in the best interest of both the city and Beaver Creek Coal Company.

REFERENCES

Beaver Creek Coal Company, 1983, Mining and reclamation plan, Huntington Canyon No. 4 Mine, chapters 6 (Geology) and 7 (Hydrology).

Danielson, T. W., ReMillard, M. D., and Fuller, R. H., 1981, Hydrology of the coal-resource areas in the upper drainages of Huntington and Cottonwood Creeks, central Utah: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-539, 85 p.

Danielson, T. W., and Sylla, D. A., 1983, Hydrology of coal-resource areas in the southern Wasatch Plateau, central Utah: U.S. Geological Survey Water-Resources Investigations Report 82-4009, 66 p.

Davis, F. D., and Doelling, H. H., 1977, Coal drilling at Trail Mountain, North Horn Mountain, and John's Peak areas, Wasatch Plateau, Utah: Utah Geological and Mineral Survey Bulletin 112, 90 p.

Doelling, H. H., 1972, Central Utah coal fields, Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery: Utah Geological and Mineral Survey Monograph Series No. 3, 570 p.

Hydro-Sciences, Inc., 1980, Ground-water hydrology in the vicinity of the Huntington No. 4 Mine: Consulting report for ARCO Coal Company, 10 p.

Intermountain Association of Petroleum Geologists, 1954, Geology of portions of the high plateaus and adjacent canyon lands, central and south-central Utah: Fifth Annual Field Conference, 145 p.

Lines, G., and others, 1983, Hydrology of area 56, northern Great Plains and Rocky Mountains coal provinces, Utah and Colorado: U.S. Geological Survey Water-Resources Investigations Open-File Report 83-38, 46 p.

Spieker, E. M., 1931, The Wasatch Plateau Coal Field, Utah: U.S. Geological Survey Bulletin 819, 210 p.

Stokes, W. L., 1964, Geologic map of Utah: University of Utah, Salt Lake City, scale 1:250,000.

Vaughn Hansen Associates, 1977, Water quality and hydrologic study in vicinity of Huntington Creek Mine No. 4 and Little Bear Spring: Consulting report for Swisher Coal Company, 22 p.

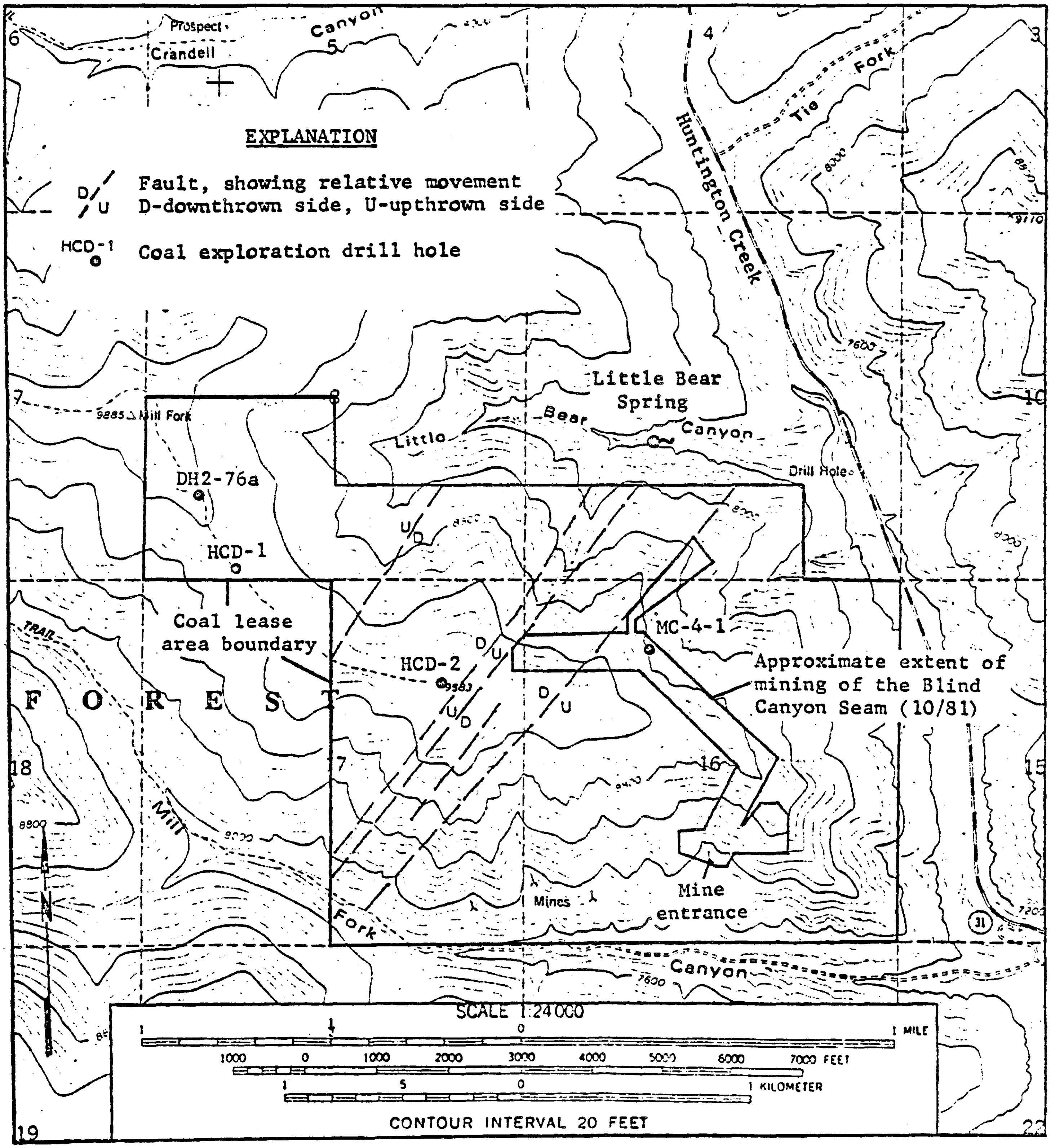
Waddell, K. M., Vickers, H. L., Upton, R. T., and Contralto, P. K., 1978, Selected hydrologic data, 1931-77, Wasatch Plateau - Book Cliffs coal fields area, Utah: Utah Department of Natural Resources Basic-Data Release No. 31, 33 p.

Waddell, K. M., Contralto, P. K., Sumsion, C. T., and Butler, J. R., 1981, Hydrologic reconnaissance of the Wasatch Plateau - Book Cliffs coal fields area, Utah: U.S. Geological Survey Water-Supply Paper 2068, 45 p.

Walton, P. T., 1954, Wasatch Plateau coal fields, <u>in</u> Intermountain Association of Petroleum Geologists, Geology of portions of the high plateaus and adjacent canyon lands, central and south-central Utah: Fifth Annual Field Conference, p. 79-85.

Attachment 1, Job No. SP-1

Base map from: USGS 7½' topo quad
Rilda Canyon, Utah 1979



Location of signficant features in the Huntington Creek No. 4 mine near Emery County

Attachment 2, report of 1/21/84 to Darrel V. Leamaster

COMMENTS ON VAUGHN HANSEN REPORT

The principal findings in the Vaughn Hansen Associates report of significance to Little Bear Spring are: (1) spring and surface water flow rates decrease in a southerly direction from canyon to canyon, particualry from Little Bear to Mill Fork to Rilda Canyons (p. 12), and (2) concentrations of most dissolved constituents in both ground water (springs) and surface water increase from north to south and west to east (p. 20). These findings led to the conclusions that: (1) water in Little Bear Spring originates primarily in the north and flows through the Star Point Sandstone (p. 14 and 21) whereas surface flow and subsurface flow in other units enters from both the north and west (p. 21), and (2) the proposed increased mining will have little or no effect on Little Bear Spring since it is south of the spring and recharge is from the north.

The conclusion that most surface and subsurface water enters from the west and north is probably correct and is supported by water quality data. However, the contention that water in Little Bear Spring is primarily from the north is not supported and is in fact contradicted in the report. It is stated that Crandell Canyon (next canyon north of Little Bear Canyon; see attachment 1) acts as a major interceptor drain cutting into the Star Point Sandstone (p. 21). If this were true and recharge to Little Bear Spring were from the north, Crandell Canyon would intercept most of the flow. The statement thus contradicts the conclusion that principal recharge to Little Bear Spring is from the north. In fact, both statements are probably incorrect. No springs are reported by Vaughn Hansen Associates or Danielson and others (1981) to be present in the Star Point in Crandell Canyon. It is apparently not acting as an interceptor drain and flow in the Star Point is probably not from north to south in this area. Other evidence given in the report for soutward flow of ground water in the Star Point is the southward decrease in flow in the so-called lower springs in Little Bear, Mill Fork, and Rilda Canyons (see figure 4, p. 13; p. B-1 and B-2 of the report). The data actually show that flow in the Mill Fork and Rilda Canyon springs alternates seasonally with respect to greatest discharge and that no significant trend exists. The only significant observation from these discharge records is that an anomalously large spring is present in Little Bear Canyon. Because the report's conclusion that mining will have no effect on Little Bear Spring is based on the above inferences which we believe to be incorrect, the UGMS is of the opinion that the report's conclusions have no credence.

DIAGRAMMATIC CROSS-SECTIONS SHOWING POSSIBLE GROUND-WATER CONDITIONS IN THE MINE AREA

Explanation

Kbh (bc, h)	Blackhawk Formation, showing coal seams bc-Blind Canyon seam, h-Hiawatha seam
Ksp	Star Point Sandstone
Km	Mancos Shale

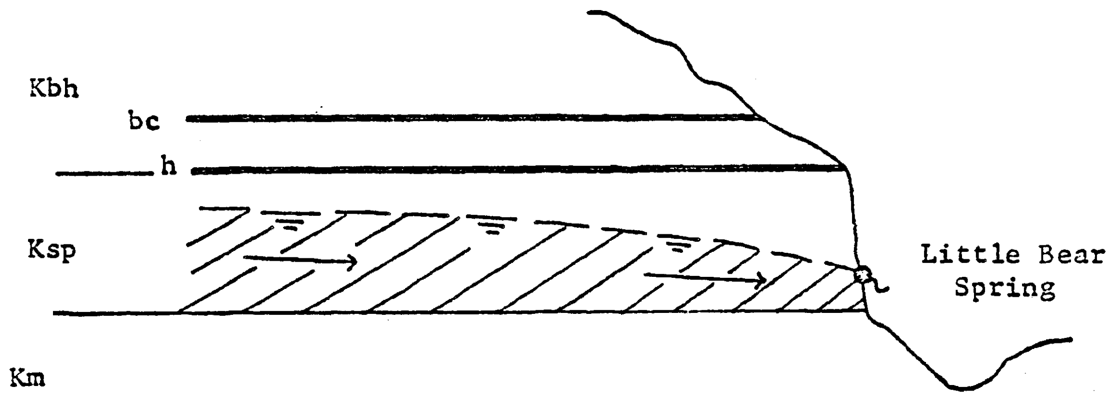
water table

piezometric surface

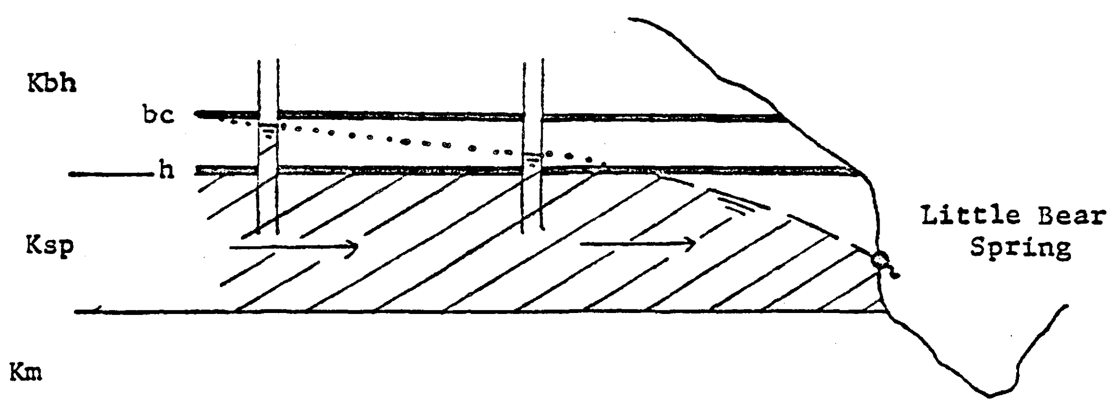
direction of ground-water movement

saturated zone

A. Unconfined water table in the Star Point Sandstone beneath the Hiawatha seam

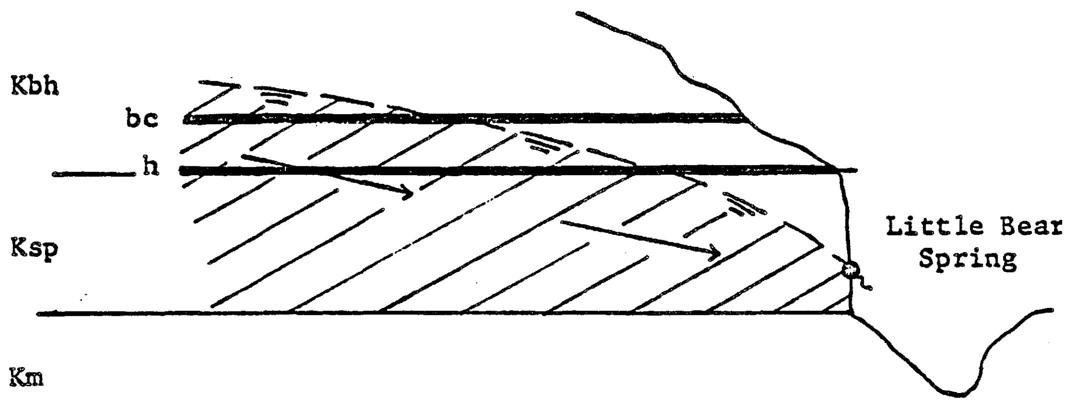


B. Confined (artesian) conditions in the Star Point Sandstone, Hiawatha seam acting as an aquiclude or confining layer



Attachment 3 (cont.)

C. Unconfined water table in the Star Point-Blackhawk aquifer



Project:			Requesting Agency:
Riverton Spring investigation - Bear Canyon			Riverton City
By: G. E. Christenson	Date: 2/28/84	County: Salt Lake	Job No.: SP-2
USGS Quadrangle: Draper (1171)			

PURPOSE AND SCOPE

The purpose of this investigation was to evaluate the potential for increasing the flow to the Riverton City culinary water system from a source in Bear Canyon. Bear Canyon is on the west flank of the Wasatch Range about 4 miles south of Little Cottonwood Canyon and two miles east of Draper (attachment 1). Water is obtained from an adit which extends from stream level into the south side of the canyon for about 300 feet. The adit was initially excavated 40-50 years ago for the purpose of collecting water for the city (oral commun., R. Munford, February, 1984). It was placed just upstream from a permanent stand of willows which indicated the year-round presence of ground water in the canyon bottom. The adit was originally advanced about 250 feet and numerous drill holes approximately 1 1/4 inches in diameter and of unknown length were drilled into the adit walls to increase flow. In 1983, the adit was extended another 50 feet, and more holes were drilled 20-24 feet into the adit walls and shot with explosive charges in an attempt to fracture the rock and further increase flow. The success of this effort is not documented by flow records, but observers report that flow was not significantly increased. At present, the city would like to obtain more water from this source and is contemplating further drilling in the adit.

The scope of work included a literature search and air-photo analysis of the area with an investigation in the adit on February 9, 1984. Because of weather conditions and snowpack, a surface reconnaissance could not be performed. I was accompanied during the adit visit by Richard Munford and Dallin Ewell of Riverton City and William R. Lund of the Utah Geological and Mineral Survey.

GEOLOGY

The adit portal is at an approximate elevation of 5120 feet on the south flank of Bear Canyon. It is about 40 feet below the shoreline bench formed by Pleistocene Lake Bonneville when it was at its highest level 15,000-16,000 years ago. Bear Creek has cut its canyon through this gravel bench and exposed the underlying quartz monzonite of the Tertiary-age Little Cottonwood stock in the adit area (Crittenden, 1965). Quartz monzonite occurs throughout the Bear Canyon drainage basin upstream from the spring and throughout all of the probable recharge area as well. Surficial deposits in the area include Lake Bonneville shoreline gravels, stream alluvium, and colluvium in lower parts of the canyon with talus and glacial deposits in upper parts at elevations above about 7000 feet (Crittenden, 1965).

The Little Cottonwood stock is a lithologically homogeneous and highly jointed (fractured) rock unit. Bromfield and Patton (1981, p. 18 and 25-26) report two major joint sets in the stock; one strikes east to northeast and is vertical and the other strikes north to northwest and dips from 40-75° W. Measurements in the adit indicate joints with two general strike directions but highly variable dip directions, some of which coincide with those of Bromfield and Patton (1981). One set strikes northeast (N. 30-50° E.) and dips from 30° NW. to 60° SE., and the other strikes north-northwest (N. 15-22° W.)and dips from 50° W. to 70° E.(attachment 2). A nearly vertical set striking northeast is present in the adit and is prominent (i.e. visible on air photos) in outcrops several hundred feet upstream. The set is roughly parallel to the Wasatch fault which crosses Bear Canyon about 1000 feet west of the adit (Cluff and others, 1970).

Most joints are tightly closed. No secondary joint fillings were observed, but slickensides and crushed rock occurred along some joints. Open joints were present locally, but these may have opened as the adit was excavated. Joints are spaced from several inches to a few feet apart. No major faults other than the Wasatch fault have been mapped in the area (Crittenden, 1965).

HYDROLOGY

The quartz monzonite of the Little Cottonwood stock is impermeable, and flow of ground water through the rock is along joints and faults. Ground water in this aquifer is recharged by snowmelt and rainfall in the Wasatch Range to the east. The principal direction of ground-water flow is from east to west, ultimately recharging the basin-fill aquifer in the Jordan Valley through underflow at depth along the valley margin. The depth to water in the basin-fill aquifer near the mouth of Bear Canyon exceeds 150 feet (Hely and others, 1971). Ground water encountered in the adit area is probably under unconfined water-table conditions, either in a perched zone or in the regional bedrock aquifer where water moving from the Wasatch Range to the Jordan Valley has built up a saturated zone in the hillside.

All visible flow of water into the adit is from drill holes. Visible joints in the adit walls are not yielding water, probably due to the dewatering effect of drill holes which extend outward and intercept water in joints before it reaches the adit. However, water is generally more than a foot deep in the adit, and some undetected flow from joints in the floor may be occurring. Flow into the adit is first encountered from holes about 175 feet from the portal and is principally from the east side. In the last 50-75 feet, flow is principally from the west side and from the face (attachment 2). Total discharge into the adit appeared to be in about equal quantities from the west and east walls with a lesser amount from the face. City records indicate that the adit delivers a constant flow of 155 to 165 gallons/minute into the system (Coon, King, and Knowlton Engineers and others, 1982, p. V-116). A temporary weir at the portal indicated total flows of 300-340 gallons/minute (0.65 to 0.75 second-feet). Discharge is significantly greater during the snowmelt period, and reportly occurs from holes higher on the adit walls which dry up later in the summer. Drippage from roof joints reportedly also occurs in springtime.

CONCLUSIONS AND RECOMMENDATIONS

Because no visible joints in the adit walls or roof were yielding water to the adit, it is uncertain which sets are the major conduits for flow of ground water. The rock is highly jointed and joints are generally closed with no indication of a major through-going, open joint set. Shear zones found in the adit are small and do not appear to vary significantly in water-carrying capacity from the jointed rock in general. Thus, from the present investigation we can draw few firm conclusions regarding the potential for increasing spring flow.

Additional drilling on the west side of the adit is not recommended since little recharge occurs from the west, and any water intercepted may only flow temporarily until the entire west side is dewatered. However, any extension of the adit or drilling of holes in the direction of principal recharge (east and southeast) has the potential for increasing flow. The amount of increase depends on the number and size of water-carrying joints intersected by the adit and/or drill holes. A major joint orientation encountered in the adit and at the surface trends N. 30-50^{o} E., roughly parallel to the Wasatch fault. Another trends N. 15-22^{o} W. Drilling perpendicular to these joint sets on bearings of S. 40-60^{o} E. and N. 68-75^{o} E., respectively, would intersect the greatest number of joints. In the latter case, drilling would be in the direction of Bear Creek where water tables are lowered by drainage into the canyon. Drilling to the southeast from the adit face would be in the general direction of principal recharge and have the greatest potential for increasing flow. However, extension of the adit in 1983 almost due south another 50 feet with drilling 20-24 feet at the face and into the east and west walls did not significantly increase flow, indicating that water-carrying joints are either widely spaced, very small and yield little water, or were previously dewatered by the adit. In either case, lengthening of drill holes or drilling of longer holes would have a greater potential for increasing flow than drilling more holes of the same length. Blasting in holes may also increase flow by further fracturing the rock and opening existing fractures resulting in a greater degree of interconnection between joints and greater potential for interception of flow.

In conclusion, it is possible that further drilling of longer holes at the face, particularly to the southeast, with blasting to increase rock fracturing may increase flow. However, data are insufficient to guaranty this and previous experience indicates that considerable time and money may be spent with little increase in discharge. Because of this uncertainty, we recommend an exploration program consisting of drilling (and blasting) one or two long holes (75-100 feet) at the adit face in a southeasterly direction perpendicular the the strike of major joint sets. Total flow from the adit should be monitored before and after drilling to document any net increases that may result. This is necessary to insure that any visible flow from new drill holes is actually additional water and not intercepted flow already tapped by the adit. Drilling should be performed in late summer, fall, or winter when fluctuations in discharge from spring snowmelt are not a factor and the discharge rate is relatively constant. If a significant increase in flow occurs from these exploratory drill holes, drilling of more holes and/or advancing the adit in the direction of the drill holes may further increase flow. If flow is not increased, the adit may already be delivering maximum flow and further attempts at increasing flow are not recommended.

REFERENCES

Bromfield, C. S., and Patton, L. L., 1981, Mineral resources of the Lone Peak wilderness study area, Utah and Salt Lake Counties, Utah: U.S. Geological Survey Bulletin 1491, 117 p.

Cluff, L. S., Brogan, G. E., and Glass, C. E., 1970, Wasatch fault, northern portion, earthquake fault investigation and evaluation: Woodward-Lundgren and Associates, Oakland, California, 27 p.

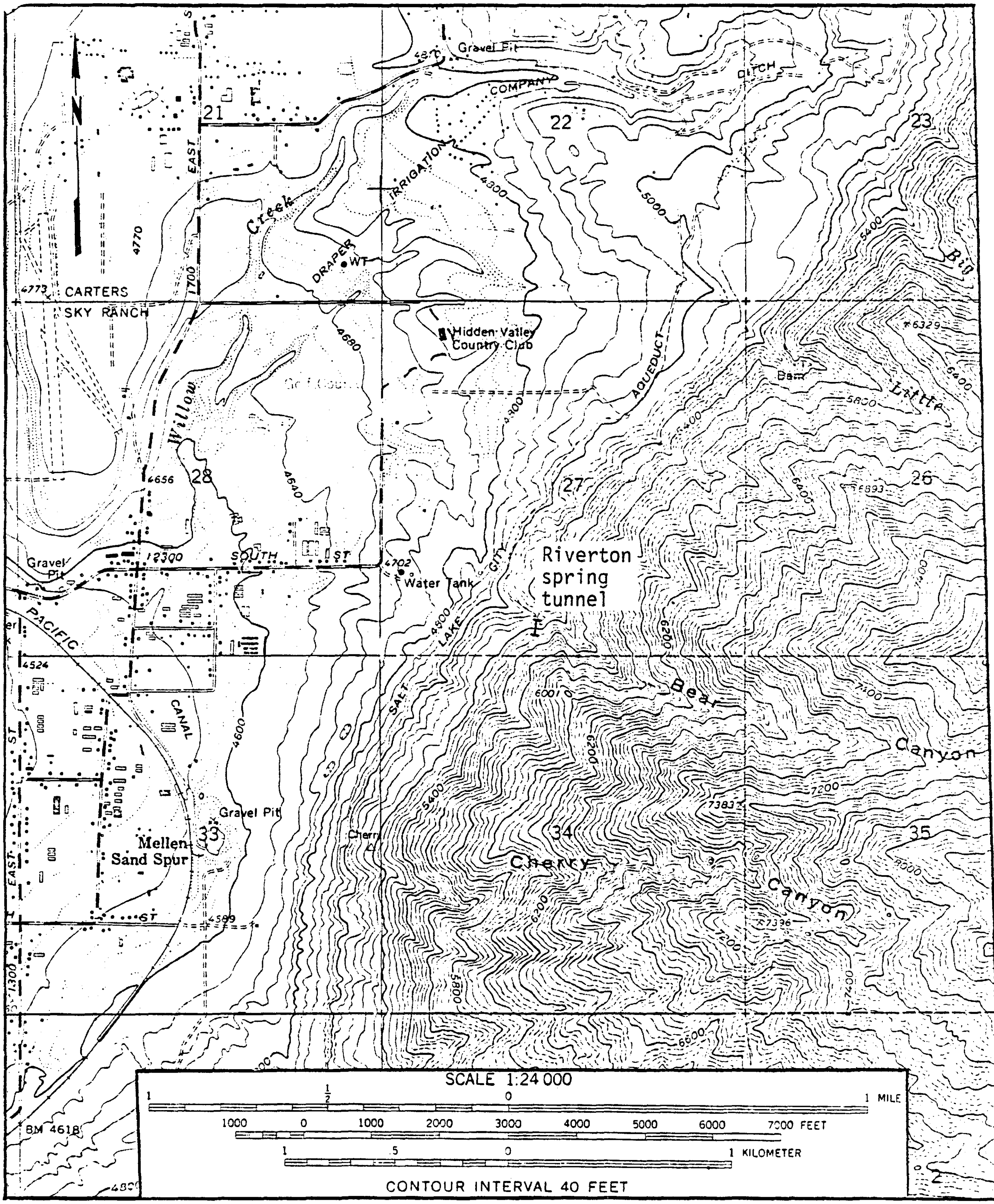
Coon, King, and Knowlton Engineers and others, 1982, Salt Lake County area-wide water study.

Crittenden, M. D., Jr., 1965, Geology of the Draper Quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-377, scale 1:24,000.

Hely, A. G., Mower, R. W., and Harr, A. C., 1971, Water resources of Salt Lake County, Utah: Utah Department of Natural Resources Technical Publication 31, 244 p.

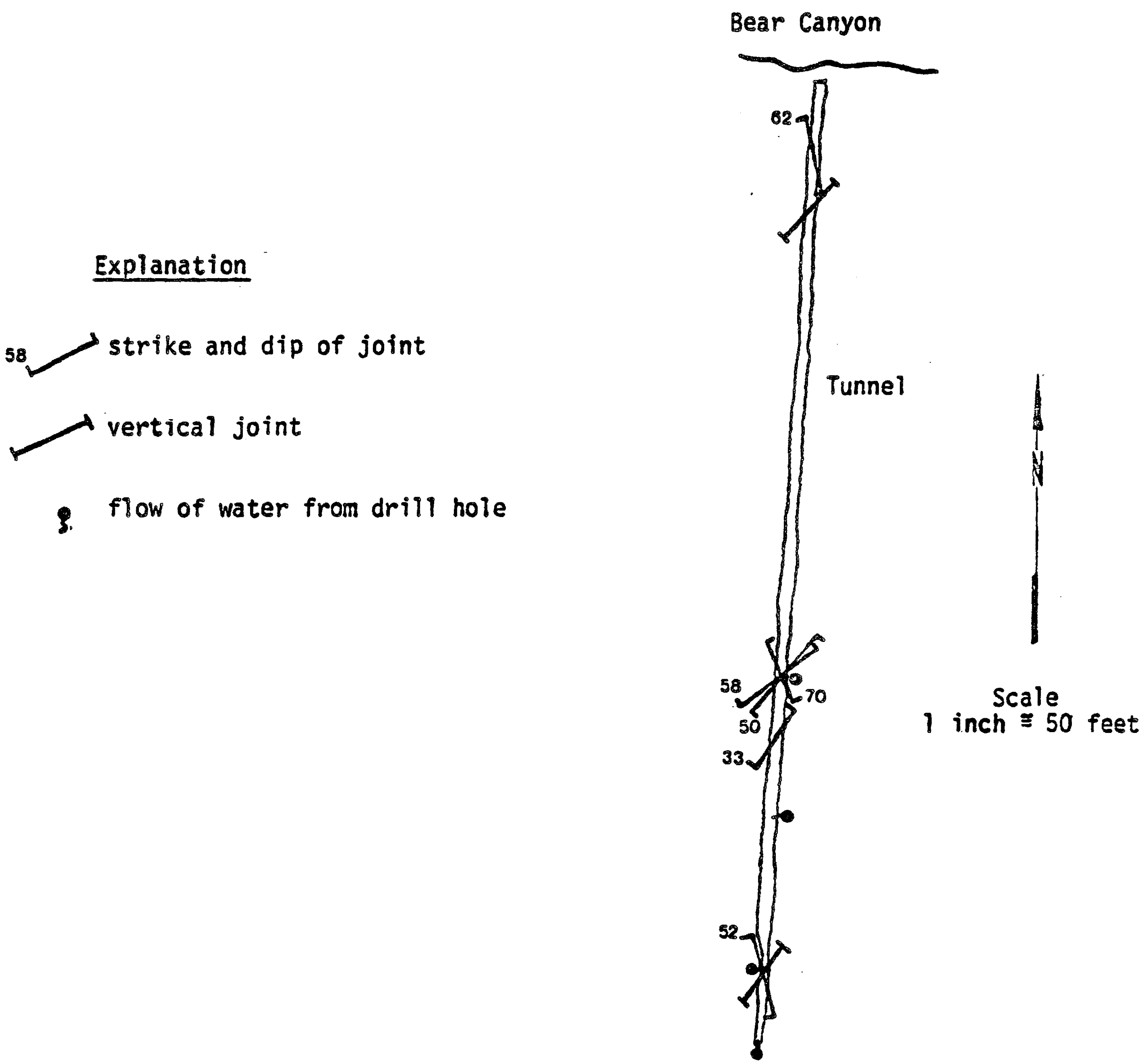
Attachment 1, Job No. SP-2

Base map from: USGS 7.5' Topo Quad
Draper, Utah



Location Map

Attachment 2, Job No. SP-2



Approximate locations of joint measurements and flow of water from drill holes, Riverton Spring tunnel in Bear Canyon

Project:			Requesting Agency:
Spring evaluation for the Daggett County Sewer and Water Improvement District			Daggett County Sewer and Water Improvement District
By: R. H. Klauk	Date: 8/31/84	County: Daggett	Job No.: SP-3
USGS Quadrangle: Jessen Butte, Utah-Wyoming (1278)			

PURPOSE AND SCOPE

This investigation was conducted at the request of Allen Campbell, Department of Sewer and Water Improvement District, Daggett County, Utah, for a spring located in the SE1/4 of sec. 21, T. 3 N., R. 19 E. (attachment 1). The purpose of the study was to determine: 1) the source of water, and 2) if the present chemical quality of the springs can be maintained with a reduction of the 1500-foot protection zone.

The scope of work for this study included: a review of published and unpublished literature pertinent to the spring area; conversations with William Briggs, Jr., owner of the water right and land on which the spring is located; consultation with the staff of the Bureau of Public Water Supply, Utah State Department of Health; review of water quality data; and a field reconnaissance of the area on July 12, 1984. No test pits or other subsurface investigations were performed during this study.

GEOLOGY

The spring is located in the Lucerne Valley on the northern flank of the Uinta Mountains 3 miles west-southwest of the town of Manila. The major drainage through the valley is Sheep Creek, which flows from west to east, eventually entering Flaming Gorge reservoir 3-1/2 miles east of Manila.

The Lucerne Valley is underlain by the Hilliard Shale and bounded to the north by hogbacks of the Wasatch Formation and to the south by low cuestas and hogbacks of the Dakota and Frontier Formations (attachment 2). Alluvial cover is thin, reaching maximun thicknesses up to 50 feet in places (Hansen and Bonilla, 1956). The Hilliard Shale is Cretaceous age and consists of dark-gray, primarily silty, calcareous, soft, fissile shale with lenses and beds of sandstone and sandy nodular limestone (Hansen, 1965). The Wasatch Formation of early Eocene age consists of red, gray, and tan colored, medium- to coarse-grained, well cemented sandstone and conglomerate which grades into finer-grained conglomerate, sandstone, and siltstone in the lower part of the formation. The alluvium in the vicinity of the spring is thought to consist of loose silt and silty sand but can possibly include stringers and lenses of dirty subangular gravel (Hansen and Bonilla, 1956). The Henrys Fork fault, a major east-west trending high-angle reverse fault dipping to the south, extends through the valley (attachment 2). The fault has thrust Hilliard Shale into contact with the Wasatch Formation.

The spring studied for this report is one of two located in the SW1/4 SE1/4 sec. 21 (attachment 1). The spring consists of a number of seeps issuing from alluvium over a 31,000 square foot area; bedrock is within 11 feet of the surface at some locations (W. Briggs Jr., oral communication, July 12, 1984). The second spring, located approximately 400 feet to the east, is smaller but also consists of a series of seeps issuing from alluvium (attachment 1).This smaller spring is located immediately north and adjacent to a brown to tan bedrock outcrop. This outcrop may be Wasatch Formation according to Bradley (1964) (attachment 2). However, Hansen and Bonilla (1956) report that a small area of bedrock on the upthrown side of the Henrys Fork fault approximately 1-1/4 miles southwest of Manila may be part of the Fort Union Formation. The outcrop adjacent to the spring more closely resembles Hansen's (1965) description of the Fort Union Formation of Tertiary age. The strike and dip of the outcrop is N. 45° E., 33° NW. which is consistant with other attitudes recorded in the area (attachment 2). This outcrop of non-Hilliard Shale and the mapping of Bradley (1964) indicate the Henrys Fork fault is present in the immediate vicinity of the springs.

GROUND WATER

Little ground-water data is available for Lucerne Valley. Kaliser (1970) conducted a study to determine the pollution potential to Birch Spring located approximately one mile east of the spring presently under investigation (attachment 1). Montgomery (1973) conducted a preliminary study of ground-water resources and potential near Manila . The following is an excerpt from the Montgomery report with direct application to this study:

> "Several relatively shallow water wells have been drilled into the Hilliard Shale at or near Manila which produce up to approximately 10 gmp of fair to poor quality water.
>
> "However, where wells have penetrated the existing Henrys Fork Fault, which is forked where it passes northeasterly through and just north of Manila, the water produced is of better quality. The Henrys Fork Fault which is a high-angle thrust fault extends from Manila westward, cutting the north flank of the Uinta Mountains clear to Peoa in Rhodes valley, over 90 miles in length.
>
> "Southwest of Manila approximately 3 miles in the northwest edge of Lucerne Valley, Flaming Gorge Water System (William M. Briggs) drilled an 8-inch well 200 feet deep in December, 1969. It apparently penetrated the Hilliard Shale and into the Henrys Fork Fault zone. Personal communication with Mr. Briggs combined with the well driller log and a water analysis report from the Division of Health has revealed the following. The static water level stands at 12 feet in the well which will pump over 100 gpm of good quality water, being piped for use in a public water system. The analysis shows total dissolved solids of 475 ppm with a hardness of 296. Of the dissolved solids no adverse element was strong. The driller perforated from 100-133 feet in what he described as sandstone, clay and gravel. The gravel is probably brecciated sandstone along the fault plane."

Birch Spring is located along the Henrys Fork fault. Kaliser (1970) reports that Birch Spring is associated with this fault and indicates the spring is recharged by a deep circulation system. The spring being studied for this report is also located in the immediate vicinity of the Henrys Fork fault. The flow from this spring is estimated to be approximately 40 gpm throughout the year (W. Briggs Jr., oral communication, July 12, 1984). A negligible seasonal fluctuation is indicative of deep circulation of ground water. The spring location along the Henry Fork fault, coupled with the constant flow throughout the year, is evidence of a deep circulation system. The attitudes of bedrock and the fault indicate recharge is likely to be southwest of the spring, possibly in the Jessen Butte area (attachment 2). Snowmelt and precipitation infiltrates into joints, fractures, and bedding planes of the various rock units and migrates down dip, eventually intercepting the more permeable fault zone and rising through artesian pressure. The water eventually exits the fault zone and migrates upward through the unconsolidated alluvial cover, forming the seeps which collectively are referred to as the spring.

Chemical analyses of the spring conducted in October and December, 1969 by the Utah Department of Health were reviewed for this study. These analyses indicate "fair" chemical quality for sulfate (Oct., 1969), tubidity (Oct., 1969), total dissolved solids (TDS) (Oct. and Dec., 1969), and iron (Oct. and Dec., 1969). The acceptable concentrations for these constituants are presented in attachment 3. Furthermore, sulfate (Dec., 1969) and fluoride (Oct. and Dec., 1969) exceed the same public drinking water standards. The concentrations for these constituents are as follows:

	October, 1969	December, 1969
Sulfate	321 mg/l	506 mg/l
Turbidity	40 turbidity units	---
TDS	902 mg/l	1264
Fluoride	2.45 mg/l	3.3 mg/l
Iron	1.8 mg/l	0.6 mg/l

Conductivities measured for these two analyses are 1145 umhos (Oct., 1969) and 1524 umhos (Dec., 1969). The conductivity measured during this reconnaissance was only 710 umhos, indicating the chemical qualitity of the spring may have improved during the past 15 years. Montgomery (1973) reports a well drilled in 1969 for W. M. Briggs encountered the Henrys Fork fault zone from 100 to 133 feet in depth. Total dissolved solids measured only 475 ppm for water from this well, indicating chemical quality may improve with depth within the fault zone.

CONCLUSIONS AND RECOMMENDATIONS

The source of the spring is a deep circulation system with the main recharge area far removed from the site. Therefore, reducing the protection zone will not adversely affect the water discharged from the deep system. However, mixing of shallow water with the deep circulating water may occur in the vicinity of the spring. This area is less than 500 feet from the adjacent property to the west (attachment 1). The ground surface generally slopes to the southeast indicating future contaminant sources located upslope could migrate toward the spring. Presently, the adjacent property (upslope) is used as pasture and provides no "immediate" contamination threat. However, future development may produce contaminants which could endanger the spring by flowing over the ground surface or migrating through the unconsolidated alluvium and mixing with the deeply circulating water. The artesian pressure of the deep circulating water would, conceivably, not allow contamination to enter the permeable brecciated fault zone. Therefore, developing the spring within the bedrock could reduce any future contamination threat and allow for a reduction in the protection zone. It is also recommended that additional chemical analyses be conducted to determine if quality of the spring water complies with Utah Department of Health standards. Developing the spring below the alluvium may improve water quality as is indicated by the data presented in Montgomery (1973).

REFERENCES CITED

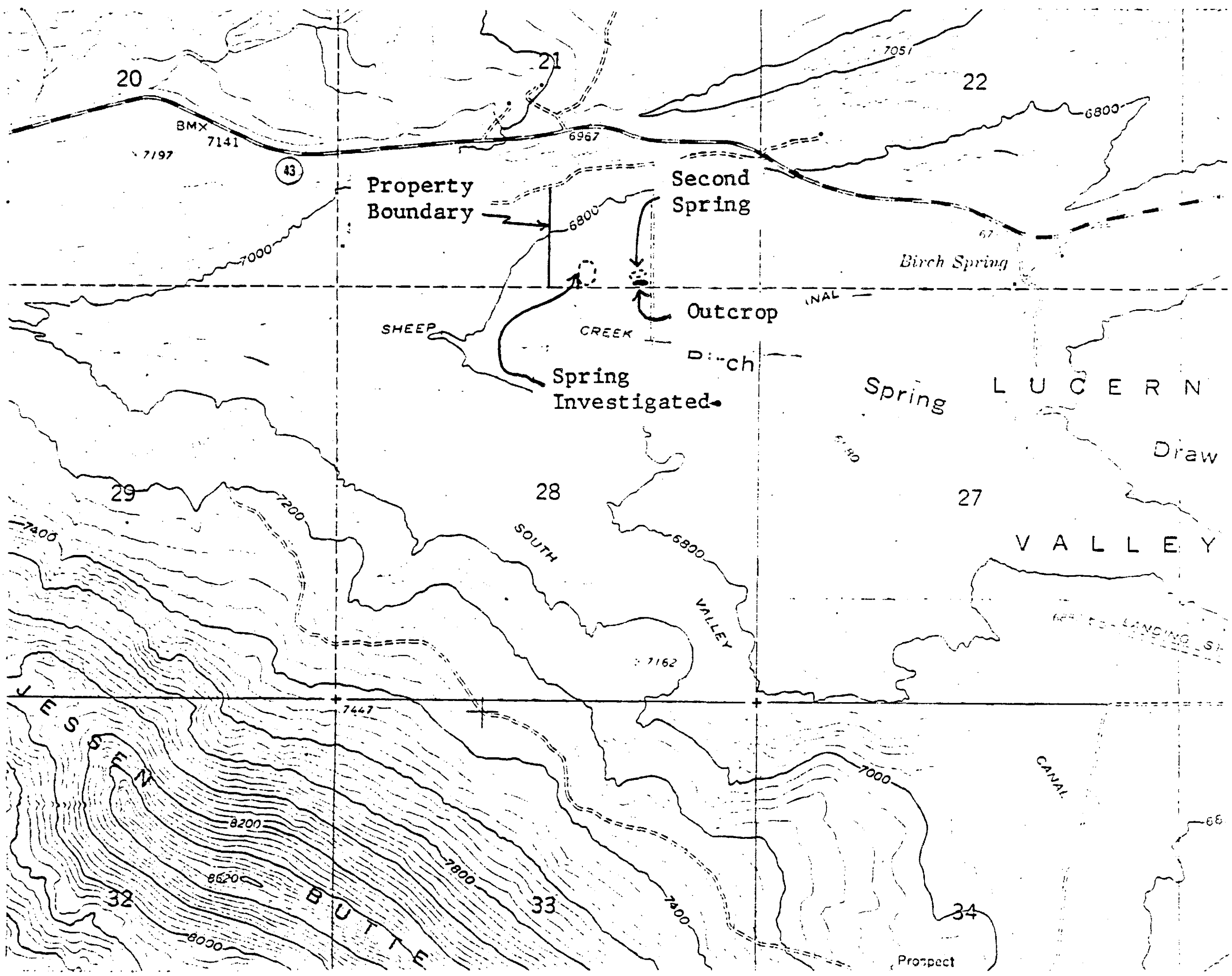
Bradley, W.H., 1964, Geology of Green River Formation and associated Eocene rocks in southwestern Wyoming and adjacent parts of Colorado and Utah: U.S. Geological Survey Professional Paper 496A, 86 p.

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

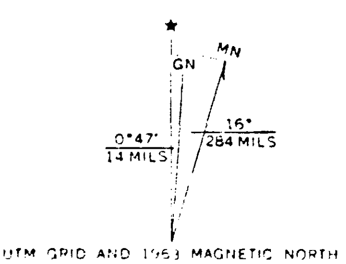
Hansen, W.R., 1965, Geology of the Flaming Gorge area Utah-Colorado-Wyoming: U.S. Geological Survey Professional Paper 490, 196 p.

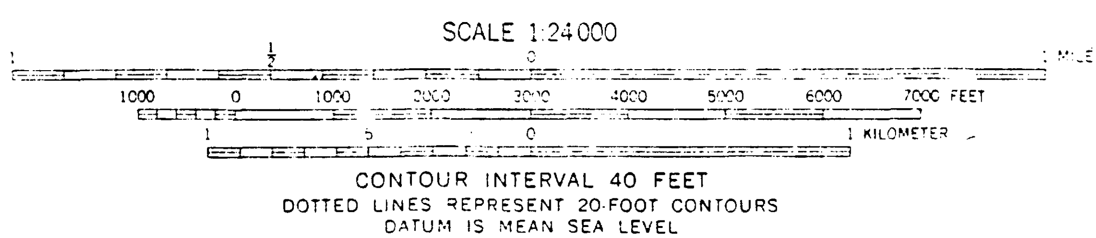
Kaliser, B.N., 1970, Birch Spring, near Manila, Daggett County, Utah: Utah Geological and Mineral Survey Report of Investigation No. 42, 4 p.

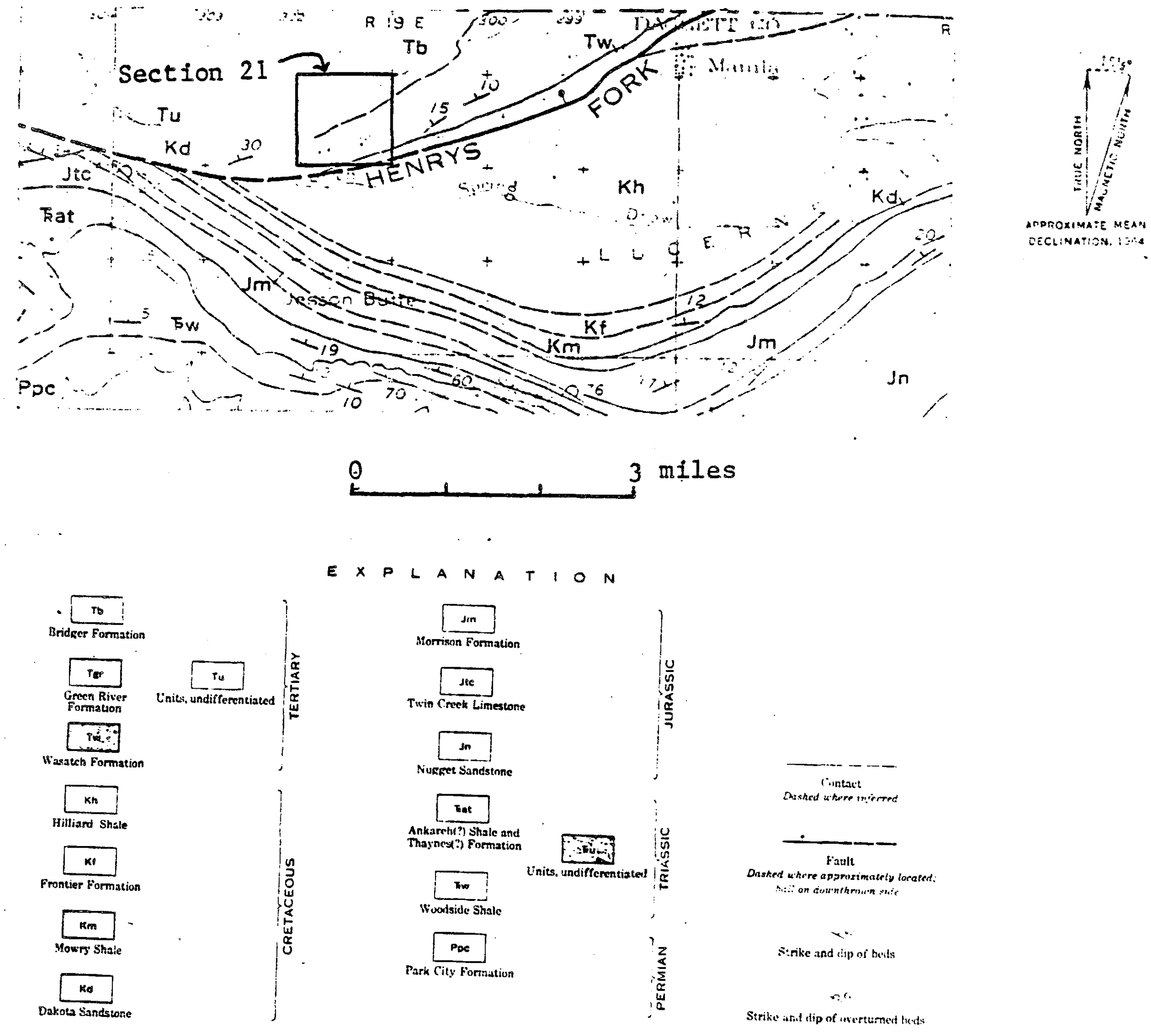
Montgomery, S.B., 1973, Groundwater potential of Daggett County, Manila vicinity: unpublished Utah Division of Water Resources memorandum, April 16, 3 p.



Base map from: U.S.G.S. 7½' topographic quadrangle Jessen Butte, Utah-Wyoming







Base map modified from: Bradley, 1964, Plate 3.

Scott M. Matheson
Governor

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Community Health Services
Environmental Health
Family Health Services
Health Care Financing and Standards

OFFICES
Administrative Services
Health Planning and Policy Development
Medical Examiner
State Health Laboratory

February 4, 1981
533-4207

UTAH DEPARTMENT OF HEALTH CHEMICAL QUALITY STANDARDS

Exceeding the following limits are grounds for rejection of a source and are called Maximum Contaminant Levels (MCLs):

Total Dissolved Solids	2000 mg/l
Sulfate	500 mg/l
Arsenic	0.05 mg/l
Barium	1.0 mg/l
Cadmium	0.01 mg/l
Chromium	0.05 mg.l
Flouride	1.6-2.2 mg/l*
Lead	0.05 mg/l
Mercury	0.002 mg/l
Nitrate as N	10. mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l

If the following limits are exceeded, the water is considered to be of only "fair" chemical quality and may contain chemicals which cause nuisances, but are not health related. These are called "secondary" standards. Water is considered to be of good quality if it is below these limits.

Copper	1.0 mg/l
Color	15 color units
Iron	0.3 mg/l
Manganese	0.05 mg/l
Sulfate	250 mg/l
Chloride	250 mg/l
Total Dissolved Solids	500 mg/l
pH	6.5-8.5
Odor	3 Threshold odor number
Turbidity	5 NTU **
Zinc	5. mg/l
Corrosivity	non corrosive
Foaming Agents	0.5 mg/l

(Over)

A water is considered to be of good chemical quality if it meets or is less than the following limits suggested by the American Water Works Association.

Turbidity	less than o.1 NTU
Suspended material	less than 0.1 mg/l
Color	less than 3 units
Odor	None
Aluminum	less than 0.05 mg/l
Iron	less than 0.05 mg/l
Manganese	less than 0.01 mg/l
Copper	less than 0.2 mg/l
Zinc	less than 1.0 mg/l
Total Dissolved Solids	less than 200 mg/l
Hardness	80 to 100 - mg/l

The Environmental Protection Agency has recommended that water contain less than 20 mg/l Sodium to minimize the possibility of heart disease occuring over a lifetime.

* Depends on local ambient minimum daily air temperature
** For groundwater sources only

Project:			Requesting Agency:
Nitrate contamination of Pearson and Griffith Springs, Cornish, Utah			Bureau of Public Water Supplies, Utah State Department of Health
By: G. E. Christenson	Date: 9/4/84	County: Cache	Job No.: SP-4
USGS Quadrangle: Trenton, Utah-Idaho (1495)			

PURPOSE AND SCOPE

The purpose of this investigation was to determine the recharge area and source of nitrate contamination at Pearson and Griffith Springs in western Cache County. Pearson Spring is located in Butler Hollow and Griffith Spring is about one mile to the south in an unnamed drainage, both in the Bergeson Hill-Pete McCombs Hill area west of the town of Cornish (attachment 1). The springs supply culinary water to Cornish, and the high-nitrate spring water must be mixed with low-nitrate well water in order to meet public drinking water standards.

The scope of work included a literature review, air photo analysis, and field reconnaissance. The field reconnaissance was performed on June 4, 1984, at which time samples for water quality analyses were taken by the Utah State Department of Health. Additional samples were taken on June 18, 1984, by the Bear River District Health Department, and results of both sets of samples were made available for this study. I was accompanied on the field investigation by Larry Scanlan and Ursula Trueman of the Utah State Department of Health (Bureau of Public Water Supplies), LaMar Tarbet and Joe Myler of Cornish, Brian Dixon of the Bear River Association of Governments, Nick Galloway of the Bear River District Health Department, and Evan Koller, owner of the property surrounding the springs.

GENERAL GEOLOGY

The springs are in western Cache Valley south of Bergeson Hill at the south end of the Malad Range (Adamson and others, 1955). Bedrock in the area consists chiefly of volcanic tuff and tuffaceous sandstone of the Tertiary-age Salt Lake Formation (Adamson and others, 1955; Williams, 1958, 1962). The Salt Lake Formation contains a wide variety of rock types and is variable both laterally and vertically over short distances. Williams (1962, p. 134-135) has subdivided it into a lower conglomerate, middle tuff, and upper conglomerate and sandstone unit, of which the upper unit has been further subdivided into four different facies. The spring area south of Bergeson Hill has been mapped as part of the tuff and tuffaceous sandstone facies of the upper unit, which includes a conglomerate consisting of rounded pebbles and cobbles in a matrix of calcium carbonate and tuffaceous sandstone. Southeast of Bergeson Hill, the tuff of this unit is silicified into a chert-like rock (Williams, 1962, p. 135).

The field investigation for this report confirmed these general observations by previous workers. Tuff and tuffaceous sandstone are found throughout the area. They are light-colored (tan, yellow), massive, generally lack distinct bedding, and fracture intensely upon exposure into thin plates and gravel-size angular blocks. The degree of primary fracturing of the rock at depth is not known. Distinct bedding was only found in exposures along the range front between the Koller and Pitcher residences (attachment 1) where the unit is silicified and exhibits Liesegang banding (concentric red and yellow bands). The strike of the bedding ranges from N-S to N. 50° W. with dips from 27 to 36 degrees to the west and southwest. Another exposure of tuff with discernable bedding near Pearson Spring has a strike of N. 25° W. and dip of 22° SW. Interbedded with the tuffaceous units are thin, fine-grained, gray, green, and blue limestone, shale, and siltstone beds. A prominent gray limestone pebble conglomerate unit is exposed in fields between Griffith and Pearson Springs and in much of the area north of Pearson Spring. The conglomerate contains pebbles of chert, sandstone, and limestone in a calcareous matrix. Clast size is generally less than 3-4 inches and clasts are well rounded. Bedding is indistinct and the strike and dip of beds is discernible in outcrop trends but generally not in individual exposures. This conglomerate thickens substantially to the north, with general bedding attitudes similar to those of tuff units (northwest strike, southwest dip of approximately 25 degrees).

Bedding dips indicate that the Salt Lake Formation has been structurally tilted to the southwest in this area. Tilting has probably occurred as the Bergeson Hill-Pete McCombs Hill area was uplifted along the north-trending Dayton fault zone which follows the range front east of Bergeson Hill (Williams, 1962). No other faults have been mapped in the immediate area.

Quaternary-age deposits of Lake Bonneville unconformably overlie bedrock units of the Salt Lake Formation. The uppermost shoreline of the lake (Bonneville level) reached an elevation of 5150 feet in this area and was occupied from about 16,000 to 14,000 years ago. A lower shoreline (Provo level) was occupied from 14,000 to 13,000 years ago following the Bonneville Flood about 14,000 years ago (Currey, 1983) and is evident as a bench at elevation 4790 feet . The lake deposits are generally thin and bedrock is within several feet of the surface. The thickest deposits are found in stream valleys where over 100 feet of lacustrine gravel, sand, and fines have accumulated in deltaic deposits filling bedrock valleys which existed prior to the rise of Lake Bonneville.. The stream in Butler Hollow has cut through these deposits into the underlying tuff, with Bonneville deposits remaining principally on the south side. No bedrock is exposed in the stream below Griffith Spring, but extensive mudslides and slumps in Bonneville deposits have recently buried much of the canyon bottom. Similar slumping has occurred along the south side of Butler Hollow.

SOILS

Soil types within the drainage basins of Butler Hollow and the canyon to the south in which Griffith Spring is found range from gravel to silt and clay. The majority of soils under cultivation are silts and silty sands with some gravel derived from lake shoreline sediments and tuffaceous bedrock (Erickson and Mortensen, 1974). Depth to bedrock varies from less than 20 inches to more than 60 inches, with bedrock exposures common on hilltops, ridges, and locally on hillsides and in fields. Because the soils have moderately slow permeabilities and shallow depths to bedrock, erosion potential is high. To compensate, the landowner has constructed retention structures in the form of dikes across major drainages and low ridges or berms through fields transverse to slopes to impede and collect runoff.

No chemical analyses of soils have been made in the area. An analysis of similar soil types (Wheelon Series; Erickson and Mortensen, 1974) in cultivated fields near Newton indicate that they are calcareous and alkaline with about 0.1 percent nitrogen in the plowed horizon, decreasing downward to about 0.05 percent nitrogen in the horizon from 12 to 24 inches (Southland and others, 1978).

HYDROLOGY

Pearson Spring

Pearson Spring is located at about elevation 4900 feet in the bottom of Butler Hollow. Collection lines were placed in the valley bottom along the south bank of the stream. The depth, length, and exact location of the lines are unknown. The spring is about 800 feet downstream (east) from the last of a series of water retention dams constructed across Butler Hollow to control soil erosion and flooding. Another retention dam on a tributary which enters Butler Hollow at the spring impounds water above and south of the spring. At the time of the investigation, most impoundments contained water and the one south of the spring was overflowing. Seeps and springs were evident in the stream bottom at or slightly downstream from impoundment structures containing water along Butler Hollow. Several springs discharge from unconsolidated deposits in the south bank of Butler Hollow upstream from Pearson Spring. Also, springs flow from the north bank of Butler Hollow near the base of the structure west of Pearson Spring, presumably representing leakage through or beneath the structure.

The Utah Division of Water Rights measured discharges of 38.5 gallons per minute (gpm) on November 29, 1979; 23.7 gpm on June 11, 1981; and 16.0 gpm on July 21, 1981, at Pearson Spring. Measurements of stream flow in Butler Hollow on May 23, 1983, indicated a net loss of water through infiltration in the zone from 200 to 700 feet below the dam, with a net gain from this point downstream. The landowner reports that springs and seeps periodically occur, particularly in springtime, in his fields west of Pearson Spring.

Observed flow in all springs is either from stream alluvium or deposits of Lake Bonneville. It appears that most water discharged at Pearson Spring is from perched shallow aquifers in unconsolidated deposits overlying less permeable bedrock. The recharge area for Pearson Spring thus consists largely of the surrounding areas of unconsolidated deposits at higher elevations. It is not known whether collection lines at Pearson Spring are below stream level, but, if so, it is possible that some stream water (chiefly seepage from the upstream pond) may be getting into the lines. A dye test in which dye was placed in the pond west of the spring was run by the Utah State Department of Health and monitored at the spring (Scanlan, 1982). No dye was found, indicating either that the pond does not recharge the spring or that soil attenuation or ground-water dilution were sufficient to preclude detection of the dye at the spring.

Little is known of the role of bedrock aquifers in the local ground-water system. If bedding dip controls flow in bedrock units, ground water would be directed away from the area to the southwest. The limestone pebble conglomerate may act as a local aquifer, carrying water in fractures and solution cavities. However, no evidence of extensive dissolution in this unit is present in outcrops. Tuff units are highly fractured where exposed, but the degree of fracturing and permeability at depth are not known.

Griffith Spring

Griffith Spring is one mile south of Pearson Spring, also at about elevation 4900 feet. A discharge of 14.0 gpm was measured at Griffith Spring on July 21, 1983, indicating that it is about equal to Pearson Spring in terms of discharge. Spring collection lines extend in a V-shape on either side of a low ridge upstream to the west and are buried beneath cultivated fields. The depth and length of lines are unknown, and much of the surface drainage basin above the spring is cultivated. An extensive network of soil erosion control berms, dikes, and dams have been constructed throughout the area, effectively reducing runoff and increasing infiltration. Recharge to Griffith Spring appears to consist principally of water infiltrating into unconsolidated deposits and shallow fractured rock in the surface drainage basin area, with discharge at Griffith Spring from a shallow perched aquifer. If water were moving in bedrock aquifers from higher elevations north of Griffith Spring, it would be intercepted by Pearson Spring which is at the same elevation in the direction of recharge. Water in rock not intercepted by Pearson Spring would likely be transmitted downdip along more permeable beds in a southwesterly direction away from Griffith Spring.

Other springs

Two springs occur in upland areas north of Pearson Spring (East and West Springs, attachment 1), and both are reportedly flowing at higher than average rates this year. East spring is at an elevation of about 4800 feet in an environment similar in terms of topography and geology to that of Griffith Spring. Cultivated land is found in the recharge area, although not to the extent found at Griffith Spring. Total flow in East Spring and others downstream was measured at 7 gpm by the Utah Division of Water Rights on April 14, 1976.

West (Whitney) Spring is above all Lake Bonneville deposits at an elevation of about 5180 feet. Collection lines for this spring have been run along a ridge to the north and down into the gulley in which the spring discharges. A flow rate of 3.5 gpm was measured on April 14, 1976, and it reportedly is dry during certain times of the year. Bedrock in this area is almost entirely the limestone pebble conglomerate, and no cultivated land is present above the spring in the probable recharge area.

Many springs are present along the range-front east of these upland springs. Saturated ground along the access road to the Cornish Cemetary and Koller home necessitated drainage measures to reduce road damage. Flow in these springs may be from a combination of shallow ground water in unconsolidated aquifers and deeply circulating ground water along the Dayton fault zone. The deeper circulation in indicated by the presence of the Trenton warm-water area, a low-temperature geothermal area which extends northward from Trenton to about the Pitcher residence east of Griffith Spring (de Vries, 1983). The warming is thought to take place through deep circulation, with subsequent rising of the warmed water along the fault zone. Such thermal water is part of a more regional ground-water system different from that which feeds Pearson and Griffith Springs and other upland springs.

Pitcher Spring is near the mountain front at the canyon mouth downstream from Griffith Spring, but is west of the fault zone . The spring was not studied, but from its location appears to be similar in character to upland springs draining perched, unconsolidated aquifers and probably is not a part of the deeply circulating system.

EXTENT OF NITRATE CONTAMINATION

Nitrate concentrations at discharge points of Pearson and Griffith Springs were first analysed in 1977, although analyses of water in the Cornish distribution system dates back to 1965. Prior to about 1980, water in the distribution system was derived from springs alone, so analyses before this time are representative of concentrations in the springs and serve to extend the record back to 1965. Mixing of well water with spring water to dilute nitrate concentrations in the distribution system began around 1980. Results of analyses are shown in tables 1, 2, and 3. Various seasonal, annual, and

Table 1.-Nitrate concentration (mg/l) in water from Pearson Spring (sampled at Koller home).

	Year (19__)							
Month	77	78	79	80	81	82	83	84
January								
February								
March								
April								
May						24.5		
June						20.3		16.1 (6-4) 15.0 (6-18)
July						18.85		
August		6.0				17.1		
September								
October		5.0	13.0					
November								
December	6.0							

Table 2.-Nitrate concentration (mg/l) in water from Griffith Spring.

	Year (19__)							
Month	77	78	79	80	81	82	83	84
January								
February								
March								
April								
May								
June						18.05		16.1 (6-18)
July						15.85		
August								
September								
October		12.75						
November								
December	12.3							

Table 3.-Nitrate concentration (mg/l) in water from the Cornish distribution system.

					Year (19__)				
Month	65	66-77	78	79	80	81	82	83	84
January		No					10.8		
February	0.2	Data	7.7			13.3			
March					13.25	10.85			
April						6.75			
May	7.5				11.5				
June						10.10	17.25		12.3 (6-4)
		No							11.7 (6-18)
July		Data			12.5				
August				13.5	13.13				
September									
October				9.0					
November									
December				13.5					

long-term trends are apparent from these data. At Pearson and Griffith Springs, a gradual decrease in concentration through the summer months is notable in the 1982 data, with highest levels in May. An overall long-term increase in nitrate levels is indicated by data taken in the same month in different years at Pearson Spring. No such data are available at Griffith Spring, and the increase noted from 1977 to 1982 may reflect only seasonal fluctuations. Nitrate levels measured in 1984 are less than or about the same as those in 1982, indicating that levels may have stabalized in recent years.

Various other water sources have been sampled for nitrates in the area (table 4, attachment 1). Springs and land drains at the mountain front are

Table 4.-Nitrate concentrations (mg/l) in various water sources, Cornish area.

Sample Source (date)*	Nitrate concentration
West (Whitney) Spring (6-4-84)	2.1
(6-18-84)	2.1
East Spring (6-4-84)	5.87
(6-18-84)	5.5
Pitcher Spring (1-31-81)	12.45
(6-18-84)	15.9
Cemetary land drain (6-18-84)	1.4
Wilson land drain north (6-18-84)	8.7
Wilson land drain south (6-18-84)	6.16
Cornish city well (6-4-84)	.01
McKnight well (6-18-84)	17.1
Butler Hollow 275 feet east of pond above Pearson Spring (6-18-84)	11.4
Butler Hollow 200 feet west of Pearson Spring (6-18-84)	13.5
Butler Hollow 75 feet west of Pearson Spring (6-18-84)	15.4
Butler Hollow tributary immediately south of Pearson Spring (6-18-64)	12.4
Pond west of Pearson Spring (6-4-81)	13.1

*See attachment 1 for sample locations.

also high in nitrates, with the exception of the cemetary land drain. Variations in nitrates in this area may be a function of the amount of mixing between shallow, high nitrate water and deep-circulating, low nitrate water rising along the Dayton fault zone.

Well water varies in nitrate concentration and is in large part dependent on the depth from which water is pumped. A 30-foot deep hand-dug well at the mountain front east of East Spring (Brad McKnight well, table 4) has a nitrate concentration of 17.1 mg/l. The depth to water recorded when the well was completed on March 4, 1936, was 12 feet. Another well which was drilled for the city of Cornish taps deeper aquifers isolated from the surface by nearly 50 feet of clay. The perforated intervals in the well are at various gravel lenses from about 50 to 85 feet below to ground surface. The highest recorded nitrate level is 2.7 mg/l, but it averages less than 1.0 mg/l with a narrow range of fluctuation and no discernable long-term upward trend.

Surface water in the area contains high nitrate concentrations. A concentration of 13.1 mg/l was measured in the pond west of Pearson Spring on June 4, 1984. Four samples of stream flow in Butler Hollow near Pearson Spring derived from underflow through the dam and surface and spring flow from the south ranged in nitrate concentration from 11.4 to 15.4 mg/l (6-18-84; table 4).

SOURCE OF NITRATES

Nitrogen is derived chiefly from organic processes at the earth's surface or as a by-product of industry. The major point sources of nitrogen in surface or ground water are municipal and industrial wastewaters, septic tank effluent, and feedlot discharges. Diffuse sources include atmospheric fallout, nitric oxide and nitrite discharges from automobile exhausts or other combustion processes, farm-site fertilizer and animal wastes, lawn fertilizer, leachate from solid waste disposal sites, and losses from natural sources such as mineralization of soil organic matter (Hem, 1970; National Academy of Sciences, 1972; Environmental Protection Agency, 1976) or leaching of bedrock or unconsolidated deposits containing nitrogen (Feth, 1966). At Griffith and Pearson Springs, point sources of contamination can be eliminated based on the absence of municipal or industrial wastewater disposal sites, septic tanks, and feedlots in the recharge areas. Diffuse sources which can be readily eliminated are lawn fertilizers, leachate from solid waste disposal sites, and discharges from automobile exhausts or other combustion processes, all of which are not present or are not significant in the area. Animal wastes are an unlikely source since they are not used for fertilizers and no extensive grazing occurs in the area. The remaining potential sources which must be evaluated are 1) atmospheric fallout, 2) natural sources in bedrock and unconsolidated deposits, 3) farm-site fertilizer, and 4) decomposition of soil organic matter.

Atmospheric fallout and nitrate contained in snow and rainfall represent diffuse sources which would affect all shallow springs in the area. Such sources are unlikely to account for the high concentrations in some and not others in such close proximity, and are unlikely to account for recent trends of increasing nitrate, since such sources have been present and essentially unchanged throughout the recent geologic past. The same can be said for possible local bedrock sources. No chemical analyses of rocks were performed, but nitrogen is a very rare constituent of rocks, and rock types exposed in spring recharge areas typically do not contain significant amounts of nitrates.

Farm-site fertilizer and decomposition of soil organic matter remain as the sources which best explain the existing pattern of nitrate contamination in the area. The lowest nitrate concentration was found in West Spring (2.1 mg/l) which has little or no cultivated land in its recharge area. Nitrate concentrations were higher in East Spring (5.87 mg/l) where a moderate level of cultivation and drainage control takes place, and highest at Pearson and Griffith Springs where the most extensive cultivation and drainage control is practiced. Nitrate concentrations in surface water in Butler Hollow are also high. These data indicate that nitrate contamination is in some way related to agriculture. Nitrogen-rich farm-site fertilizers are used in dry-farming operations in spring recharge areas and in close proximity to all springs except West Spring. Although plant material which decomposes and replenishes soil with nitrogen-rich organic matter is present throughout the area, differences in soil organic matter and leaching may be a function of differences in vegetation type and land-use which relate to farming. Under natural conditions, vegetation is diffuse and soil organic content is probably low.

CONCLUSIONS AND RECOMMENDATIONS

Both Pearson and Griffith Springs appear to be discharging from shallow perched ground-water aquifers, chiefly unconsolidated deposits and shallow fractured bedrock overlying less permeable fresher bedrock. Other springs in Butler Hollow and the canyon below Griffith Spring were seen to discharge directly from Lake Bonneville deposits exposed in valley sides. West Spring is above the highest Lake Bonneville shoreline where little unconsolidated material is present, and discharges in an area of predominantly conglomeratic bedrock. No springs were seen to discharge from tuffaceous bedrock. Principal recharge to each spring probably occurs in the surface drainage basin upstream from the spring to the drainage divide. These springs are not believed to receive significant recharge from bedrock aquifers carrying water from great distances outside the immediate drainage basins. Studies that would be necessary to gain a further understanding of the local ground-water system include:

1) Detailed geologic mapping including delineation of the extent and thickness of various facies within the Salt Lake Formation, Lake Bonneville deposits, and stream alluvium; mapping of structural features (faults, bedding attitudes, joints); and delineation of all perennial and intermittant seeps and springs.

2) Drilling of exploratory borings in recharge areas to determine the thickness of unconsolidated deposits and the presence of water in these materials and in bedrock at depth.

3) Further dye testing, including injection of dye: a) in stream water in Butler Hollow below the dam but above the Pearson Spring collection lines to evaluate the stream's contribution to the spring, and b) in the pond south of Pearson Spring which is another likely source of recharge.

Nitrate contamination in springs is believed to be related to agriculture. Concentrations in spring water were found to vary directly with the amount of cultivated land and the extent of drainage control in the recharge area. The nitrates in springs are probably derived from infiltration of nitrate-rich surface runoff which collects in man-made ponds and troughs and from infiltration of direct precipitation through soils rich in nitrate from fertilizer and/or decomposition of the organic material. In order to determine to what extent land-use is affecting nitrate concentrations in soils and ultimately in ground water, whether through fertilizing or decomposition of soil organic material, the following would be required:

1) Measurement of nitrate concentrations in soils and ground water in test pits or borings in typical cultivated and undisturbed soils for comparison. Soils with similar geologic parent material, slope aspect, and elevation should be used in order that all variables except land-use be held constant.

2) Soil testing for phosphates, potassium, or other elements unique to the fertilizer which could be used to determine whether high nitrate concentrations, if present, are due to fertilizers or natural decay of organic material.

3) Correlation of water quality fluctuations with fertilizing schedules, requiring periodic (monthly) monitoring of nitrate concentrations in each spring.

4) Comparison of soil tests in fertilized and unfertilized fields (if present) to differentiate between nitrates derived from fertilizers or decomposition of organic material.

Assuming nitrates in springs are derived from the agricultural sources listed above, residual nitrates in soils, ground water, and surface water may persist for a period of time even after the source of nitrates is eliminated. If the rate of decrease in nitrate levels during summer months (see 1982 data in tables 1 and 2) continues throughout the winter, nitrate levels could be below the public drinking water standard of 10 mg/l in a year or less. However, it is not known if the rate of decrease will be sustained or if the source of nitrates can be entirely eliminated. Elimination of the source to the extent possible would require enforcement of a 1500-foot protection zone allowing no fertilizing and possibly no cultivation, with removal of impoundment structures from fields and drainages and diversion of all upstream runoff from the zone. However, it is not certain that this would reduce nitrate concentrations to safe levels for drinking water because of residual nitrates in soil and water and possible infiltration of nitrate-rich water along permeable zones from outside the protection zone.

Because the springs are believed to be discharging from shallow, perched ground-water systems which derive nitrates from infiltrating surface water, further development of springs in the collection area will probably not substantially reduce the nitrate levels. Collection lines may be isolated from direct infiltration of local surface water by placement of an impermeable cover and local diversions of stream flow, but it is probable that all ground water in the area contains high nitrate levels and the problem is not localized to the immediate collection area.

REFERENCES

Adamson, R.D., Hardy, C.T., and Williams, J.S., 1955, Tertiary rocks of Cache Valley, Utah and Idaho, in Eardley, A.J., ed., Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geological Society Guidebook to the Geology of Utah No. 10, p. 1-22.

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

Clyde, C.G., Oaks, R.Q., Kolesar, P.T., and Fisk, E.P., 1981, The potential for ground-water contamination along basin margins in the arid west; alluvial fans and lake features: Utah Water Research Laboratory Hydraulics and Hydrology Series, UWRL/H-81/05, 82 p.

de Vries, J.L., 1982, Evaluation of low-temperature geothermal potential in Cache Valley, Utah: Utah Geological and Mineral Survey Report of Investigation No. 174, 96 p.

Erickson, A.S., and Mortensen, V.L., 1974, Soil survey of Cache Valley area, Utah: USDA Soil Conservation Service and Forest Service and Utah Agricultural Experiment Station, 192 p.

Feth, J.H., 1966, Nitrogen compounds in natural water - a review: Water Resources Research, v. 2, no. 1, p. 41-58.

Fisk, E.P., and Clyde, C.G., 1981, A survey and evaluation of shallow ground-water contamination hazards in the State of Utah: Utah Water Research Laboratory Hydraulics and Hydrology Series UWRL/H-81/04, 45 p.

Hem, J.D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water Supply Paper 1473, 363 p.

McGreevy, L.J., and Bjorklund, L.J., 1970, Selected hydrologic data, Cache Valley, Utah and Idaho: Utah Basic-Data Release No. 21, 51 p.

Scanlan, Larry, 1982, Report of survey and dye test, Cornish Town: Utah State Department of Health letter to the Mayor and Town Council of Cornish, August 2, 1982, 10 p.

Smith, Neal, 1953, Tertiary stratigraphy of northern Utah and southeastern Idaho, in Intermountain Association of Petroleum Geologists, Guidebook to the geology of northern Utah and southeastern Idaho: Fourth Annual Field Conference, p. 73-77.

Southard, A.R., Wilson, LaMoyne, and Erickson, A.J., 1978, Chemical and physical properties of the soils of the Cache Valley area and the eastern portion of Box Elder County, Utah: Utah Agricultural Experiment Station Research Report 31, 112 p.

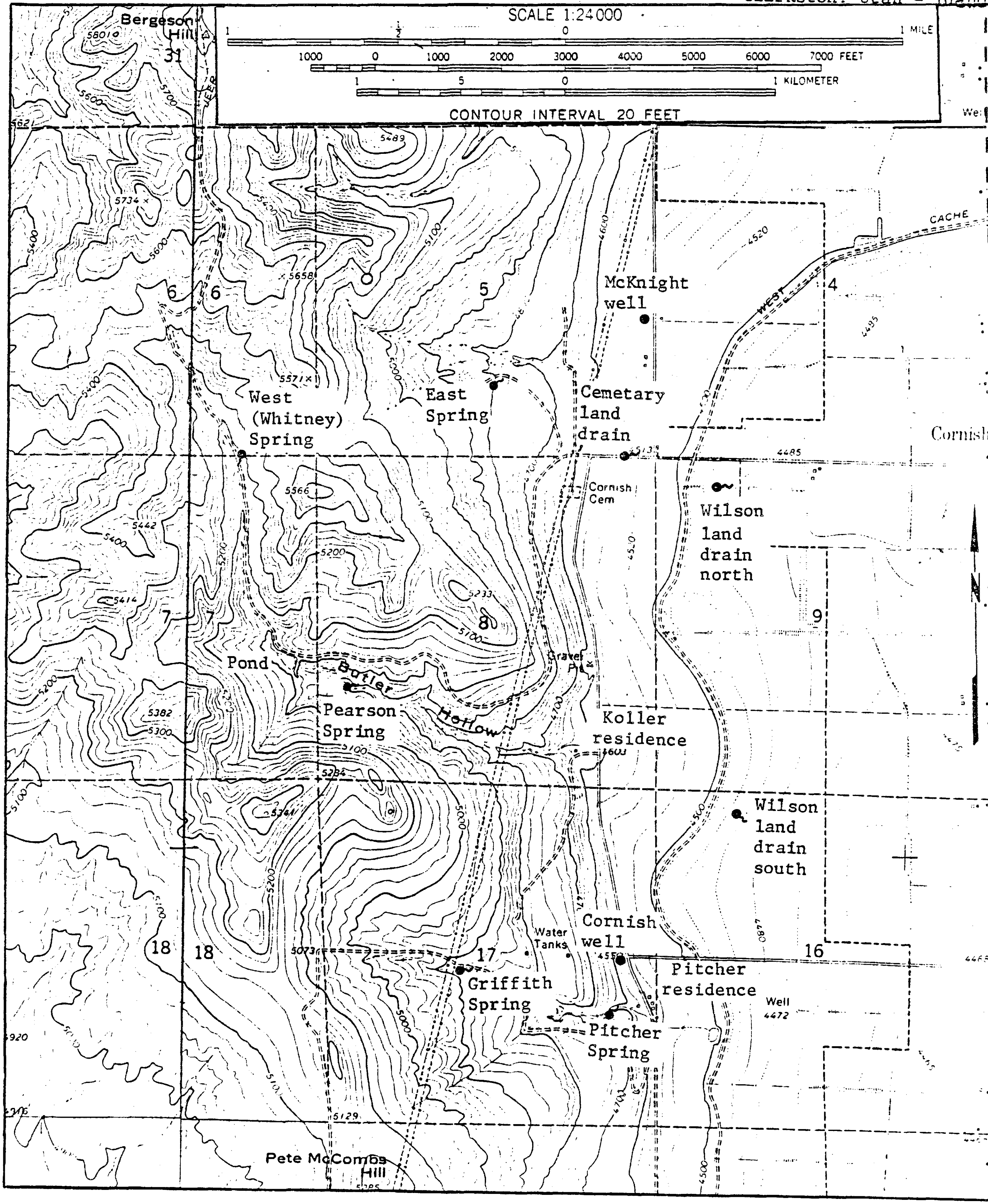
Stanley, W.D., 1971, An integrated geophysical study related to ground-water conditions in Cache Valley, Utah and Idaho: Salt Lake City, University of Utah, unpub. PhD dissertation, 142 p.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: Washington, D.C., 256 p.

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

------- 1962, Lake Bonneville: Geology of southern Cache Valley, Utah: U.S. Geological Survey Professional Paper 257-C, p. 131-152.

Base map from USGS 7½' Topo Quad
Trenton, Utah - Idaho
Clarkston, Utah - Idaho



Location map, Cornish area Cache County

Project:			Requesting Agency:
Lehi City springs evaluation			Lehi City Corporation
By: H. E. Gill	Date: 11/7/84	County: Utah	Job No.: SP-5
USGS Quadrangle: Lehi (1130)			

In response to a request from George F. Tripp, Mayor of Lehi City Corporation, an evaluation was made of seven springs used as a source of culinary water by Lehi and Alpine Cities. The springs are on land owned by the Moyle family, and there has been an ongoing dispute over water rights between the cities and the property owners since the late 1800's. The cities are attempting to settle the matter by purchasing the land surrounding the springs. The purpose of the investigation was to determine the recharge area for the springs and recommend adequate protection zones to prevent their contamination. The size of the protection zones will determine the amount of land that will be purchased.

SCOPE OF WORK

To accomplish the objectives of the study, the following scope of work was undertaken:

1. Review of applicable published and available unpublished literature including reports, memos, maps, and other data pertaining to the study area.

2. Field reconnaissance of the study area accompanied by Mr. Dale Walker, Water Superintendent for Lehi, City; Mr. De Vere Fowler, member of the Lehi City Council; and Mr. Lorin Powell, of Arix Engineering.

3. Consultation with Ursula Trueman, from the Utah Department of Health.

SETTING

The area under investigation is in the mountains approximately 2 miles northeast of Alpine, Utah (attachment 1). The study area encompases approximately 190 acres and is at the junction of the Wasatch Range, on the north and east, and the Traverse Mountains on the west. Several unnamed streams and drainages cross the study area. The largest trends northeast-southwest through the southeast corner of the site, and another north-south drainage is near the western boundry of the study area. The streams are perennial, however, the amount of flow varies with the season. The streams are tributaries to Dry Creek, the major drainage in the area. Dry Creek Canyon and Chipman Canyon are the two major drainages south of the study area (attachment 1). Elevations in the study area vary from about 5560 to 6240 feet above sea level and slopes range from 3 to 50 percent. Climate in northern Utah Valley is temperate and semi-arid, with precipitation along the mountain front reaching up to 25 inches per year (Hunt and others, 1953).

Of the seven springs evaluated, four occur on steep slopes in the northern portion of the study area (attachment 1). They are: Birch Spring (B), and three of the Schoolhouse Springs (SH4, SH5, and SH6; number designations established by L. Powell during site reconnaisance). The remaining three springs, Schoolhouse Springs 1 and 3 (SH1 and SH3), and Pig Trough Spring (PT), are in the southern half of the study area which is characterized by gentler slopes.

GEOLOGY AND HYDROLOGY

Geologic units in the study area are from oldest to youngest the: Pennyslvanian/Permian Oquirrh Formation; Tertiary Little Cottonwood Stock; and Quaternary glacial, alluvial, and colluvial deposits. In the study area, the Oquirrh Formation is chiefly quartzitic sandstone. The Little Cottonwood Stock is quartz monzonite and occupies more than half of the Dry Creek drainage basin (Hunt and others, 1953). In Early Pleistocene time, glaciers reached the mouths of Dry Creek and Chipman Canyons and deposited chiefly granitic material as glacial morains and outwash (Fairbanks, 1982). Colluvium and alluvium of varying thickness on mountain slopes and along stream channels constitute the remaining unconsolidated deposits in the study area. In general, bedrock exposures are poor with most units covered by quartzite talus, and colluvium.

Three bedrock faults, labeled 1,2, and 3 for this study, cross the study area (Davis, 1983). Faults 1 and 3 trend east-west through the site and fault 2 trends northeast-southwest (attachment 2). During the field investigation little evidence of these faults was observed because of a lack of bedrock exposures and heavy vegetative cover. A small portion of fault 1 forms the steep slope that trends through Schoolhouse Spring 1 and north of Pig Trough Spring (attachment 2).

Only one bedrock exposure was observed in the study area. It was quartz monzonite of the Little Cottonwood Stock and was highly jointed. The predominant joint set had a strike of N. 37° E. and a dip of 39° SE. Bullock (1958) writes; "The Oquirrh Formation in the East Traverse Range is highly fractured to the extent that few pieces were observed over a foot in maximum dimensions" and "Jointing has played an important part in the fracturing of the Cottonwood stock." Therefore, it is assumed that the Oquirrh Formation and the Little Cottonwood Stock are both highly fractured in the study area and provide ready access for infiltration of precipitation.

The large amount of fractured rock in the Wasatch Range and the Traverse Mountains bounding the study area suggest that the rock will accept a large volume of water from precipitation and snowmelt. The source for the water in the study area is the bedrock aquifers to the north and east recharged by snowmelt entering the fractured Little Cottonwood Stock and Oquirrh Formation. The subsurface flow from the bedrock enters the unconsolidated materials that occupy small drainages and meadows, and it is in these materials that the collection systems are located. Although the collection lines are buried deep, contaminated surface water can percolate through the unconsolidated materials and enter the collection lines.

SPRING DISCRIPTION AND DEVELOPMENT

At each spring site, perforated clay pipe is used for collection and solid steel pipe is used for distribution of the water. Concrete and 36-inch galvanized steel culvert is used for collection boxes. The clay pipe isplaced in trenches, usually beneath marshy areas, in an array disigned to intercept the most water. The clay pipe transports water to the collection boxes which extend from the ground surface to beneath the collection lines, in some instances to depths as great as 25 feet. In most cases, the steel distribution lines are placed between the collection boxes in the same trenches as the clay pipe to transport water between the boxes and ultimately to the main distribution line leading to the city. The collection and distribution lines were covered with one foot of 1.5-to 3-inch gravel and sheets of plastic, and then the trenches were backfilled to the ground surface with excavated material (oral commun., D. Walker, 1984).

SPRING EVALUATIONS

School House Spring 1 (SH1; attachment 3 & 4)

Location: NE1/4 NW1/4 SE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Schoolhouse Spring 1 is in the bottom of a small alluvial filled drainage which trends north-south near the western edge of the study area. The spring was originally developed using a 2-inch diameter cast iron pipe (early 1900's), and was redeveloped in 1960-61. The original pipe is not conected to the culinary system at this time, however, a small amount of water continues to flow from it and combined with the flow in the drainage contributes to the ground water at the site. The collection system consists of approximately 135 feet of perforated clay pipe (4-inch diameter), 100 feet of solid steel distribution line (4-inch diameter), and 3 collection boxes (galvanized steel culvert, 36-inch diameter). The system is placed in the middle of the drainage in trenches 12 to 20 feet deep. Vegetation is primarily low grass and water plants.

Geology & soils: Schoolhouse Spring 1 is near the contact between Pennsylvanian/Permian Oquirrh Formation and Quaternary glacial deposits (Davis, 1983). Fault 1 trends through the spring location. No outcrops were observed due to colluvial and vegetative cover. U.S. Department of Agriculture Soil Conservation Service (SCS) mapping identifies site soils as the Kilburn stoney sandy loam. This unit is primarily silty sand or silty gravel and has high permeability.

Summary: It is believed that water is migrating upward along fault 1 which trends through the spring site, as well as percolating through the fractured Oquirrh Formation to the west. Ground water is primarily controlled by subsurface discharge from the bedrock slope to the west (oral commun., D. Walker, 1984). A marsh has formed in the drainage bottom and the collection lines are in this area.

School House Spring 3 (SH3; attachment 3 & 5)

Location: NW1/4 NE1/4 SE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Schoolhouse Spring 3 is the largest spring in the system (500+ gallons per minute, representing approximately 25 percent of the total flow to the system). The spring was originally developed in the early 1900's and was redeveloped in 1960-61. The collectionarea is in unconsolidated materials that extend approximately 30+ feet south of a steep south-facing bedrock slope. The collection system consists of approximately 25 feet of perforated clay pipe (6-inch diameter), 25 feet of solid steel distribution line (8-inch diameter), and two collection boxes (galvanized steel culvert, 36-inch diameter). The system was placed in a trench 16 feet deep at the bedrock slope and 12 feet deep at the collection box. Vegetation in the area is low grass.

Geology & soils: Bedrock in the vicinity of Schoolhouse Spring 3 is the Little Cottonwood Stock. Granitic float was observed in the area but colluviam obscures the bedrock. Fault 1 trends approximately 250 feet south of the spring (Davis, 1983). Soils in the area were mapped as the Kilburn stoney sandy loam consisting of silty sand or silty gravel and has high permeability.

Summary: Ground water at the site is directly related to subsurface flow issuing from the fractured bedrock aquifer to the north. Subsurface water saturated the unconsolidated materials south of the slope prior to redevelopment (oral commun., D. Walker, 1984), and it is in this area that the collection system is located. Dry site conditions at the time of the investigation indicate that the collection lines are intercepting most of the ground water.

School House Spring 4 (SH4; attachment 3 & 6)

Location: SW1/4 SE1/4 NE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Schoolhouse Spring 4 is in a small meadow filled with alluvial and colluvial material and is bounded on the north and west by moderately steep slopes. The spring was originally developed in the early 1900's and was redeveloped in 1962. The collection system consists of approximately 380 feet of perforated clay pipe (4-inch diameter), 190 feet of solid steel distribution line (4 and 6-inch diameter), and five collection boxes (galvanized steel culvert, 36-inch diameter). The system was placed in the northwestern half of the meadow in trenches 8 to 12 feet deep. Vegetation is primarily low grass with some water plants.

Geology & soils: Bedrock in the area is the Little Cottonwood Stock. The bedrock is highly fractured, due in part to the intersection of faults 2 and 3 approximately 100 feet northwest of the spring site (Davis, 1983). No outcrops were observed in the field. SCS mapping does not extend onto National Forest land where the spring is located. Mr. Walker stated that during instalation of the collection system sand, gravel, and cobbles were observed to the trench bottom, and that no bedrock was encountered.

Summary: Ground water is migrating upward along faults in the area as well as percolating through the fractured and jointed bedrock north of the site. The collection lines have intercepted most of the ground water which previously created marshy conditions at the site. However, there remains a small wet area near the southwest end on the collection area.

School House Spring 5 (SH5; attachment 3 & 7)

Location: NW1/4 SE1/4 NE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Schoolhouse Spring 5 is in a small meadow filled with alluvial and colluvial material and is bounded by steep slopes to the north and west. The spring was originally developed in the early 1900's by digging a 6-foot diameter tunnel into bedrock (length unknown). The spring was redeveloped in 1962. The collection system contains the original tunnel, approximately 325 feet of perforated clay pipe (4-inch diameter), 325 feet of solid steel distribution line (4-inch diameter), and three collection boxes (galvanized steel culvert, 36-inch diameter). The collection system, which is beneath most of the meadow, was placed in trenches 10 to 12 feet deep. Vegetation is low grass and some water plants.

Geology & soils: Bedrock in the area is granodiorite of the Little Cottonwood Stock. The bedrock is believed to be highly fractured because faults 2 and 3 intersecting approximately 100 feet southeast of the spring site (Davis, 1983). Colluvial cover obscures the bedrock. Subsurface soils are a combination of sand, gravel, and cobbles, and no bedrock was encountered to the depth of the trenches (oral commun., D. Walker, 1984).

Summary: The water source for the spring is upward migration of ground water through faults in the area as well as percolation through the fractured and jointed bedrock north of the site. Ground water in the meadow is controlled by discharge from the bedrock aquifer, and although collection lines have intercepted most of the ground water, a small wet area remains at the southern end of the collection system.

School House Spring 6 (SH6; attachment 3 & 8)

Location: SE1/4 SW1/4 NE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Schoolhouse Spring 6 was originally developed in the early 1900's by digging a 6-foot diameter tunnel into bedrock (length unknown). The spring was redeveloped in 1962. Subsurface flow from fractured bedrock to the north saturates a small area of unconsolidated material extending approximately 30+ feet south of the slope. The collection system is located in this area and consists of the original tunnel, 25 feet of four-inch perforated clay pipe and solid steel distribution line, and one collection box (galvanized steel culvert, 36-inch diameter). The collection and distribution lines were placed in a trench 10 feet deep. Vegetation is low grass and some water plants.

Geology & soils: Bedrock in the vicinity of Schoolhouse Spring 6 is granodiorite of the Little Cottonwood Stock. Faults 2 and 3 intersect approximately 150 feet southwest of the spring site, and fault 2 trends through the site. No outcrops were observed due to colluvial and vegetative cover. Subsurface soils consist of sand, gravel, and cobbles, and no bedrock was encountered to the depth of the trenches (oral commun., D. Walker, 1984).

Summary: Ground water is controlled by upward migration along faults in the area, and seepage in the fractured and jointed bedrock aquifer to the north. Collection lines do not intercept all the flow from the bedrock and a small area of unconsolidated material at the site remains wet.

Birch Spring (B; attachment 3 & 9)

Location: NE1/4 SE1/4 NE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Birch Spring is in the bottom of a narrow alluvium-filled drainage. The spring was originally developed in the early 1900's and was redeveloped in 1969. The collection system consists of approximately 150 feet of perforated clay pipe (6-inch diameter) and a single concrete collection box (36-inch diameter). The collection and distribution lines were placed along the eastern edge of the drainage in a trench about six feet deep. Vegetation is low grass.

Geology & soils: Birch Spring is near the contact between Quaternary glacial deposits and the Little Cottonwood Stock. Two faults trend near the spring. Fault 2 terminates approximately 500 feet west of the spring, and fault 3 is mapped approximately 1,800 feet south of the site. Mr. Walker stated that subsurface soils were sand, gravel, and cobbles to the depth of the trench, and that no bedrock was encountered.

Summary: The ground-water source for the spring is the fractured bedrock aquifer to the east. The area was extremely wet prior to redevelopment (oral commun., D. Walker, 1984) but at the time of the investigation was dry. The collection lines appear to have intercepted most of the ground water, however, an unknown volume of water may enter the culinary system from surface flow in the drainage during storms and spring snowmelt.

Pig Trough Spring (PT; attachment 3 & 10)

Location: SE1/4 NW1/4 SE1/4 sec. 7, T. 4 S., R. 2 E., SLB&M.

Spring description: Pig Trough Spring is in a large alluvium-filled meadow bounded on the north by a steep bedrock slope. Originally developed in the early 1900's, the spring was redeveloped in 1959. Flow from the old collection line (2-inch diameter cast iron pipe) issues from the bedrock slope. The pipe is not connected to the culinary system, however, its flow contributes to the ground water at the site. The new collection system consists of approximately 550 feet of perforated clay pipe (4-inch diameter), 250 feet of solid steel distribution line (4-inch diameter), and two collection boxes (galvanized steel culvert, 36-inch diameter). The system was placed in the southern half of the meadow and is in trenches 6 to 7 feet deep. Vegetation is primarily low grass with some water plants.

Geology & soils: Pig Trough Spring is on the contact between Quaternary glacial deposits and stream deposited alluvium (Davis, 1983). Fault 1 forms the steep slope bounding the meadow on the north (Davis, 1983). Soils mapped at the site are the Kilburn stoney sandy loam, consisting primarily of silty sand or silty gravel exhibiting rapid permeability.

Summary: Pig Trough Spring issues from unconsolidated glacial deposits and stream alluvium. The water for Pig Trough Spring comes from three sources: 1) migration upward along fault 1, which trends along the northern boundry of the spring site, 2) leakage from springs north of the site percolating through unconsolidated slope materials, and 3) surface water from streams crossing the meadow. The collection area is in the southern half of the meadow (a marshy area) and all water entering the collection system must percolate through the unconsolidated materials in the meadow.

CONCLUSIONS

Springs in the study area can be grouped into three catagories: 1) springs on Forest Service land fed by deep bedrock aquifers, 2) springs on private land fed by deep bedrock aquifers, and 3) springs on private land fed from a shallow unconsolidated aquifer. Schoolhouse Springs 4, 5, and 6, and Birch Spring are in catagory 1. It is our understanding that the Forest Service land will not be developed in the future. This would minimize the polution hazard to recharge areas but protection of the collection areas from local sources of pollution is still necessary. Because the springs are fed by ground water migrating from depth along faults or joints in bedrock, they are in many many analogous to deep wells (as defined by the Utah State Division of Environmental Health, State of Utah Public Drinking Water Standards, Part II, 6.2.3.2). Therefore, a protection zone of 100 feet (distance required by the Health Department for protection zones around deep wells) is recommended (attachment 11). However, should future development be proposed near these springs, the protection zones should be reevaluated.

Schoolhouse Springs 1 and 3 are in catagory 2. Private land near the springs may be developed in the future, therefore, protection of areas that contribute surface recharge to the springs is required. Slopes north of the springs, and the flat area northwest and upslope from Schoolhouse Spring 1, as well as the collection areas around the springs, have been included in the recommended protection zone (attachment 11).

Pig Trough Spring is unlike the other six springs because its water source comes from a shallow unconsolidated aquifer. The spring requires a large protection zone for the following reasons: 1) the primary source of water for the spring is leakage from springs to the north infiltrating through unconsolidated materials on slopes and in the meadow, 2) the area of unconsolidated material (in which the collection system is located) is extensive, and 3) an unknown volume of surface water infiltrating from streams crossing the meadow is entering the system. Therefore, a recharge area encompassing all the unconsolidated materials north of the meadow and east along Chipman Creek is included in the recommended protection zone (attachment 11). The northern boundary of the protection zone terminates at the national forest boundary beyond which no development is anticipated. If Pig Trough Spring were removed from the culinary system the area south of the dashed line on attachment 11 could be eliminated from the recommended protection zone.

SELECTED REFERENCES

Baker, A. A., 1959, Faults in the Wasatch Range near Provo, Utah, in Williams, N. C., ed., Guidebook to the geology of the Wasatch and Uinta Mountains Transition Area: Tenth Annual Field Conference, Intermountain Association of Petroleum Geologists, p. 153-158.

Baker, A. A., and Crittenden, M. D., Jr., 1961, Geologic map of the Timpanogas Cave Quadrangle, Utah: U.S. Geological Survey Geological Quadrangle Map GQ-132, Scale 1:24,000.

Bullock, R. L., 1958, The geology of Lehi Quadrangle: Brigham Young University unpublished masters thesis, 59 p.

Cordova, R. M., and Subitzky, Seymour, 1965, Ground water in northern Utah Valley, Utah: a progress report for the period 1948-63: U.S. Geological Survey in cooperation with the Utah State Engineer, Technical Publication No. 11, 41 p.

Crone, A. J., editor, 1983, Paleoseismicity along the Wasatch Front and adjacent areas, central Utah, in Geologic excersions in neotectonics and engineering geology in Utah: Utah Geological and Mineral Survey Special Studies 62, p. 12.

Davis, F.D., 1983, Geologic map of the southern Wasatch Front, Utah: Utah Geological and Mineral Survey Map 55-A, Scale 1:100,000.

Dustin, J. D., and Merritt, L. B., 1980, Hydrology of Utah Lake with emphasis on Goshen Bay: Utah Geological and Mineral Survey Water Resources Bulletin 23, 50 p.

Fairbanks, P. E., 1982, Chemical changes in ground water of northern Utah Valley, Utah: Utah State University unpublished masters thesis, 82 p.

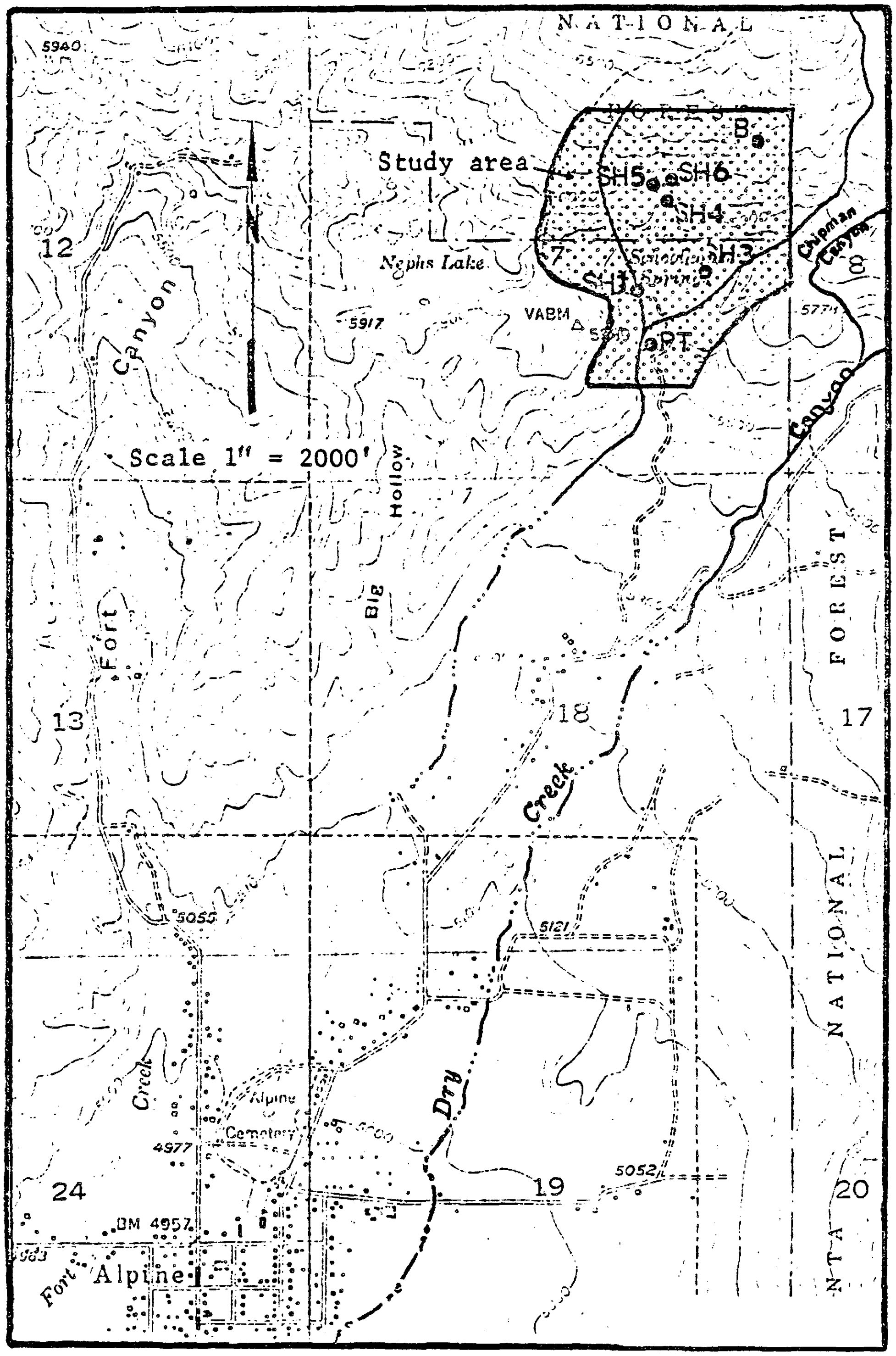
Gill, H. E., 1980, Preliminary geologic investigation to locate additional sources of culinary ground water for Highland City, Utah: Utah Geological and Mineral Survey Report of Investigation No. 159, 10 p.

Hunt, C. B., Varnes, H. D., and Thomas, H. E., 1953, Lake Bonneville: geology of northern Utah Valley, Utah: U.S. Geological Survey Professional Paper 257-A, 99 p.

Klauk, R., H., 1979, Shallow ground water occurrence in northern Utah Valley, Utah: Utah Geological and Mineral Survey Report of Investigation No. 130, 12 p.

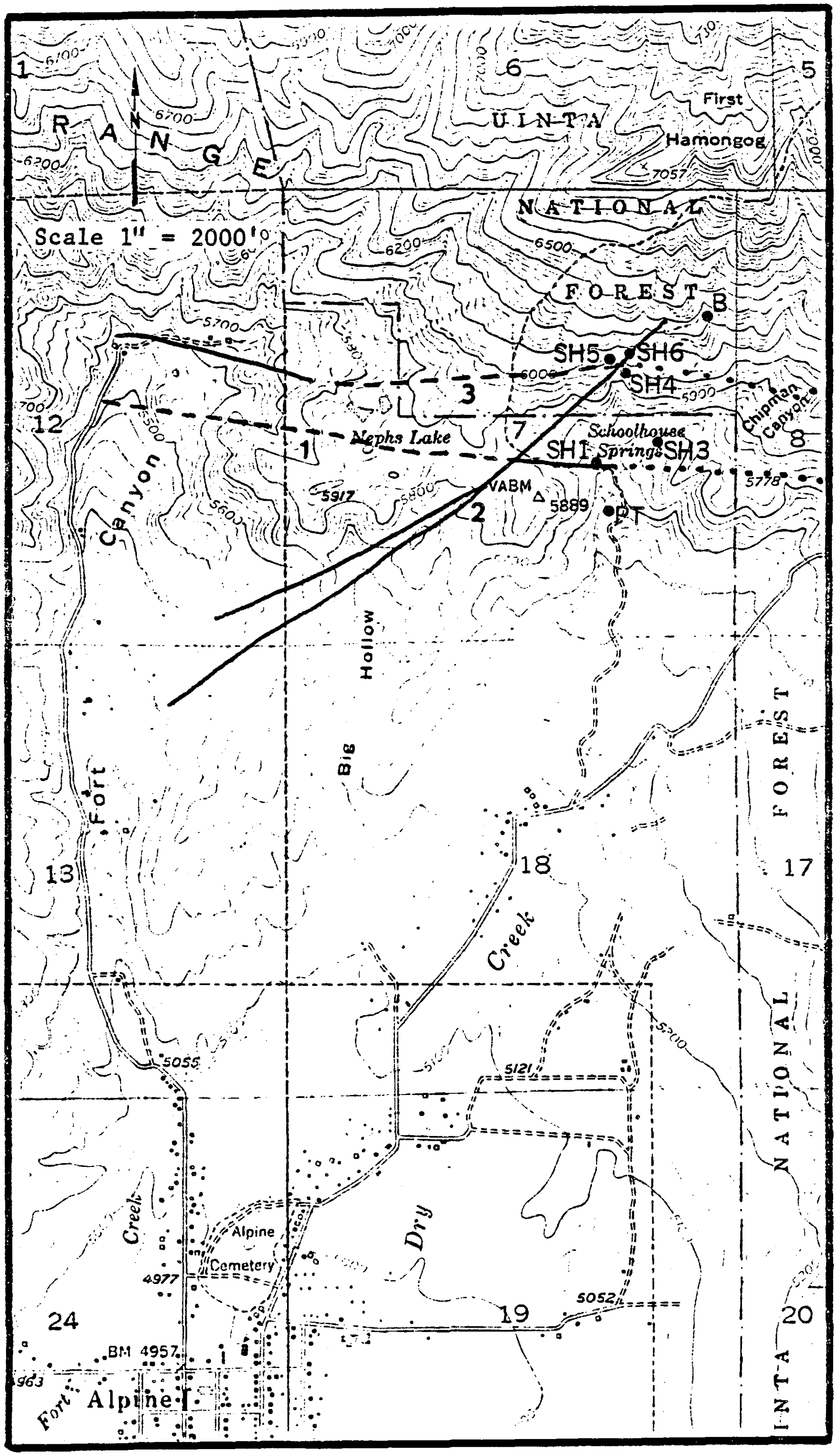
State of Utah Department of Health, 1984, State of Utah public drinking water regulations: Division of Environmental Health, Bureau of Public Water Supplies, 225 p.

Swenson, J. L., and others, 1972, Soil survey of Utah County, Utah, central part: U.S. Soil Conservation Service in cooperation with Utah Agricultural Experiment Station, 161 p.



General location map, Schoolhouse Springs study area.

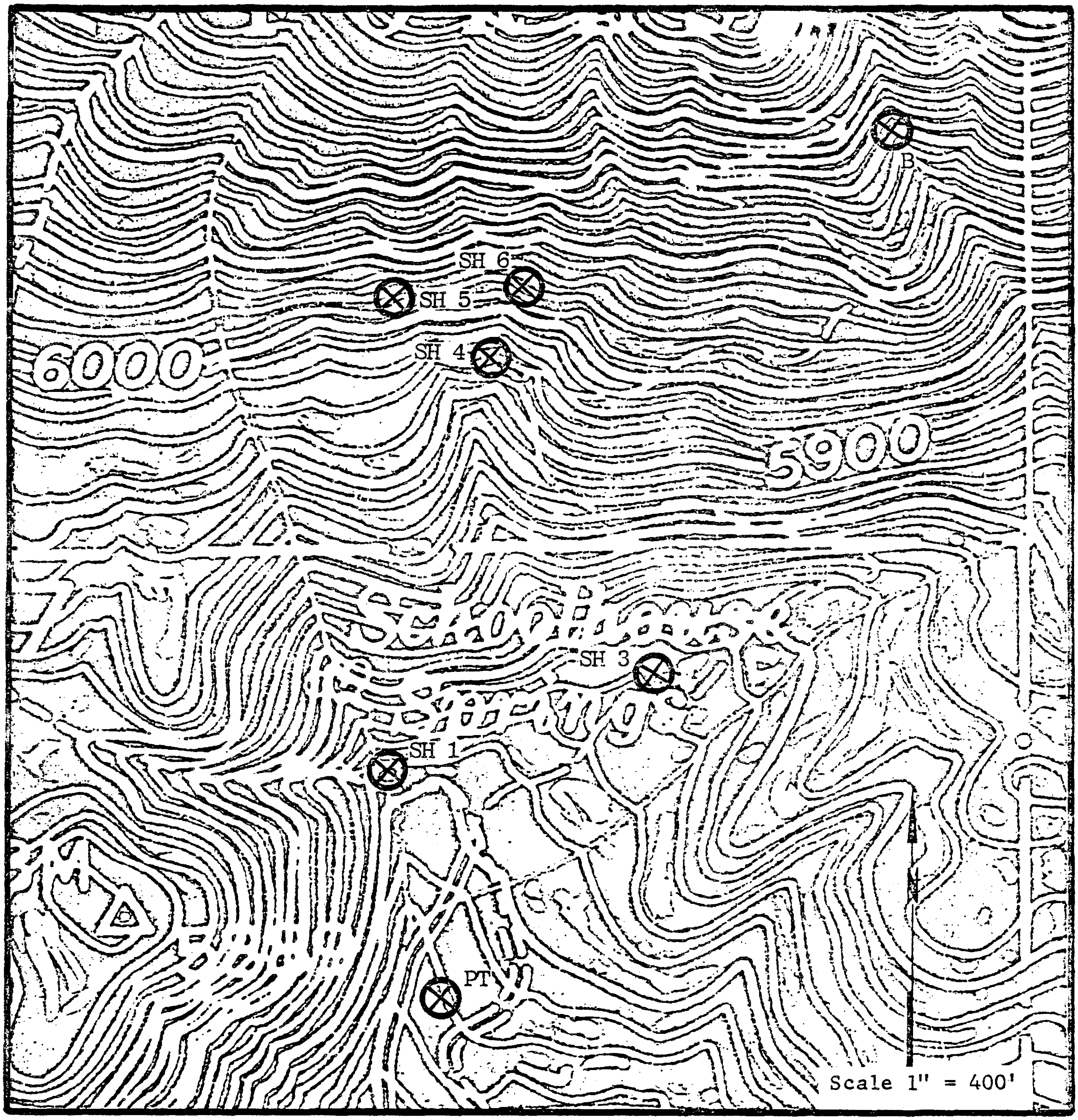
●PT Spring location



Fault location map (from Davis, 1983).

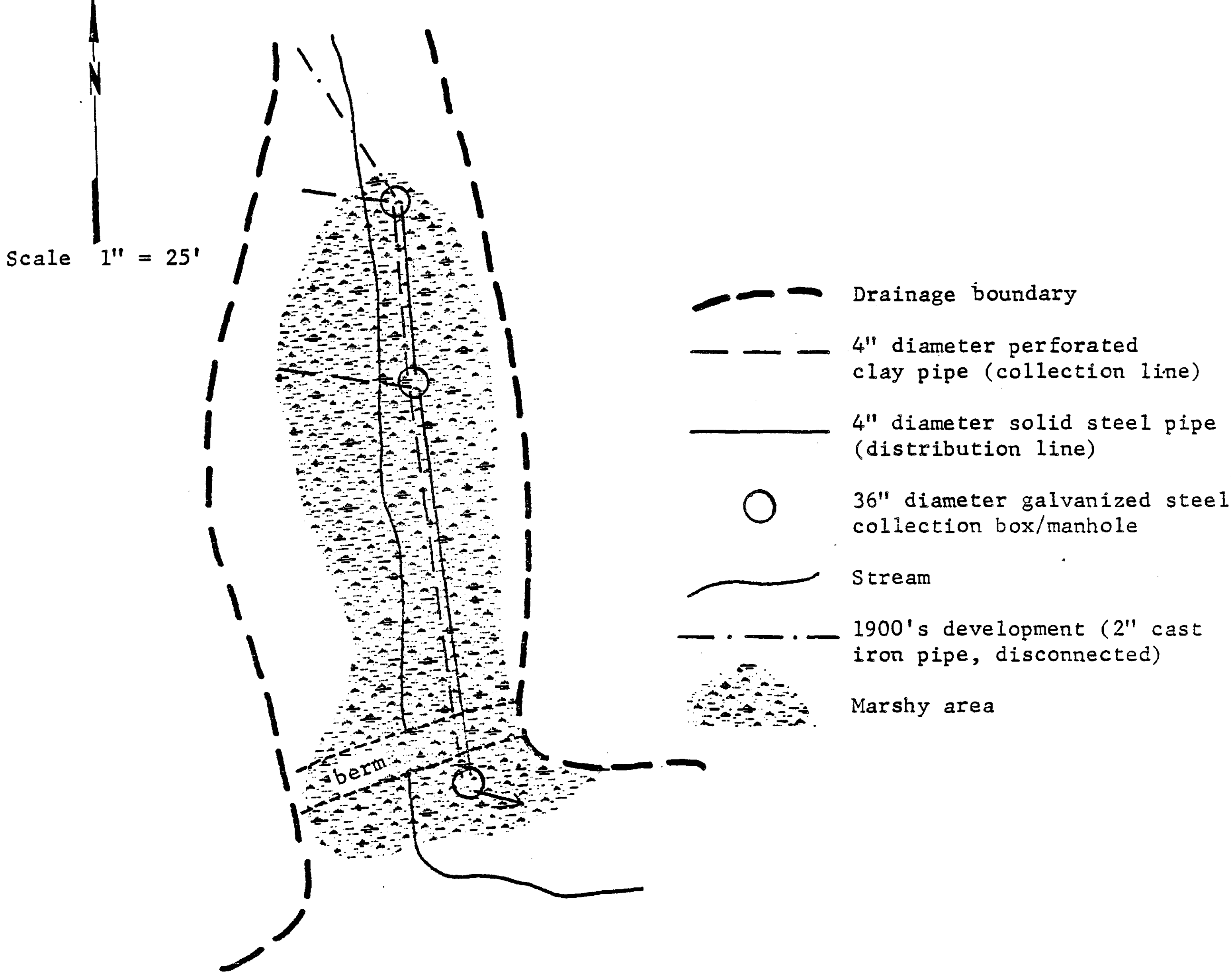
2 Fault, dashed where approximately located, dotted where concealed

•SH6 Spring location

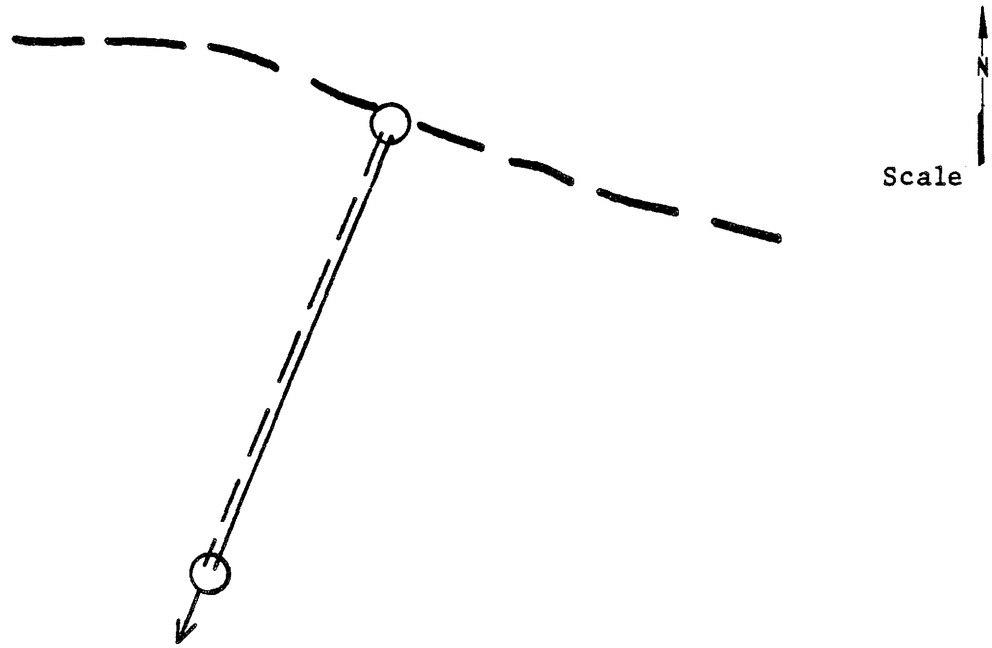


Spring location map, Schoolhouse Springs study area.

Spring location



Schoolhouse Spring 1



Scale 1" = 10'

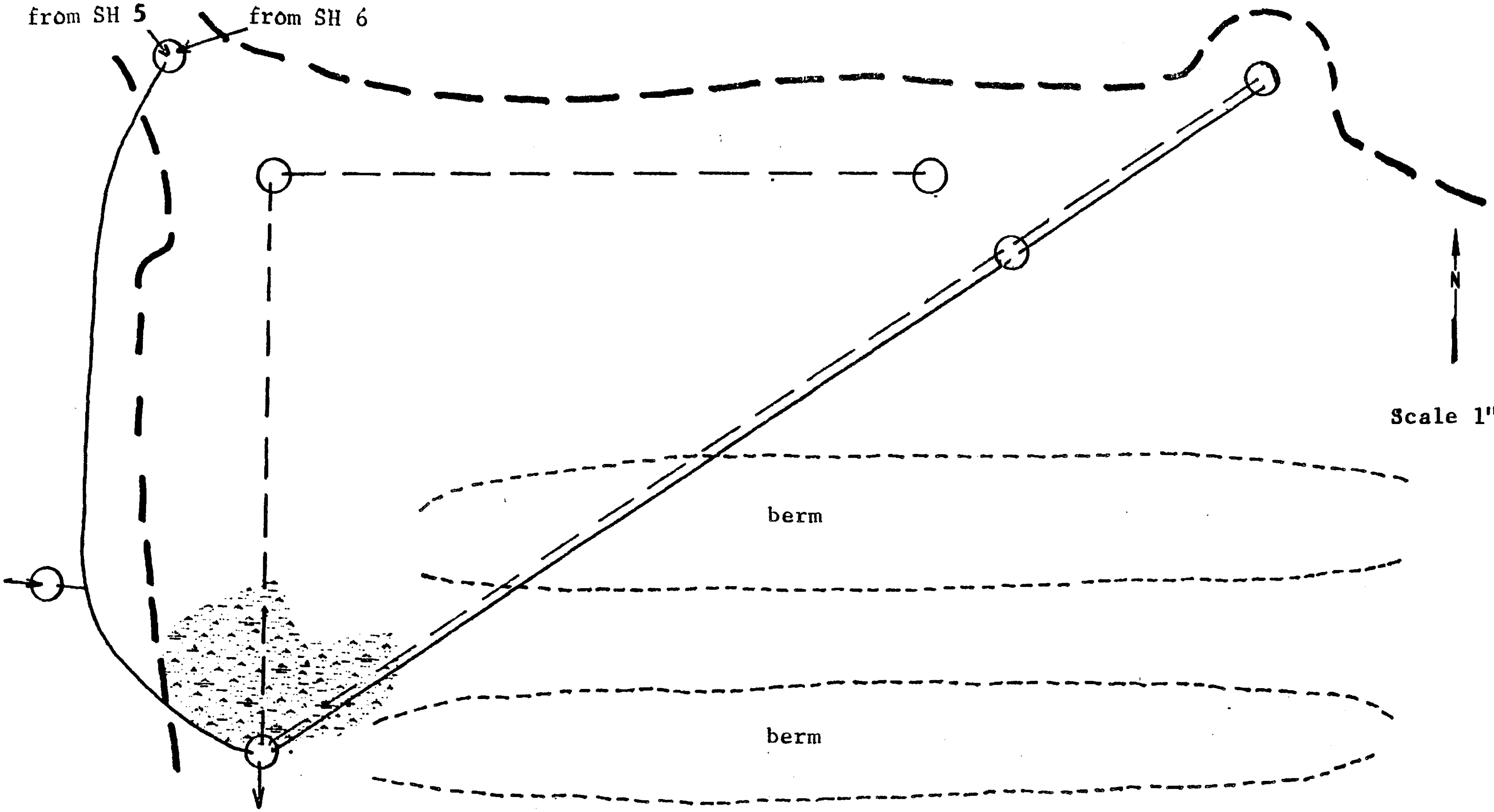
Schoolhouse Spring 3

Slope boundary

6" diameter perforated clay pipe (collection line)

8" diameter solid steel pipe (distribution line)

36" diameter galvanized steel collection box/manhole



Schoolhouse Spring 4

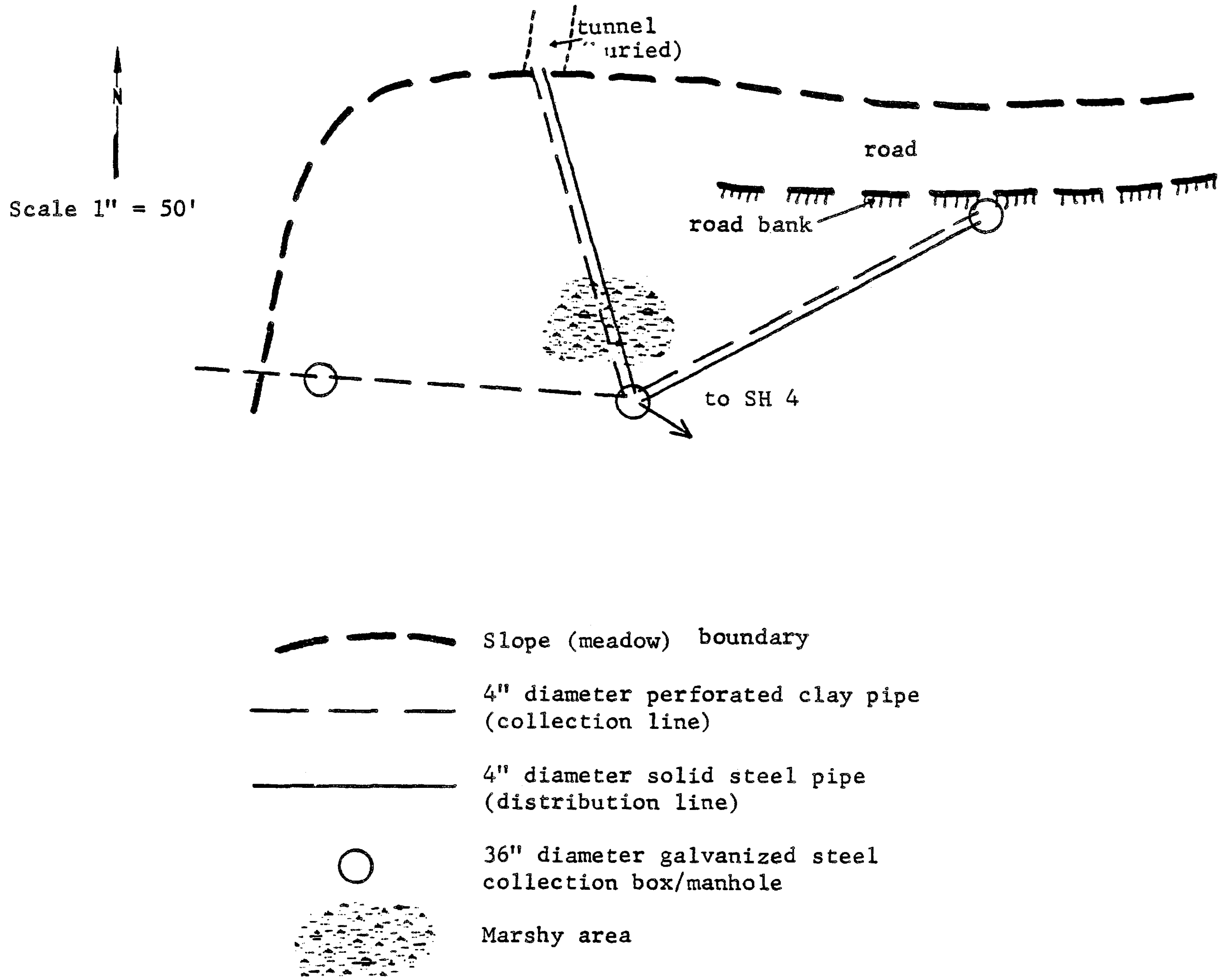
Slope (meadow) boundary

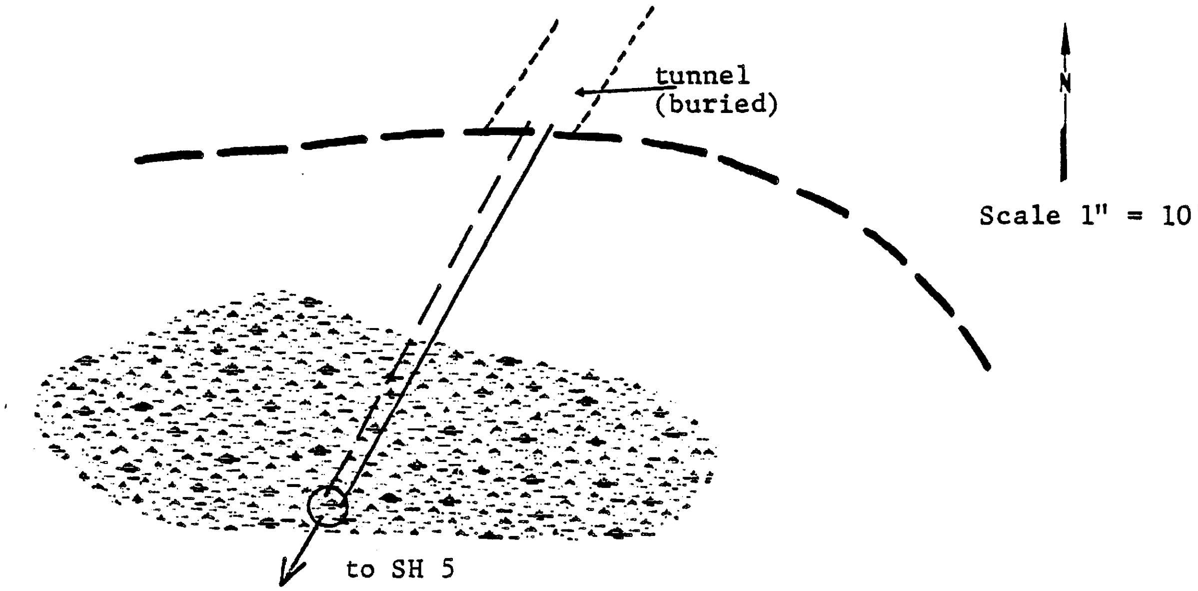
4" diameter perforated clay pipe (collection line)

4 and 6" diameter solid steel pipe (distribution line)

36" diameter galvanized steel collection box/manhole

Marshy area


tunnel
uried)
N
Scale 1" = 50'
road
road bank
to SH 4
Slope (meadow) boundary
4" diameter perforated clay pipe (collection line)
4" diameter solid steel pipe (distribution line)
36" diameter galvanized steel collection box/manhole
Marshy area



Schoolhouse Spring 6

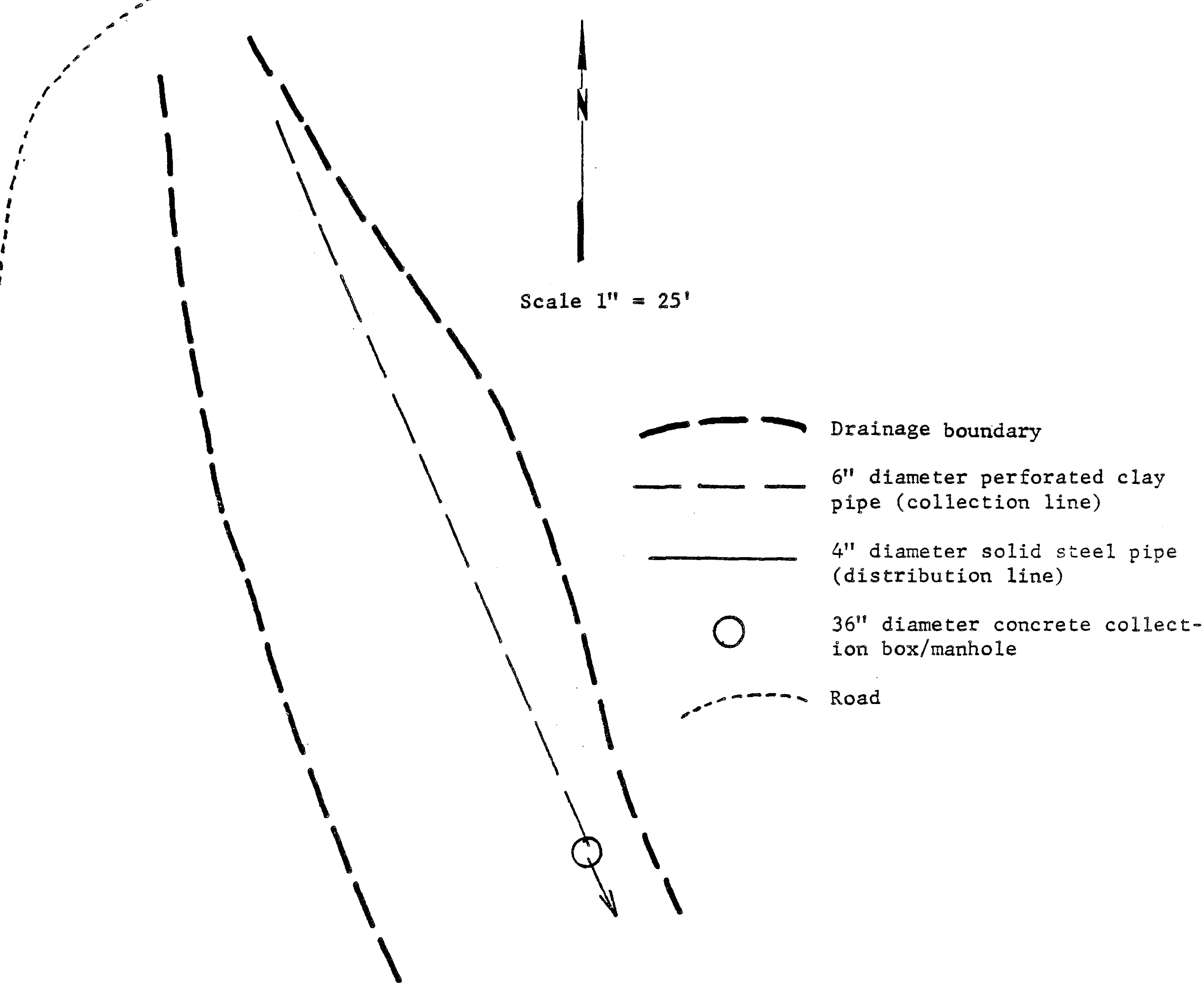
Slope boundary

4" diameter perforated clay pipe
(collection line)

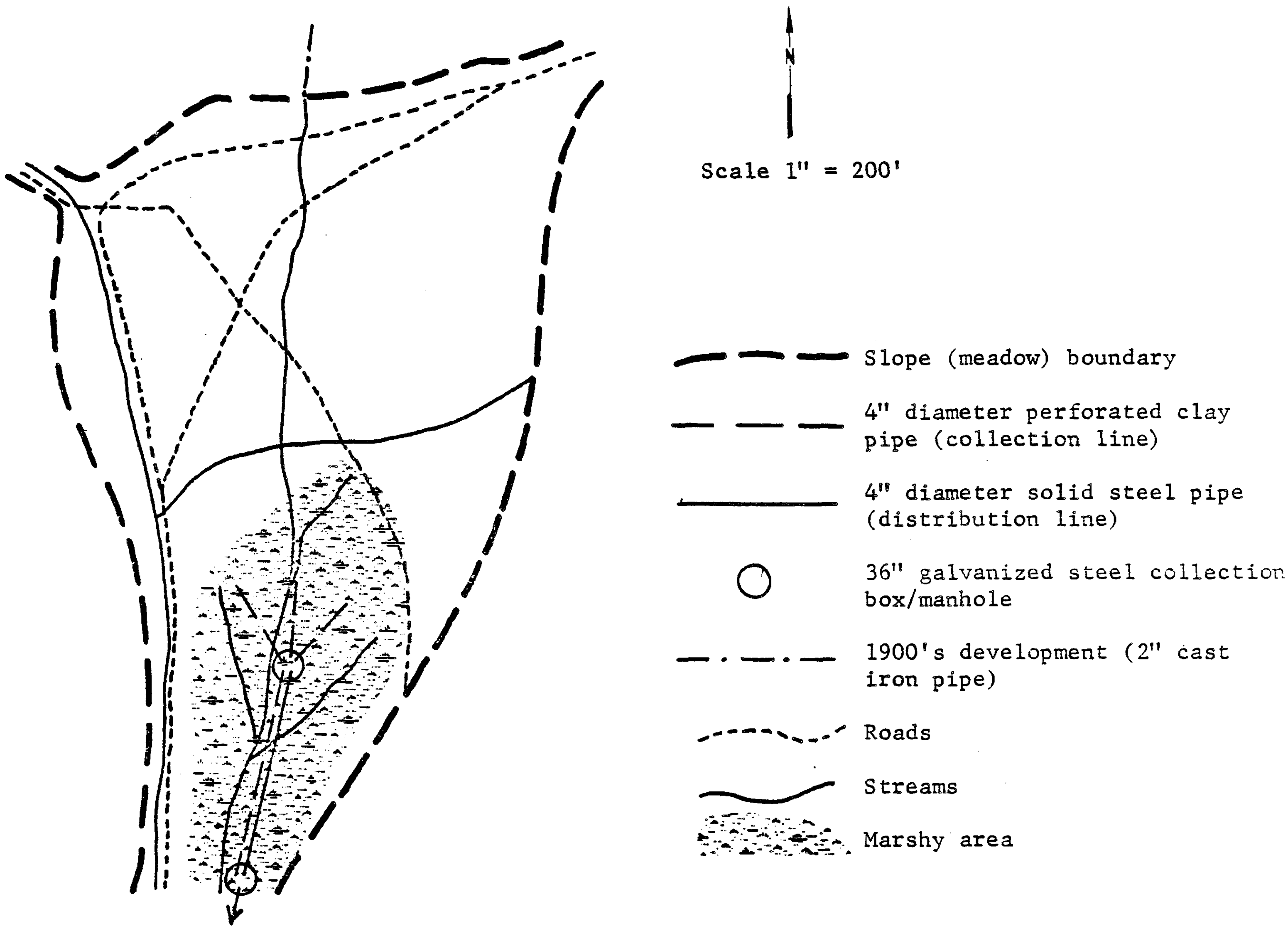
4" diameter solid steel pipe
(distribution line)

36" diameter galvanized steel
collection box/manhole

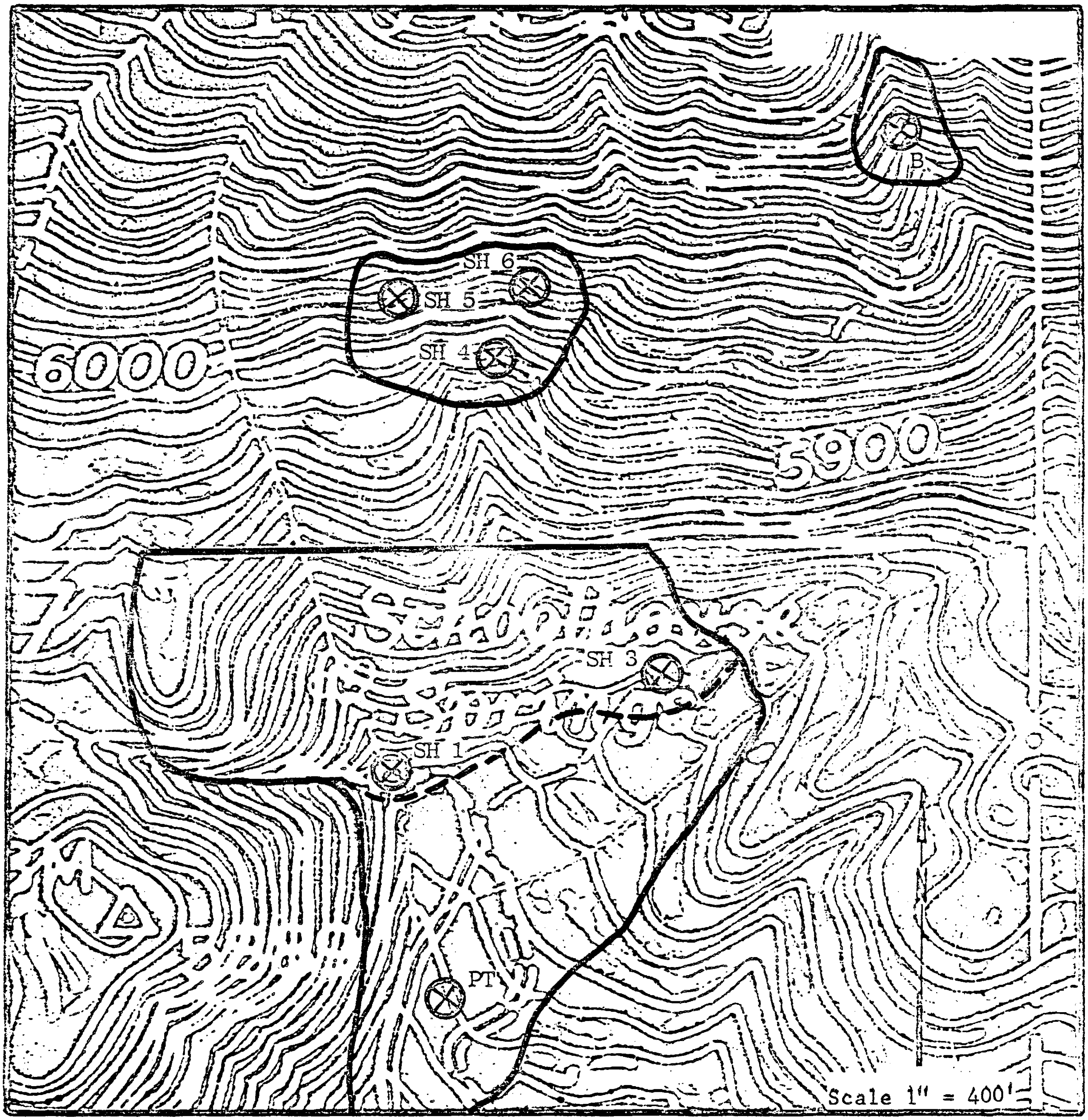
Marshy area



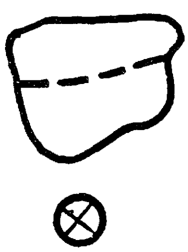
<u>Birch Spring</u>



Pig Trough Spring



Minimum protection zone, Schoolhouse Springs study area.



Protection zone boundary (area south of dotted line would be eliminated if Pig Trough Spring is removed from the culinary system)

Spring location

Project:			Requesting Agency:
Springs and debris flow evaluation for the Manila Culinary Water Company			Manila Culinary Water Company
By: R. H. Klauk	Date: 11/26/84	County: Utah	Job No.: SP-6
USGS Quadrangle: Timpanogos Cave (1129)			

PURPOSE AND SCOPE

This report presents the results of an investigation of two springs located in the NW1/4 of sec. 16 and the NE1/4 of sec. 17, T. 5 S., R. 2 E., Utah County, Utah (attachment 1). The purpose of this study was to determine: 1) the best method for developing the second spring which has appeared within the past two years and is located approximately 400 feet north of a developed spring, and 2) the most effective method of stabilizing a water line that extends from the developed spring across a recently active earth flow to a reservoir (attachment 1). The study was conducted at the request of Boyd L. Fugal, president of the Manila Culinary Water Company.

The scope of work for this study included: a review of published geologic and hydrologic literature pertinent to the area, communication with Mr. Fugal, air photo analysis, and a field reconnaissance on October 25, 1984. No test pits or other subsurface investigations were performed during this study.

BACKGROUND

According to Mr. Fugal (written commun., October 17, 1984), an earth flow has pushed a 6-inch cast iron pipe, connecting a spring collection box with a storage reservoir, out of alignment. See attachment 1 for the location of the water line with regard to the earth flow. Movement of the earth flow was first detected in February, 1983, but three surges have occured since then. The final recorded movement, in January, 1984, severed the line causing an offset of 4 feet vertically and 12 feet laterally. Prior to that time, the pipe was buried at a depth of approximately 4 feet in the vicinity of the break. To repair the damage, the water company installed 150 feet of new pipe at an average depth of 9 feet along the previous alignment. No movement of the pipe or the earth flow has been observed since installation of the new water line.

The new spring has developed in the remnants of a trench excavated by the water company in 1955 (B. Fugal, oral commun., October 25, 1984). The trench was dug in an unsuccessful attempt to locate a tunnel excavated by a former owner to increase flow in a spring. The tunnel was reported to be in bedrock. The trench is presently 10 to 15 feet deep. Mr. Fugal reported that originally the trench was excavated to a depth of approximately 25 feet and no bedrock or water was encountered. The water company abandoned this site and moved to the location of the developed spring. For this report, the developed spring will be referred to as spring A and the new spring as spring B (attachment 1).

GEOLOGY

Bedrock in the study area is principally the Manning Canyon Shale, consisting of black shale and interbedded gray to black shaley limestone. This formation is in fault contact with the Great Blue Limestone less than 200 feet east of spring A (attachment 2). Spring A issues from a solution cavity in calcareous tufa below a layer of colluvium at a depth of approximately 7 feet. Flow varies from a maximum of 200 gpm in the fall to a minimum of 150 gpm at other times of the year (Mr. Fugal, oral commun., November 25, 1984). The calcareous tufa has been deposited by the spring(s) on the Manning Canyon Shale. The tufa deposit appears extensive; a massive 15-foot outcrop was noted west of spring A during the site reconnaissance. Attachment 1 presents the location of the outcrop and an estimate of the areal extent of the tufa deposit. The extent and thickness of the deposit indicates the spring system has been in existance for a considerable period of time. Peak flow for spring A occurs in the fall, indicating that recharge originating as snowmelt and precipitation in the spring of the year has a longer travel time than is normal for shallow ground-water systems. Recharge is believed to be circulating through fracture zones in the Great Blue Limestone, coming in contact with the less permeable or impermeable Manning Canyon Shale at the fault, and migrating to the surface. Spring B issues from colluvium eroded into the abandoned trench and has appeared within the past 2 years, during a period of higher-than-normal precipitation. Its appearance coincided with saturation of the earth flow and may indicate a common source for both; that being a shallow localized ground-water system. Spring B is not thought to be recharged in the same manner as spring A for the following reasons: 1) spring B is at a lower elevation than spring A and would therefore have been flowing previously if both springs were part of the same ground-water system., 2) spring A has not experienced a recent increase in flow indicating that recharge from the last two wet years has not reached the spring.

The earth flow consists of rock fragments in a clay and silt matrix weathered from the Manning Canyon Shale. The flow appears on pre-1973 air photographs (Cluff and others, 1973). Renewed movement of the flow was caused by increases in moisture content caused by a recent rise in the ground-water table. This rise is the result of the recent wet cycle adding more recharge to the local ground-water system. Mr. Fugal indicates no movement was detected from 1955 to 1983, suggesting that the earth flow was present prior to 1955 and the original water line was installed within the unstable material. Recent increases in moisture content of the flow resulted in movement that eventually severed the water line. It is not known at this time if the new, deeper water line has been placed below this material because no geologic examination was made of trenches dug for the new line. Lack of disruption in the new line may be due to non-movement of the earth flow or emplacement below the unstable material. Water discharging from spring B flows accross the earth flow.

CONCLUSIONS AND RECOMMENDATIONS

Although thought to be recharged by a shallow ground-water system the source of spring B is not known with certainty. Before development of the spring can be justified, more information is needed. We recommend, therefore, that the following data be collected prior to development. First, monitor flow rates preferrably for a year or longer. Fluctuations in discharge occurring simultaneously with those in spring A would indicate a common source of recharge. However, peak discharge occurring in late spring or early summer is characteristic of shallow flow systems which may dry up during years of normal or below normal precipitation. Second, complete chemical analyses for both springs. Similar chemistries will indicate a common source, while, dis-similar chemistries will indicate different sources.

It is not necessary to move the existing water line at this time. However, the line should be monitored closely for future movement. If such movement occurs, the pipe should be relocated to the south, off of the earth flow and on to the tufa deposit. This would place the pipe in a stable area. It is also recommended, that discharge from spring B be diverted away from the earth flow, to reduce moisture content of the unstable material and increase stability.

Selected References

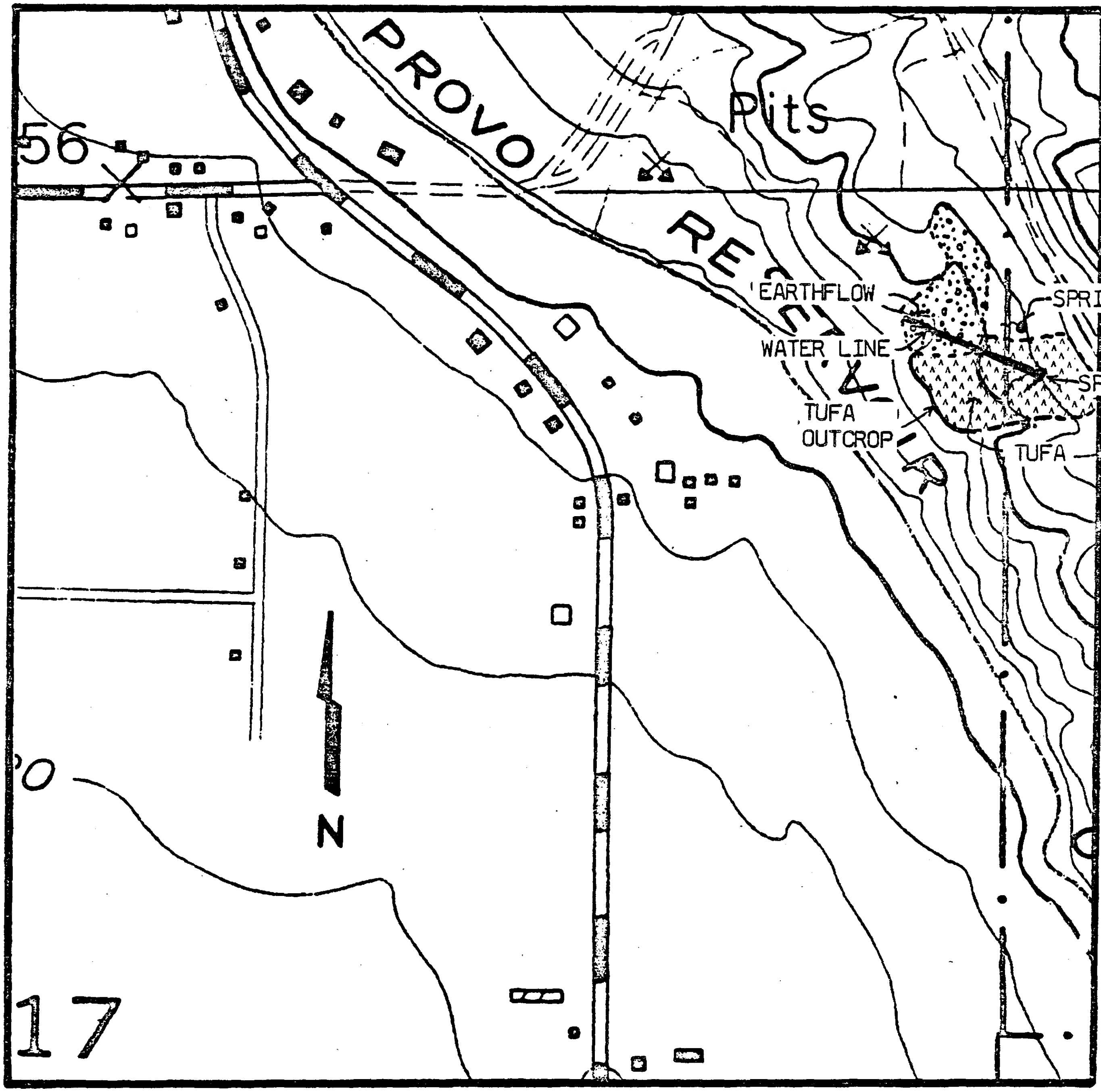
Baker, A.A., and Crittenden, M.D., Jr., 1961, Geologic map of the Timpanogos Cave quadrangle, Utah: U.S. Geological Survey Quadrangle Map GQ-132, scale 1:24,000.

Clark, D.W., and Appel, C.L., 1984, Ground-water resources of northern Utah Valley, Utah: U.S. Geological Survey Open-File Report 84-455, 110 p.

Cluff, L.S., Brogan, G.E., and Glass, C.E., 1973, Wasatch fault southern portion, earthquake fault investigation and evaluation: Woodward-Lungren and Associates, Oakland, California, 79 p.

Hunt, C.B., Varnes, H.D., and Thomas, H.E., 1953, Lake Bonneville:geology of northern Utah Valley, Utah: U.S. Geological Survey Professional Paper 257 A, 99 p.

R. 2 E.



T. 5 S.

Base map modified from: U. S. G. S. 7 1/2' topographic quadrangle map Timpanogos Cave, Utah.

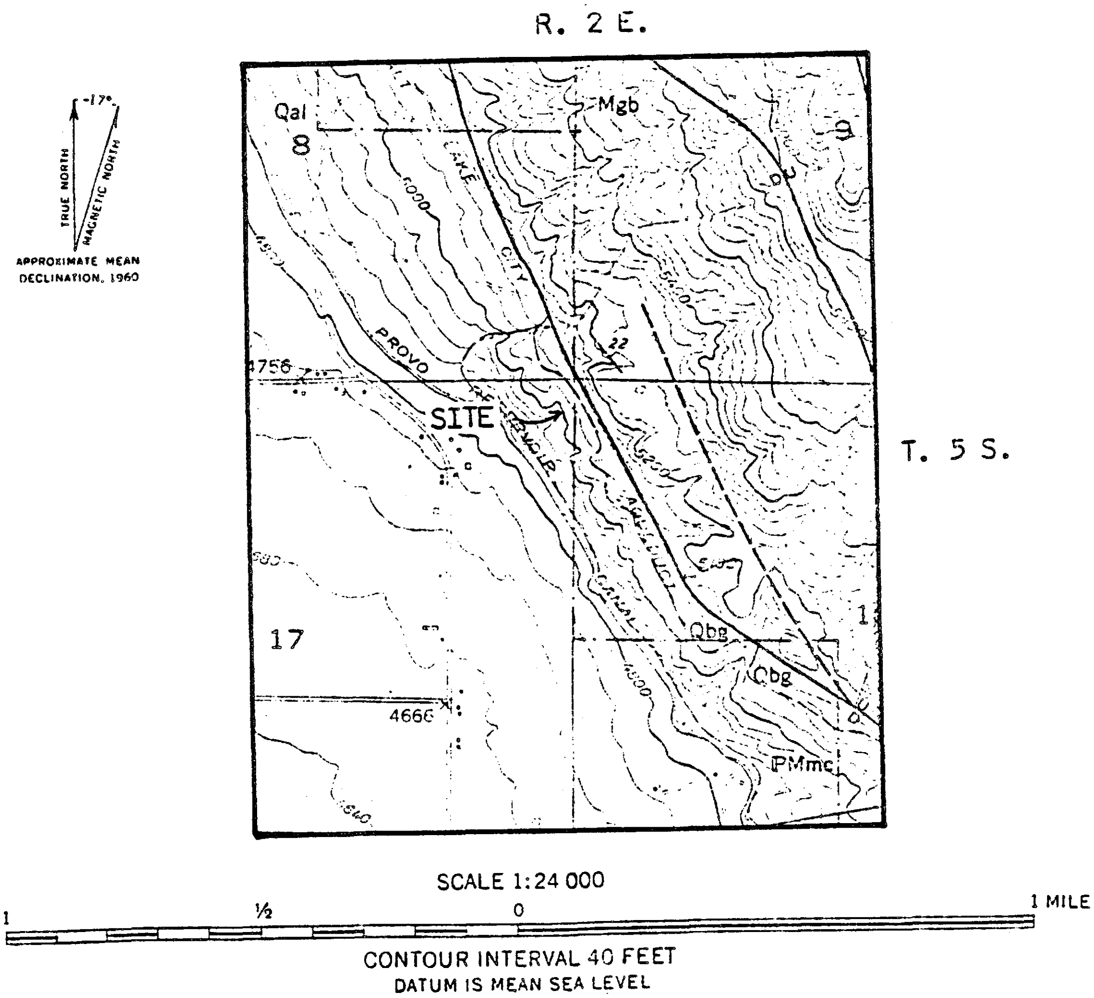
SCALE

0 1/10 2/10 3/10 MILE

CONTOUR INTERVAL 40 FEET

Location of the Manila Culinary Water Company springs

Location of the Manila Culinary Water Company springs area.



EXPLANATION

Qal Qt
Qls Qbg

Alluvial deposits

PMmc

Manning Canyon shale

Mgb

Great Blue limestone

Mh

Humbug formation

Contact

Dashed where approximately located, dotted where concealed

Fault, showing dip

Dashed where approximately located, dotted where concealed. U, upthrown side; D, downthrown side

Strike and dip of beds

Base map modified from: Baker and Crittenden, 1961.

SANITARY LANDFILLS

Project: Summit County landfill, Brown's Canyon			Requesting Agency: Bureau of Solid and Hazardous Wastes, Utah State Dept. of Health
By: G. E. Christenson	Date: 9/5/84	County: Summit	Job No.: LF-1
USGS Quadrangle: Park City East (1209)			

BACKGROUND

In response to a request from Kent Montague of the Utah State Department of Health (Bureau of Solid and Hazardous Waste), a preliminary geological analysis of a proposed landfill site in Summit County was performed. The analysis covered the Browns Canyon part of section 29, T. 1 S., R. 5 E., SLB&M (attachment 1) east of Park City. The scope of work included a literature review and interpretation of air photos. A field reconnaissance and subsurface investigation for a landfill site in section 32 of the same township has been performed previously (see UGMS Memo of October 25, 1983 from Gary E. Christenson to William R. Lund). A field investigation was not conducted for this study.

SETTING

The site area is in Browns Canyon south of Highway 196 about midway between Peoa and Keetley Junction. A ridge trends from southwest to northeast diagonally through the center of section 29, reaching elevations of up to 7200 feet. Browns Canyon traverses the southeast corner of the section, with canyon-bottom elevations ranging from about 6900 feet in the south to 6700 feet in the north. An intermittant stream flows in the canyon from south to north in response to snowmelt and cloudburst storms. The exact location of the proposed site in section 29 is not known.

GEOLOGY AND SOILS

Section 29 is underlain by Oligocene-age volcanic rocks of the Keetley Volcanics (Bromfield and Crittenden, 1971). Rhydacitic to andesitic volcanic breccia are found in the ridge northwest of Browns Canyon. The strike of bedding in the volcanic rocks is generally parallel to the ridge (northeast), with dips of 25-45 degrees to the northwest. Several northeast-trending faults along the flanks and crest of the ridge have been mapped, as well as several isolated outcrops of Mesozoic sedimentary rocks (Ankarah Formation and Nugget Sandstone). Browns Canyon is underlain by tuff and volcanic gravels. Although not confirmed by field inspection, observations made in the previous study and by Baker (1970) regarding the highly fractured nature of the rock probably apply.

Alluvium through section 29 in Browns Canyon is probably thinner than that found in section 32, which exceeded 8-10 feet in the canyon bottom. USDA Soil Conservation Service and others (1977) maps show the soils in the canyon bottom to consist principally of gravelly and cobbly clay loam overlying andesitic bedrock at a depth of 35 inches. Soils along the valley flanks are generally thinner and more coarse-grained.

GROUND WATER

Tertiary volcanic rocks similar to those at the site provide water to more wells in the Heber-Park City-Kamas area than any other bedrock formation (Baker, 1970). All rock units are highly fractured and, on a broad scale, act as a single aquifer with water contained in interconnecting fractures. On a local scale, the permeability of the rock aquifer depends on the degree of interconnection and width of fractures. Water is recharged into the fracture system from the surface and moves rapidly downward. A well six miles south of the site in Tertiary volcanic rocks shows a water-level rise within hours of precipitation events (Baker, 1970).

According to records at the Utah State Engineer's office, a well is located in Browns Canyon in section 29 (attachment 1). This well is on the south side of the canyon and had a static water level on May 30, 1977 of 86 feet below the surface. The location of this well has not been confirmed, but if present it indicates a relatively shallow depth to ground water in the area. Some question as to the well location exists because the driller's log indicates clay and boulders to 70 feet overlying blue shale to 205 feet. Interpretations by Bromfield and Crittenden (1971) indicate volcanic rock at or near the surface extending to a depth of several hundred feet in this area. Another well to the northeast in section 21 (attachment 1) recorded 90 feet of clay over volcanic bedrock to 300 feet with water encountered at 260 feet. No static water level was recorded. In any case, although the depth to water is uncertain, section 29 is probably a site of recharge to local bedrock aquifers.

Shallow ground water in canyon-bottom alluvium was encountered in test pits excavated for the previous investigation in section 32. The ground water was not thought to indicate that the entire thickness of alluvium was saturated, but rather appeared to be water infiltrating from the surface and moving laterally through the ground along permeable layers. Ground water conditions in alluvium in section 29 are not known.

PRELIMINARY EVALUATION OF SITE SUITABILITY FOR A LANDFILL

In general, conclusions and recommendations made for the site in section 32 apply in section 29. Geologic and hydrologic conditions in the two areas are similar. However, sites in section 29 are probably less suitable than the site previously investigated in section 32 because soils (alluvium) are thinner and bedrock more near the surface, creating a greater potential for contamination of ground water and providing less material for cover. The presence of faults in section 29 may indicate a greater degree of fracturing and higher permeability of rock aquifers which would increase the potential for contamination of ground water. Because of these potential problems, we suggest a thorough field investigation before proceeding further with plans for a landfill at this site. Based on this preliminary analysis, conditions appear to be less favorable than those in section 32 and recommendations for further work at that site apply to this site as well.

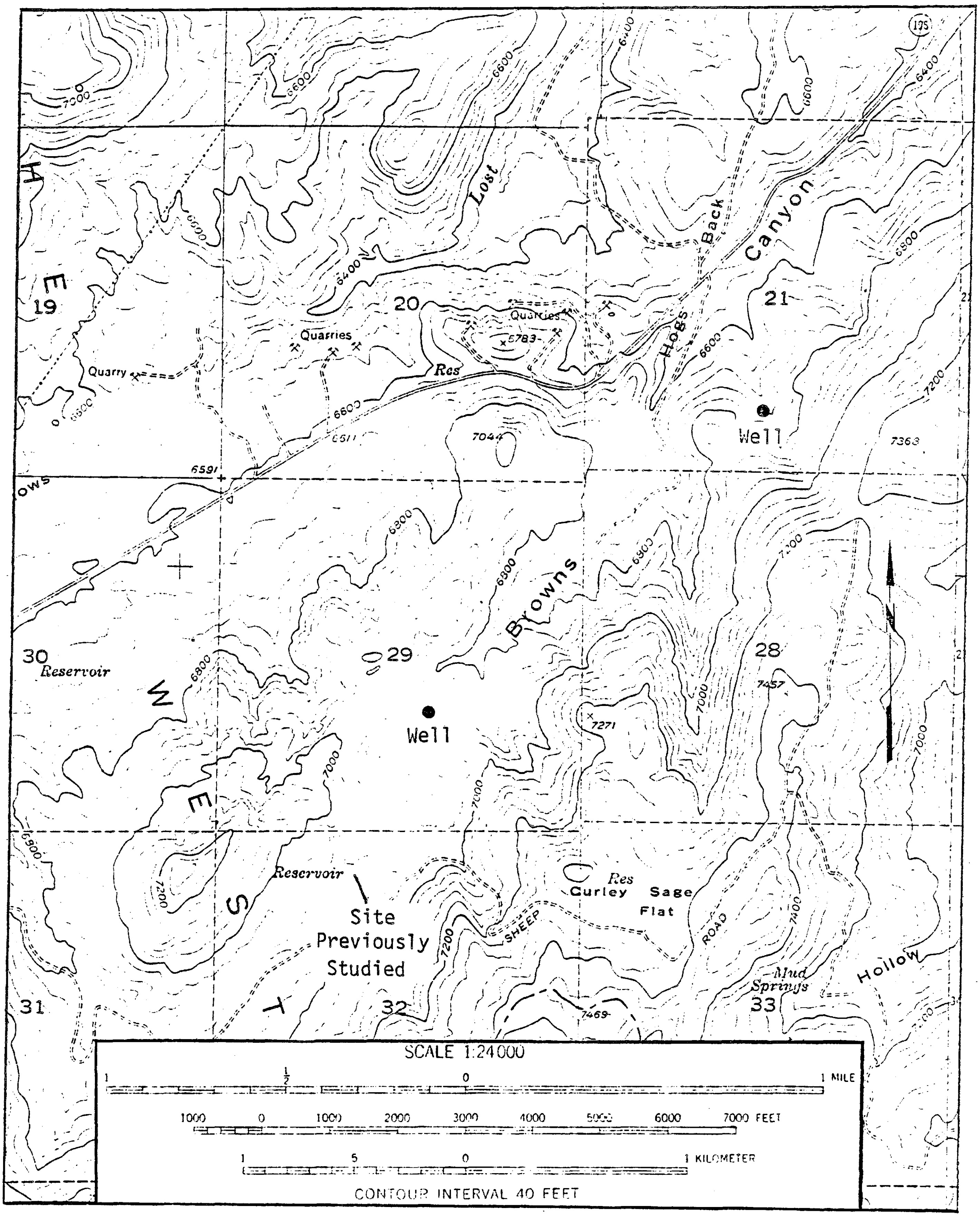
REFERENCES

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

USDA Soil Conservation Service, Utah State University, Summit County Commission, and Park City Planning Commission, 1977, Soil survey and interpretations, Parley's Park portion of soil survey of Summit Valley, Summit County, Utah: Utah Agricultural Experiment Station Bulletin 495, 302 p.

Base map from: USGS 7.5 Topo Quad
Park City East, Utah



Location Map

WASTEWATER DISPOSAL

Project:			Requesting Agency:
Review of soil and percolation test results to determine suitability for a deep trench soil absorption system			City-County Health Dept. of Utah County
By: W. R. Lund	Date: 1/13/84	County: Utah	Job No.: WW-1
USGS Quadrangle: Timpanogos Cave (1129)			

A review has been made of soil test results provided by the City-County Health Department of Utah County for lot 13-C in Cedar Hills subdivision. The purpose of the review was to determine soil suitability for a deep trench (greater than 8 feet) soil absorbtion system proposed for the lot. Because detailed soil logs and sieve analyses are not available, this evaluation is based on the soil consistency (Atterberg) limits reported by the developer's engineer and the results of nearby percolation tests. It is also understood (D. Johnson, oral comm., 1984) that a percolation test was run on lot 13-C and that the infiltration rate was slower than 60 minutes per inch. The actual percolation rate determined from that test was not included in the information provided by the health department.

Based on the consistency limits, the developer's engineer has correctly classified the soils on lot 13-C according to the Unified Soil Classification System. The soils below a depth of 8 feet are clays (CL) and clay-silt (CL-ML) mixtures, and as such normally exhibit low permeability. A high percentage of sand and gravel mixed with the clay could increase permeability, but grain-size distribution information is not available for the soils. Percolation test results from nearby lots (12-C, 15-C, 18-C, 20-C) show a wide range of infiltration rates both above and below 60 minutes per inch (the lower limit of allowable percolation rates for soil absorption system installation). No information was provided on the soil types in which the tests were taken or their depth, but it is assumed that the slow rates came from deep clay soils and the fast rates from shallow (0 to 8 feet) silty soils. If this is the case, it would indicate that the clay soils are nearly impervious and not suitable for soil absorption systems. However, if percolation rates faster than 60 minutes per inch were obtained from the clay soil, it may reflect a high percentage of sand and gravel in the clay or the presence of secondary soil structures (desiccation cracks, root holes, etc.) in the soil mass. While a gravelly or sandy clay may possess sufficient permeability to be acceptable for soil absorption system installation, any increased permeability resulting from secondary soil structures would quickly be eliminated as the clay absorbs water and expands.

It is recommended that sieve analyses be performed for the soils on lot 13-C and that an additional percolation test be run in the clay soils below a depth of 8 feet. If a significant percentage of sand and gravel is present and the percolation rate is faster than 60 minutes per inch a deep trench soil absorption system should function satisfactorily. If no sand or gravel is found, a percolation rate greater than 60 minutes per inch likely reflects the presence of secondary soil structures which will close with time, leaving the soil nearly impervious. Installation of a deep soil absorption system is not recommended under those conditions.

Project: Reconnaissance of subsurface disposal ponds for produced water from oil and gas wells, Chalk Creek Canyon			Requesting Agency: Summit County Health Department
By: G. E. Christenson	Date: 5/29/84	County: Summit	Job No.: WW-2
USGS Quadrangle: Turner Hollow (1290) Upton (1289)			

PURPOSE AND SCOPE

The purpose of the investigation was to evaluate the potential for leakage and ground-water contamination from surface disposal ponds at two sites in Chalk Creek Canyon east of Coalville. The ponds are used to dispose of produced water from oil and gas wells and are regulated under Part VI of the Utah State Department of Health Wastewater Disposal Regulations. The sites are located north of Highway 133 about five miles (Ron Robinson property; NE 1/4, sec. 7, T. 2 N., R. 6 E.; attachment 1) and 14 miles (Wayne Jones property; NE 1/4, sec. 5, T. 2. N., R. 7. E.; attachment 2) east of Coalville. The ponds at both sites have been in operation for about a year. A brief field reconnaissance was performed at each site to look for leakage and to evaluate geologic conditions. A literature review and air photo analysis were also completed. Robert Swenson of the Summit County Health Department was present during the investigation and Mr. Robinson and Mr. Jones were contacted for discussions of their respective sites.

SITE CONDITIONS

Robinson Property

Two ponds are present at the site; a larger pond to the south and smaller pond to the north. They are located on an alluvial fan at the mouth of an unnamed drainage that flows onto Chalk Creek (attachment 1). The site was previously investigated by the Utah Geological and Mineral Survey (letter of June 6, 1983 from Harold E. Gill to Steve Jenkins), and soils were found to consist of a lower red sandy clay overlain and cut by coarse-grained stream deposits containing sand, gravel, and cobbles. According to the landowner, in situ soils were used to construct embankments and an unknown thickness of bentonitic lining material was placed in the bottom of the ponds. Embankments are composed of red sandy clay except in access areas where rounded stream gravel and cobbles have been imported to improve trafficability.

No data on subsurface conditions at the site are available. The thickness and nature of alluvium in the valley are not known, and bedrock structure in the area is complex. The site is near the intersection of a north-trending anticlinal axis and a northwest-trending fault in Cretaceous-age sandstone and shale (Shelley, 1959). Coarse-grained layers within the alluvium and massive, fractured sandstone layers in the bedrock are both potential aquifers, and both may recharge the alluvial aquifer in Chalk Creek which is used for culinary water.

Evidence of leakage through embankments was not found at the site. A stream channel up to 10 feet deep to the east and the highway cut to the south were also checked for evidence of seepage from the ponds, but none was found. The possibility of downward leakage into aquifers beneath the ponds remains a possibility which can only be evaluated through subsurface investigations. No percolation tests on in situ soils or on lining materials have been made, and no monitoring wells have been drilled.

Potential problems in embankments are visible in the form of open longitudinal cracks along the crest of the southernmost embankment. These are an indication of soil shrinkage and cracking with subsequent erosion which may result in a piping or internal erosion problem in the embankment. These embankments were reportedly constructed with scrapers which removed material from the pond bottom and placed it in embankments. Control over compaction and moisture content during placement of the fill is not documented. In addition, a potential erosion problem exists in the northeast corner of the ponds where the stream from the canyon to the north is deflected to the east by the embankments. Embankment soils are fine-grained and no riprap has been placed to protect the fill from erosion. Undercutting is not evident to date, but extreme cutting may occur during a cloudburst flood.

Jones Property

The site contains two long, narrow, east-west trending ponds which parallel Highway 133 (attachment 2), with the southern pond partitioned into several separate areas. It is located on a bench cut into a steep hillside which is underlain by shale of either the Cretaceous Wanship Formation (Intermountain Association of Geologist, 1969) or Tertiary-Cretaceous Wasatch and Evanston Formations (Mullens, 1971). The cut north of the ponds exposes variegated shales dipping gently to the west overlain by deposits of clean, rounded, limonite-stained, sandy gravel with cobbles of a probable Chalk Creek river terrace. The weathered shales and terrace materials have apparently been mixed and used in embankments. These embankments contain gravel, cobbles, and boulders in a sandy clay matrix. Materials exposed in the westernmost partition in the southern pond appear to be in-place terrace gravels for the total depth of the pond (approximately 10 feet), with none of the underlying shale exposed. Bentonitic clay was reportedly used to line the northern pond, but the southern pond is unlined. No percolation rate data on in situ soils or lining materials are available.

Subsurface geohydrologic data are lacking, but it is unlikely that the terrace gravel or underlying shales are important aquifers. However, the alluvium of Chalk Creek is an important local aquifer which may be contaminated by water leaking from the ponds. At present, water seeping from the slope into the highway borrow pits may ultimately be infiltrating into this alluvium. Rock aquifers beneath shale beds, if present, may potentially be contaminated as well.

Slumping is occurring in the western end of the southern embankment with formation of arcuate cracks in the top of the fill and seepage of water in the toe area of the slumps midway down the embankment. This zone of slumping is above the water level in the nearest pond, and does not appear to be related to seepage from the pond. However, wet zones probably indicative of slow seepage through the southern embankment are evident at its western end below ponds containing water. No seepage was evident at the contact between the embankment and the underlying natural slope, but contaminated water is seeping below this zone from the natural slope into the borrow pit along the north side of Highway 133. Leakage of water from the ponds has probably built up a perched water table on less permeable shale beds beneath stream gravels, colluvium, and fill in the pond area. The limonite (yellow) stain in the water seeping in the borrow pit area may be derived from a similar natural stain in the terrace gravels, but oil residues are also present. Chemical analyses of seepage water would be advisable to more conclusively determine its origin.

CONCLUSIONS AND RECOMMENDATIONS

Utah State Department of Health regulations state that surface disposal ponds for produced water from oil and gas wells may use either in situ soils or clay liners (minimum 2 feet thick) to contain wastewater as long as maximum permeabilities are less than 10^{-6} cm/sec. Where it can be demonstrated that wastewater will not migrate to aquifers or otherwise cause contamination problems, these permeability restrictions may be relaxed. Neither case has been adequately demonstrated through geotechnical studies or lab testing at these sites. Monitoring of ground water is also required, but no monitoring wells are in place. Regulations require at least one well either to the first aquifer zone or to 200 feet (whichever is shallower) in the downdip direction. The well is required to be at least 10 feet but not more than 50 feet from the edge of the disposal site or as requested by the regulating agency.

We recommend that these ponds be brought into compliance with Utah State Department of Health regulations. This includes a geotechnical evaluation of the site with soil testing and subsurface exploration. Percolation tests on soils in pond bottoms and sides should be performed. If in situ soils are of sufficiently low permeability, soil test borings or pits are required to demonstrate the continuity of these impermeable soil layers in the subsurface. If soils are too permeable, clay liners should be used.

Because little is known of geologic conditions at these sites, particularly with respect to soil types and presence of aquifers, locations and depths of monitoring wells are difficult to recommend. Specifications for well construction are not given in Health Department regulations, but the well must be constructed so that water levels can be adequately monitored and representative water samples taken of the aquifer interval. Staff at the Division of Environment Health (Bureau of Water Pollution Control) should be contacted to obtain recommended well construction specifications. Further conclusions and recommendations specific to each site are:

Robinson Site - No immediate problems are apparent at this site. The major potential problem is downward leakage of contaminated water into either alluvial or rock aquifers below the pits. Based on our reconnaissance, we recommend placing at least one exploratory boring between Highway 133 and the southern pond (just south of the center of the pond area) to a depth of at least 200 feet to evaluate aquifer conditions. This boring should be logged in detail by geotechnical personnel with attention to soil or rock type and presence of water. The boring can be developed as a monitoring well following completion with construction as necessary to monitor the first (most shallow) aquifer encountered.

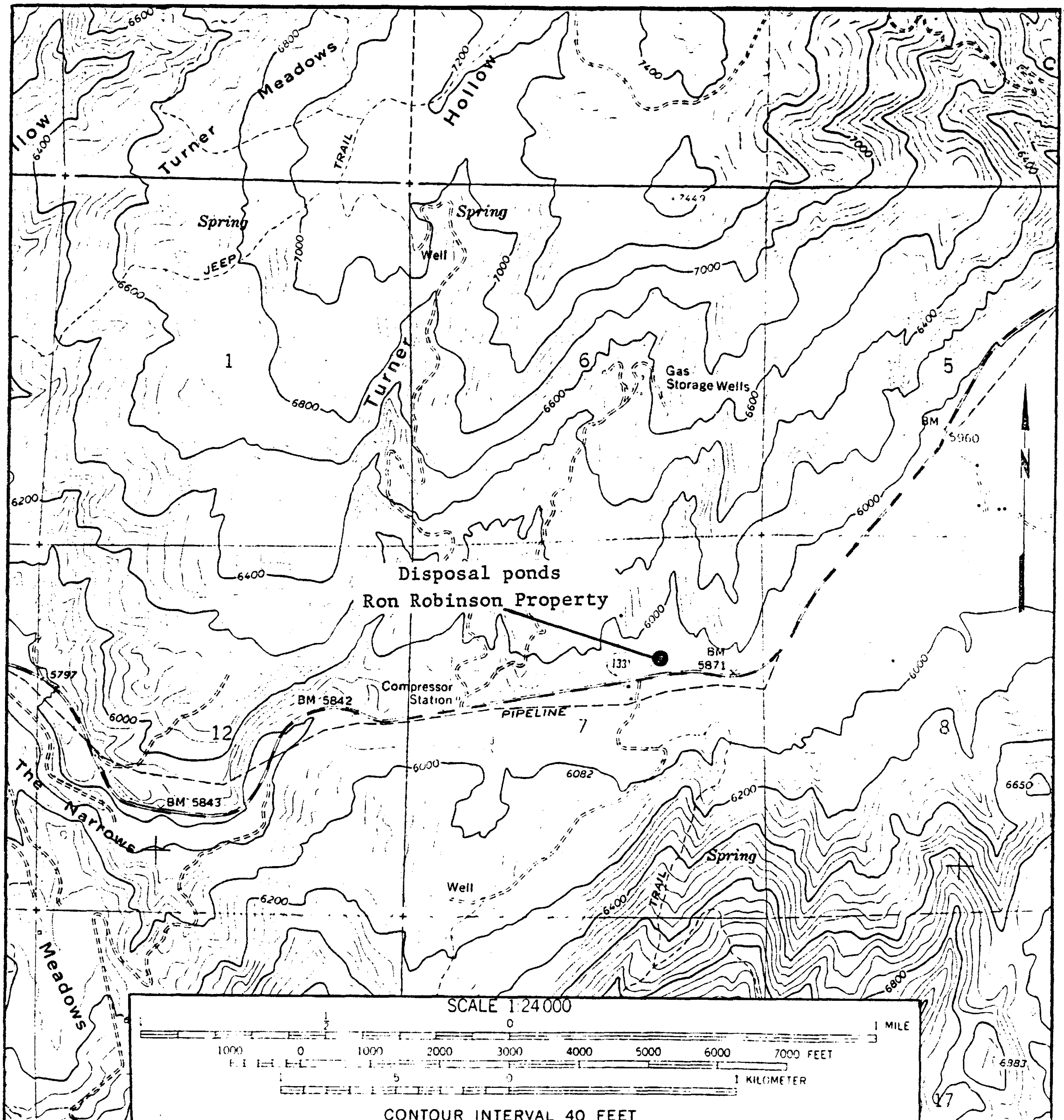
Jones Site - These ponds are on a bench bounded to the south by a steep slope. Leakage from ponds appears to have contributed to a build-up of ground water in this slope with discharge into the borrow pit north of Highway 133. In addition to the environmental contamination caused by this leakage, saturation of the slope may cause instability and possible failure of the slope and embankment. This situation should be corrected by bringing the ponds into compliance with state regulations. It is probable that lining of the ponds will be necessary. Also, a well should be placed as close as possible to the south edge of the site to monitor water quality in the alluvium of Chalk Creek into which the contaminated water appears to be seeping. The ponds are underlain by shale which may protect deeper aquifers from contamination. However, because subsurface conditions at the site may be considerably different from those to the south where the monitoring well should be placed, we suggest an exploratory boring in the pond area. If aquifers are found in this boring, they should also be monitored for water quality. The depth of monitoring will depend on subsurface conditons encountered during drilling, and both borings should be logged by qualified geotechnical personnel.

REFERENCES

Lindsay, J.B., 1969, Geologic guidebook of the Uinta Mountains: Intermountain Association of Geologists Sixteenth Annual Field Conference, 237 p.

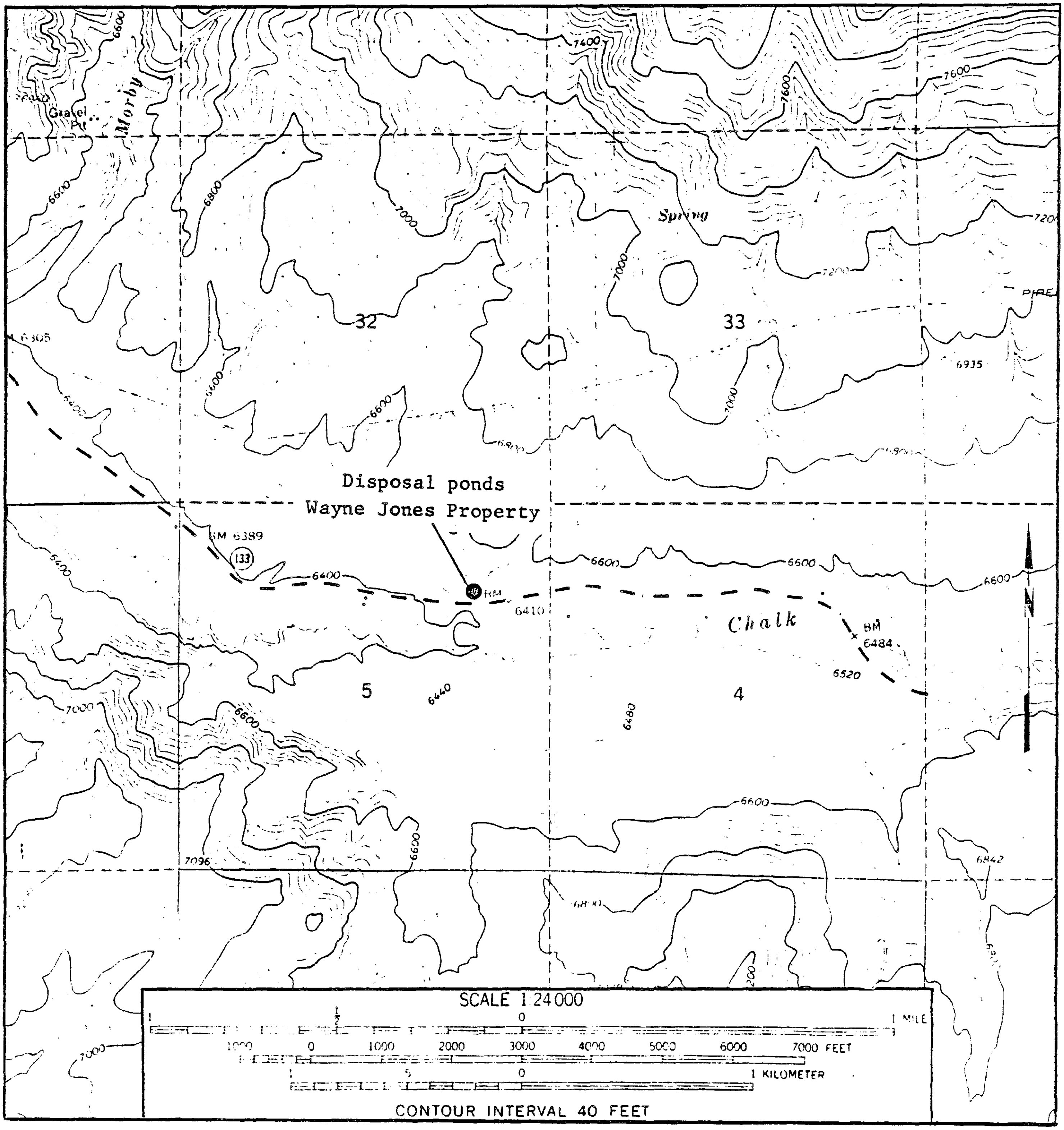
Mullens, T.E., 1971, Reconnaissance study of the Wasatch, Evanston, and Echo Canyon Formations in part of northern Utah: U.S. Geological Survey Bulletin 1311-D, 31 p.

Shelley, C. T., 1959, Coalville anticline, Summit County, Utah, in Williams, N.C., ed., Guidebook to the geology of the Wasatch and Uinta Mountains transition area: Intermountain Association of Petroleum Geologists Tenth Annual Field Conference, p 189-192.



Location of wastewater disposal ponds, Ron Robinson property, Chalk Creek Canyon east of Coalville

Base map from: USGS 7½' topo quad Upton, Utah



Location of wastewater disposal ponds, Wayne Jones property, Chalk Creek Canyon east of Coalville

Project:		Requesting Agency:
Evaluation of fill material placed on a commercial building lot in Providence, Utah		Utah Health Dept. Bureau of General Sanitation
By: W. R. Lund	Date: 7/18/84	County: Cache	Job No.: WW-3
USGS Quadrangle: Logan (1444)		

A geologic investigation was conducted on June 29, 1984, of a commercial building lot in Providence, Utah (attachment 1). The purpose of the investigation was to evaluate the suitability of fill material placed on the lot for installation of an onsite wastewater disposal system. The scope of work included a review of available literature, a field reconnaissance, and examination of three test pits. Present during the site visit were Mr. Steven Thiriot, Utah Health Department; Mr. Joel Hoyt, Bear River District Health Department; and members of Mr. Hoyt's staff.

SITE DESCRIPTION

The property is rectangular and approximately 1.5 acres in size (attachment 2). It is bounded on the north by Spring Creek, on the west by State Highway 165, on the south by 1200 South Street, and on the east by a parking lot for nearby commercial buildings. Spring Creek enters a culvert beneath State Highway 165 at the northwest corner of the property. At the time of the field visit, the culvert could not accomodate the stream flow and minor flooding was occurring north of the lot. A ditch had been dug south from the culvert parallel to State Highway 165 to a point where a subsurface drain reportedly installed on the property (N. Galloway and R. Ball, oral commun., 6-29-84) enters a second culvert beneath the highway. An estimated two second-feet of water was being diverted from Spring Creek through the second culvert.

The ground surface across the property is generally flat. The fill used to bring the lot to grade with adjacent streets could be seen over the entire site. Dumping is still taking place on the southeast portion of the property (attachment 2). In addition to gravel and cobbles, the mounds of recent fill material contained lumber, metal and PVC pipe, broken concrete, cement blocks, asphalt, tires, sod, grass cuttings, and tree limbs.

SUBSURFACE INVESTIGATION

Three backhoe pits were excavated on the property (attachment 2). Ground water was encountered in all three and caving of the test pit walls made examination of the deeper soils difficult. Soils logs are presented in attachment 3. Test pit 1 exposed 0.5 feet of clayey gravelly sand over 1.3 feet of rubble comprised of broken brick, tile, lumber and metal strapping bands in a matrix of clay and clayey sand. An additional 2.1 feet of imported material, mostly gravelly sand with some lumber and twine, increased the total depth of fill to 3.9 feet. Beneath the fill was a dark gray, highly plastic clay with a strong organic odor. Williams (1962) and Bjorklund and McGreevy (1971) identify the clay as the silt and clay member of the Provo Formation deposited in Lake Bonneville. Erickson and Mortensen (1974) of the U.S. Soil Conservation Service classify it as the Collett silty clay loam derived from mixed calcareous lake sediments. The soil was saturated below 4.2 feet and the water level was at 7.0 feet at the time the test pit was logged. Forty-five minutes later the depth to water was 6.4 feet, and it is expected that the water table would have eventually stabilized at 4.2 feet had the test pit remained open. Well developed soil mottling in the clay extending to the contact with the fill material is further evidence of a seasonally high water table. Examination of the material excavated from the test pit showed no evidence of a change in material type below the level of standing water, and it is believed that the clay continued to the bottom of the excavation.

Depth to standing water in test pit 2 was 3.7 feet when it was logged and 3.4 feet 30 minutes later. The soil was saturated below 2.9 feet and that is the level at which the water table is expected to stabilize. Only fill material was exposed in the test pit walls above the level of standing water. It consisted of 0.3 feet of gravelly clayey sand over 3.4 feet of sandy gravel containing some lumber, bricks, and broken cement blocks. Examination of the excavated material indicated that a dark gray to black, highly plastic clay lies beneath the fill. Although the contact between the fill and the clay could not be observed, the backhoe operator indicated that the fill section was 4 to 5 feet thick.

Water was standing in test pit 3 at 2.8 feet. Above that point the test pit walls were dry to moist indicating that the water table had stabilized. Fill extended from the surface to the water table and consisted of 1.4 feet of tan, sandy clay over 1.4 feet of clayey, sandy gravel. The fill was free of construction debris and organic matter. Dark gray, high plasticity clay capped the pile of material excavated from the test pit, indicating that the clay underlies the fill. Leona Lundstrum, Bear River District Health Department, stated that a previous examination of the test pit, prior to stabilization of the water table, had shown the fill to be 5 feet thick.

An examination was made of the material excavated from the shallow ditch connecting the two culverts on the west side of the property. Gravel and large cobbles predominated, but slabs of concrete and asphalt up to 3 feet in long dimension were locally abundant. Numerous void spaces between the randomly placed cement slabs were observed in the sides of the ditch.

CONCLUSIONS

A layer of fill, ranging in thickness from about 3 to 5 feet, covers the property. Its composition is highly variable both horizontally and vertically, and it contains considerable construction debris. Neither the type of material accepted for fill nor its placement appear to have been subject to control. The fill is underlain by a high plasticity, low permeability (Erickson and Mortenson, 1974) clay of unknown thickness. A shallow water table exists on the property. Depth to water may be influenced by proximity to Spring Creek, but the difference in the elevation of the water table between test pits 1 and 3 (4.2 versus 2.8 feet) may be due to a subsurface drain, the exact location of which is unknown. The extent to which the flooding near the northwest corner of the property has effected the depth to ground water is considered minimal. Erickson and Mortensen (1974) state that the Collett silty clay loam is subject to a high water table with an average depth to water of 20 to 36 inches. Bjorklund and McGreevy (1971) show the seasonal depth to water beneath the property to be 0 to 10 feet (attachment 4). Adjacent properties where no fill has been placed are covered with cattails indicating a high water table throughout the area. In addition, the mottling of the clay in test pit 1 is an indicator of a seasonally fluctuating water table that has come within at least 3.9 feet of the ground surface.

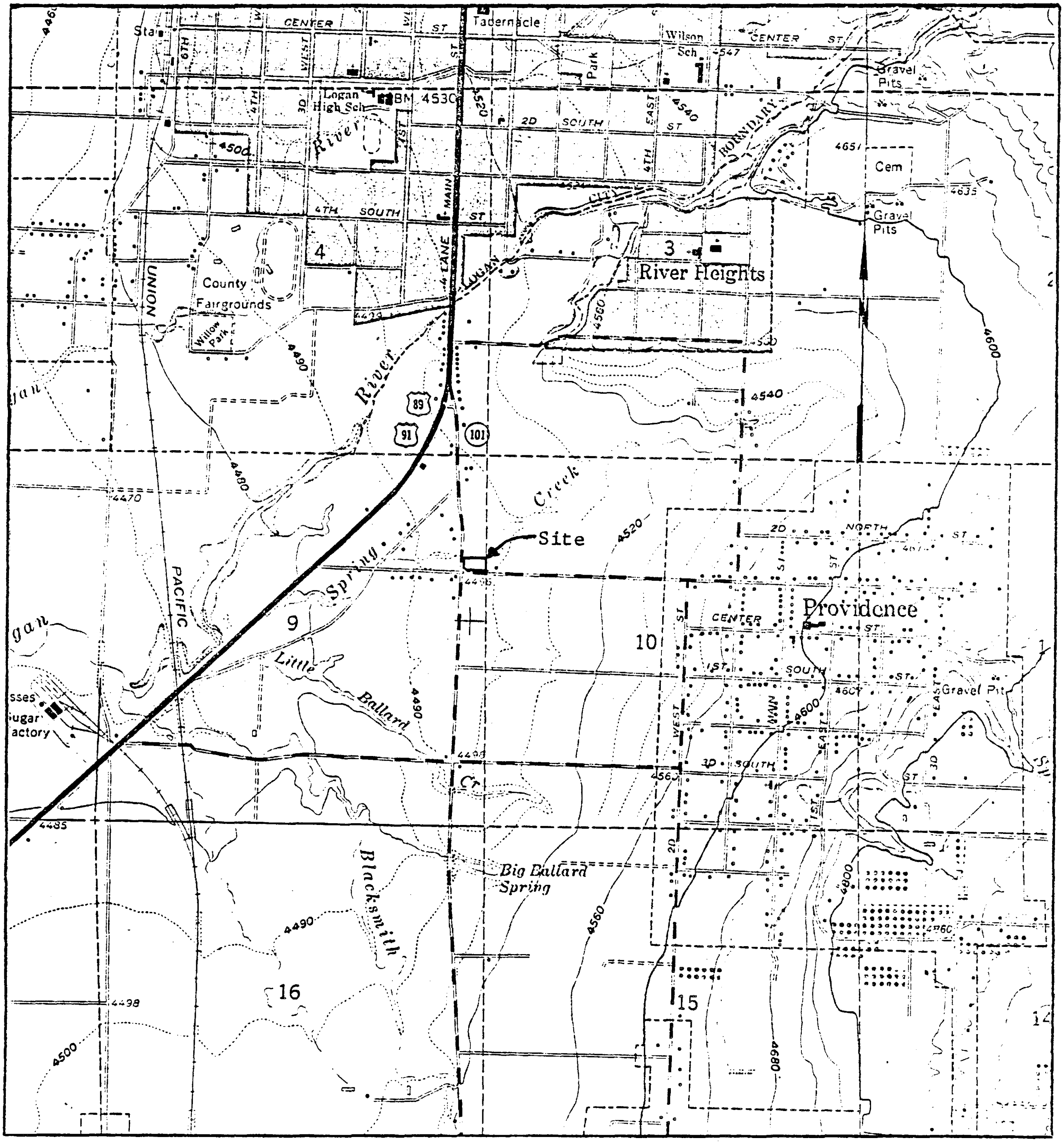
The characteristics of the fill are such (presence of construction debris and trash) that installation of a standard septic tank and soil absorption system is not recommended. Thickness of the fill varies and in places may be so thin that a soil absorption field would be partially or completely in the underlying clay. The clay's high plasticity and low permeability make it unsuitable for such use. The high water table beneath the property further complicates the siting of soil absorption systems. It is unlikely that a standard soil absorption field could meet the required two-foot minimum seperation from ground water on a year-round basis. Considering the nature of the fill, the suitability of a Wisconsin Mound or other alternative wastewater disposal system for the property is questionable. Before proceeding with an alternative system, it is recommended that inquiries be made of the system designer concerning its applicability with such fill, or to other state health departments with experience under similar conditions.

Selected References

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

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

Williams, J.S., 1962, Lake Bonneville: Geology of southern Cache Valley, Utah: U.S. Geological Survey Professional Paper 257-O, 152 p.

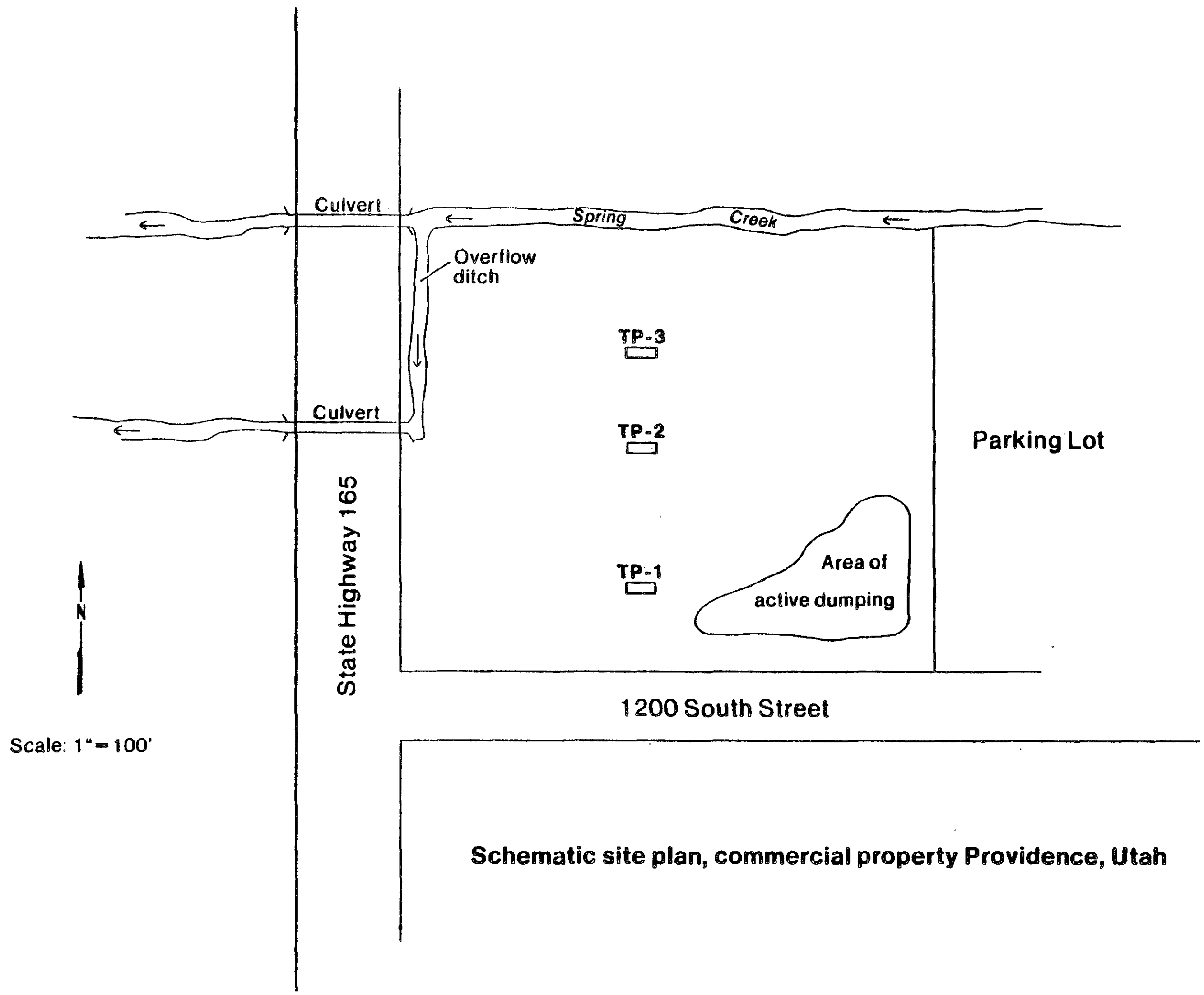


Map showing location of commercial property. Scale 1:24,000

Base from US Geological Survey 7-1/2 minute Logan, Utah topographic map.

Utah Geological and Mineral Survey Site Investigation Section

Attachment 2, Job No. WW-3



Schematic site plan, commercial property Providence, Utah

Utah Geological and Mineral Survey

Site Investigations Section

Attachment 3, Job No. WW-3

Test Pit Logs*

Commercial Property Providence, Utah

<u>Test pit 1</u>

0.0' - 0.5'	Fill; clayey gravelly sand (SC); dark brown, low density, low to medium plasticity fines, moist, nonindurated; 30 percent gravel to 2-inch diameter, 30 percent clay.
0.5' - 1.8'	Fill; broken brick, tile, lumber, and metal strapping bands in a matrix of clayey sand and sandy clay (SC, CL).
1.8' - 3.9'	Fill; gravelly sand (SP); brown, low to medium density, nonplastic, moist to wet with depth, nonindurated; contains some lumber and twine, 40 percent gravel.
3.9' - 7.0'	Clay (CL-CH); gray, soft, medium to high plasticity, saturated below 4.2 feet, nonindurated; iron stain mottling throughout, strong organic odor.

Note: 1.) Standing water at 7.0 feet when test pit logged. Water level had risen to 6.4 feet 45 minutes after first measurement. Soils saturated and making water below 4.2 feet.

2.) Inspection of material in spoil pile indicates that clay continues to bottom (8.5 feet) of test pit.

<u>Test pit 2</u>

0.0' - 0.3'	Fill, gravelly clayey sand (SC); light brown, medium dense, low plasticity, dry, nonindurated; 30 percent gravel to 1-1/2 inch diameter, 30 percent clay.
0.3' - 3.7'	Fill; sandy gravel (GP); brown, low density, nonplastic, moist to saturated with depth, nonindurated; contains lumber, broken brick, and cement blocks.

Note: 1.) Standing water at 3.7 feet when test pit logged. Water level had risen to 3.4 feet 30 minutes after first measurement. Soils saturated and making water below 2.9 feet.

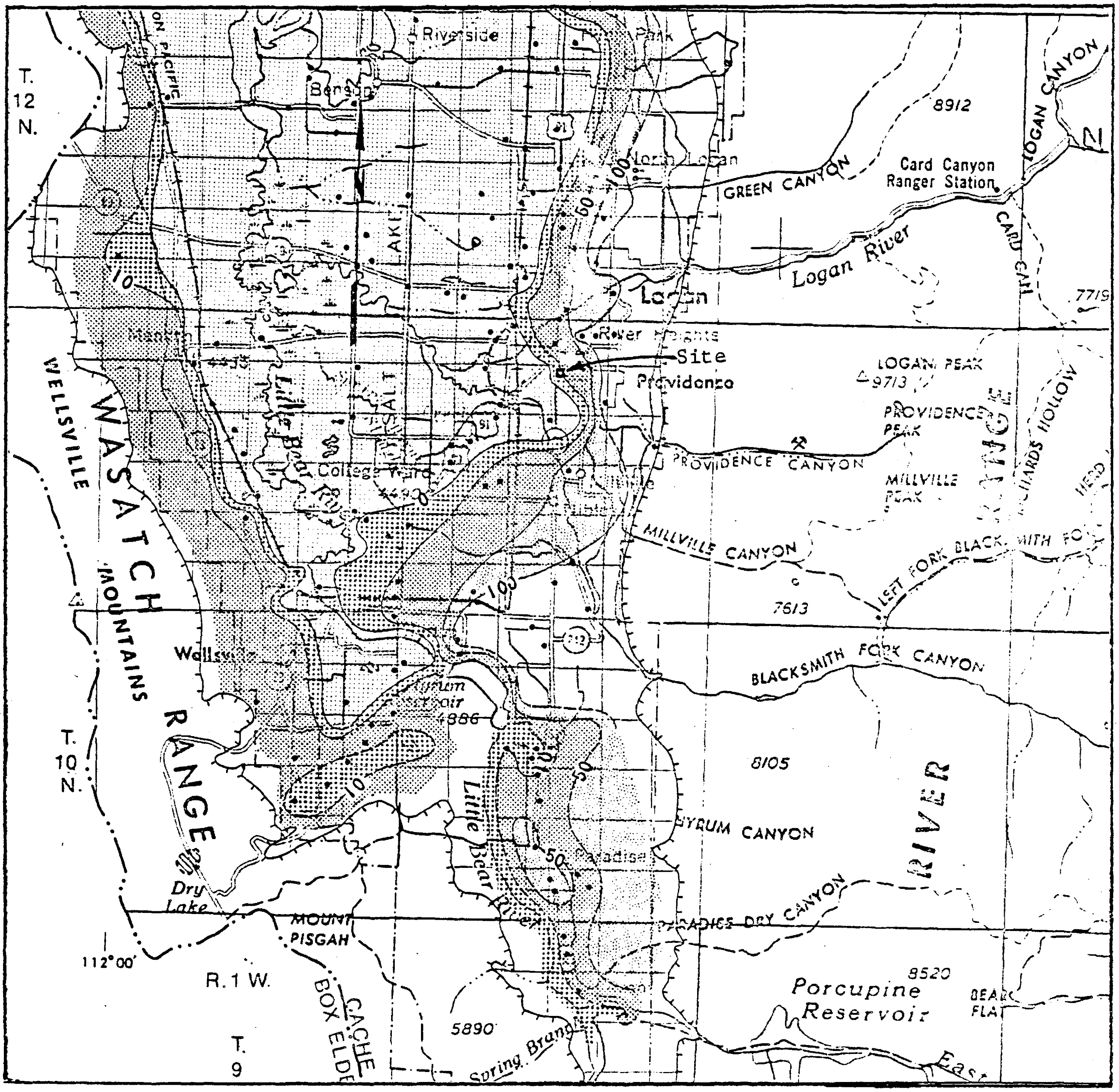
2.) Dark gray to black clay (CH) on spoil pile indicates that clay underlies fill. The fill-clay contact is below the water level.

Test pit 3

0.0' - 1.4'	Fill; clay with sand (CL-CH); light tan, stiff, high plasticity, dry to moist, nonindurated.
1.4' - 2.8'	Fill; clayey sandy gravel (GC); dark brown to black, dense, medium plasticity fines, moist to saturated, nonindurated; 40 percent gravel.

Note: 1.) Standing water at 2.8 feet. Level remained constant during site investigation.
2.) Dark brown to black clay (CH) on spoil pile indicates that clay underlies fill. The fill clay contact is below the water level.

*Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (Reapproved 1975), Description of Soils (Visual Manual Procedure). Percentages recorded for various size fractions are field estimates.



Depth to shallow ground water (feet) southern Cache Valley (after Bjorklund & McGreevy, 1971).

Project: Investigation of 6 test pits for Wasatch County Health Department; suitability for septic tank drainfields			Requesting Agency: Wasatch County Health Department
By: H. Gill & W. Lund	Date: 7/18/84	County: Wasatch	Job No.: WW-4
USGS Quadrangle: Aspen Grove (1128)			

On July 9, 1984 an inspection was made of six test pits located on a proposed extension of the Canyon Meadows subdivision, Wasatch County, Utah. The purpose of the inspection was to determine if the subsurface soil and water conditions are suitable for installation of septic tank and drainfield systems. Detailed logs of the test pits are included as an attachment to this report.

Canyon Meadows subdivision is located near the head of Provo Canyon approximately three quaters of a mile southwest of Deer Creek Dam (attachment 1). The development is within the Sulphur Springs window of the Deer Creek thrust fault. The Sulphur Springs window is an area of approximately 2 1/2 square miles where geologic formations comprising the upper plate of the Deer Creek thrust fault have been eroded away exposing the underlying strata. The formation that crops out in the window in Canyon Meadows subdivision is the Manning Canyon Shale. Consisting predominantly of brown to black shale with thin interbeds of sandstone, quartzite, and limestone, this formation has been associated in other areas along the Wasatch Front with foundation and slope stability problems. The soils derived from the weathering of the shale are typically clayey, with low to very low permeability and moderate to high shrink/swell capacity. Aerial photo interpretation and subsequent field reconnaissance of the proposed subdivision extension indicates the site is located on landslide deposits derived from the ridge to the northwest composed entirely of Manning Canyon Shale.

The soils exposed in the six test pits (attachment 2) were found to be generally similar with the exception of test pit 2. The upper soil horizon in all test pits consists of 1 to 2.5 feet of dark brown, silty clay topsoil with varying percentages of sand, gravel, and cobbles. Beneath the topsoil horizon and extending to their total depth, test pits 1, 3, 7, 8, and 9 (numerical designations after the developer) exhibit a layer of brown, gravelly clay/clayey gravel, with varying amounts of sand and gravel. In test pit number 7 the upper foot of the gravelly clay/clayey gravel is moderately indurated probably a result of secondary cementation by gypsum (attachment 3). A brown, highly plastic clay was found in the bottom of test pit 1, however, it does not appear to be continuous and may represent a lens within the gravelly clay/clayey gravel horizon. In test pit 2 the gravelly clay/clayey gravel layer is replaced by a brown, clayey sand extending to the bottom of the excavation (attachment 3). The U.S. Soil Conservation Service has mapped the area and identified the soil as the Henefer series, a cobbly clay with a moderate to high shrink/swell potential. The soil has been classified for engineering uses and rated as severely limited for septic tank absorption fields because of low permeability. Percolation tests have been run in each of the test pits at the site and the reported results ranged from

20 to 44 min/inch; well within the upper and lower limits of 1 min/inch and 60 min/inch set by the Utah Department of Health for soil absorption systems. Ground water was not encountered in any of the test pits.

Clayey soils were observed at the site, but based on test pit examinations and results of the percolation testing, we feel there is adequate coarse-grained material accompanying the clay for septic tank absorption fields to function properly. The systems should be adequately sized to accomodate the volume of effluent produced. Although the site appears to be located on landslide deposits, the soil development observed in the test pits and the secondary cementation found in test pit 7 (attachment 3) represents a long period of stability. However, extensive disturbance of the soils by lot and/or road grading as well as introducing irrigation or wastewater into the subsurface may cause slope stability problems. It is recommended that a slope stability analysis be completed prior to development.

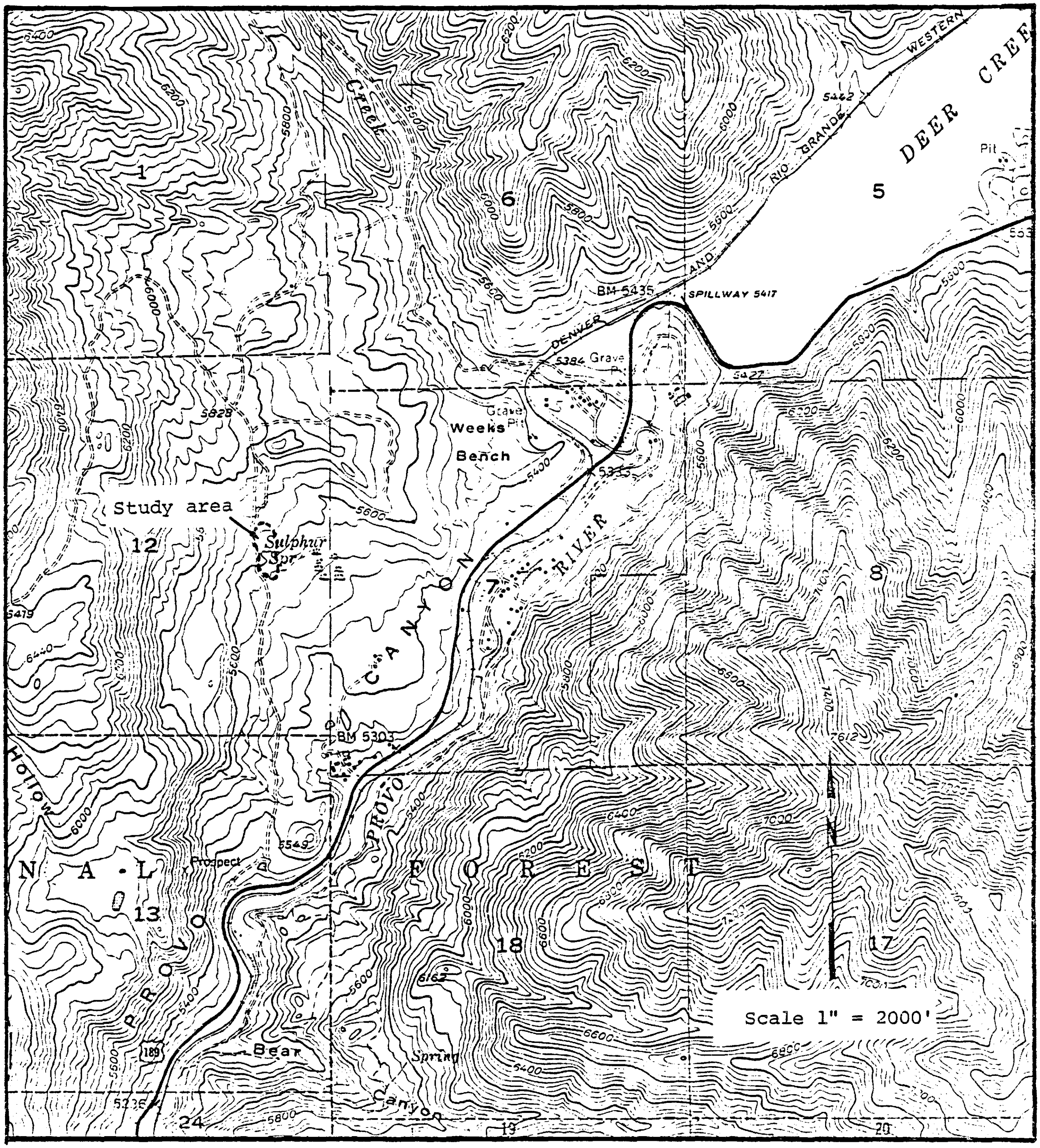
Selected References

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

Lund, W. R., 1982, Letter of June, 17, 1982, concerning Canyon Meadows subdivision, to Phillip Wright, Wasatch County Health Department: Utah Geological and Mineral Survey unpublished data, 7 p.

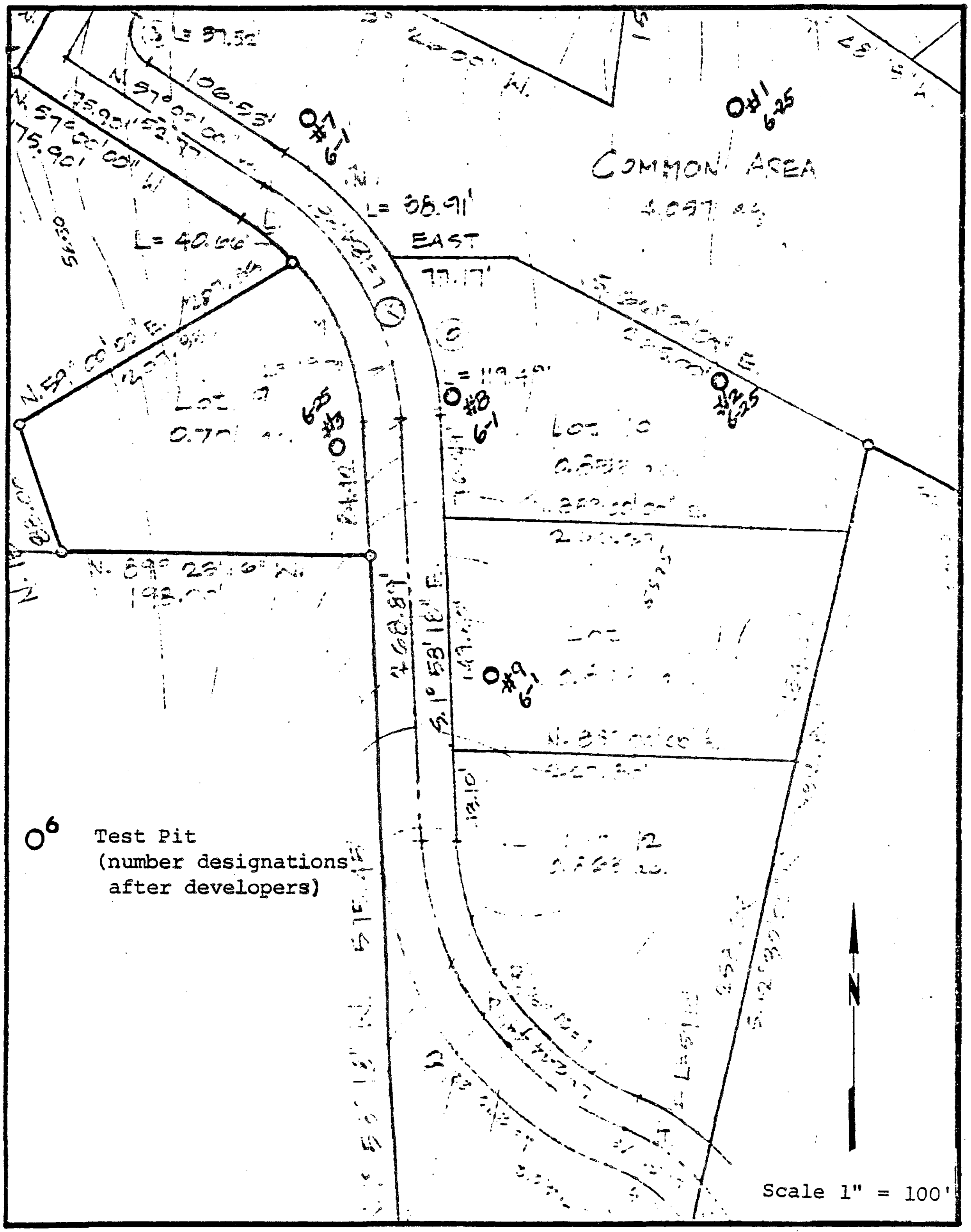
Reeves, C. C., Jr., 1976, Caliche: Lubock, Texas, Estacado Books, 233 p.

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



General Location Map Canyon Meadows Subdivision

Attachment 2, Job No. WW-4



Plat Map and Test Pit Locations   Canyon Meadows Subdivision

Attachment 3, Job No. WW-4

Logs of Test Holes, Canyon Meadows Subdivision*

Test Pit 1 6/25

0.0' - 1.5'	Sandy clay (CL); top soil, dark brown, firm, medium plasticity, nonindurated, moist.
1.5' - 5.0'	Sandy, gravelly clay (CL); brown, stiff, medium plasticity, nonindurated, slightly moist.
5.0' - 6.6'	Clay (CH); brown, very stiff, high plasticity, nonindurated, moist; does not appear to be continuous, probably a lense within the gravely clay unit.

Test Pit 2 6/25

0.0' - 1.8'	Sandy clay (CL); topsoil, dark brown, soft, medium plasticity, nonindurated, moist.
1.8' - 7.7'	Clayey sand (SC); brown, medium density, medium plasticity, weakly indurated, moist; clay content increases with depth.

Test Pit 3 6/25

0.0' - 1.2'	Sandy clay (CL); topsoil, dark brown, soft to firm, medium plasticity, nonindurated, moist.
1.2' - 7.8'	Gravelly clay/clayey gravel (CL/GC); brown, very stiff/medium dense, medium plasticity, none to weak induration, dry.

Test Pit 7 6/1

0.0' - 1.0'	Silty clay (CL); topsoil, dark brown, firm, medium plasticity, nonindurated, moist.
1.0' - 2.0'	Sandy clay (CL); white, stiff, medium plasticity, moderately indurated, moist; secondary cementation probably by gypsum.
2.0' - 8.0'	Clayey gravel (GC); brown, high density, medium plasticity, weakly indurated, moist.

Test Pit 8 6/1

0.0' - 1.3'	Sandy clay (CL); topsoil, dark brown, firm, low plasticity, nonindurated, slightly moist.
1.3' - 8.0'	Gravelly clay/clayey gravel (CL/GC); brown, stiff to very stiff/medium to high density, medium plasticity, weakly to moderately indurated, slightly moist.

*Soils classified in accordance with procedures outlined in ASTM Standard D2488-69 (revised 1975), Description of Soils (Visual Manual Procedure). Percentages recorded for various size fractions are field estimates.

Attachment 3, Job No. WW-4

Test Pit 9 6/1

0.0' - 2.5'	Sandy clay (CL); topsoil, dark brown, firm, medium plasticity, nonindurated, slightly moist; consistency increases with depth.
2.5' - 8.9'	Gravelly clay/clayey gravel (CL/GC); brown, very stiff/medium dense, medium plasticity, none to weakly indurated, moist; clay content increases with depth.

Note: Ground water not encountered in any of the test pits.

Project: Examination of Mancos Shale in Carbon County with regard to wastewater disposal			Requesting Agency: Utah Dept. of Health
By: W. R. Lund	Date: 6/10/84	County: Carbon	Job No.: WW-5
USGS Quadrangle: Price (835)			

A trip to southeastern Utah was made between June 4-6, 1984. The purpose of the trip was three fold:

1. (WW-5) To examine exposures of the Mancos Shale in the vicinity of Price and Wellington, Utah with representatives of the State Health Department and the Southeastern Utah District Health Department (S. Thiriot and G. Storey respectively). Problems have developed with a number of septic tank/drainfield systems installed in the Mancos Shale in Carbon and Emery Counties. Other systems, also installed in the shale appear to be working satisfactorily. New health department regulations prohibit installation of drainfields in bedrock, a fact which has created considerable controversy in the Price area. This examination was to determine what if any modifications in the regulations should be made for the Mancos Shale and/or what kinds of alternate disposal systems might be appropriate for Mancos terrain. It was determined that additional information regarding the number of failing vs. functioning systems is required. G. Storey (Southeastern Utah Health District agreed to examine their files and contact individual owners as necessary to obtain that information.

2. (GH-6) Investigation of an underground gasoline leak in Green River, Utah. Considerable quantities of gasoline have been discovered in portions of the Green River sewer system. The suspected source is a leak in an underground storage tank at one of two nearby gas stations. The UGMS gas detection device was used to measure the concentration of gasoline fumes at the manhole where the gasoline occurs and also at a nearby sewer pump station. Readings of 9 and 2 percent were obtained respectively. A number of other manholes within a two-block area were also checked, none showed evidence of gasoline. It appears that the gasoline is coming from the stations as suspected. A sample of the gasoline will now be analyzed to identify the chemical tracer present. Each major oil company (in this case Husky and Shell) use a distinctive tracer in their product to allow its identification in cases such as this. Further UGMS involvement is likely only if the source of the gasoline cannot be identified by its tracer.

3. (PF-5) Examination of a million gallon water tank in Moab, Utah the foundation of which has begun to crack and settle. The water tank is approximately three years old and is located on a norrow ridge top northwest of Moab. The city engineer (Mr. Keogh) claims that he saw cracks in the top of the ridge paralleling those in the tank foundation and is concerned that a landslide may be developing adjacent to and beneath the water tank. A careful examination of the site and both sides of the ridge showed no evidence of slope movement (the cracks reported by the city engineer were no longer visable). A foundation investigation was

the city engineer were no longer visable). A foundation investigation was not performed for the tank nor is there any documentation of the materials exposed in the foundation excavation at finished grade. Bedrock is exposed on the ridge top and on the south ridge slope, the north slope is underlain by colluvium of variable thickness. It is not known if the bedrock-colluvium contact lies beneath the water tank, but it is the colluvium side of the tank that is settling. It was suggested to the city engineer that a series of monitoring points be established on the slope and their evaluations surveyed periodically in an attempt to detect any evidence of slope movement. He agreed to establish the monitoring net and will contact UGMS when he has some data.

Project:			**Requesting Agency:**
Evaluation of a proposed wastewater disposal system in Kanab Creek Canyon, Kane Co., Utah			Southwestern Utah District Health Dept.
By: W. R. Lund	**Date:** 11/15/84	**County:** Kane	**Job No.:** WW-6
USGS Quadrangle: Kanab, Utah-Arizona (15 minute series)			

In response to a request from Mr. Donald Wudarski, Southwestern Utah District Health Department, an investigation was conducted on October 25, 1984, of a proposed wastewater disposal site in Kanab Creek Canyon near Kanab, Utah (attachment 1). The purpose of the investigation was to evaluate the geologic setting of the site to determine the effect of a septic tank and soil absorption system on nearby springs. The scope of the investigation included a review of existing geologic and hydrologic information, an air photo analysis, and a field reconnaissance.

Kanab Creek has incised its channel into the Navajo Sandstone creating a narrow, steep-walled canyon. The proposed disposal site is at the top of a cliff that forms the west side of the canyon at this location. The disposal system would serve a religious retreat house intended to accomodate 10 full-time residents with complete kitchen and laundry facilities. The site is underlain by sandstone bedrock which is covered by a layer of fine eolian sand of variable thickness. Test pits were not excavated, but the site reconnaissance indicated that depth to bedrock ranges from a few inches near outcrops to several feet in low areas where eolian deposits have accumulate. The Navajo Sandstone is exposed in canyon walls and consists of massive, moderately cemented, quartz sandstone. Widely spaced, through-going, open, vertical joints were observed in the cliff face.

The springs, of concern, are near the base of the canyon wall about 220 feet below the proposed disposal site (attachment 1). A ground-water seep occurs for several hundred feet along a prominent, nearly horizontal bedding plane (less than 5 degree dip to the southeast) exposed in the cliff face. Springs have been developed at two locations by drilling a hole (3- to 4-inch diameter) into the rock along the bedding plane and cementing a drain pipe in place. The water from the springs is of culinary quality (D. Wudarski, oral commun., October 25, 1984) and of sufficient quantity to supply a small pressurized irrigation system and a stock watering pond.

Cordova (1981) identifies the Navajo Sandstone as a major bedrock aquifer in the Kanab Creek basin. The altitude of the water level in the main zone of saturation beneath the site is approximately 5150 feet and the direction of ground-water flow is to the southeast (Cordova, 1981, plate 2). The elevation of the springs is about 5350 feet placing them 200 feet above the main zone of saturation. This indicates that ground water supplying the springs comes from a perched water table that has developed along the bedding plane. Several vertical joints intersect the bedding plane in the vicinity of the springs. No increase in flow was observed at the intersections, and the joints were dry. The absence of water along the joints shows that the area at the top of the cliff is not large enough to provide a continuous source of recharge and that most of the water in the perched zone is moving down dip along the bedding plane from the northwest.

The shallow, permeable soils and jointed bedrock at the site would permit wastewater from the disposal system to reach the perched water table with little effluent renovation. Low annual precipitation and a small catchment area at the top of the cliff combine to limit natural recharge, but a disposal system large enough to serve the proposed retreat house would put 1200 to 1500 gallons of wastewater per day into the soil. The house would be occupied year round, so the annual volume of wastewater produced would likely exceed 500,000 gallons. Much of this water can be expected to reach the perched water table and eventually the springs. For that reason, a conventional septic tank and soil absorption system is not recommended at this site. Alternative methods of wastewater disposal may include piping the effluent to a soil absorption system in the canyon bottom at an elevation below the springs, or constructing a lined evapo-transpiration system that would prevent the wastewater from reaching the fractured bedrock.

Selected References

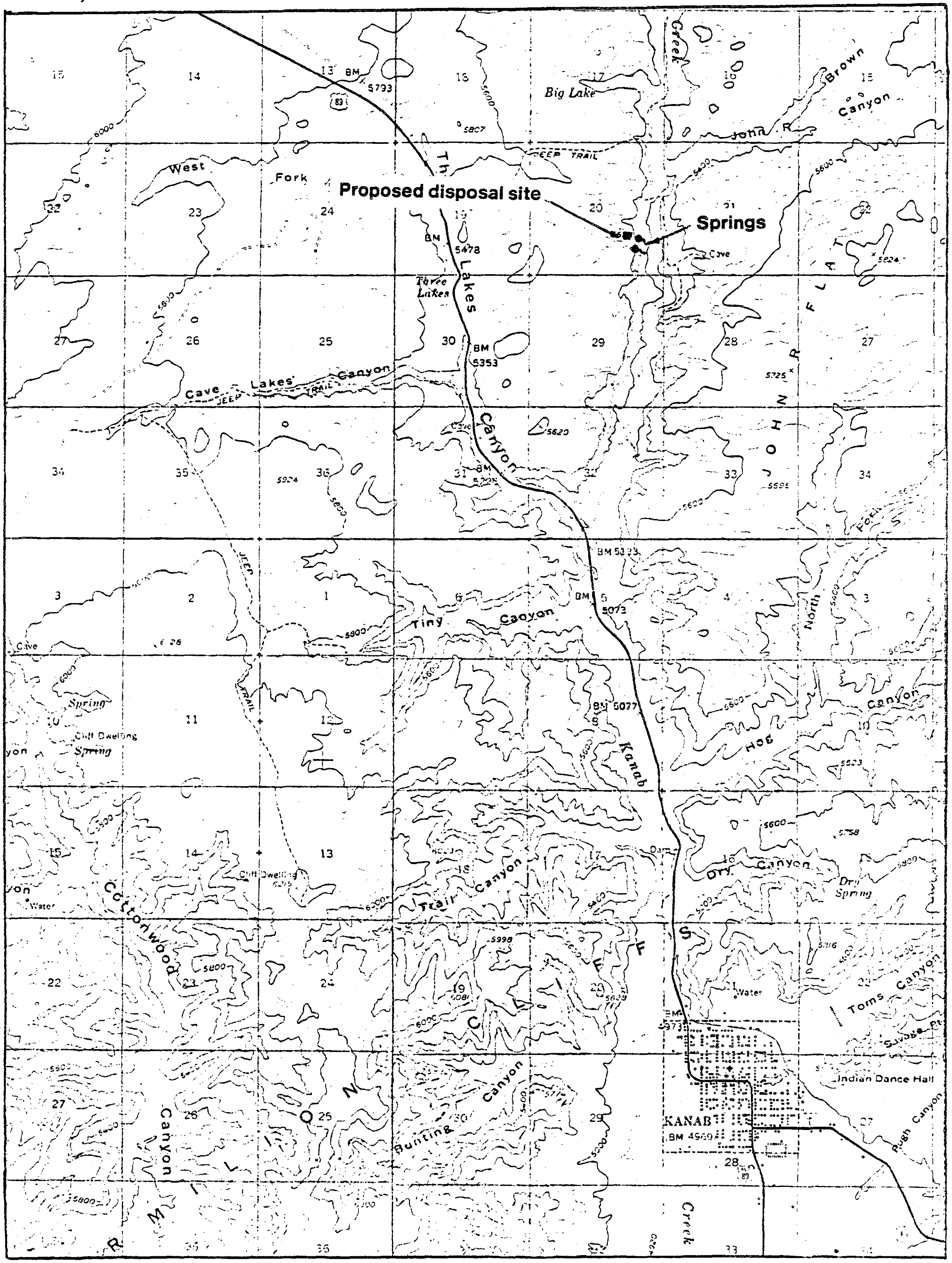
Cordova, R. M., 1981, Ground-water conditions in the upper Virgin River and Kanab Creek basins area, Utah, with emphasis on the Navajo Sandstone: State of Utah Department of Natural Resources Technical Publication No. 70, 87 p.

Goode, H. D., 1964, Reconnaissance of water resources of a part of western Kane County, Utah: Utah Geological and Mineral Survey Water-Resource Bulletin 5, 64 p.

- - - - - -1966, Second reconnaissance of water resources in western Kane County, Utah: Utah Geological and Mineral Survey Water-Resources Bulletin 8, 44 p.

Gregory, H. E., 1950, Geology and geography of the Zion Park region, Utah and Arizona: U.S. Geological Survey Professional Paper 220.

Stokes, W. L., compiler, 1964, Geologic map of Utah: University of Utah, scale 1:250,000.



Location map showing proposed disposal sites and existing springs; scale 1:62,500

Base map from U.S. Geological Survey Kanab, Utah-Arizona topographic quadrangle.

Utah Geological and Mineral Survey

Site Investigation Section

WATER WELLS

Project:			Requesting Agency:
Water well siting for the proposed Provo City sanitary landfill			Provo City Sanitation Department
By: R. H. Klauk	Date: 3/6/84	County: Utah	Job No.: W-1
USGS Quadrangle: Goshen Valley North (1008)			

This investigation was performed to determine the best site for a culinary water well at a proposed Provo City sanitary landfill. The scope of work included a review of published and unpublished literature pertinent to the landfill site, and a field reconnaissance conducted on January 31, 1984. The landfill encompasses all of sec. 17, T. 9 S., R. 1 W. SLB&M in Goshen Valley, Utah County, Utah (attachment A). The ground surface generally slopes from west to east with a total relief across the site of approximately 170 feet. Three shallow, roughly parallel, intermittent drainages trend east-west across the property. Surficial deposits to a depth of 50 feet consist of interbedded clay, silt, sand, gravel, and some cobbles (Chen and Associates, Inc., 1980; Rollins, Brown, and Gunnell, Inc., 1983).

Cordova (1970) and Dustin and Merritt (1980) identified four aquifers in Goshen Valley. They are from shallowest to deepest: 1) the water-table aquifer, 2) the shallow Pleistocene aquifer, 3) the deep Pleistocene aquifer, and 4) the Tertiary aquifer. Cordova (1970) indicated that artesian conditions exist in the three deeper aquifers in the eastern half of the valley. According to Cordova (1970), depth to the water-table aquifer beneath the site ranges from approximately 250 feet on the west to 130 feet on the east. This data was collected in the mid-sixties, and depths may vary at the present time. The exact depth to the top of the shallow Pleistocene aquifer is not known due to a lack of well data. However, it is estimated to be from 250 feet (east) to 400 feet (west) beneath the surface. A similar lack of data makes estimates of the depth to the deep Pleistocene and Tertiary aquifers speculative, so values are not given. It is not known if the aquifers beneath the property are artesian because the landfill is located in the transition zone from water-table to artesian conditions that exists between western and eastern Goshen Valley.

Recharge to the aquifers in Goshen Valley comes from: (1) seepage from water ways, (2) infiltration of precipitation, and (3) subsurface flow from the East Tintic Mountains (Cordova, 1970; Dustin and Merritt, 1980). The ground-water gradients are small and slope from west to east (Cordova, 1970; Dustin and Merritt, 1980). The direction of ground-water flow may be locally modified in the aquifers by pumping of irrigation wells. Pump tests are not known to have been conducted in the area, so data are unavailable on aquifer characteristics or their response to pumping of large irrigation wells. Information is not available on the size of the cone of depression which will be associated with the proposed well, or the possible effect of cones created by future irrigation wells drilled near the landfill.

Chemical quality of ground water in this portion of the Goshen Valley is considered in the fair to poor range. The Utah Geological and Mineral Survey sampled two wells in the area in 1981. Well (C-10-1) 4cbb, located approximately 4.5 miles south of the landfill, contained a total dissolved solids (TDS) concentration of 700 mg/l which, according to Utah Department of Health (attachment 2), is considered "fair" chemical quality. A second well (C-9-1) 5ddb, located one mile to the north, contained 460 mg/l TDS which is considered "good" quality. These two samples were not analyzed for all elements in the attached standards; however, with the exception of TDS, the elements tested were within acceptable limits. Further water quality analyses would be requiried to determine if ground water in the vicinity of the landfill meets all safe drinking water standards.

Since ground-water gradients beneath section 17 generally slope from west to east, it is recommended that the well be located at the western margin of the property and as far from the actual landfill as possible. Average annual precipitation at the site is less than 10 inches per year (Utah State University-Utah Division of Water Resources, no date) Although leachate development in this arid environment is considered unlikely (a landfill test reported by Gianelli (1969) resulted in no leachate production when exposed to 18.7 inches of precipitation over a period of 18 months), locating the well to the west eliminates the possibility of contamination from that source. It is our understanding, that a septic tank and soil absorption system is also planned for the site (D. Stevenson, oral commun., January 31, 1984). The system should be located east of, and as far downslope from, the well as possible. This would eliminate any hazard from sewage contamination. It is also recommended that the well be completed in the shallow Pleistocene aquifer which should be encountered at a depth of 350 to 450 feet below the surface at the western margin of the site. This aquifer ought to provide the 100 gallons per minute of water considered by Dale Stevenson (oral commun., January 25, 1984) as necessary for the landfill operation, and will likely be of adequate chemical quality to meet Utah safe drinking water standards without treatment. The well should be cased and grouted through the upper water-table aquifer.

References Cited

Cordova, R.M., 1970, Ground-water conditions in southern Utah Valley and Goshen Valley, Utah: Utah Department of Natural Resources Technical Publication No. 28, 79 p.

Dustin, J.D., and Merritt, L.B., 1980, Hydrogeology of Utah Lake with emphasis on Goshen Bay: Utah Geological and Mineral Survey Water Resources Bulletin 23, 50 p.

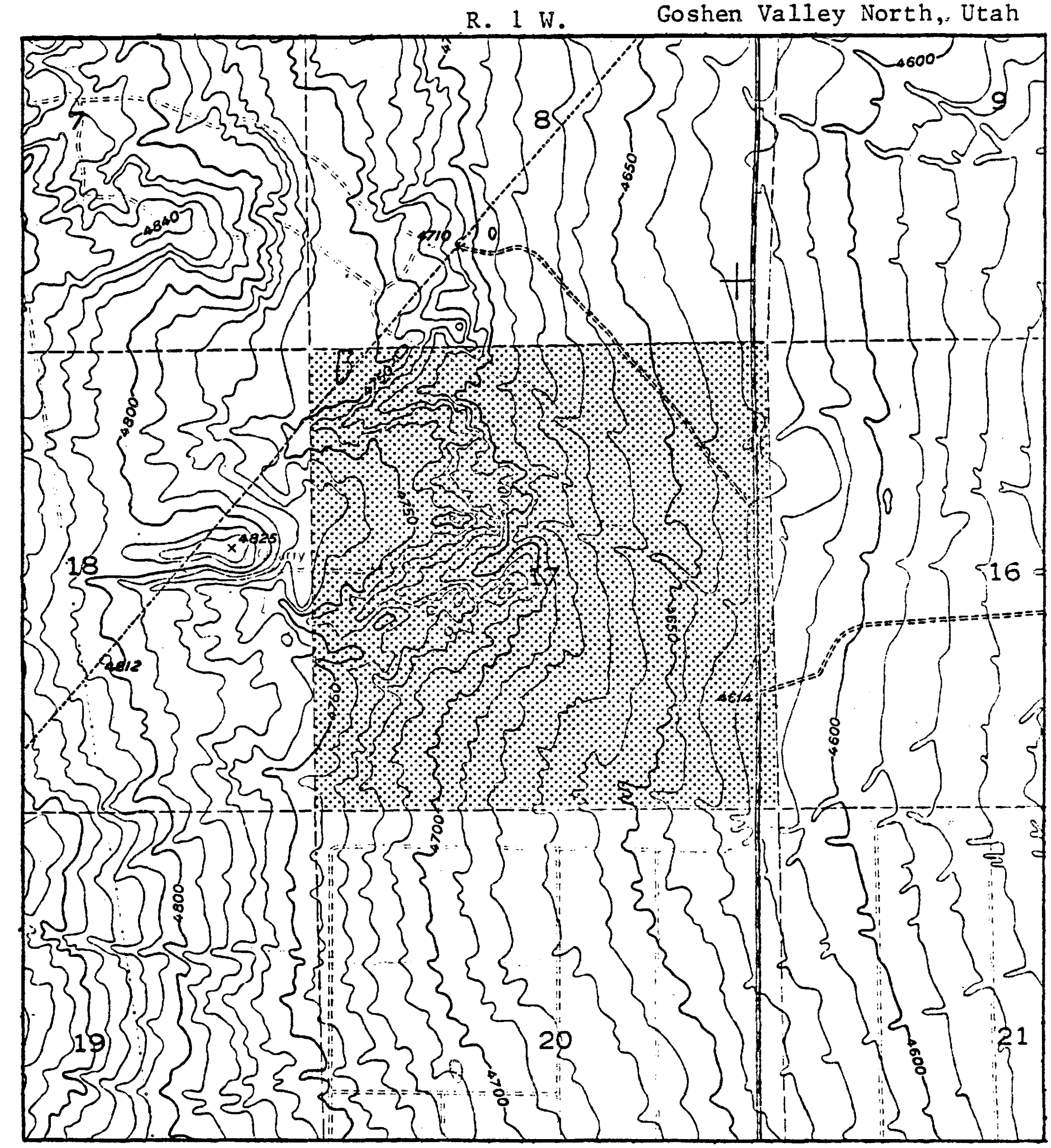
Gianelli, W.R., 1969, Sanitary landfill studies: State of California Department of Water Resouces Bulletin no. 147-5, 115 p.

Rollins, R.L., 1983, Letter of investigation regarding the Provo City landfill: Rollins, Brown, and Gunnell, Inc. unpublished report, 8 p.

Sorenson, L.G., 1980, Proposed sanitary landfill site City of Provo, Utah: Chen and Associates, Inc. unpublished report, 14 p.

Utah State University-Utah Division of Water Resources, no date, Hydrologic atlas of Utah: Salt Lake City, 306 p.

Base map from: USGS 7.5' topo quad
Goshen Valley North, Utah



0 ½ 1 mile

Contour Interval 10 Feet

North

Location of the proposed Provo City sanitary landfill site, Goshen Valley, Utah County, Utah.

Attachment B, Job No. W-1

STATE OF UTAH
DEPARTMENT OF HEALTH
DIVISION OF ENVIRONMENTAL HEALTH
150 West North Temple, P.O. Box 2500, Salt Lake City, Utah 84110

Alvin E. Rickers, Director
Room 426 801-533-6121

James O. Mason, M.D., Dr.P.H.
Executive Director
801-533-6111

DIVISIONS
Community Health Services
Environmental Health
Family Health Services
Health Care Financing and Standards

OFFICES
Administrative Services
Health Planning and Policy Development
Medical Examiner
State Health Laboratory

February 4, 1981
533-4207

UTAH DEPARTMENT OF HEALTH CHEMICAL QUALITY STANDARDS

Exceeding the following limits are grounds for rejection of a source and are called Maximum Contaminant Levels (MCLs):

Total Dissolved Solids	2000 mg/l
Sulfate	500 mg/l
Arsenic	0.05 mg/l
Barium	1.0 mg/l
Cadmium	0.01 mg/l
Chromium	0.05 mg.l
Flouride	1.6-2.2 mg/l*
Lead	0.05 mg/l
Mercury	0.002 mg/l
Nitrate as N	10. mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l

If the following limits are exceeded, the water is considered to be of only "fair" chemical quality and may contain chemicals which cause nuisances, but are not health related. These are called "secondary" standards. Water is considered to be of good quality if it is below these limits.

Copper	1.0 mg/l
Color	15 color units
Iron	0.3 mg/l
Manganese	0.05 mg/l
Sulfate	250 mg/l
Chloride	250 mg/l
Total Dissolved Solids	500 mg/l
pH	6.5-8.5
Odor	3 Threshold odor number
Turbidity	5 NTU **
Zinc	5. mg/l
Corrosivit,	non corrosive
Foaming Agents	0.5 mg/l

(Over)

Attachment B, Job No. W-1

A water is considered to be of good chemical quality if it meets or is less than the following limits suggested by the American Water Works Association.

Turbidity	less than o.1 NTU
Suspended material	less than 0.1 mg/l
Color	less than 3 units
Odor	None
Aluminum	less than 0.05 mg/l
Iron	less than 0.05 mg/l
Manganese	less than 0.01 mg/l
Copper	less than 0.2 mg/l
Zinc	less than 1.0 mg/l
Total Dissolved Solids	less than 200 mg/l
Hardness	80 to 100 mg/l

The Environmental Protection Agency has recommended that water contain less than 20 mg/l Sodium to minimize the possibility of heart disease occuring over a lifetime.

* Depends on local ambient miximum daily air temperature
** For groundwater sources only

Project:			**Requesting Agency:**
Reclassification of well at Soldier Creek Estates, Strawberry Lake			Bureau of Public Water Supplies, Utah State Dept. of Public Health
By: G. E. Christenson	**Date:** 4/5/84	**County:** Wasatch	**Job No.:** W-2
USGS Quadrangle: Strawberry Reservoir NE			

The purpose of this report is to transmit our recommendations with regard to reclassifying the well serving Soldier Creek Estates at Strawberry Reservior in Wasatch County from a shallow well to a deep well. In order to be classified as a deep well, one of the requirements in the Utah State Department of Health regulations states that: "an effective geologic seal must exist between the ground surface and the water-bearing aquifer. It must be of sufficient thickness and continuity to give confidence in its uniformity throughout the region generally."

The area in question is underlain by the Tertiary-age Uintah Formation. This formation consists of a sequence of interbedded shale, claystone, and sandstone units which are variable both in thickness and lateral extent. Well logs confirm this, and indicate in general that shale and claystone beds are thicker and more numerous than sandstone beds. Although no single shale bed probably underlies the entire region and is continous with the shale bed in the upper 20 feet recorded at the well, the total aggregate thickness of shale in the area probably prevents surface water from infiltrating very deep into the subsurface, at least in areas where beds are undisturbed. However, the well is in a fault zone which strikes roughly N. 20^{o} E. One fault within this zone passes about 100 feet east of the well, and another probable trace is found about 1200 feet to the west. The well appears to be in a graben between these two faults. The faults represent breaks in the continuity of any postulated "geologic seal" above the aquifer and these breaks extend to the surface. Springs are found along these faults where they cross topographically low areas such as drainages. Soldier Springs along Highway 40 occur in such an area and are a major discharge area for an aquifer system with principal recharge from the north. Water encountered in the well is under artesian pressure, indicating that permeability in beds overlying the fractured sandstone aquifer is less than that in the aquifer. The well reportly flows in springtime, but it is not known whether springs just downstream along the fault flow at this time also. In any case, the presence of springs along the fault downstream, as indicated by dense vegatation at and below where the fault crosses the drainage, shows that water moves along the fault and that it is not impermeable. While upward seepage under artesian pressure may protect the well from downward infiltration along the fault zone, pumping at the well may reduce the piezometric surface to a point below the top of the aquifer. This drawdown would most likely occur in late summer when homes are in use and both pumping and septic tank usage are greatest and water levels are lowest.

For these reasons, we recommend that the well not be reclassified as a deep well, but retain its status as a shallow well. However, we would suggest that a variance to the 1500-foot protection zone be granted allowing use of soil absorption systems on lots east of the fault (or its projected trend; see EarthFax letter of March 30, 1984, Fig. 1). The dip of beds in the area is in a N. 60^{o} E. direction and effluent originating on lots east of the fault will migrate downdip along shale and claystone layers away from the well. However, effluent from lots east of the fault may migrate downdip into the fault zone, ultimately entering the aquifer and reaching the well. If the well were reclassified to a deep well, not only the western part of the existing proposed subdivision but all the area within the 1500-foot protection zone west of the fault could potentially be developed. We feel this would represent a distinct hazard to the water quality in the well.

Since the fault is the principal geologic feature in determining which lots are considered safe for the use of soil absorption systems and which are not, we recommend that the developer perform further work to determine the location of the fault as accurately as possible. It is very distinct and easily recognized north of the well, but less well-defined to the south through the subdivision area. Detailed air photo analysis and geologic inspection of existing exposures should be sufficient. Various geophysical techniques are also available which may be applicable to such an investigation.

Project:	Requesting Agency:
Riverton water well (Bear Canyon area)	City of Riverton

By:	Date:	County:	Job No.:
G. E. Christenson	8/13/84	Salt Lake	W-3

USGS Quadrangle:
Draper (1171)

PURPOSE AND SCOPE

The purpose of this investigation was to evaluate the feasibility of producing water by drilling a well on property owned by Riverton City in the Bear Canyon area east of Draper (attachment 1), and to determine the most favorable location for a well should one be feasible. Riverton City presently derives water from an adit in Bear Canyon (see UGMS Site Investigation Section Job No. 84-006, February 28, 1984), and is interested in finding additional sources in the area.

The scope of work included a literature search, air photo analysis, and collection of existing well records from the Utah Division of Water Rights. A brief site visit was performed on July 25, 1984.

GEOLOGY

Bedrock in the area consists principally of the Little Cottonwood stock, a quartz monzonite intrusion of Tertiary age (Crittenden, 1965). The rock is lithologically homogeneous and highly fractured. North of Bear Canyon, southeast-dipping beds of the Precambrian-age Big Cottonwood Formation (quartzite, shale, siltstone) are exposed. Below an elevation of about 5150 feet along the mountain front, unconsolidated lacustrine deposits of Pleistocene-age Lake Bonneville and alluvial deposits of Bear Creek are found. These deposits consist of interbedded, clean, well-sorted sand and gravel; poorly sorted sand and gravel with both larger clasts and fines; and thin silt and clay beds.

The Wasatch fault trends northeastward through the area at the base of the mountains. The fault is principally a single trace through this area which is found within a few hundred feet west and parallel to the Salt Lake City Aqueduct. Several possible associated fault segments are mapped west of the main trace (Cluff and others, 1970).

HYDROLOGY

The principal bedrock aquifer in the area is the quartz monzonite of the Little Cottonwood stock. Flow of ground water in the aquifer is through joints and faults, with principal recharge from snowmelt and rainfall in the Wasatch Range to the east. For a more detailed discussion of ground water in this aquifer, see UGMS Site Investigation Section Report SP-2 regarding the

Bear Canyon adit. It is not believed that the sedimentary rocks of the Big Cottonwood Formation found north of Bear Canyon near the base of the mountain front play a significant role in the recharge or movement of ground water in the area.

The principal direction of ground-water flow is from east to west, with bedrock aquifers ultimately recharging basin-fill aquifers in the Salt Lake Valley through underflow at depth along the valley margin. Around the valley periphery, ground water occurs under unconfined conditions in the coarse-grained basin-fill sediments. Because no fine-grained confining layers separate the water table from the ground surface, some recharge occurs from direct infiltration from Bear Creek as it flows from the mountain front across its alluvial fan into the Salt Lake Valley. The depth to the water table at a well near the mouth of Bear Canyon (attachment 1) was recorded at 91 feet on September 30, 1983. Hely and others (1971) state that the deep unconfined basin-fill aquifer near the mountains generally yields little water to wells, either because water is too deep or deposits are too thin to contain significant water. For this well, the latter was the case with bedrock encountered at a depth of 114 feet, giving a saturated thickness in the aquifer of only 23 feet. A bailer test yielded total drawdown (dewatering of the aquifer) after one hour of flow at 2 gpm.

Although no data are available on the chemical quality of water in the area, it can be expected to be good and probably of comparable quality to that in the Bear Canyon adit. The highest quality water (lowest total dissolved solids) in the Salt Lake Valley occurs along the front of the Wasatch Range with TDS not exceeding 1000 mg/l and generally less than 500 mg/l (Hely and others, 1971).

It is not known what role the Wasatch fault plays in the overall east-to-west flow of ground water in the area. It may: 1) be impermeable and block flow, causing a build-up of ground water in bedrock aquifers forming springs at the mountain front, 2) have greater permeability than surrounding rock due to fracturing and readily transmit water into the basin fill or to springs at the mountain front (if hydraulic head is sufficient), or 3) have no discernible effect. No major springs are found along the Wasatch fault here, so it does not appear to be greatly altering the underflow of water from bedrock to basin-fill aquifers in the valley.

CONCLUSIONS AND RECOMMENDATIONS

Additional development of the bedrock aquifer is not recommended. Production of water from a well drilled into bedrock depends on the fortuitous interception of water-carrying joints, many of which are vertical or steeply dipping in this area. The steep terrain would make drilling expensive and difficult, and additional depletion of this aquifer in the vicinity of the adit may also reduce flow in the adit. At the mountain front, the poor yield of the well drilled at the mouth of Bear Canyon in the Wasatch fault zone indicates that the potential for developing water in this area is also low, although it is possible that deeper drilling (greater than 110 feet) may have encountered water in the bedrock aquifer.

The area with the highest potential for placing a well to produce significant quantities of water would be along the west edge of the property where, presumably, the greatest thickness of basin fill is found. Drilling to a depth probably exceeding 200 feet and ideally to bedrock will be required to give the greatest potential for success. However, well yields in basin margin areas where deep unconfined conditions exist are typically not great. Only locally have moderate to large yields of good quality water been found.

In conclusion, it is possible although not certain that a significant basin-fill aquifer may exist beneath the property. We suggest drilling an exploratory boring to a depth of at least 200 feet (or to bedrock) in the northwestern corner of the property where the thickness of unconsolidated deposits is probably greatest and depth to water least. Detailed logs of the boring should be prepared showing water-producing zones and describing the basin fill. If a sufficiently thick sand and gravel aquifer or series of aquifers is found, testing to determine water quality and hydraulic characteristics of the aquifer should then be performed.

REFERENCES

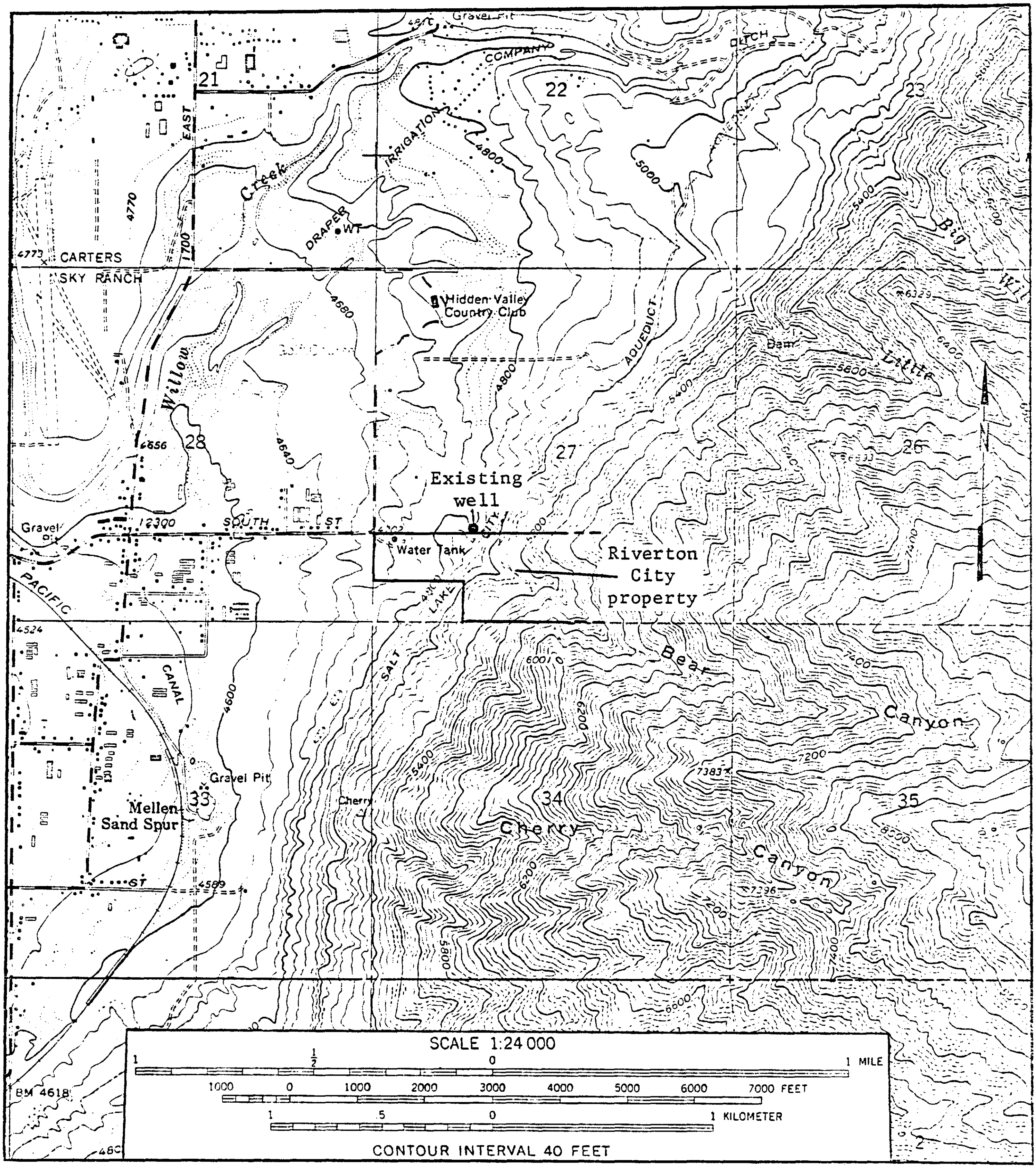
Cluff, L.S., Brogan, G.E., and Glass, C.E., 1970, Wasatch fault, northern portion, earthquake fault investigation and evaluation: Woodward-Lundgren and Associates, Oakland, California, 27 p.

Crittenden, M.D., Jr., 1965, Geology of the Draper Quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-377, scale 1:24,000.

Hely, A.G., Mower, R.W., and Harr, A.C., 1971, Water resources of Salt Lake County, Utah: Utah Department of Natural Resources Technical Publication 31, 244 p.

Base Map from: USGS 7½ Topo Quad
Draper, Utah

Attachment 1, Job No. W-3



Location Map

GROUND WATER

Project:			Requesting Agency:
Mount Pleasant ground-water study			City of Mount Pleasant
By: G. E. Christenson	Date: 8/30/84	County: Sanpete	Job No.: GW-1
USGS Quadrangle: Mount Pleasant (840)			

PURPOSE AND SCOPE

The purpose of this investigation was to determine the source of shallow ground water in southwestern Mount Pleasant and suggest means of permanently lowering the water table and alleviating basement flooding. The approximate area of Mount Pleasant affected by shallow water is shown in attachment 1. The problem has existed for many years, but previous basement flooding only occurred in late summer. During the last two years of increased precipitation, basement flooding has become a year-round problem and the area affected has enlarged, principally to the east toward State Highway 89 (State Steet)..

The city of Mount Pleasant contracted with Mountain West Design of Logan, Utah, in early 1984 to evaluate the extent of the flooding problem and to design a subsurface drainage system to lower the water table. The city is presently in the process of installing the subsurface drains. An outfall line to Pleasant Creek along 500 West between 100 and 600 South and a lateral line along 400 South are partially complete. The amount of water encountered has exceeded the capacity of the drains, necessitating consideration of another outfall to the west at 400 South.

The scope of our investigation included inspection of a section of the trench open along 400 South from 400 to 500 West, review of the final report by Mountain West Design, and field reconnaissance and air photo interpretation of the problem area. I was accompanied on the field investigation by Amoir Deuel, Mayor of Mount Pleasant, and Gary Potter of Alpine Land Surveyors, consultant to the city on the project.

GEOLOGY AND SOILS

Mount Pleasant is on the broad piedmont alluvial plain extending westward from the base of the Wasatch Plateau into the Sanpete Valley. Two alluvial fans coalesce in the area; one is comprised of sediment deposited by Pleasant Creek and the other, to the south, deposited by Twin and Cedar Creeks. Most of the city is on the Pleasant Creek alluvial fan although the southwestern part is in the zone of contact with the Twin-Cedar Creek alluvial fan. This contact zone is topographically lower than the axial portions of either fan, where Pleasant Creek and Cedar Creek presently flow. Twin Creek flows in the trough between the two fans and, in the past, flowed northwestward through southern Mount Pleasant. At present, water in Twin Creek is diverted for irrigation and distributed through town in canals running along major east-west streets.

Alluvial-fan deposits underlying Mount Pleasant consist of sand and gravel with varying percentages of boulders, cobbles, and fines. In the trench inspected during the field investigation, the soils consisted of a variable thickness (4 to 9 feet) of red to yellow (limonite-stained) clayey and silty sand overlying well-graded, rounded gravel with cobbles. Soil mottling indicative of saturated conditions below the water table was present near the bottom of the upper sandy layer. Above this, the limonite-staining in the sand indicates unsaturated, oxidizing conditions with through-flow of water in a zone above the water table. Soil mapping by the USDA Soil Conservation Service and others (1981) and test pits by Mountain West Design (1984) indicate that the upper sandy layer extends throughout the area but with some variability in soil types to include silt and clay locally. Gravels with boulders and cobbles generally occur beneath this layer throughout the area and extend to depths of several hundred feet.

GROUND WATER

The ground water in the area is recharged principally from infiltration of surface runoff in Pleasant Creek, Twin Creek, and associated irrigation canals, and underflow from bedrock aquifers to the east in the Wasatch Plateau. Ground water occurs under unconfined (water-table) conditions in the Mount Pleasant area, with depths to water ranging from about 10 feet on the west edge of town to over 100 feet along the east edge (Robinson, 1971). Driller's logs for wells in the area do not record significant confining clay beds in the unconsolidated alluvial-fan aquifer, and no artesian pressures are reported in deep wells in the area. This indicates that recharge from all sources, including deep underflow from mountainous areas to the east, contribute to the unconfined ground water in Mount Pleasant. Hydrographs for wells in the area indicate recharge from about April or May until July each year with a seasonal rise in water table of 10 to 20 feet (Robinson, 1971, p. 29). Longer term fluctuations also occur in direct response to precipitation, as indicated by elevated levels during the last two wet years (1983-1984).

Shallow ground-water problems are localized in southwestern Mount Pleasant because it is topographically lower than the surrounding area and is recharged directly by unlined irrigation canals as well as from infiltration along Pleasant and Twin Creeks. Where observed, upper soil layers are sufficiently permeable to allow rapid downward percolation of stream and canal water directly to the water table. The underlying gravel is highly permeable, as evidenced by rapid flow from this layer in the 400 West 400 South trench excavation. The study by Mountain West Design (1984) found permeabilities in the range from 0.4 to 7.0 inches/hour in soils in the upper 9 to 10 feet, with permeability generally increasing with depth.

RECOMMENDATIONS

High water tables have been a recurrent problem in southwestern Mount Pleasant and will continue be unless mitigating measures are taken. In order to permanently lower the water table in the area, recharge to ground water must be reduced and/or drainage provided. Practical measures to reduce recharge include lining of irrigation canals or piping of irrigation water through the city. A considerable amount of recharge probably also occurs from Pleasant Creek and Twin Creek (before it is diverted into irrigation ditches), and lining or diversion of these drainages would also reduce infiltration. Little can be done to reduce recharge through underflow from mountainous areas to the east because it occurs at depths exceeding 100 feet.

Another effective means of reducing the water table is to place subsurface drains below basement levels in the part of the city affected. Soils are homogeneous and highly permeable, and a properly designed drainage system should operate satisfactorily under these soil conditions. This is substantiated by the quantity of water being discharged to the partially completed system under construction, which has reportedly been effective in dewatering basements along lines installed to date. The effectiveness of the system will depend on the depth and spacing of lines which will be dictated by soil permeability and the location of lines in relation to major sources of recharge (irrigation ditches, underflow from the southeast). On-going design changes may be required during construction as the effects of lines installed are documented and analyzed.

REFERENCES

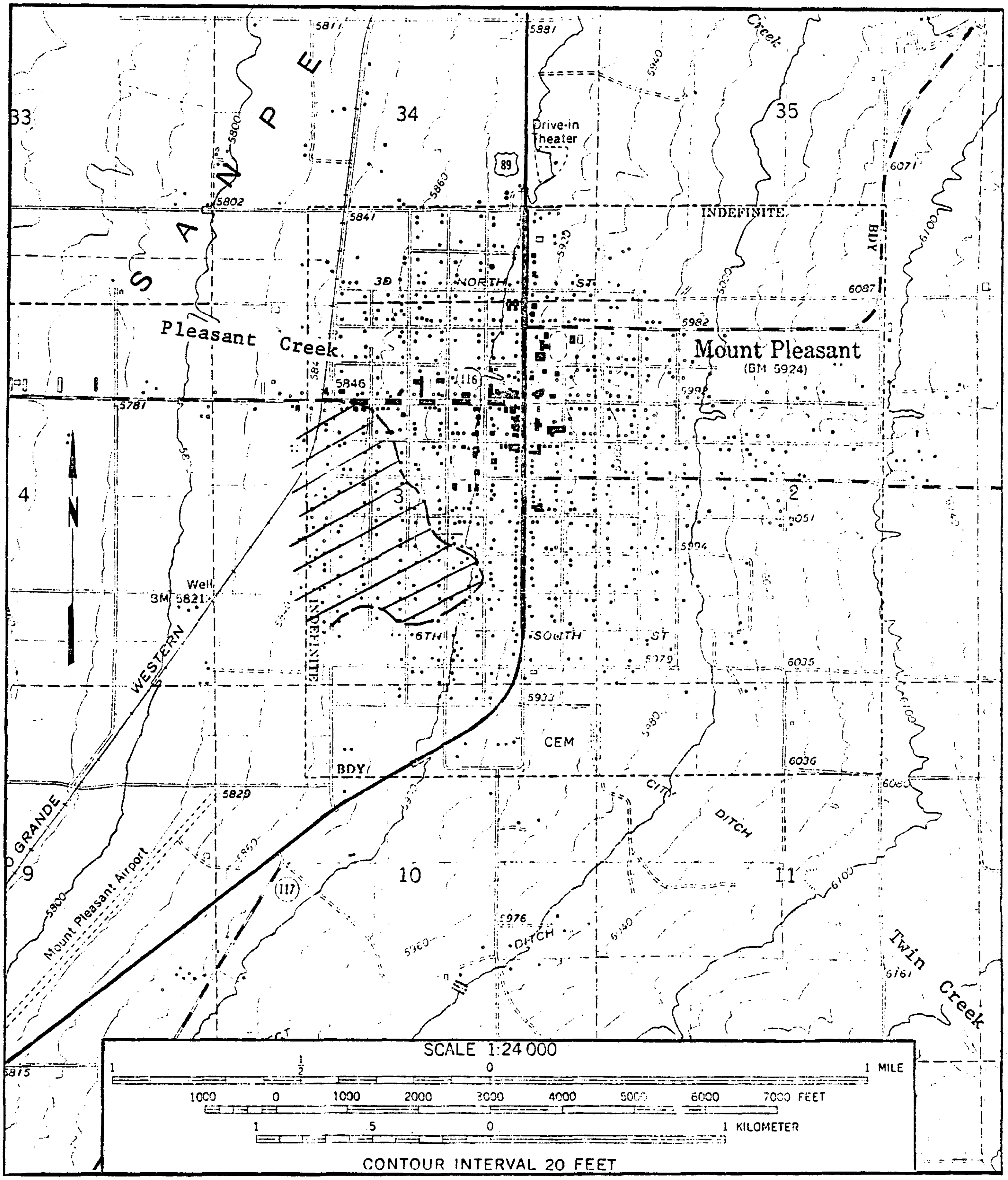
Gill, H.E., 1982, Geologic and hydrologic evaluation of Mt. Pleasant watershed, Sanpete County, Utah: Utah Geological and Mineral Survey Report of Investigation 169, 18 p.

Mountain West Design, 1984, Subsurface drainage investigation for the city of Mt. Pleasant, Utah: Logan, Utah, consultant's report to the city of Mount Pleasant, 9 p.

Robinson, G.B., Jr., 1968, Selected hydrologic data, San Pitch River drainage basin, Utah: U.S. Geological Survey and Utah Department of Natural Resources Basic-Data Report 14, 44 p.

Robinson, G.B., Jr., 1971, Ground-water hydrology of the San Pitch River drainage basin, Sanpete County, Utah: U.S. Geological Survey Water-Supply Paper 1896, 80 p.

USDA Soil Conservation Service and others, 1981, Soil Survey of Sanpete Valley area, Utah, parts of Utah and Sanpete Counties: 179 p.



Location map showing area of Mount Pleasant with depths to ground water of 8 feet or less (from Mountain West Design, 1984)

GEOLOGIC HAZARDS

Project: Inspection of landslides adjacent to Hill Air Force Base in Davis County			Requesting Agency: Division of Environmental Health
By: W. R. Lund	Date: 4/19/84	County: Davis	Job No.: GH-1
USGS Quadrangle: Ogden (1345)			

On April 16, 1984, at the request of Marvin Maxell, Assistant Director, Division of Environmental Health, an inspection was made of several landslides along the bluff on the south side of the Weber River in Davis County (attachment 1). The landslides are of concern to the State Health Department because they are immediately adjacent to a landfill at the top of the bluff operated by Hill Air Force Base. The landfill has received a variety of wastes (the type and quantities are not known at this time) from the 1940's until it was closed in the early 1980's. The Health Department was alerted to a possible contamination problem by the owners of the Davis and Weber Counties Canal Company whose canal runs along the side of the bluff at approximately the 4600-foot contour. Strong petroleum and pesticide-type odors are evident when walking over the landslides, and discolored water, often with an oily film or brownish froth, emerges from springs in the landslide mass. Drainage from the springs flows into the canal and the Health Department has initiated a sampling program to determine if toxic substances are present.

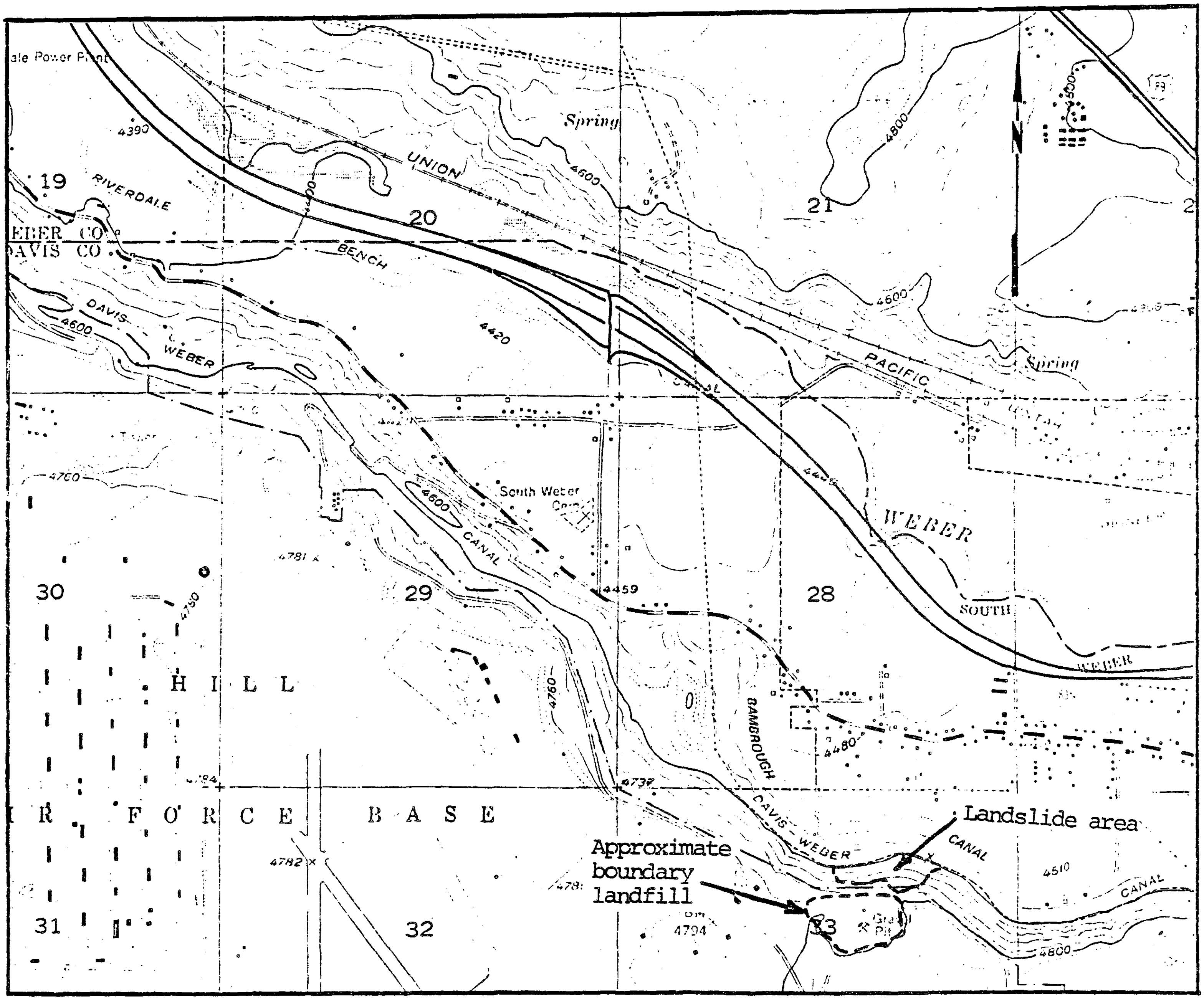
The bluff along which the landslides occur is located in an area generally referred to as the Washington Terrace landslide complex. Numerous landslides, both young and old, extend for several miles along the bluffs on both sides of the river. The past two years of high precipitation have accelerated the mass-wasting process in many areas.

The landslides of concern to the Health Department form an inter-connecting series of slump-earth flow type failures for a distance of three to four hundred yards along the bluff. The largest failure is approximately 150 feet wide and extends from the perimeter fence of Hill Air Force Base at the top of the bluff to the Davis-Weber canal, a distance of about 225 feet. The failure planes along which the slippage is occurring appear to be shallow and show no evidence of passing under the canal. However, the canal has experienced considerable damage where the toes of the various slides have encroached on its right-of-way. The concrete liner on the upslope embankment has been destroyed in several places and landslide debris has partially filled the canal.

Information supplied by the Air Force indicates that a buffer zone of in-place, natural material exists between the edge of the bluff (perimeter fence) and the landfill. The headwall scarp for the largest slide is presently (4-16-84) at the perimeter fence and any renewed movement would begin to erode the buffer zone. The slides have been relatively stable during the past several days of warm, dry weather, but renewed wet weather, especially for a prolonged period, could cause futher movement.

Attachment 1, Job No. GH-1

Base map from USGS Ogden
7½ minute topographic quadrangle



Location map showing approximate boundaries of landfill and landslide area

Scale: 1:24,000
ContourInterval 40 feet

Project: Helicopter reconnaissance of Settlement, Middle, and Butterfield Canyons, Oquirrh Mountains, Utah			Requesting Agency: Tooele County/ Tooele City
By: W. R. Lund	Date: 5/21/84	County: Tooele/Salt Lake	Job No.: GH-2
USGS Quadrangle: Lowe Peak (1133), Lark (1173), Bingham Canyon (1174), Tooele (1175)			

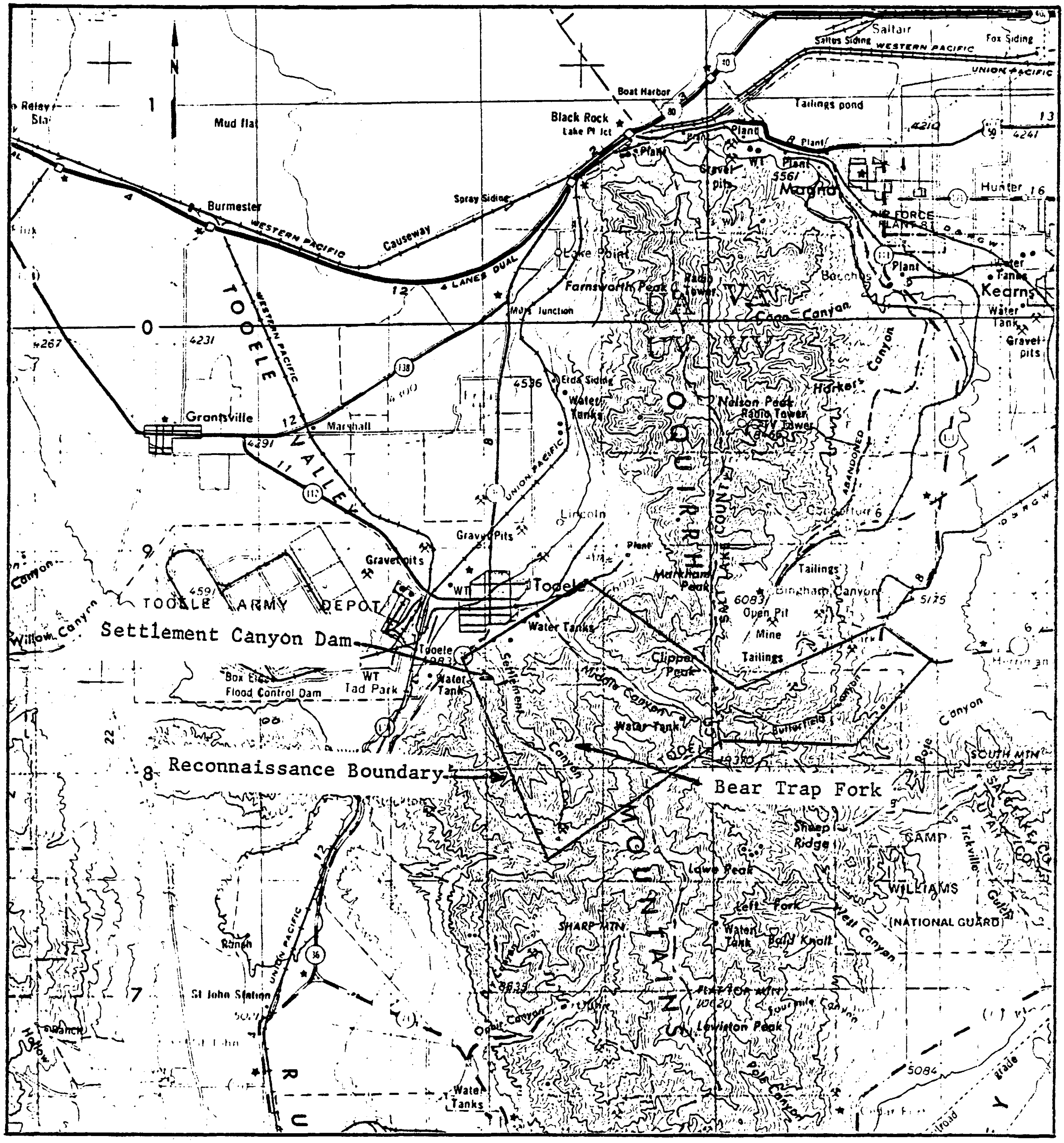
A helicopter reconnaissance was conducted on May 16, 1984, of Settlement, Middle, and Butterfield Canyons in the Oquirrh Mountains (attachment 1). The purpose of the reconnaissance was to investigate flooding in the canyons and to identify existing or potential slope failures caused by the spring snowmelt. Settlement and Middle Canyons are on the west side of the Oquirrh Mountains. Above normal runoff from those canyons beginning on May 13 caused flooding in and around Tooele City. A debris flood reached Settlement Canyon Dam (attachment 2) on May 14 and quickly filled the reservoir causing the spillway to begin spilling water. Eyewitness accounts indicate that the debris flood started as a slope failure high in a tributary canyon to Settlement Creek. Local officials were concerned about the potential for additional debris flows/floods and their possible effect on the dam. Butterfield Canyon is on the east slope of the Oquirrhs. It was examined in response to reports of erratic stream flow in the lower canyon, possibly the result of slope failures blocking the stream channel at higher canyon elevations. Messrs. Lee Bracken, Tooele County Commissioner, and Joe England, Tooele City Engineer, participated in the flyover of Middle and Settlement Canyons.

The reconnaissance of Settlement Canyon showed that the road up the canyon had been washed out in many places and that extensive damage had been done to picnic/camping facilities. Numerous debris flows, all originating as debris avalanches near the snowline on south-facing slopes, were observed. The largest, and the one responsible for the debris flood that reached the dam, originated in Bear Trap Fork approximately 2.5 miles above the dam. Other tributary canyons experienced debris flows with runouts of a half mile to a mile. They include Left Hand Fork Settlement Canyon, Left Hand Fork Kelsey Canyon, Right Hand Fork Kelsey Canyon, and upper Settlement Canyon known locally as Rocky Fork. A cracked, detached slide mass was observed next to the debris avalanche scars in Bear Trap Fork. The size of the detached mass did not appear large, but landing sites were not available for a ground examination. Cracking was not observed in other areas, but may be obscured by snow or vegetation.

Extensive flooding has occurred in Middle Canyon which is narrower and has more exposed bedrock than Settlement Canyon. Flooding at the canyon mouth endangered a well field supplying culinary water to Tooele City and caused rapid erosion of stream banks on a nearby farm. The canyon road is washed out in many areas, and a high pressure natural gasline buried in the road bed could be seen at several locations. No breaks were seen in the pipeline. Numerous small debris flows were observed in Left Hand Fork Middle Canyon and a debris flow in Shingle Gulch hit a summer home. It did not appear that the debris flows were sufficiently large to continue down Middle Canyon. Snow avalanches were seen in White Pine Canyon, Harkers Canyon, and an unnamed canyon east of Harkers Canyon. All snow avalanches originated on north-facing slopes and most appeared to be weeks or months old.

Butterfield Canyon showed evidence of flooding related to runoff but no slope failures were observed. Changes in stream flow at the canyon mouth may be the result of debris dams formed by material carried in the runoff water which then overtop and send water surges down the canyon.

Commissioner Bracken and City Engineer England were advised that a potential for debris flows/floods still exists in both Settlement and Middle Canyons and it was recommended that a canyon watch be instituted to provide warning of any future events. Upon completion of the reconnaissance, a call was placed to Ms. Lorayne Tempest, Director, Division of Comprehensive Emergency Management, and a verbal report given of conditions in the canyons.

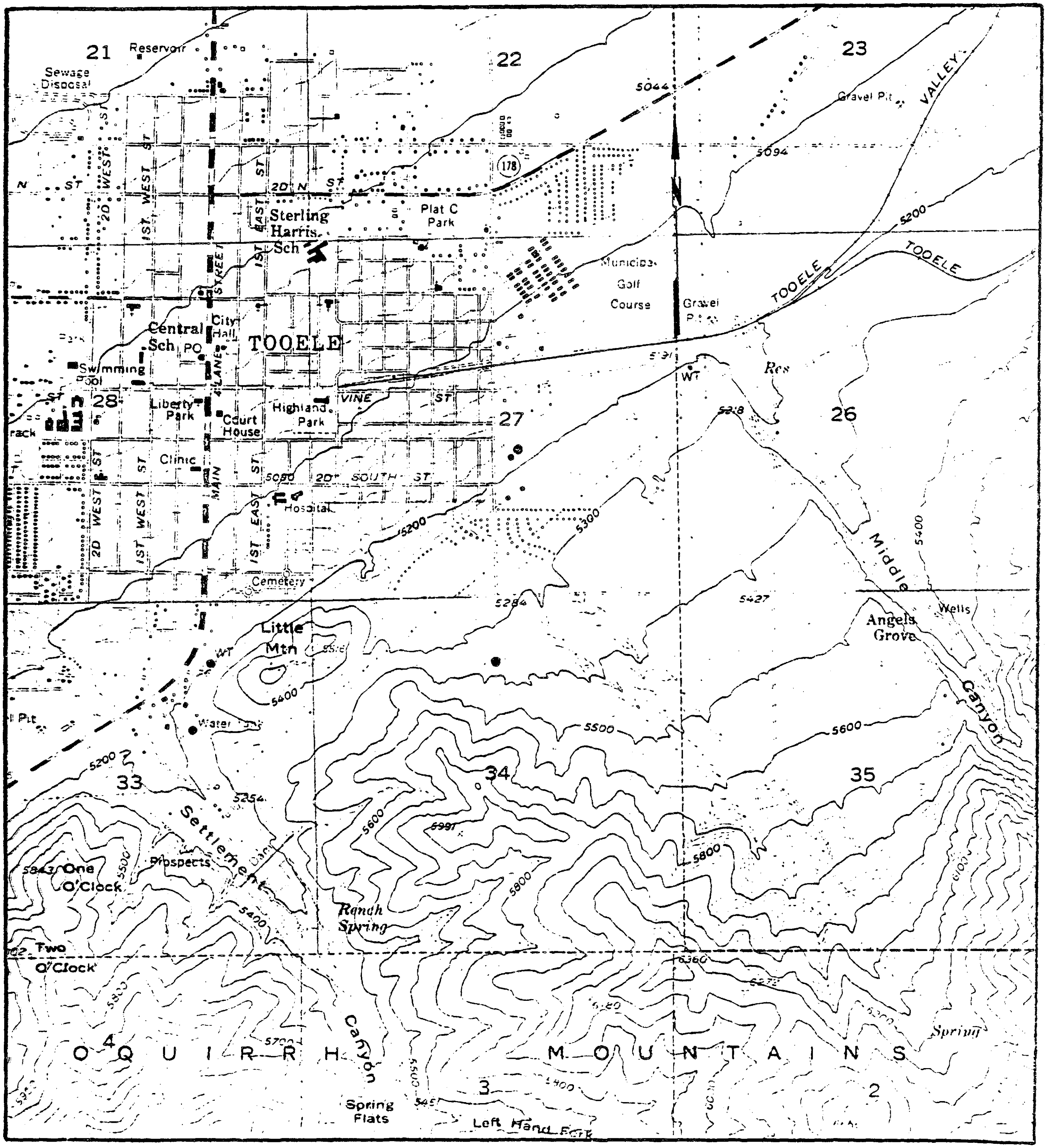


Location map showing area of helicopter reconnaissance

Scale 1:250,000
Contour Interval 200 feet

Base Tooele
1^{o} x 2^{o} topographic sheet

Attachment 2, Job No. GH-2



Map showing the mouths of Settlement and Middle Canyons and Settlement Canyon Dam

Scale 1:24,000
Contour Interval 20 feet

Base USGS
Tooele 7½' Topographic quadrangle map

Project: Investigation of fatal trench cave-in AMAX Magnesium Corporation facility near Rowley, Utah			Requesting Agency: Utah Industrial Commission
By: W. R. Lund	Date: 6/4/84	County: Tooele	Job No.: GH-3
USGS Quadrangle: Corral Canyon (1259)			

An investigation was conducted on May 14, 1984 of the AMAX Magnesium Corporation magnesium recovery facility at the south end of Great Salt Lake near Rowley, Utah (attachment 1). The purpose of the investigation was to evaluate the geologic and hydrologic conditions at the site of a fatal trench cave-in. The cave-in occurred at the AMAX south retention pond (A.K. Huntsman, oral commun., 5-14-84) which was under construction at the time of the accident. Pond construction consists of placing large rectangular steel plates on end in a trench and welding them together to form a water-tight barrier. The trench is excavated by a large track-mounted backhoe and is roughly 8 feet deep and 4 feet wide with near vertical sides (attachment 2, photo 1). Backfilling begins soon after the plate is in place so only 50 to 60 feet of trench are open at any one time. About 6 feet of the steel plate is left above ground to form the pond wall. The fatality occurred when a portion of the trench wall collapsed on a welder. Mr. Alfred Huntsman, compliance inspector for the Utah Industrial Commission, was present during the field visit to the site.

The AMAX south retention pond is located on a mud flat adjacent to the Great Salt Lake. The sediment consists chiefly of silt, clay, and fine oolitic sand. Prior to construction, the site was occupied by a shallow solar evaporation pond in which 2 to 3 feet of hard indurated salt accumulated on top of the mud-flat sediment. Where the trench was being excavated, additional loose salt scraped from what will be the new pond floor was piled up to give additional height to the pond wall. Attachment 3 is a schematic cross section of the pond wall and shows the stratigraphy exposed in the trench. It should be noted that construction continued following the fatality and that the segement of trench examined during the field visit was 75 to 100 feet away from the accident site. The area where the fatality occurred had been back-filled; however, it is believed that conditions in the portion of the trench examined were essentially the same as those where the accident occurred.

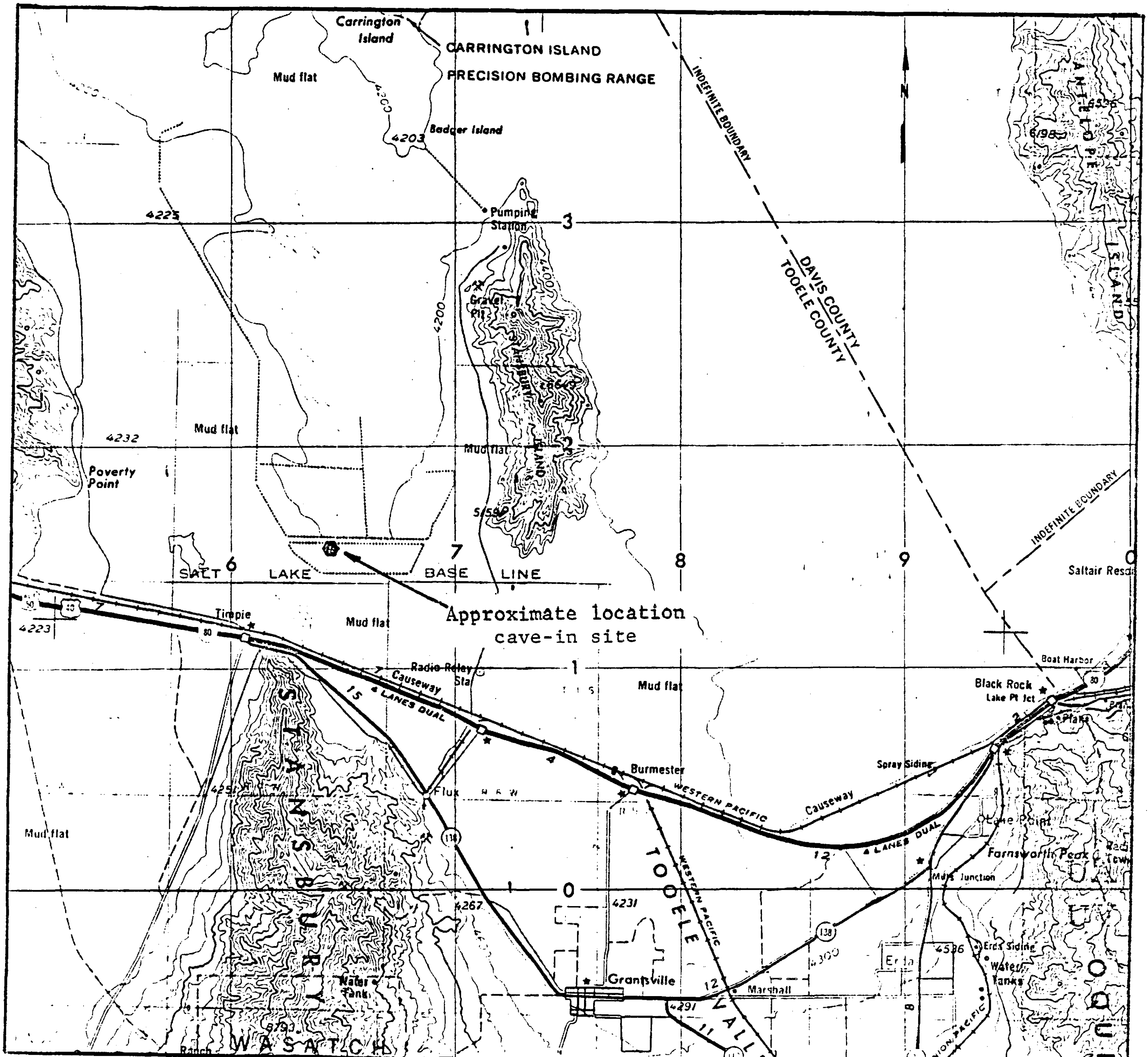
High ground water is present in the mud-flat area, and it appeared that only an extensive dike system prevented the site from being flooded by the Great Salt Lake. Mr Tom Hartman, welding foreman, indicated that most of the trench was below the water table and that it took two hours each morning to pump it dry. The pumping had to continue through the day to allow access to the trench. The morning high water mark could be seen on the last wall plate about 2 feet below the ground surface (attachment 3), indicating that the bottom 6 feet of the trench was below the water table. Ground water was observed entering the trench at the contact between the mud-flat sediments and the overlying indurated salt. The water collected on the trench floor and flowed to a sump where a 3-inch pump operated continuously at an estimated 50 gallons per minute.

Examination of the material exposed in the trench wall showed that the mud-flat sediment consists of gray, saturated, low to medium plasticity, sandy clay/clayey sand. The sand fraction is comprised of both spherical and rod-shaped calcareous ooids with some brine shrimp eggs and gypsum particles. In-place sediment is soft; unconfined strengths measured with a pocket penetrometer ranged from 0.5 to 0.75 tons/ft^2 which are typical of soft fine-grained soils. The indurated salt layer has an interlocking crystalline structure that makes it relatively hard. Two or three hammer blows were usually required to break a piece loose. The unconsolidated salt placed in the trench area is identical to the indurated layer except that it has been crushed and therefore exhibits the properties of a coarse, noncohesive sand.

Extensive caving of the mud-flat sediments into the trench was observed during the field visit (attachment 2, photo 2). The soft, saturated sandy clay/clayey sand material is not capable of standing in a vertical cut. As the caving proceeds, the overlying indurated salt layer is undercut and creates overhangs that extend a foot or more back from the original trench wall (attachment 2, photo 3). Once the unsupported weight of the salt exceeds its shear strength, a section of the salt breaks off and collapses into the trench. The construction superintendent indicated that in other areas along the trench longitudial cracks 20 to 30 feet long and several inches wide developed parallel to the trench walls (J. Niehelsel, oral commun., 5-14-84). The cracks were usually set back several feet from the trench and exhibited differential settlement with the trench side down. This indicates that the mud-flat sediments are not strong enough to support the weight of the salt once a free face is created by trenching. The weight of the salt acts as a driving force to accelerate the rate of sediment slumping into the trench.

In conclusion, geologic and hydrologic conditions at the site create extremely hazardous trenching conditions. The high water table; soft, low-strength sediments beneath a heavy indurated salt layer; and a vertical cut combine to cause unstable trench walls. The almost continuous caving of the mud-flat sediments along the length of the trench and the development of longitudinal cracks in the salt parallel to the trench walls are clear indicators of instability which should have been recognized by construction personnel. The hazard of working in the trench could have been reduced by either: 1) laying the trench walls back to an angle that prevented caving, 2) shoring the trench in work areas, or 3) using a trench box.

Attachment 1, Job No. GH-3



Map showing approximate location of fatal trench cave-in
Scale 1:250,000

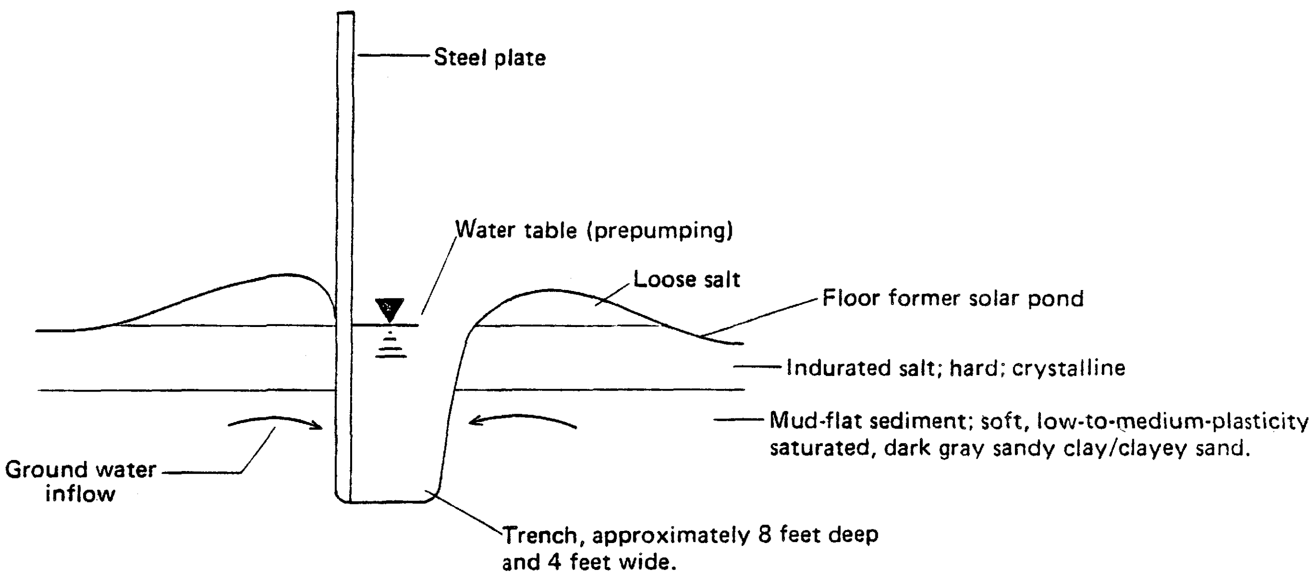
Base map Tooele $1^{o} \times 2^{o}$ topographic sheet

View of trench and pond wall under construction (Photo 1)

Caving of mud-flat sediments into trench (Photo 2)

Overhang created when mud-flat sediments cave from beneath indurated salt layer (Photo 3)

Attachment 3, Job No. GH-3



Schematic cross section of pond construction showing stratigraphy and water table.

Project:			Requesting Agency:
Geologic hazards evaluation of a property in the northeast area of the Weber State College campus, Ogden, Utah			Weber State College
By: G. E. Christenson	Date: 6/13/84	County: Weber	Job No.: GH-4
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

The purpose of this investigation was to perform a geologic hazards evaluation of a 9-acre property owned by Weber State College in the northeast area of campus (attachment 1). The property is near the mouth of Strongs Canyon in Ogden's east bench area at the front of the Wasatch Range. It slopes gently to the west from an elevation of 4740 feet along the east side to an elevation of about 4640 feet along the west. A step-like series of benches are present to the east between the mountain front and the property. It is at the base of the most prominent one, the top of which is at an elevation of about 4800 feet. An abandoned, paved access road crosses the property but no structures are present. The South Ogden Highline (Pineview) Canal forms the eastern boundary.

The investigation was requested by Dr. Garth L. Welch, Executive Director of Business Affairs for Weber State College. It consisted of a literature review and air photo analysis with a field reconnaissance performed on May 31, 1984. Emphasis was placed on assessing geologic hazards, and the investigation did not include subsurface exploration to evaluate soil foundation conditions or depth to ground water.

GENERAL GEOLOGY

Bedrock in the Wasatch Range east of the property includes the Precambrian-age metamorphic Farmington Canyon complex, consisting of mica schist and quartz monzonite gneiss, and the Cambrian-age Tintic quartzite (Bryant, 1979). At the mountain front, the Weber State College campus is underlain by unconsolidated deposits of Lake Bonneville. The property is located at the north edge of the Weber delta (Feth and others, 1966), a large delta constructed at the mouth of the Weber River where it flowed into Lake Bonneville from about 10,000-20,000 years ago. The bench east of the property is underlain by deposits ranging from massive, medium to coarse-grained red sand to thin-bedded yellow fine sand and red clay. These deposits are probably deltaic and lacustrine deposits of Lake Bonneville. The top of this bench is at an elevation of about 4800 feet and represents what is termed the Provo level of the lake, a stable shoreline occupied from about 14,000 to 13,000 years ago (Currey, 1982). Following recession of the lake from this level, debris flows and floods from Strongs Canyon deposited coarse-grained, angular gravels containing cobbles and boulders in the area. The thickness of these deposits is unknown, but they occur over much of the bench area (Feth and others, 1966; Miller, 1980). West of the bench on the Weber State property, heavy vegetation and thick organic soil horizons make it difficult to determine sediment types. They have been mapped as shoreline and deltaic gravel and sand of Lake Bonneville when it was at the Provo level by Feth and others (1966) and Miller (1980).

The tectonically active Wasatch fault parallels the mountain front east of the property. Several prominent north-trending fault scarps offsetting Lake Bonneville deposits and overlying younger debris-flow deposits are evident from 200 to 1000 feet east of the property. The slope along the northern edge of the property may also be a fault scarp (Cluff and others, 1970). This faulting may have played a role in diverting Strongs Creek to its present position north of the site. The age of most recent faulting is unknown. Studies to the south in Kaysville have indicated two events in about the last 1600 years, with the most recent occurring perhaps in the last few hundred years (Swan and others, 1981).

GEOLOGIC HAZARDS

Slope stability

The property is bounded to the east by a steep slope below the canal. No evidence of instability was found in this slope. However, soils exposed in the canal cut include clay beds and materials that are potentially unstable if saturated or undercut. If extensive grading is planned, care should be taken to prevent destabilizing slopes.

Flooding and debris flows

The flood and debris-flow hazard at the property is considered low. The area is not included in the 100-year flood plain of Strongs Creek by the U.S. Department of Housing and Urban Development (1977). Flood hazard is high in areas along Strongs Creek to the north, however, and Wieczorek and others (1983) have indicated a high potential for flooding (termed debris flooding in their report) along Strongs Creek upstream from the water tanks near the apex of the alluvial fan at the canyon mouth. The stream is not deeply incised in this area, and overbank flooding where banks are low (such as where water-line intakes for the water tank are found) may result in diversion of the stream westward toward the water tanks and the Weber State property. Such a diversion is possible during extreme flooding or debris-flow events, but most normal flooding will follow the present stream course north of the property.

The possibilty of flooding, particularly of the lowest areas, by ground water cannot be determined without subsurface investigation. Shallow ground water and seepage into foundations has occurred on the Weber State College campus to the southeast (Dames and Moore, 1983), and it is possible that such conditions exist at this site. No seeps, springs, or standing water were observed on the property at the time of the investigation.

Seismic hazard

The property is within the Wasatch fault zone and may be subjected at any time to surface fault rupture, strong ground shaking, and ground failure induced by seismic shaking (liquefaction, slope failure) accompanying an earthquake. The nearest mapped trace of the Wasatch fault traverses the eastern boundary of the property and other traces are within a few hundred feet to the east. Seismic hazard is thus high and the property is in Uniform Building Code seismic zone 3 and Utah Seismic Safety Advisory Council seismic zone 4, the zones of highest risk in the respective classifications in Utah. The potential for ground failure induced by shaking is in large part dependent on ground-water and soil conditions which are not known at this time.

CONCLUSIONS

The property is in a zone of high seismic risk, with potential for surface fault rupture as well as strong ground shaking. Depending on subsurface conditions, ground failure (liquefaction, slope failures) may also accompany earthquake shaking. Prior to construction, a soil foundation and seismic hazard investigation should be performed to address these concerns as well as ground-water conditions. Under present conditions, flood and debris-flow hazards are considered low and slopes appear stable.

REFERENCES

Bolke, E.L., and Waddell, K.M., 1972, Ground-water conditions in the East Shore area, Box Elder, Davis, and Weber Counties, Utah: Utah Department of Natural Resources Technical Publication No. 35, 59 p.

Bryant, Bruce, 1979, Reconnaissance geologic map of the Precambrian Farmington Canyon complex and surrounding rocks in the Wasatch Mountains between Ogden and Bountiful, Utah: U.S. Geological Survey Open-File Report 79-709, scale 1:50,000.

Cluff, L.S., Brogan, G.E., and Glass, C.E., 1970, Wasatch fault, northern portion, earthquake fault investigation and evaluation: Oakland, consulting report by Woodward-Lungren and Associates for the Utah Geological and Mineral Survey, 27 p.

Currey, D.R., 1982, Lake Bonneville: Selected features of relevance to neotectonic analysis: U.S. Geological Survey Open-File Report 82-1070, 30 p.

Dames and Moore, 1983, Evaluation of ground-water seepage problems and methods of ground-water seepage control for Weber State University, Ogden, Utah: Dames and Moore Job No. 4000-049-06, 43 p.

Eardley, A.J., 1944, Geology of the north-central Wasatch Mountains, Utah: Geological Society of America Bulletin, v. 55, p. 819-894.

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.

Miller, R.D., 1980, Surficial geologic map along part of the Wasatch Front, Salt Lake Valley, Utah: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1198, scale 1:100,000.

Pashley, E.F., and Wiggins, R.A., 1972, Landslides of the northern Wasatch Front, in Hilbert, L.S., ed., Environmental geology of the Wasatch Front, 1971: Utah Geological Association Publication 1, p. K1-K16.

Smith, R.E., 1961, Records and water-level measurements of selected wells and chemical analyses of ground water, East Shore area, Davis, Weber, and Box Elder Counties, Utah: Utah Basic-Data Release 1, 35 p.

Swan, F.H., III, Schwartz, D.P., Hansen, K.L., Kneupfer, P.L., and Cluff, L.S., 1981, Study of earthquake recurrence intervals on the Wasatch fault at the Kaysville site, Utah: U.S. Geological Survey Open-File Report 81-228, 33 p.

Thomas, H.E., 1945, The Ogden Valley artesian reservoir: Utah State Engineer Technical Publication 2, 37 p.

Van Horn, Richard, Baer, J.L., and Pashley, E.F., 1972, Landslides along the Wasatch Front, Utah, in Hilbert, L.S., ed., Environmental geology of the Wasatch Front, 1971: Utah Geological Association Publication 1, p. J1-J16.

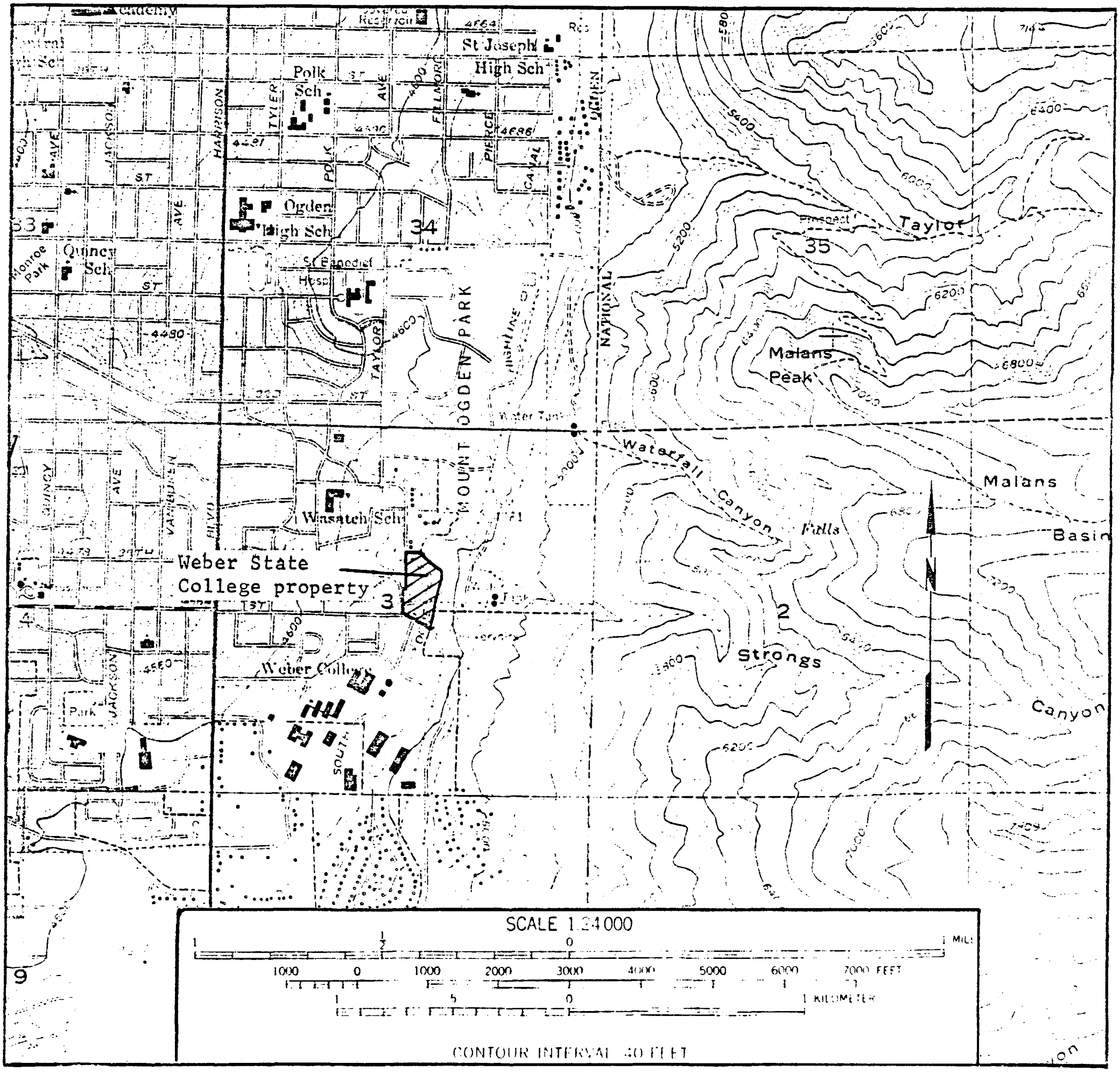
U.S. Department of Housing and Urban Development, 1977, Flood hazard boundary map, city of Ogden, Utah: Federal Insurance Administration Community-Panel No. 490189-0002A.

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

Wieczorek, G,F., Ellen, Stephen, Lips, E.W., and Cannon, S.H., 1983, Potential for debris flow and debris flood along the Wasatch Front between Salt Lake City and Willard, Utah, and measures for their mitigation: U.S. Geological Survey Open-File Report 83-635, 45 p.

Base map from USGS 7½' TopoQuad
Ogden, Utah

Attachment 1, Job No. GH-4



Location of Weber State College property, Ogden, Utah

Project:			Requesting Agency:
Sinkhole in Cedar View Subdivision near Vernal, Utah			Unitah County Engineer's Office
By: G. E. Christenson	Date: 8/13/84	County: Uintah	Job No.: GH-5
USGS Quadrangle: Vernal NE (1112)			

An investigation of two recently developed sinkholes in the Cedar View Subdivision about 5 miles south of Vernal (SW 1/4 NE 1/4 sec. 14, T. 5 S., R. 21 E., SLBM) was performed on July 26, 1984. The sinkholes were discovered on July 20, 1984, and consist of one hole which developed beneath the recently rerouted Highline Canal and another approximately 30 feet to the west in an open field. The sinkhole beneath the canal reportedly drained the canal for a period of time before filling, forming a pool and restoring flow downstream. This sinkhole had been backfilled and the canal floor regraded at the time of the investigation. The sinkhole to the west was left open, and ground cracks were visible between the two sinkholes. The western sinkhole is a tear-drop shape, elongate in the north-south direction, and is ten feet deep at its deepest part at the south end. It is about 33 feet wide and 47 feet long. No standing water was present in this sinkhole and none has reportedly ever been present.

Stratigraphy in the open sinkhole consists of six feet of silty sand (probably eolian in origin) with a caliche horizon from one to three feet, underlain by a coarse-grained, crossbedded, friable sandstone with minor laminated silt and clay interbeds. Vertical open fractures with partial carbonate fillings trending N. 35-40° W. and N. 10° E. were present in the sandstone. The sandstone is within the Cretaceous-age Asphalt Ridge Member of the Mesaverde Group and strikes N. 45° E. and dips 12° NW. This strike is at right angles to the regional strike of bedding in Asphalt Ridge which is roughly northwest with dips from 5-10 degrees to the southwest. The reason for the local anomaly in the bedding attitude is unknown.

The sinkholes are found in an area of shallow bedrock in an abandoned field which was previously irrigated. Bedrock crops out south of the area and floors the canal south of the sinkholes for several hundred feet. To the north, soil thicknesses increase and no bedrock was observed. The sandstone bedrock exposed in the sinkhole and surrounding area, although highly weathered and friable, is not susceptible to dissolution or piping and is probably not responsible for the collapse. Judging from the amount of soil and rock material lost in the collapse and the reported quantity of water which drained from the canal, substantial subsurface voids must exist beneath the sandstone. No evidence of a unit susceptible to dissolution was found, although the Asphalt Ridge Member reportedly contains gypsum. Water losses from the canal indicate that voids remain in the subsurface following collapse of the sinkholes. Reports by local farmers of periodic sinkhole development in irrigated fields to the southeast along the general strike of bedding in Asphalt Ridge indicate that such a bed is probably present throughout the area.

We recommend no further building on this site until the nature and extent of the problem can be defined through geotechnical investigations. Drilling with continuous core recovery would be required to verify the presence, thickness, and extent of the unit susceptible to dissolution. In addition, geophysical surveys may also be useful in mapping the unit as well as in identifying existing large subsurface void spaces. It is possible that such voids may be present anywhere in the area. Although the voids which collapsed to form these sinkholes may have existed prior to diversion of the Highline Canal through the area, enlargement and eventual collapse was probably related to the introduction of water in the rerouted canal. Lining of the canal to reduce infiltration and providing drainage for the subdivision into the lined canal or out of the area would aid in preventing further problems.

Project: Investigation of a gasoline leak in Green River, Utah			Requesting Agency: Southeastern Utah Health District
By: W. R. Lund	Date: 6/10/84	County: Emery	Job No.: GH-6
USGS Quadrangle: Green River (625)			

A trip to southeastern Utah was made between June 4-6, 1984. The purpose of the trip was three fold:

1. (WW-5) To examine exposures of the Mancos Shale in the vicinity of Price and Wellington, Utah with representatives of the State Health Department and the Southeastern Utah District Health Department (S. Thiriot and G. Storey respectively). Problems have developed with a number of septic tank/drainfield systems installed in the Mancos Shale in Carbon and Emery Counties. Other systems, also installed in the shale appear to be working satisfactorily. New health department regulations prohibit installation of drainfields in bedrock, a fact which has created considerable controversy in the Price area. This examination was to determine what if any modifications in the regulations should be made for the Mancos Shale and/or what kinds of alternate disposal systems might be appropriate for Mancos terrain. It was determined that additional information regarding the number of failing vs. functioning systems is required. G. Storey (Southeastern Utah Health District agreed to examine their files and contact individual owners as necessary to obtain that information.

2. (GH-6) Investigation of an underground gasoline leak in Green River, Utah. Considerable quantities of gasoline have been discovered in portions of the Green River sewer system. The suspected source is a leak in an underground storage tank at one of two nearby gas stations. The UGMS gas detection device was used to measure the concentration of gasoline fumes at the manhole where the gasoline occurs and also at a nearby sewer pump station. Readings of 9 and 2 percent were obtained respectively. A number of other manholes within a two-block area were also checked, none showed evidence of gasoline. It appears that the gasoline is coming from the stations as suspected. A sample of the gasoline will now be analyzed to identify the chemical tracer present. Each major oil company (in this case Husky and Shell) use a distinctive tracer in their product to allow its identification in cases such as this. Further UGMS involvement is likely only if the source of the gasoline cannot be identified by its tracer.

3. (PF-5) Examination of a million gallon water tank in Moab, Utah the foundation of which has begun to crack and settle. The water tank is approximately three years old and is located on a norrow ridge top northwest of Moab. The city engineer (Mr. Keogh) claims that he saw cracks in the top of the ridge paralleling those in the tank foundation and is concerned that a landslide may be developing adjacent to and beneath the water tank. A careful examination of the site and both sides of the ridge showed no evidence of slope movement (the cracks reported by the city engineer were no longer visable). A foundation investigation was

not performed for the tank nor is there any documentation of the materials exposed in the foundation excavation at finished grade. Bedrock is exposed on the ridge top and on the south ridge slope, the north slope is underlain by colluvium of variable thickness. It is not known if the bedrock-colluvium contact lies beneath the water tank, but it is the colluvium side of the tank that is settling. It was suggested to the city engineer that a series of monitoring points be established on the slope and their evaluations surveyed periodically in an attempt to detect any evidence of slope movement. He agreed to establish the monitoring net and will contact UGMS when he has some data.

Project:			Requesting Agency:
Review of report on basement flooding in South Jordan/Riverton near Kennecott evaporation ponds			Bureau of Water Pollution Control, Utah State Dept. of Health
By: G. E. Christenson	Date: 11/29/84	County: Salt Lake	Job No.: GH-7
USGS Quadrangle: Midvale (1172)			

The purpose of this report is to review the technical evaluation by Intera Technologies, Inc. (1984) for Kennecott (Utah Copper Division) regarding basement flooding along 11800 South Street in South Jordan and Riverton. The flooding has occurred in homes betweem 3600 West and the Provo Reservoir Canal within a mile east of seven new evaporation ponds built by Kennecott in 1983. Some of these new ponds were first used in August, 1984, and all but one were filled in 1984. The ponds received flow of both treated and untreated water from the Bingham Canyon Mine area.

The new ponds are along the south arm of a V-shaped (cuspate) sand and gravel beach of Pleistocene Lake Bonneville deposited when the lake was at the Provo level about 13,000 to 14,000 years ago (Miller, 1980; Currey, 1982; Davis, 1983). The largest pond is on the beach ridge and is lined with material excavated from the lower ponds to the east. The lower ponds are in finer-grained sand/silt/clay material deposited offshore (southeast of the beach ridge) in Lake Bonneville (Woodward and others, 1974; Miller, 1980). Two of these ponds were constructed under emergency conditions in 1983 and are not lined. In the remainder of the lower ponds the natural material in the bottom was compacted to form a liner. An older group of unlined evaporation ponds are found along the north arm of this V-shaped beach, and seepage has occurred along the base of the beach deposit from leakage from these ponds.

In evaluating the possibility that basement flooding along 11800 South is caused by leakage from Kennecott's new evaporation ponds, Intera Technologies, Inc. (1984) make the following observations:

1) The area is in a zone of known perched ground water, and a natural rise of the water table is expected in response to recent wet years. Well logs in the area of basement flooding indicate approximately 30 feet of gravel, presumably saturated to within several feet of the surface, overlying clay on which the ground water is assumed to be perched. In the Kennecott pond area, piezometer holes are dry to 90 feet.

2) Seepage known to be derived from the old evaporation ponds is of poor quality with high conductivities, whereas water in basements is of a quality similar to background levels in wells in the area. This indicates that the shallow ground water is natural and not pond leakage water.

3) Quantitative estimates of seepage rates from permeabilitiy tests in the new ponds indicates insufficient time for water to migrate from the ponds 4000 feet to the homes being flooded.

From these lines of evidence, Intera Technologies, Inc. (1984) conclude that the new evaporation ponds are probably not the cause of basement flooding along 11800 South Street, although it is conceded that the data are not 100 percent conclusive.

In reviewing the report, it was found that supporting data for these conclusions were generally not presented and that alternative explanations for some of the observations were not considered. Also, a more detailed geohydrologic investigation seemed warrented for this site-specific and very localized problem. In response to each of the three major observations made in the Intera report, we make the following comments:

1) The existence of a shallow perched water table is well-established (Hely and others, 1971), and the rise of that water table to near the surface is the probable cause of basement flooding. However, details of the subsurface geology and water-table configuration as determined from existing well and test hole logs and morphostratigraphic interpretations of the local Lake Bonneville geology were not adequately addressed in the Intera report. Such an analysis is necessary to evaluate sources and travel paths of ground water. The conceptual diagram (figure 4) is too generalized to be relevant to the immediate problem, and detailed cross sections similar to those constructed by Kennecott (1984b, figures 20 and 21) from well log data along Bingham Creek and north-south through the evaporation pond area should have been constructed along 11800 South Street. These cross sections would yield information on the depth to the deep aquifer, the lateral continuity of upper confining layers, and the depth to water. Also, no well logs or construction specifications regarding piezometers in the pond area referred to on page 4 (paragraph 2) are provided. This may be the best information available to evaluate the contribution of the ponds to the perched water table, yet it is only briefly mentioned.

2) Actual quality analyses of water in basements, seeps, and ponds are not provided and relationships between them not thoroughly addressed. Also, the determination of background levels was made from wells tapping the deep aquifer and not the shallow aquifer which is responsible for the flooding. In the comparison of water quality in basements and evaporation ponds, no consideration is given to possible attenuation of contaminants by fine-grained materials in pond liners and between the homes and the ponds. The poor quality of seepage from old ponds is expected because of the sand and gravel medium, but water which has migrated through silt and clay moves more slowly and may receive sufficient treatment to improve water quality in transit to the homes 4000 feet away. In addition, increased hydrostatic pressure (head) in the local ground-water system resulting from possible pond leakage may cause a rise in water levels down-gradient to the east before the contaminated water actually migrates the entire distance.

3) Estimates of permeability and flow rates from laboratory tests were not adequately explained or documented. The final range of permeabilities used to make calculations of seepage rates (page 6, paragraph 2) is not the actual range measured, but a range of calculated means. The maximum used in seepage calculations is a mean of eight tests ranging from 0.7 to 100 feet/year rather than the

actual measured maximum rate. Water will exploit zones of greatest permeability, and a "worst case" calculation in generally in order in an evaluation such as this. It is pointed out in the report conclusion that even the highest measured rate of 100 feet/year (assuming that this actually is the highest rate and that no permeable zones in the subsurface or breaks in clay linings exist) would not be sufficient to cause flooding 4000 feet away within a month or two of filling of the ponds. However, as mentioned in item 2) above, it is possible the the rise in water table is due to an increase in hydrostatic pressure and not actual movement of water the entire distance.

In summary, the report presents several lines of evidence in support of the conclusion that the ponds are not contributing to basement flooding. We believe that the local geologic and hydrologic setting are not sufficiently documented in the Intera report to support this conclusion, and that alternative explanations for the observed conditions have not been adequately addressed. It appears that a significant amount of water well log data and Kennecott water quality and boring log data (Kennecott, 1984a, 1984b) are now available which were either overlooked or were not available at the time this report was prepared. This material should be thoroughly reviewed before a final conclusion is reached.

If these additional data are inconclusive, a detailed study of the perched aquifer will be necessary. Most existing monitoring wells tap only the deep aquifer, and additional data regarding water-table conditions, soil types, and water quality in the perched aquifer may be needed. These data would best be acquired from monitoring wells and exploratory borings to depths of 30 to 50 feet in the zone between the ponds and the flooded homes. They would be used to determine the configuration of the water table, discern trends in water quality, and evaluate subsurface geologic conditions including identification of permeable zones and determination of the extent and continuity of the clay bed on which ground water is perched, particularly as it extends to the west beneath the ponds. Included in the study should be an evaluation of the many possible sources of recharge to the perched aquifer, including leakage from the Provo Reservoir Canal, infiltration from flood irrigation and stream flow, and direct precipitation, as well as pond leakage. Correlations between filling of ponds, flow in canals and streams, precipitation records, and flood irrigation practices with fluctuations in the water table will be required to evaluate the relative importance of each source. Tracer dye tests may also be useful locally.

REFERENCES

Currey, D.R., 1982, Lake Bonneville: selected features of relevance to neotectonic analysis: U.S. Geological Survey Open-File Report 82-1070, 30 p.

Davis, F.D., compiler, 1983, Geologic map of the central Wasatch Front, Utah; Utah Geological and Mineral Survey Map 54-A, scale 1:100,000.

Hely, A.G., Mower, R.W., and Harr, A.C., 1971, Water resources of Salt Lake County: Utah Department of Natural Resources Technical Publication 31, 244 p.

Intera Technologies, Inc., 1984, Technical evaluation of basement flooding problem near Kennecott's evaporation ponds: Houston, consultants report for Kennecott, 7 p.

Kennecott, 1984a, Bingham Canyon storm water management: Treatments, control and impoundment of excess storm water during the July 1, 1983-June 30, 1984 record precipitation year: Utah Copper Division, Environmental Engineering Department, 9 p.

----- 1984b, Geologic, ground and surface water data background and progress report of Kennecott's Utah Copper Division (UCD) mine hydrogeologic study: Report 1, 45 p.

Marine, I.W., and Price, Don, 1964, Geology and ground-water resources of the Jordan Valley, Utah: Utah Geological and Mineral Survey Water-Resources Bulletin 7, 68 p.

Miller, R.D., compiler, 1980, Surficial geologic map along part of the Wasatch Front, Salt Lake Valley, Utah: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1198, scale 1:100,000.

Seiler, R.L., and Waddell, K.M., 1984, Reconnaissance of the shallow-unconfined aquifer in Salt Lake Valley, Utah: U.S. Geological Survey Water-Resources Investigations Report 83-4272, 34 p.

Woodward, J.L., and others, 1974, Soil survey of Salt Lake area, Utah: U.S. Soil Conservation Service in cooperation with Utah Agricultural Experiment Station, 132 p.

Project:			Requesting Agency:
Basement flooding by ground water along 11400 South Street, South Jordan, Utah			City of South Jordan
By: G. E. Christenson	Date: 11/6/84	County: Salt Lake	Job No.: GH-8
USGS Quadrangle: Midvale (1172)			

BACKGROUND

The purpose of this investigation was to determine the source of shallow ground water which is flooding basements and septic tank drain fields in the 1500 West, 11400 South area of South Jordan (attachment 1). The basements of many homes along 11400 South both east and west of the South Jordan Canal are being flooded, some for the first time and others for a longer time and more severely than in previous years (attachment 1). Local residents believe that a Salt Lake County Water Conservancy District water line installed along 11400 South in 1983 is conveying ground water from the west into the area through the sand and gravel pack around the 33-inch pipe which is at depths from 6 to 12 feet below the surface. The pipe is passed through a 48-inch casing packed with sand under the South Jordan Canal at about 1500 West. Residents believe this causes a constriction in the flow path and "dams" ground water which subsequently flows laterally away from the pipeline and raises the local water table causing basement flooding. An evaluation of this and other possible sources of ground water, as well as recommendations for remedies and/or further study, are included as a part of this study.

SCOPE OF WORK

The scope of work included a literature review, air photo analysis, review of well logs from the Utah Division of Water Rights, and installation of 6 monitoring wells in the area. Five of the monitoring wells (wells 1-5) were drilled with a 4-inch diameter auger and cased with 1.5-inch PVC pipe. The upper 2 to 3 feet of pipe were unperforated and the annulus sealed with either clay or cement at the top. The remainder of the casing was perforated with holes at 4-inch intervals and the annulus packed with gravel. Two wells were drilled in 11400 South Street over the water line, and three south of the street (attachment 2). The remaining monitoring well (well 6) is to the north in an existing borehole drilled by the LDS Church, and was constructed in a manner similar to wells 1-5. Logs of monitoring wells 1-5 are shown in attachment 3. Ground-water levels were measured in all monitoring wells and in existing excavations at the Rasmussen and Grow homes. Depths to water were measured from reference elevations (well heads or other local datums) which were surveyed to an accuracy of 0.1 foot, and adjusted to an arbitrary datum taken at 8 feet below the top of well 5. Water levels were measured on four occasions and are shown, along with reference and water-table elevations, in attachment 4. Three cross sections depicting the configuration of the water table on September 24, 1984, are presented in attachment 5. Locations of cross sections are shown in attachment 2.

GEOLOGY AND SOILS

The study area is underlain by lake-bottom sediments of Pleistocene-age Lake Bonneville (Miller, 1980; Davis, 1982). These deposits consist chiefly of silt and clay with minor sand beds and are flat-lying. Monitoring wells 3, 4, and 5 were drilled in undisturbed material and encountered stiff, fat clay (CH) from depths of about 6 feet to 14 feet or more. At wells 4 and 5 a thin sand layer was encountered from 5 to 6 feet. Upper soil layers consist of lean clay and silt (CL or ML; Woodward and others, 1974).

Monitoring wells 1 and 2 were drilled in trench backfill above the Salt Lake County Water Conservancy District water line. Backfill around the water line reportedly consists of sand to about a foot above the line and then another foot of sand and gravel mix. The excavated material was used to backfill the remainder of the trench. In wells 1 and 2, the backfill consists of about 3 feet of asphalt and gravelly road-base material underlain by lean clay (CL) to depths of 5.5 and 8.0 feet, respectively. Drilling was stopped at these depths to avoid damage to the water line. According to construction drawings, the bottom of the well should have been within 1 to 2 feet of the water line, although it is not believed that the gravel and sand pack around the pipe was encountered in either drill hole.

GROUND WATER

Regional

In the South Jordan area, ground water occurs both in a deep confined aquifer and in a shallow unconfined aquifer (Hely and others, 1971). The deep confined aquifer consists of a series of sand and gravel layers interbedded with silt and clay layers. This aquifer extends throughout central Salt Lake County and artesian conditions exist along the Jordan River at the valley axis. Hely and others (1971) show the area of artesian flow in February, 1969, as extending west of the South Jordan Canal into the study area. Elsewhere in the southern Salt Lake Valley it is generally restricted to the Jordan River flood plain. Impermeable layers above the confined aquifer extend westward to about 5000 West. The confined aquifer is generally found at depths of 100 feet or more in the study area.

The shallow unconfined aquifer is above the clay beds that confine the deep aquifer. It consists of sand, silt, and clay and is recharged from surface water (infiltration from stream flow, irrigation, unlined canals, and direct precipitation) as well as leakage upward from the confined aquifer where artesian conditions exist (Seiler and Waddell, 1984). Ground-water flow in all aquifers in the southwestern Salt Lake Valley is from west to east toward the Jordan River.

Local

Ground water in both the deep confined and shallow unconfined aquifers are of concern in the study area. A deep well south of the Stallings home tapping the confined aquifer (attachment 2) had a water level of 10 feet on October 17, 1982 when it was drilled. The total depth of the well is 150 feet and it was cased with an unperforated 8-inch diameter pipe with no gravel pack. At the time of this investigation, the water level had risen to near the top of the casing, and on September 20-21 and October 1 water was observed overflowing the casing which is several inches above the ground surface. This indicates increased artesian pressures in the deep aquifer which may result in increased upward leakage into the shallow unconfined aquifer.

The depth to water in the shallow unconfined aquifer at the time of this study ranged from about 3 to 7 feet, with the deepest water table found east of the canal (attachment 4). Unpublished UGMS data and Seiler and Waddell (1984) indicate a depth to water of about 10 feet in the shallow unconfined aquifer in the area prior to the wet years of 1983 and 1984. Basement flooding both east and west of the canal has occurred to a minor extent in previous years. The general area of basement flooding is shown in attachment 1.

Water-table elevations are shown below in table 1. Depths to water and other details of water-level measurements are given in attachment 4. Except where influenced by pumping, the elevation of the water table in the shallow unconfined aquifer is uniform (cross sections A-A' and B-B', attachment 5) with an eastward gradient that steepens in the vicinity of the South Jordan Canal (cross section C-C', attachment 5). Monitoring wells shown in cross section A-A' were placed as far from areas being pumped as possible to permit an evaluation of natural water-table conditions. Monitoring well 1 (cross section B-B', attachment 5) was placed over the pipeline to evaluate the water table between two homes along the canal where the greatest influence of a "damming" effect at the canal would be found. Water levels were also measured in excavations at the Rasmussen and Grow homes, both of which were periodically pumped or bailed. Monitoring well 5 was installed to evaluate water-table conditions east of the canal.

Table 1.-Water-table elevations in feet above arbitrary datum

Location	Water-table Elevation			
	Sept. 21, 1984	Sept. 24, 1984	Oct. 1, 1984	Oct. 16, 1984
Monitoring well 1	8.5	8.3	7.7	7.5
Rassmussen backhoe pit	7.2	8.0	6.4	-
Grow water-line trench	8.3	8.3	Backfilled	
Grow backhoe pit	5.8	5.4	Backfilled	
Monitoring well 2	11.8	11.6	11.5	11.5
Monitoring well 3	11.6	11.4	10.9	10.9
Monitoring well 4	11.8	11.5	11.3	11.3
Monitoring well 6	13.9	12.0	11.5	11.5
South Jordan Canal	6.4	6.4	5.4	5.0
Monitoring well 5	0.8	1.0	0.6	0.6
Stallings well	13.2+	13.1	13.2+	13.1

The eastward slope of the water table indicates recharge from the west. The water table to the west is above the water level in the canal, indicating that the canal is acting as a drain for ground water flowing from west to east. Drainage into the canal is one cause of the slight steepening of the water table in this area. Another cause is the steepening of the slope of the ground surface at and east of the canal. The high level in monitoring well 6 on September 21 (table 1) was probably caused by flood irrigation from a canal east of Redwood Road on September 20, 1984. The level had stabilized by October 1. The low water table in the backhoe pit behind the Grow home probably represents a water table not fully recovered following continuous pumping of a nearby shallow well (total depth-25 feet) for more than a month prior to this study. Mr. Grow reported a rise in the depth to water in the well from about 11 feet to 4.5 feet around mid-summer causing him to begin pumping. The level to which the water table may have risen with no pumping is unknown.

Source

The water in the shallow unconfined aquifer which is causing basement flooding in the area is derived from many sources. Those present in previous years include: 1) irrigation, 2) infiltration from unlined canals, 3) upward leakage from the deep artesian aquifer, 4) discharges from septic tank drain fields, 5) direct precipitation, and 6) flow of ground water from the west. These sources have caused minor basement flooding in at least two homes (Rasmussen home and a home east of the canal) in previous years. Potential sources and conduits for flow which are either new this year or are increased over past years are: 1) the water line along 11400 South (completed in June, 1983), 2) increased duration of flow in unlined canals to drain Utah Lake, 3) increased artesian pressure in the deep aquifer from a previous level 10 feet below the ground surface to one above the surface, 4) increased direct precipitation and westward flow of ground water in the shallow aquifer, and 5) seepage from several new Kennecott evaporation ponds west of the area.

Unlined canals have probably been a major factor in the rise of the water table in the area, and it is likely that canals to the west are still contributing. However, the South Jordan Canal at present is acting as a drain rather than as a source of recharge, at least for ground water to the west. Because the level to which ground water is drained depends on the water level in the canal, the canal exerts a direct influence on the water table. Recharge from irrigation and septic tank drain fields is presumably contributing amounts of water equal to that previously. However, upward leakage from the confined aquifer, precipitation, and flow from the west are greater than in previous years.

It is unlikely that the Salt Lake County Water Conservancy District water line is playing a significant role in the flooding. Surface infiltration rates above the water line should be less than in surrounding areas because it is covered with an impermeable layer of asphalt and backfilled (above the sand and gravel pack and below the road base) with compacted clayey material. The backfill may also act as a barrier to lateral ground-water flow except along the waterline where the permeable sand and gravel are found. Considering the contrast in permeability between the clayey natural soils and the sand and gravel pack around the water line, any effect the water line is having on the flow of ground water should be reflected in the configuration of the water table above the line. The water table above the water line should be lower than in adjacent areas if it is acting as a drain, and should be higher if it is acting as a source of recharge. No such differences in the water table above the water line are apparent in cross section A-A' (away from the effects of pumping), indicating that water is neither being conveyed into or out of the area along the water line. Cross section B-B' is less definitive because water levels are affected by pumping at the Rasmussen backhoe pit and home and at the Grow Well (attachment 2). However, the water table above the water line between the Rasmussen and Grow homes is still relatively flat.

When originally installed, the water line was reportedly above the water table, with water encountered in the trench excavation only in the vicinity of the canal. The water line is presently below the water table, as are the sand

and gravel pack and much of the overlying backfill, and ground-water flow is eastward into and beneath the canal. However, a reduction in permeability at the canal may affect this flow and cause mounding to the west. The lateral extent of the mounding would depend on the relative permeability and lateral extend of the less permeable zone. The effect of reduced permeability in a narrow zone such as along the water line would be localized and, under present water-table conditions, would be readily drained away by the canal.

The remaining additional potential source of ground water is a series of new Kennecott evaporation ponds constructed in 1983 between 11400 and 11800 South at about 4500 West. Older ponds in the same area have been filled previously causing no problems and were again filled in 1983. One of the new ponds was first used in August, 1983, and the others were first filled in spring of 1984, several months before basement flooding occurred along 11400 South. Residents believe leakage from the new ponds is picked up by the water line along 11400 South and transmitted eastward to their homes at 1500 West. This is unlikely because the ponds are more than 3 miles west of the study area and 1.5 miles west of the Jordan Aqueduct along 3200 West where the water line begins. The time between filling of the ponds and flooding along 1500 West is only a matter of months, and considering the existing hydraulic gradient and the permeabilities of soils (particularly between the ponds and 3200 West), this is insufficient time for ground-water to travel the 3-mile distance. Also, it is unlikely that these ponds could contribute to flooding 3 miles away without causing extensive flooding in the intervening area along 11400 South Street.

CONCLUSIONS AND RECOMMENDATIONS

The ground-water flooding problem along 11400 South Street appears to be the result of a natural high water table throughout the area. Recharge to the water table is from many sources, including direct precipitation, unlined irrigation canals, flood irrigation of fields, septic tank drain fields, upward leakage from the confined aquifer, and flow of ground water from the west in the shallow unconfined aquifer. The relative contribution from each source cannot be determined from the existing data. A long-term study with installation of monitoring wells throughout the area and close correlation of water-level changes with irrigation practices, septic tank usage, canal losses, and precipitation would be required to determine specific sources.

The Salt Lake County Water Conservancy District water line is presently below the water table and our data do not indicate that it plays a significant role in the movement of ground water. The line was in place during the 1983 irrigation season and no unusual flooding was reported along 11400 South. The fact that homes both east and west of the canal are flooded indicates that the problem is area wide, and the fact that basement flooding occurred in previous years at the Rasmussen home just west of the canal before the water line was installed indicates that the problem is a recurrent one not necessarily related to the water line.

Pumping of ground water is a common solution to basement flooding problems. Sump-pumps are effective in relieving flooding, but require maintenance and depend on an external power source. Pumping from well points outside homes will also lower the water table, but their effectiveness is dependent on soil permeability. Considering the low hydraulic gradient (70 feet/mile) and low soil permeabilities in the area, flow of ground water through all materials is very slow. Even under the increased hydraulic gradients caused by pumping, the clayey materials will yield little water and only dewater a local area immediately around the pumping center. Pumping from the permeable zone along the water line has the greatest potential for lowering the water table over the greatest area. Such pumping should initiate flow along this zone beneath the water table, providing a linear drain for all areas adjacent to and above the line along 11400 South. However, residents of 11400 South Street placed a well (vertical perforated metal culvert) to a depth of about 8 feet adjacent to the water line just west of the canal on September 29, 1984 (attachment 1). They report that day-long intermittant pumping from this culvert only drops the water level 50 feet away at monitoring well 1 about 0.5 feet, and the water level recovers by morning. No change in water level caused by pumping at this well was noted in any of the other monitoring wells on October 16, 1984 (table 1). The very limited success of this pumping indicates that recharge is sufficient to offset the pumping. Also, drawdown in this well to levels below the canal would alter local ground-water flow directions and actually draw water from the canal. Continued pumping may eventually lower the water table in the area, but from this preliminary data it appears that considerable time and a large number of well points may be required to effectively lower the water table throughout the area.

Because of this, we do not recommend pumping as a long-term solution to relieve basement flooding in the area. A more effective remedy which does not depend on the availability and reliability of an external power source is the installation of gravity drains around homes at depths below basement floors. Such drains would generally consist of a perforated drain pipe buried in gravel in a trench surrounding each home, with an outlet at a lower elevation to allow gravity flow of water away from the home. Such drain systems are common in many areas throughout the Salt Lake Valley and detailed specifications for construction are readily available. It is possible that the water table may naturally drop as recharge from precipitation and irrigation decreases during the winter. However, the high water table may persist and/or return in following years, particularly if wet conditions continue.

REFERENCES

Currey, D.R., 1982, Lake Bonneville: selected features of relevance to neotectonic analysis: U.S. Geological Survey Open-File Report 82-1070, 30 p.

Davis, F.D., compiler, 1983, Geologic map of the central Wasatch Front, Utah; Utah Geological and Mineral Survey Map 54-A, scale 1:100,000.

Hely, A.G., Mower, R.W., and Harr, A.C., 1971, Water resources of Salt Lake County: Utah Department of Natural Resources Technical Publication 31, 244 p.

Intera Technologies, Inc., 1984, Technical evaluation of basement flooding problem near Kennecott's evaporation ponds: Houston, consultant's report for Kennecott, 7 p.

Kennecott, 1984a, Bingham Canyon storm water management: treatments, control and impoundment of excess storm water during the July 1, 1983-June 30, 1984 record precipitation year: Utah Copper Division, Environmental Engineering Department, 9 p.

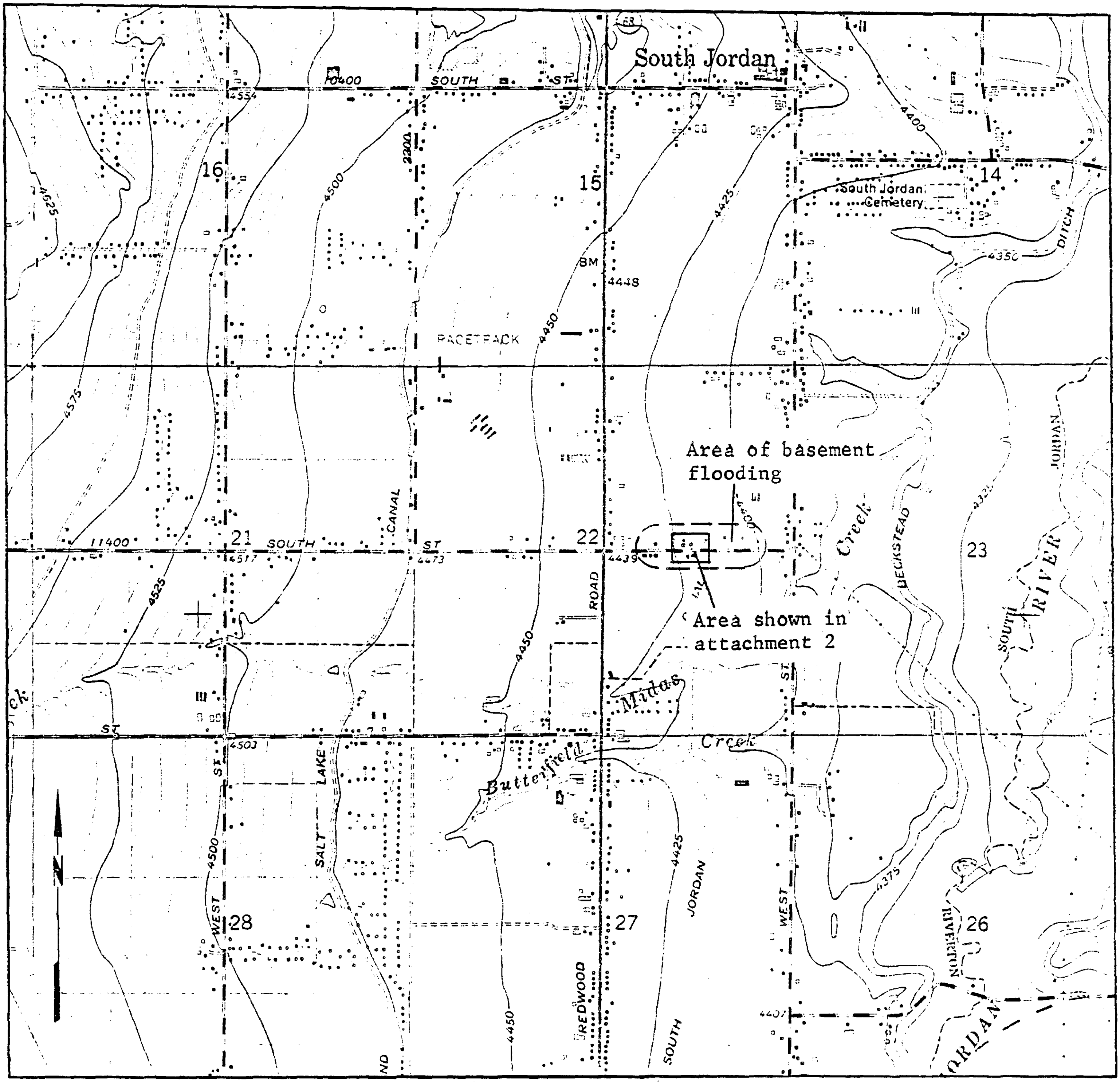
-----------1984b, Geologic, ground- and surface-water data background and progress report of Kennecott's Utah Copper Division (UCD) mine hydrogeologic study: Report 1, 45 p.

Marine, I.W., and Price, Don, 1964, Geology and ground-water resources of the Jordan Valley, Utah: Utah Geological and Mineral Survey Water-Resources Bulletin 7, 68 p.

Miller, R.D., compiler, 1980, Surficial geologic map along part of the Wasatch Front, Salt Lake Valley, Utah: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1198, scale 1:100,000.

Seiler, R.L., and Waddell, K.M., 1984, Reconnaissance of the shallow-unconfined aquifer in Salt Lake Valley, Utah: U.S. Geological Survey Water-Resources Investigations Report 83-4272, 34 p.

Woodward, J.L., and others, 1974, Soil survey of Salt Lake area, Utah: U.S. Soil Conservation Service in cooperation with Utah Agricultural Experiment Station, 132 p.



SCALE 1:24000

1 ½ 0 1 MILE

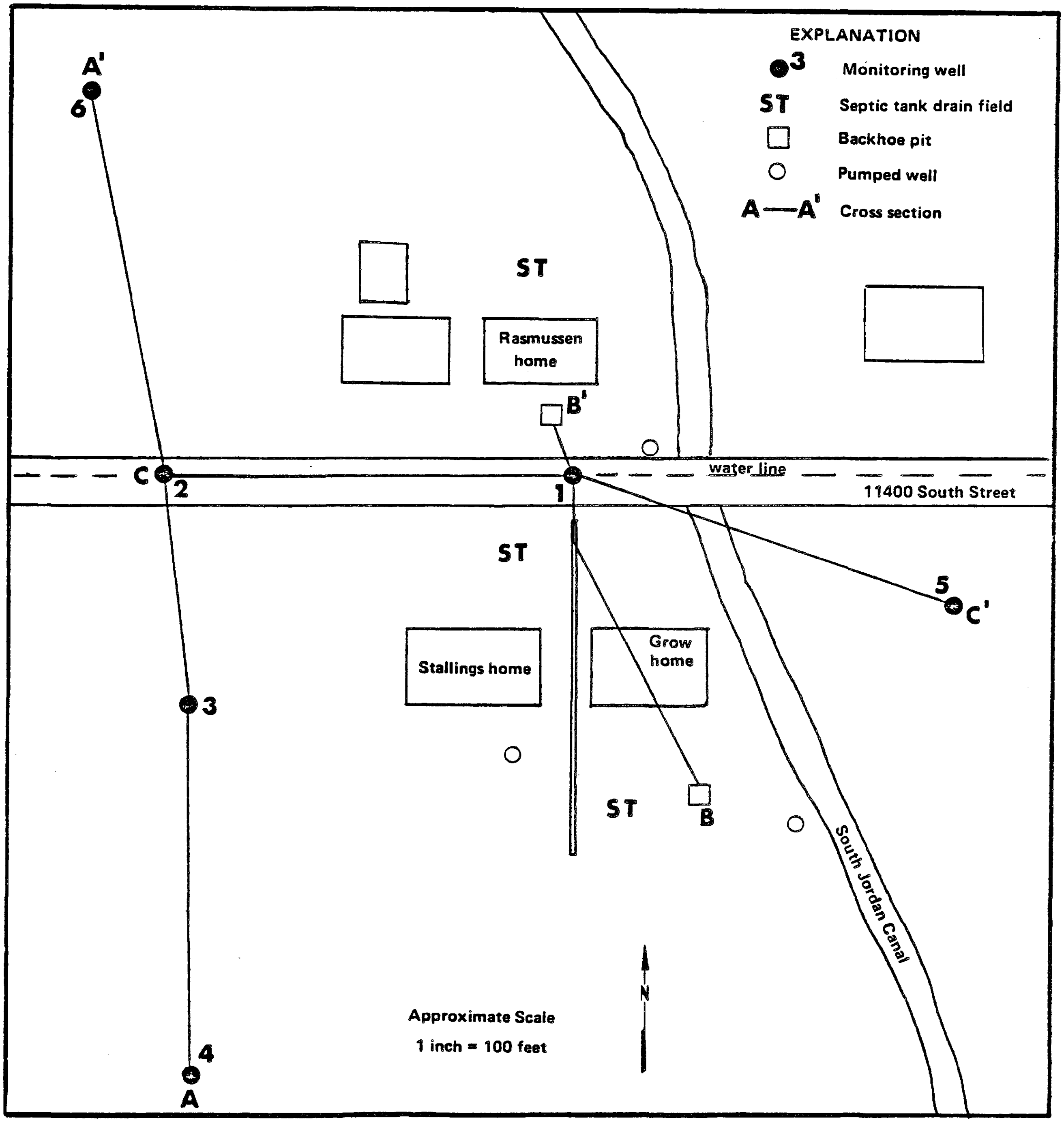
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 5 FEET

Location map

Attachment 2, Job No. GH-8



Detail of area along South Jordan Canal showing water-level monitoring stations.

Attachment 3, Job No. GH-8

Logs of Monitoring Wells*

Soil Description

Well 1

0'-1'	Well-graded sand with gravel (SW); brown; upper 2 inches-asphalt.
1'-2'	Silty sand with gravel (SM); brown; road base.
2'-3'	Clayey sand with gravel (SC); brown; road base.
3'-8'	Lean clay (CL); brown; trench backfill.
	Note: Casing perforated from 3 to 8 feet.

Well 2

0'-1'	Well-graded sand with gravel (SW); brown; upper 2 inches-asphalt.
1'-2'	Silty sand with gravel (SM); brown; road base.
2'-3'	Clayey sand with gravel (SC); brown; road base.
3'-5.5'	Lean clay (CL); brown; trench backfill.
	Note: Casing perforated from 2.5 to 5.5 feet.

Well 3

0'-5'	Lean clay (CL); brown, moist.
5'-14'	Fat clay (CH); gray-blue; limonite stained.
	Note: Casing perforated from 2 to 14 feet.

Well 4

0'-5'	Lean clay (CL); brown; silty.
5'-6'	Poorly-graded sand (SP); yellow.
6'-19'	Fat clay (CL); gray-blue to white.
	Note: Casing perforated from 2 to 19 feet.

*see attachment 4 and table 1 for ground-water level measurements.

Well 5

0'-5' Lean clay with gravel (CL); brown; fill.

5'-6' Sandy lean clay (CL); brown.

6'-7' Sandy lean clay (CL); yellow.

7'-14' Fat clay (CH); green.

Note: Casing perforated from 4 to 14 feet.

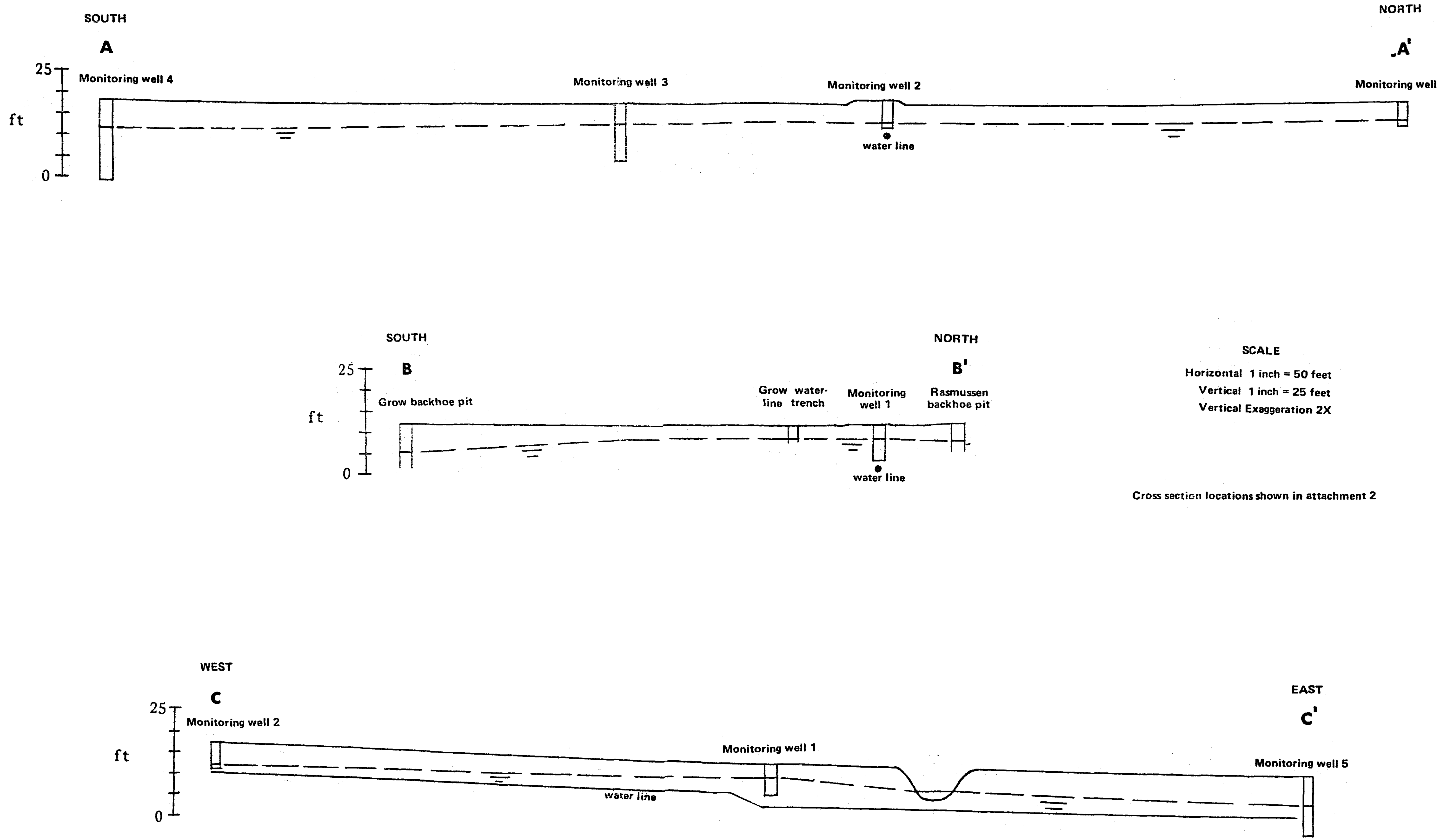
*see attachment 4 and table 1 for ground-water level measurements.

Attachment 4, Job No. GH-8

Location	Ref. Elev.	9/21/84 Depth to Water	9/21/84 Water Table Elev.	9/24/84 Depth to Water	9/24/84 Water Table Elev.	10/1/84* Depth to Water	10/1/84* Water Table Elev.	10/16/84** Depth to Water	10/16/84** Water Table Elev.
Mon. well 1	11.4	2.9	8.5	3.1	8.3	3.7	7.7	3.9	7.5
Rassmussen backhoe pit	12.1	4.9	7.2[a]	4.1	8.0[a]	5.7	6.4[b]	-	-
Grow water-line trench	11.3	3.0	8.3	3.0	8.3[c]	Backfilled			
Grow back-hoe pit	11.8	6.0	5.8[d]	6.4	5.4[b]	Backfilled			
Mon. well 2	16.7	4.9	11.8	5.1	11.6	5.2	11.5	5.2	11.5
Mon. well 3	15.7	4.1	11.6	4.3	11.4	4.8	10.9	4.8	10.9
Mon. well 4	17.8	6.0	11.8	6.3	11.5	6.5	11.3	6.5	11.3
Mon. well 6	16.3	2.4	13.9	4.3	12.0	4.8	11.5	4.8	11.5
South Jordan Canal	6.4	-	6.4	-	-	-	5.4[e]	-	5.0[f]
Mon. well 5	8.0	7.2	0.8	7.0	1.0	7.4	0.6	7.4	0.6
Stallings well[f]	13.2	0	13.2+	0.1	13.1	0	13.2+	0.1	13.1

*Pumping from culvert adjacent to water line underway for 2 days.
**Pumping from culvert adjacent to water line underway for 17 days, measurements taken at 5:00 P.M. after full day of pumping.
[a]Time since last pumped more than 6 hours.
[b]Time since last pumped unknown.
[c]Estimate; trench partially backfilled.
[d]Time since opened approximately 3 hours.
[e]Estimated from previous level.
[f]Deep confined aquifer, + indicates flowing condition.

Depth to water and water-table elevations in feet above arbitrary datum.



Cross sections showing water-table configuration on 9/24/84.

Project:			Requesting Agency:
Inspection of parking terrace excavation wall, 25th Street & Ogden Avenue, Ogden, Utah			Utah OSHA
By: W. F. Case	Date: 12/11/84	County: Weber	Job No.: GH-9
USGS Quadrangle: Ogden (1345)			

An investigation of a parking terrace excavation wall was conducted on December 10, 1984. The excavation is located along the west side of Ogden Avenue between 25th and 26th Streets, just south of the Ben Lomond Tower Hotel (attachment 1). The excavation wall appears to lie partially underneath Ogden Avenue. The purpose of the investigation was to determine if the slope was unstable and presented a hazard to workmen. Don Anderson, Utah OSHA, contacted William R. Lund, Chief of the Site Investigation Section and requested that the site be inspected.

The excavation wall is about 10 feet high and trends north-south, parallel to Ogden Avenue and the east footing of the parking terrace. The footing wall was completed and sealed at the time of the investigation. The space between the footing and the excavation wall is approximately 5 feet. The most striking thing about the situation is the undercutting of the pavement of Ogden Avenue. It is assumed that the overhanging pavement represents the parking area along the west side of Ogden Avenue. The pavement consists of a 6-8 inch base topped with a 2-3 inch blacktop. It is undercut up to 4 feet in places. The undercut slabs are supported by 4 x 4 wood beams tied together by 2 x 4's. The cause of undercutting is sluffing of fill beneath the pavement. The angle of repose of loose fill was measured at between 30 and 40 degrees. The inplace fill was stabilized at a near-vertical angle.

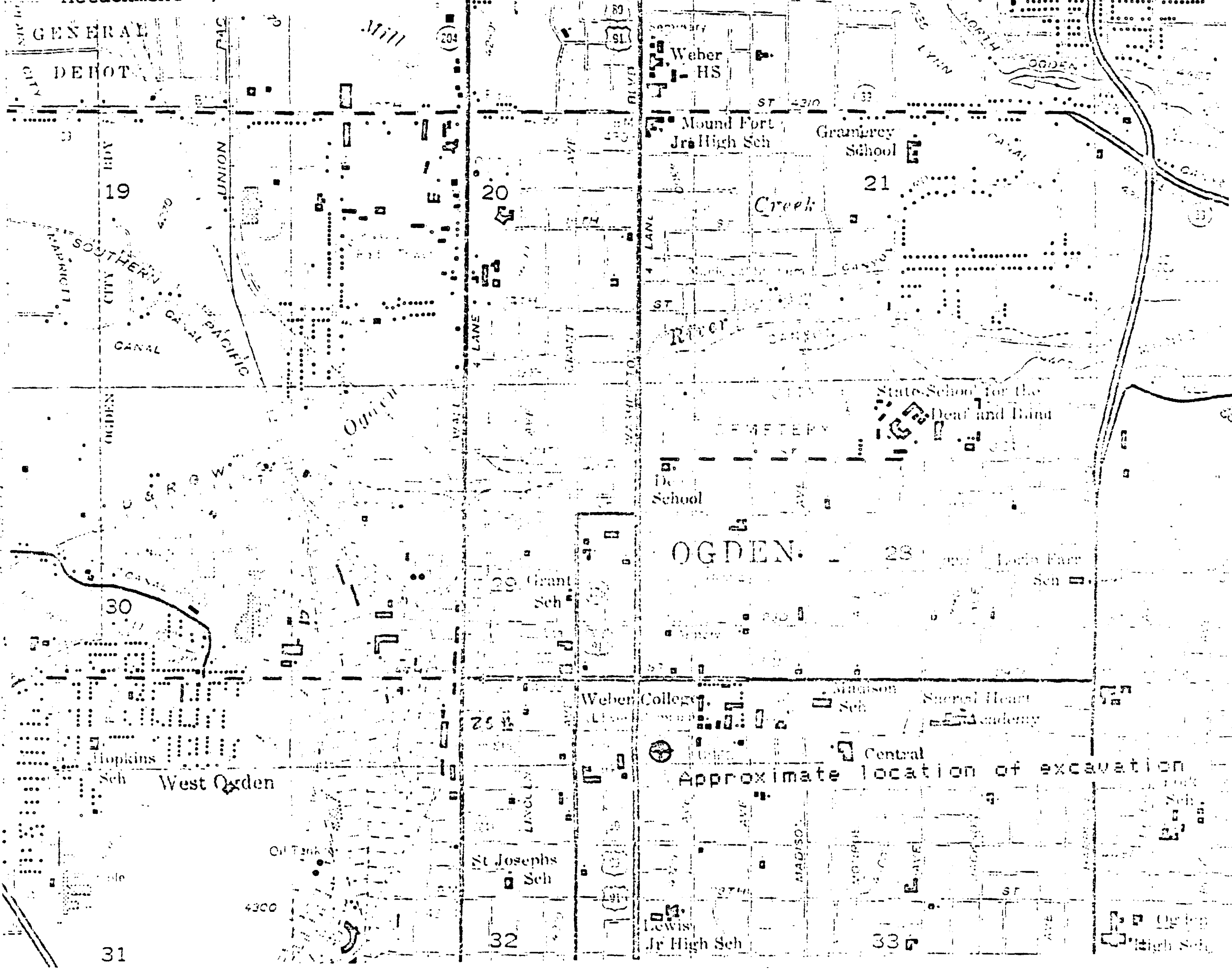
The fill consists of a heterogenous mixture of displaced natural sediments and artifacts such as broken bricks and bottles. The excavation wall consists of approximately 5 feet of fill at the top. The fill appears to be well-bedded and compacted into approximately 4-inch thick lifts near the pavement and to be more massive near the bottom of the cut. Various utility lines and a 4 x 3 foot concrete box conduit are buried in the fill and exposed in the excavation.

The material from the base of the fill to the bottom of the section consists of well-graded, sub-angular silty sand with trace amounts of 2-inch long, well-rounded pebbles. Most of the material is massive but some cross-beds could be found. Therefore, the material may be natural, inplace sediments probably fluvial in origin. The material is moist but not saturated. The material maintained a slope of 50 to 60 degrees at the outcrop and approximately 30 degrees angle of repose at the surface of the small talus cones at the base.

The stability of the excavation is marginal. The most obvious hazard is the overhanging pavement. The material in the excavation wall seems to be relatively stable, at least for the moisture regime that existed during the investigation. The fill that sluffed from beneath the pavement was removed from the site prior to this investigation and, therefore, poses no hazard.

The remaining fill is at near-vertical angles. The silty sand is stable at the present slope and moisture content. Talus piles of fill and sand are at their natural angles of repose, none of the talus piles were close to the footing. The slopes were compared with regulations outlined in the Industrial Commission of Utah publication "Excavation & Trenching Operations," revised December 1, 1976. The slope of the excavation wall corresponded more with that of the recommended slope for compacted angular gravels than compacted sharp sand but the moisture probably helped hold a steep slope. There was no standing water at the base of the excavation nor was water issuing from the wall. According to Randy Brady, Big D Construction foreman, the area was to be back-filled as soon as a floor could be emplaced. Personnel are not required to enter the excavation, the only need is to keep personnel and equipment off the top and from underneath the overhanging pavement. It is recommended that the overhanging pieces be removed.

Attachment 1, Job No. GH-9



Index Map showing approximate location of excavation

Scale 1:24 000

Base Map Ogden 7 1/2 minute Quadrangle, USGS topographic sheet

Project:			Requesting Agency:
Investigation of a debris/earth slide at 2300 E. Cottonwood Cove Lane, Salt Lake City, Utah			Salt Lake County Emergency Services Dept.
By: W. R. Lund	Date: 11/20/84	County: Salt Lake	Job No.: GH-10
USGS Quadrangle: Draper (1171)			

In response to a request from Al Britton, Salt Lake City Emergency Services Director, the Utah Geological and Mineral Survey provided geologic assistance at the scene of a debris/earth slide at 2300 E. Cottonwood Cove Lane. The slide occurred at 7:18 P.M. on October 31, 1984, and destroyed a house located at the base of a steep slope on the north side of Little Cottonwood Creek (attachment 1). Approximately 200 feet long and 100 feet wide at the toe, the slide was confined to the lot on which the house was sitting. Homes immediately to the east and west, and at the top of the slope were not affected.

The materials involved in the slope failure consisted of eolian sand over Lake Bonneville silty sand and sandy silt. The sand and silt are underlain by a gray silty clay that extends from about the middle of the slide area to the bottom of the slope. The material above the clay contact was wet, indicating that the clay was impeding the downward movement of water and creating perched water-table conditions.

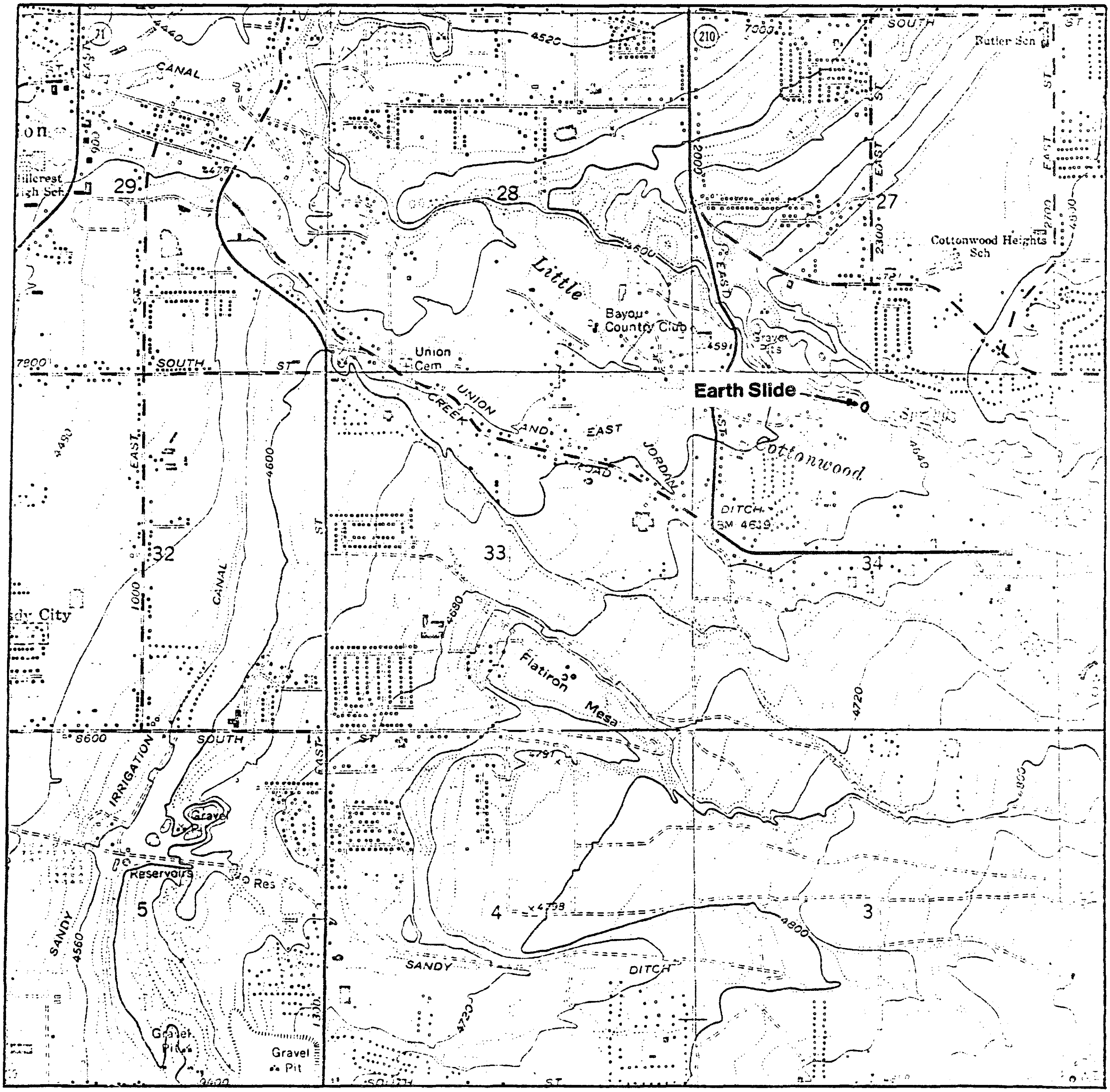
According to the homeowner, Mr. Merle Struh, the slope behind his home had been moving for more than a year, necessitating the removal of a large amount of slide material from his backyard. He further indicated that the slide had moved a few weeks previously and pushed part of the house off its foundation. Investigators from the Salt Lake County Cottonwood Sanitary District were called to Mr. Struh's home in March to determine if a nearby sewer line was leaking water to the slope. No leak was found, however, they did document the slide on video tape at that time.

The initial reconnaissance of the landslide on the evening of October 31 was hampered by darkness. After examining both the toe and head of the slide, the sheriff's department was advised to keep emergency workers away from the bottom of the slope in the slide area. Detached masses of earth at the top of the slide presented a hazard to anyone working in the slide track. The sheriff was further advised that there was no immediate danger to the homes at the top of the slope or to a power line in that area. However, conditions were such that a determination could not be made regarding the safety of the homes on either side of the landslide. The residents of those homes had already voluntarily evacuated, and it was recommended that the evacuation remain in effect until morning when a more complete examination could be made.

The following morning a meeting was held with various county officials, the sheriff's department, and homeowners. The warning regarding working in the slide area at the base of the slope was repeated, and arrangements were made to examine the landslide and adjacent slopes with representatives of the Salt Lake County Engineers office. Results of the examination showed that unstable areas associated with the slide were confined to a small area near its head and that there was no immediate danger to adjacent homes or facilities. This information was jointly communicated to the sheriff's department by the Salt Lake County engineer (Mr. Roy Baty, Jr.) and myself. A followup examination two days later (November 3) showed no evidence of renewed movement.

Base map USGS Draper, Utah $7\frac{1}{2}$ minute topographic quadrangle.

Attachment 1, Job No. GH-10



Map showing location of debris/earth slide at 2300 E. Cottonwood Cove Lane, Salt Lake County, Ut
Scale 1:24,000

Project:			Requesting Agency:
Rock-fall hazard, West Black Ridge, St. George, Washington County, Utah			U.S. Bureau of Land Management
By: G. E. Christenson	Date: 12/21/84	County: Washington	Job No.: GH-11
USGS Quadrangle: St. George (78)			

PURPOSE AND SCOPE

The purpose of this investigation was to evaluate the rock-fall hazard at the new Bureau of Land Management (BLM) Dixie Resource Area office (237 North Bluff Street) in St. George (attachment 1) and make recommendations to mitigate the hazard. The existence of the hazard became evident about a year ago when a boulder reportedly weighing several tons rolled down the slope onto a property to the north. In a subsequent study by Bush and Gudgell, Inc. (dated November 12, 1984), a rock-fall hazard was identified and it was recommended that the building be vacated until steps to reduce the risk were undertaken. The BLM followed this recommendation and is examining methods of reducing the risk at the building so that it can be reoccupied.

The scope of work consisted of a literature review, review of the Bush and Gudgell report, and a field reconnaissance on December 10 and 11, 1984. Slopes north of the site were also studied to evaluate the extent of the hazard and the effectiveness of mitigation techniques used in these areas.

SITE DESCRIPTION

The BLM building is set back into the base of the slope along the east side of West Black Ridge. A steep cut about 25 feet high has been made behind the building and a chain-link fence placed between the base of this cut and the building. A rock-fall catchment bench has been excavated at the top of the cut (lower bench, attachment 2). The bench is about 10 feet wide at its north end and is backed by a steep cut face about 10 feet high. The bench widens to 20 feet at its south end where the hillside is less steep and it was not necessary to make a significant cut. The bench slopes to the south for drainage and dips slightly into the hill. Above the bench, the hillside extends upward over 100 feet at a maximum grade of about 60 percent. It is steepest to the north and is capped by a vertical rock ledge about 15 feet high. A road 15-20 feet wide was cut along the base of this ledge in 1965 for temporary use during installation of sewer and water lines serving West Black Ridge (attachment 2). The road is presently blocked by several large rock falls and has been abandoned.

GEOLOGY

West Black Ridge is a north-south trending narrow mesa capped by a Quaternary-age basaltic lava flow and underlain by the Triassic-age Moenave Formation. Geomorphically, the ridge represents an inversion of topography.

The basalt flow now capping the ridge originally flowed down the valley of an ancestral tributary of the Virgin River from the Pine Valley Mountains to the north. Once the lava solidified, it was more erosion-resistant than the softer sedimentary rocks of the Moenave Formation. The stream was diverted and began downcutting between the basalt flow and the adjacent valley walls. As the landscape was lowered by erosion, the resistant lava flow remained as an isolated ridge. Remnants of the stream-bottom alluvium over which the lava flowed are preserved beneath the basalt.

The Moenave Formation consists of red and green, thin-bedded siltstone and sandstone which dips 5-15 degrees to the northeast and strikes N. 25^{o} W. Where weathered it is friable and crumbly. A prominent joint set strikes N-S to N. 10^{o} W. (roughly parallel to the slope) and is near vertical. These joints are widely spaced. No other prominent sets were observed. The Moenave Formation in the slopes of West Black Ridge is buried under a thin layer of colluvium composed chiefly of rock-fall debris, locally including boulders up to 4 feet in diameter. Most of the colluvium is derived from the lava flow capping the ridge. The flow is 10-12 feet thick with well-developed columnar joints. Because of this jointing, the flow breaks up into columnar to equidimensional blocks.

SLOPE STABILITY

The chief types of failures in this hillside are rock falls and rock topples involving joint blocks of basalt from the top of the ridge. The relatively rapid erosion of the underlying Moenave Formation and stream alluvium has undercut the lava, and the resulting rock-fall debris has accumulated on the slope. Much of the rock-fall activity probably occurred thousands of years ago when a wetter, colder climate existed in the area and rates of erosion and frost-wedging were greater. Under the present climate and prior to alteration of these hillsides by man, it is believed that slopes were relatively stable and that rock falls were less frequent. However, induced instability of the slope began with cutting of the road below the basalt ledge at the top of the ridge. Excavation of this road removed debris from the base of the flow and pushed it onto the slope below. This resulted in removal of lateral support from the base of the flow and placed potentially unstable debris on the slope. Several large rock falls and topples have occurred since the road was cut, most of which were contained by the road. One large topple above the northwest corner of the building has separated from the flow and tilted downslope. It is believed that an increase in moisture content in the underlying alluvium and/or removal of lateral support from the alluvium and base of the flow induced this failure. An increase in moisture content could be a natural condition or could have been aggravated by water applied to the top of the lava flow by man. Tension cracks have developed along the outside edge of the road below the topple as outward movement of the mass has caused a bulge and oversteepened the slope. Movement will probably continue, occurring chiefly during wet periods. At least one boulder at the edge of the road may be dislodged by this failure. Other rock falls onto the road do not pose an immediate hazard, but boulders on the slope rolled into place during constructio of the road are potentially unstable. These boulders protrude from a thin layer of unconsolidated sand and gravel, also pushed onto the slope, which is not vegetated and subject to erosion. Erosion of material from around the bases of the boulders during periods of heavy precipitation, accompanied by saturation of underlying materials, could remove support and cause them to roll downslope. Ground shaking in a moderate earthquake such as occurred in the area in 1902 could also dislodge the unstable boulders. A newspaper report of the effects of this earthquake in St. George states,". . . clouds of dust arose as rocks crashed down mountains over an area twenty-five miles across."

Other slope stability concerns are related to the steep cut slopes in the Moenave Formation. This formation consists principally of thin-bedded sandstone and siltstone which is nearly flat-lying. It is stable in vertical cut slopes along the road to the St. George airport and along I-15 at Middleton Black Ridge. It has also remained stable in steep natural slopes in the St. George area during the recent geologic past, except where the underlying failure-prone Chinle Formation is exposed near the base of the slopes. For the above reasons, the Moenave is considered capable of supporting near-vertical cuts as long a proper drainage is provided and excessive loading is avoided. Where the highly weathered upper layers and overlying colluvium are exposed in cut slopes (such as at the south end of the bench behind the BLM building), steep cuts should be avoided and allowance made for ravelling of the rock and falling of lava blocks contained in the colluvium.

ROCK-FALL HAZARD MITIGATION

Many methods of reducing rock-fall hazards exist. Two that have been recommended at this site by Bush and Gudgell include: 1) construction of a high wall (extending above the lower bench) behind the building with backfilling against the slope to provide a wide bench and barrier wall, and 2) removal of loose boulders and anchoring (with wire mesh or rock bolts) of those which cannot be removed. We suggest that the following possible methods also be considered:

1. Widen the lower bench in the hillside above the building. The final width of the bench will depend on the angle and length of slope above the bench and on boulder size. The widening will require laying back a portion of the hillside above the bench to produce a smooth slope with no steep segments. At present, particularly at the north end, a bouncing or rolling rock could travel over the bench from the top of the cut made when the bench was excavated and onto the building. In addition to increasing the width of the bench, a wall or berm should be constructed on the outside edge (or a trench excavated on the inside edge) to provide further protection. Construction of a second bench further up the slope would reduce the width required for the lower bench.

2. Cut a bench diagonally across the slope from north to south (with a berm along the outside edge or trench along the inside edge) to deflect falling rocks to the south into a catchment area. The width of the bench could be reduced by placing several parallel benches across the slope, perhaps one near the base of the basalt ledge and another just above the lower bench.

3. Lay back the entire hillside at an even grade from behind the building to a point about midway up the slope or higher, with excavation of a ditch and construction of a concrete or gabion wall behind the building. The slope modification would insure that any rocks would not become airborn in areas of steeper slopes and would roll or bounce directly downward behind the building. The ditch and wall would stop the rocks and protect the building. The slope design would be a compromise between maximizing the

distance between the back of the building and base of the slope and minimizing the angle of the slope and distance up the slope requiring modification.

The above methods may be used individually or in combination as required to stabilize the slope. Proper design of bench widths, trench depths, and wall heights is necessary for these methods to be effective. A bench cut into the hillside at an unoccupied building site to the north has been ineffective in stopping rolling rocks. The bench is only 10-12 feet wide with a steep cut upslope. Many boulders up to 2 feet in diameter have been dislodged from the hillside, probably by children, and have not been stopped by the bench. They have rolled into the building site for distances of up to 30 feet from the base of the slope. Similar conditions exist at the north end of the BLM building where the slope is steepest and the bench only 10 feet wide.

CONCLUSIONS AND RECOMMENDATIONS

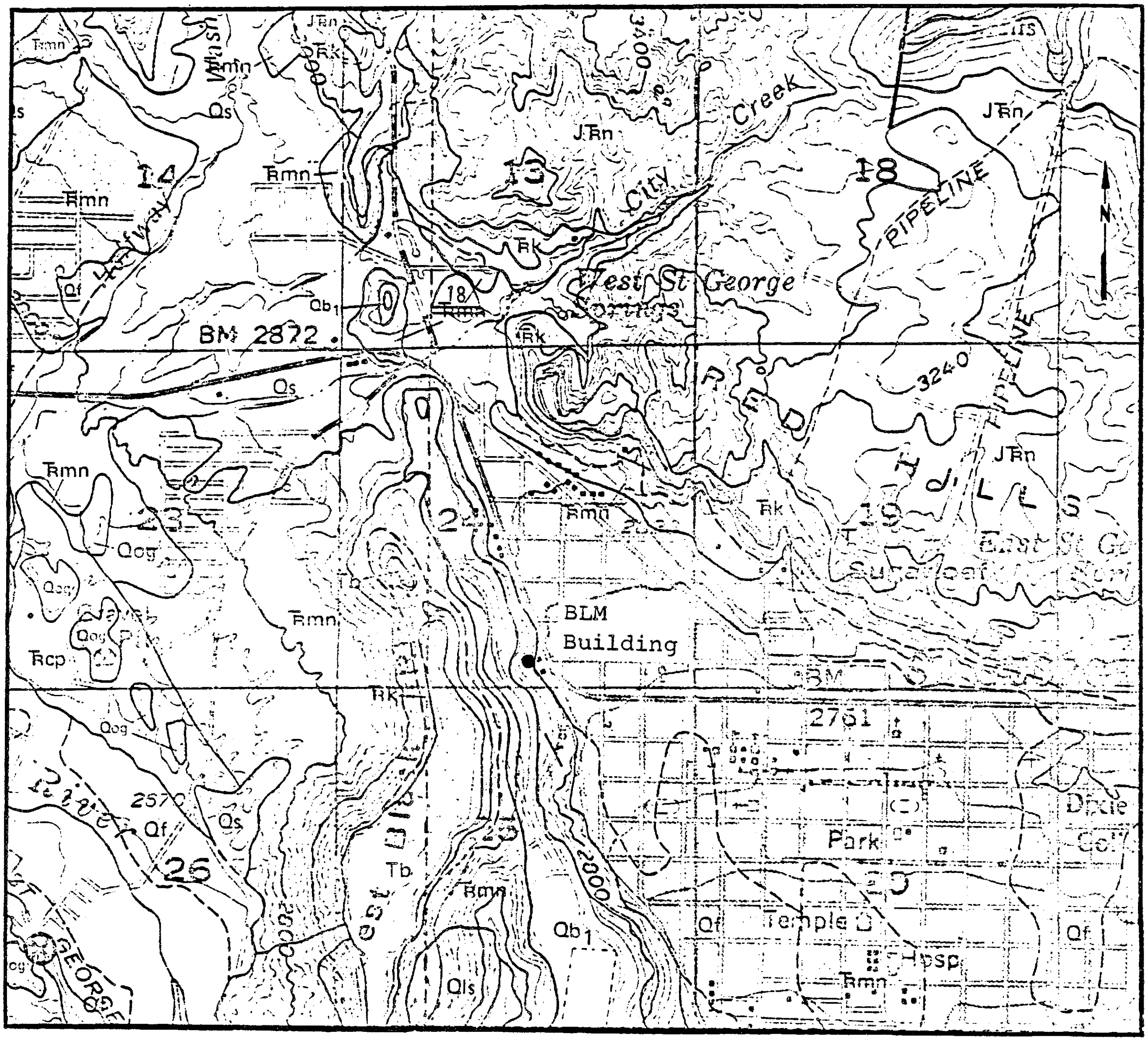
A clear rock-fall hazard exists at the site, particularly in the event of an earthquake or prolonged period of precipitation causing saturation of the slope. The hazard must be mitigated in order to provide a safe building for occupancy. The existing bench and chain-link fence are sufficient to catch smaller rock-fall debris or debris from immediately upslope, but are inadequate to trap large boulders from upper parts of the slope. It is believed that the building can be protected from rock-fall debris by the methods listed above. The technology for engineering slopes in the manner suggested is used extensively in the design of highway and railroad cuts. It is recommended that experts with experience in such designs be consulted to prioritize alternatives and provide specifications and cost estimates. The large rock topple above the northwest corner of the building is probably the most significant slope failure in progress which may potentially affect the building. Removal of all or part of the material or additional widening of benches downslope may be required to provide adequate protection for the building.

REFERENCES

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

Schuster, R.L., and Krizek, R.J., editors, 1978, Landslides, analysis and control: National Academy of Sciences Special Report 170, 234 p.

Base map from: USGS 15' Topo Quad
St. George, Utah



Scale 1:31,250

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CONTOUR INTERVAL 40 FEET

Geologic map of St. George area showing location of BLM building (geology from Christenson and Deen, 1983; explanation on following page).

EXPLANATION

QUATERNARY

Qf | Qs

Alluvial and eolian deposits

Qf, *Chiefly fine-grained (silt and clay)*

Qs, *Chiefly sand*

Qog

Older alluvial gravel deposits

Qls

Landslide deposits

Qb_1

Basalt

TERTIARY

Tb

Basalt

UNCONFORMITY

JURASSIC TRIASSIC

JTRn

Navajo Sandstone

TRIASSIC

TRk

Kayenta Formation

Shale, siltstone, and sandstone

TRmn

Moenave Formation

Shale, siltstone, and sandstone

UNCONFORMITY

TRcp

TRcs

Chinle Formation

TRcp, Petrified Forest Member, *shale and sandstone*

TRcs, Shinarump Member, *sandstone and conglomerate*

SYMBOLS

Contact

Dashed where gradational or approximate

U

D

Fault, showing relative movement

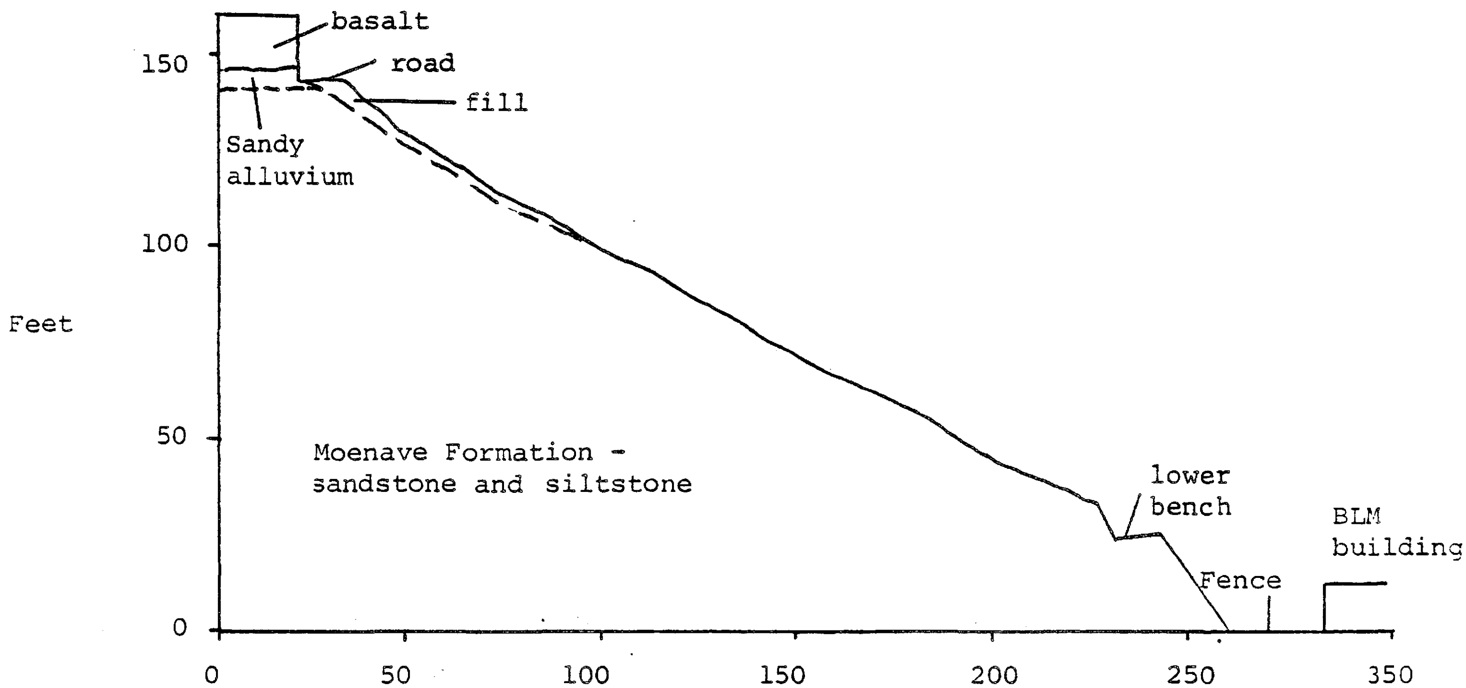
(U, upthrown side, D, downthrown side), dashed where approximate, dotted where buried or inferred

20

Strike and dip of bedding

⊗

Area where modern slope failure has occurred



Diagrammatic (approximate scale 1 inch - 50 feet; no vertical exaggeration) cross section showing slope west of BLM building, St. George, Utah

APPENDIX

List of 1984 Applied Geology Publications

Special Studies

66. Engineering geology of Park City, Summit County, Utah, by H. E. Gill and W. R. Lund, 42 p., 15 figs., 3 tables.

Maps

73. Major levels of Great Salt Lake and Lake Bonneville, by Donald R. Currey, Genevieve Atwood, and Don R. Mabey.

Reports of Investigation

182. Preliminary geologic evaluation of five proposed hazardous waste sites in Utah, by W. R. Lund, 30 p., 6 figs., 1 table.

187. Geologic evaluation of five culinary water facilities and Settlement Canyon Dam for Tooele City, Tooele County, Utah, by W. R. Lund, 32 p., 4 figs.

188. Assessment of potential damage to real property from major debris flow in Standel Cove subdivision, Salt Lake County, Utah, by B. N. Kaliser, R. W. Jeppson, and R. S. Baty, Jr., 27 p., 4 figs., 1 table.

189. Sediment source study - Little Cottonwood, Big Cottonwood and Mill Creeks, Salt Lake County, Utah, by G. E. Christensen, 22 p., 3 tables, 2 pls..

190. Technical letters and memoranda for 1983 - Site Investigation Section, W. R. Lund, editor, 1985, 221 p.

Open-File Reports

44. Geologic cross sections from West-Central Utah, by K. E. Budding, S. N. Eldredge, and D. R. Mabey, 71 p.

59. Fault hazard zonation of Mapleton City, Utah County, Utah, by B. N. Kaliser, 1 p., 1 pl.