REPORT

GEOLOGIC HAZARDS EVALUATION

THE RESERVE AT CRIMSON RIDGE, LOT 2-R

1013 NORTH VALLEY VIEW DRIVE

LIBERTY, WEBER COUNTY, UTAH

Prepared for

Dr. James Anderson
759 West 2525 South
Syracuse, Utah 84075

July 8, 2016

Prepared by

Western GeoLogic, LLC
2150 South 1300 East, Suite 500
Salt Lake City, Utah 84106

Voice: 801.359.7222
Fax: 801.990.4601
Web: www.westerngeologic.com

WESTERN GEOLOGIC, LLC
2150 SOUTH 1300 EAST, SUITE 500
SALT LAKE CITY, UT 84106 USA

Phone: 801.359.7222 Fax: 801.990.4601 Email: cnelson@westerngeologic.com

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SUBJECT: Geologic Hazards Evaluation
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

Dear Mr. Anderson:

This report presents results of an engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for lot 2-R in The Reserve at Crimson Ridge subdivision in Eden, Utah (Figure 1 – Project Location). The Project is identified as Weber County Assessor's parcel number 20-105-0002 (1013 North Valley View Drive). The site is on east- to northeast-facing slopes in western Ogden Valley at the eastern base of the Wasatch Range, and is in the NW1/4 Section 10, Township 6 North, Range 1 East (Salt Lake Base Line and Meridian; Figure 1). Elevation of the property ranges from about 6,630 feet to 6,730 feet above sea level. It is our understanding that the current intended site use is for development of a single-family residential home.

A prior geologic hazards and engineering geotechnical evaluation was conducted for the original Pineview Estates at Radford Hills development by Western GeoLogic (2006) and Earthtec Testing & Engineering (ETE, 2006). This development subsequently became the current Reserve at Crimson Ridge subdivision. The Project is identified as lot 5 on the site plan included in the 2006 investigation. Portions of this report may include discussions from Western GeoLogic (2006) or ETE (2006) where relevant to our current investigation, although this study should be considered to replace the findings and recommendations previously provided in 2006.

PURPOSE AND SCOPE

The purpose and scope of this investigation is to identify and interpret geologic conditions at the site to identify potential risk from geologic hazards to the Project. This investigation is intended to: (1) provide geologic information and assessment of geologic conditions at the site; (2) identify potential geologic hazards that may be present and qualitatively assess their risk to the intended site use; and (3) provide recommendations for additional site- and hazard-specific studies or mitigation measures, as may be needed based on our findings. Such recommendations could require further multi-disciplinary evaluations, and/or may need design criteria that are beyond our professional scope.

The following services were performed in accordance with the above stated purpose and scope:

- A site reconnaissance conducted by an experienced certified engineering geologist to assess the site setting and look for adverse geologic conditions;
- Excavation and logging of one trench and three test pits at the site between June 30 and July 2, 2016 to evaluate subsurface conditions at the property;
- Review of readily-available geologic maps, reports, and air photos; and
- Evaluation of available data and preparation of this report, which presents the results of our study.

The engineering geology section of this report has been prepared in accordance with current generally accepted professional engineering geologic principles and practice in Utah, and meets specifications provided in Chapter 27 of the Weber County Land Use Code.

PRIOR STUDIES

Western GeoLogic (2006) conducted a previous geologic hazards evaluation for the Pineview Estates development in 2006. This report identified potential geologic hazards from earthquake ground shaking, stream flooding, debris flows, and landsliding based on surficial observations, review of geologic mapping and aerial photos, and subsurface data. The 2006 investigation included excavation and logging of one trench across the presumed location of the West Ogden Valley fault about 215 feet southeast of the property, as well as 11 test pits in other areas of the development. With regard to potential geologic hazards at the site, Western GeoLogic (2006) recommended that: (1) proposed homes be designed and constructed to current seismic standards; (2) site hydrology, runoff, and/or potential for debris-flow hazards be addressed in civil engineering design for the development; and (3) a design-level geotechnical engineering study be conducted to address soil conditions with regard to foundation design and site preparation, provide recommendations to reduce seismic risk, and evaluate stability of slopes along the western site margin. Western Geologic (2006) further identified a potential hazard from radon, although this hazard is an indoor environmental health issue that is no longer addressed in our reports.

Western GeoLogic (2006) was incorporated as an appendix to a geotechnical engineering evaluation prepared for the Pineview Estates development by ETE (2006). ETE (2006) conducted a slope stability evaluation for the proposed development that found the lots along the western margin of the subdivision to have a high risk for slope instability due to low factors of safety. The Project is one of these high-risk lots. ETE (2006) further provided recommendations regarding footing and foundation design, seismic design, site grading, surface and subsurface drainage, and pavement construction.

HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the Huntsville Quadrangle shows the site is on the western margin of Ogden Valley about 2,500 feet west of the west marina for Pineview Reservoir (Figure 1). The Project is in an area between two unnamed canyons on the northwest and southwest and Ogden Valley to the east (Figure 1). Both of these canyons have small drainages that flow into Pineview Reservoir. The unnamed drainage flowing from the canyon on the southwest is nearest and about 300 feet to the southeast. No active drainages are shown crossing the Project on Figure 1.

The site is at the western margin of Ogden Valley, which is dominated in the valley bottom by unconsolidated lacustrine and alluvial basin-fill deposits. Slopes in the site area are mainly underlain by weathered Tertiary-age tuffaceous bedrock and a surficial veneer of unconsolidated Quaternary alluvial and colluvial deposits. Three borings were conducts for a concurrent geotechnical study being conducted by GSH. Field logs indicate that boring B-2 southwest of the proposed home encountered groundwater at a depth of 22 feet below the ground surface (bgs), and boring B-3 to the northwest encountered groundwater at 32 feet bgs. No groundwater was encountered in boring B-1, which only extended to a depth of 20 feet. Seeps were also encountered in the trench excavated for this study, as well as test pit TP-1. The latter filled with water shortly after excavation. Groundwater depths at the site likely vary seasonally from snowmelt runoff and annually from climatic fluctuations, as would be expected for an alpine environment, and locally above less-permeable, clay-rich bedrock layers in the subsurface. Perched conditions were observed at one location by ETE (2006), and groundwater seepage was also observed in the trench and TP-1 exposures conducted for this study. Given the above, we anticipate groundwater to be around 35 feet bgs in the upper (western) part of the site and gradually shallow to around 10 feet bgs in the lower (eastern) part.

Avery (1994) indicates groundwater in Ogden Valley occurs under perched, confined, and unconfined conditions in the valley fill to depths of 750 feet or more. A well-stratified lacustrine silt layer forms a leaky confining bed in the upper part of the valley-fill aquifer. The aquifer below the confining beds is the principal aquifer, which is in primarily fluvial and alluvial-fan deposits. The principal aquifer is recharged from precipitation, seepage from surface water, and subsurface inflow from bedrock into valley fill along the valley margins (Avery, 1994). The confined aquifer is typically overlain by a shallow, unconfined aquifer recharged from surface flow and upward leakage. Groundwater flow is generally from the valley margins into the valley fill, and then toward the head of Ogden Canyon (Avery, 1994). Based on topography, we expect groundwater flow at the site to be generally to the east.

GEOLOGY

Surficial Geology

The site is located on the western margin of Ogden Valley, a sediment-filled intermontane valley within the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes; 1977, 1986). Surficial geology of the site is mapped by Coogan and King (2016; Figure 2) as Quaternary mass-movement deposits (unit Qms), although we note that prior published and unpublished mapping (including Coogan and King, 2001) show the site in alluvium and colluvium (unit Qac) rather than landslide deposits. Coogan and King (2016) describe surficial geologic units in the site area on Figure 2 as follows:

Qlamh - *Lacustrine, marsh, and alluvial deposits, undivided (Historical).* Sand, silt, and clay mapped where streams enter Pineview Reservoir, and reservoir levels fluctuate such that lacustrine, marsh, and alluvial deposits are intermixed; thickness uncertain.

Qaf, Qafy, Qaf3, Qaf3?, Qaf4, Qaf4?, Qaf5 - *Alluvial-fan deposits (Holocene and Pleistocene).* Mostly sand, silt, and gravel that is poorly bedded and poorly sorted and that is not close to late Pleistocene Lake Bonneville and is geographically in the Huff Creek and upper Bear River drainages; variably consolidated; includes debris flows, particularly in drainages and at drainage mouths (fan heads); generally less than 60 feet (18 m) thick. Qaf with no suffix used where age uncertain or for composite fans where portions of fans with multiple ages cannot be shown separately at map scale; toes of some fans have been removed by human disturbances, so their age cannot be determined.

Where possible, subdivided into relative ages, indicated by letter and number suffixes (like Qa and Qat suffixes) and relative ages only apply to the local drainage, with unit Qafy being the lowest (youngest) fans and unit 3 may or may not post-date Lake Bonneville. Relative ages of these fans are partly based on heights above present drainages at drainage-eroded edge of fan. The relative age is queried where the age is uncertain, generally due to the height not fitting into the typical order of surfaces. The various deposits listed, Qafy and Qaf3 through Qaf5, are 20 to 140 feet (6-40 m) above and west of Saleratus Creek, and also above Yellow Creek and the Bear River. Qafy fans are active, impinge on present-day floodplains, divert active streams, and overlie low terraces.

Qac - *Alluvium and colluvium (Holocene and Pleistocene).* Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show at map scale; typically mapped along smaller drainages that lack flat bottoms; more extensive east of Henefer where Wasatch Formation (Tw) strata easily weather to debris that "chokes" drainages; 6 to 20 feet (2-6 m) thick. Some deposits are "perched" on benches 80 feet (25 m) and more above present-day drainages like Left Fork Heiners Creek (Heiners Creek quadrangle) and Harris Canyon (Henefer quadrangle). In the Devils Slide quadrangle, some deposits are "perched" on benches about 60 to 130 feet (18-40 m) above Quarry Cottonwood Canyon indicating the alluvium is at least partly Lake Bonneville age and older (see Qab and Qao in tables 1 and 2).

Qms, Qms?, Qmsy, Qmsy?, Qmso, Qmso? - *Landslide deposits (Holocene and upper and middle? Pleistocene).* Poorly sorted clay- to boulder sized material; includes slides, slumps, and locally flows and floods; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced blocks;

composition depends on local sources; morphology becomes more subdued with time and amount of water in material during emplacement; Qms may be in contact with Qms when landslides are different/distinct; thickness highly variable, up to about 20 to 30 feet (6-9 m) for small slides, and 80 to 100 feet (25-30 m) thick for larger landslides. Qmsy and Qmso queried where relative age uncertain; Qms queried where classification uncertain. Numerous landslides are too small to show at map scale and more detailed maps shown in the index to geologic mapping should be examined.

Qms without a suffix is mapped where the age is uncertain (though likely Holocene and/or late Pleistocene), where portions of slide complexes have different ages but cannot be shown separately at map scale, or where boundaries between slides of different ages are not distinct. Estimated time of emplacement is indicated by relative-age letter suffixes with: Qmsy mapped where landslides deflect streams or failures are in Lake Bonneville deposits, and scarps are variably vegetated; Qmso typically mapped where deposits are "perched" above present drainages, rumpled morphology typical of mass movements has been diminished, and/or younger surficial deposits cover or cut Qmso. Lower perched Qmso deposits are at Qao heights above drainages (95 ka and older) and the higher perched deposits may correlate with high level alluvium (QTa_) (likely older than 780 ka) (see table 1). Suffixes y and o indicate probable Holocene and Pleistocene ages, respectively, with all Qmso likely emplaced before Lake Bonneville transgression. These older deposits are as unstable as other slides, and are easily reactivated with the addition of water, be it irrigation or septic tank drain fields.

Qmc *- Landslide and colluvial deposits, undivided (Holocene and Pleistocene).* Poorly sorted to unsorted clay- to boulder-sized material; mapped where landslide deposits are difficult to distinguish from colluvium (slopewash and soil creep) and where mapping separate, small, intermingled areas of landslide and colluvial deposits is not possible at map scale; locally includes talus and debris flow and flood deposits; typically mapped where landslides are thin ("shallow"); also mapped where the blocky or rumpled morphology that is characteristic of landslides has been diminished ("smoothed") by slopewash and soil creep; composition depends on local sources; 6 to 40 feet (2-12 m) thick. These deposits are as unstable as other landslide units (Qms, Qmsy, Qmso).

Qafp, Qafp?, Qafb, Qafb?, Qafpb, Qafpb? *- Lake Bonneville-age alluvial-fan deposits (upper Pleistocene).* Like undivided alluvial fans, but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits (see table 1); these fans are inactive, unconsolidated to weakly consolidated, and locally dissected; fans labeled Qafp and Qafb are related to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively, while unit Qafpb is used where fans may be related to the Provo or Bonneville shoreline (for example Qafpb is ~40 feet [12 m] above Lost Creek Valley), or where fans of different ages cannot be shown separately at map scale; Qafp fans typically contain well-rounded, recycled Lake Bonneville gravel and sand

and are moderately well sorted; generally 10 to less than 60 feet (3-18 m) thick. Lake Bonneville-age fans are queried where relative age is uncertain (see Qaf for details); fans labeled Qafpb? are above the Bonneville shoreline and might be Qafo or like Qafm; see the note under Qao about two possible ages of older alluvium (Qao, Qato, and Qafo). Most of the Lake Bonneville-age fans in the James Peak quadrangle are far from the Bonneville shoreline and their age is inferred from their stratigraphic relationship(s) to coeval Pinedale glacial outwash (see age equality in Table 3).

The channels (Qafp/Qdlb) on the Weber River delta and Lake Bonneville fines (Qafp on Qlfb) probably record scour and fill during the rapid drawdown of the lake as it fell from the Bonneville shoreline to the Provo shoreline.

Qls, Qls?, Qlsp, Qlsb, Qlsb? - *Lake Bonneville sand (upper Pleistocene).* Mostly sand with some silt and gravel deposited nearshore below and near the Provo shoreline (Qlsp) and between the Provo and Bonneville shorelines (Qlsb); Qls mapped downslope from slope break below Provo shoreline beach deposits where thin Lake Bonneville regressional sand may overlie transgressional sand; grades downslope into unit Qlf with decreasing sand content and laterally with more gravel into units Qdlp, Qdlb, and upslope with more gravel into unit Qlgb; Qls and Qlsb queried where grain size or unit identification uncertain; may be as much as 75 feet (25 m) thick, and thickest near Ogden; typically less than 20 feet (6 m) thick in Morgan Valley; may include small deltas and deltas that lack typical delta shape.

Qla, Qla? - *Lake Bonneville lacustrine deposits and post- and pre-Lake Bonneville alluvial deposits, undivided (Holocene and upper? Pleistocene).* Mostly poorly sorted and poorly bedded sand, silt, and clay, with some gravel; mapped where Lake Bonneville deposits are reworked by later stream action or covered by thin stream and fan deposits, and where lake deposits are thin and overlie older alluvial deposits; unit queried where may be dominantly alluvium; deposits typically eroded from shallow Norwood Formation; mostly mapped near Bonneville shoreline; also mapped in Peterson quadrangle along upper Deep Creek above Bonneville shoreline where lake deposits seem to indicate landslide dam of creek; thickness uncertain.

Tn, Tn? - *Norwood Formation (lower Oligocene and upper Eocene).* Typically light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate; unaltered tuff, present in type section south of Morgan, is rare; locally colored light shades of red and green; variable calcareous cement and zeolitization; involved in numerous landslides of various sizes; estimate 2000-foot *(600 m) thick in exposures on west side of Ogden Valley (based on bedding dip,* outcrop width, and topography). Norwood Formation queried where poor exposures may actually be surficial deposits. For detailed Norwood Formation information see description under heading "Sub-Willard Thrust - Ogden Canyon Area" since most of this unit is in and near Morgan Valley and covers the Willard thrust, Ogden Canyon, and Durst Mountain areas.

Zmcg, Zmcg? *- Maple Canyon Formation, Lower (green arkose) member (Neoproterozoic).* Grayish-green, fine-grained arkosic (feldspathic) meta-sandstone and sandy argillite (meta-graywacke), with local quartzite lenses up to 200 feet (60 m) thick; weathers darker gray to brown to greenish-gray and greenish-brown; 500 to 1000 feet (150-305 m) thick and lower thickness would eliminate the need for faulting in southwest part of Huntsville quadrangle. This unit is prone to slope failures.

Zarx *- Argillite of lower member of Maple Canyon Formation or upper member of Formation of Perry Canyon (Proterozoic).* Greenish-gray argillite to meta-graywacke in poor exposures on east side of Ogden Valley (Zarx and Qdlb/Zarx) and on dip slope west of Ogden Valley; weathering, lack of bedding, and lack of exposures of overlying conglomerate member of Maple Canyon preclude separation of these stratigraphically adjacent units. This unit is prone to slope failures.

Zpu, Zpu? *- Formation of Perry Canyon, Upper member (Neoproterozoic).* Olive drab to gray, thin-bedded slate to argillite to phyllite to micaceous meta-siltstone to meta-graywacke to meta-sandstone in variable proportions such that unit looks like both the "greywacke-sandstone" and "mudstone" members of previous workers; unit identification based on underlying diamictite in Mantua quadrangle; rare meta-gritstone and meta-diamictite (actually conglomerate?); locally schistose; meta-sandstone contains poorly sorted lithic, quartz, and feldspar grains in silty to micaceous matrix; meta-sandstone is quartzose in outcrops on west margin of Mantua quadrangle (Crittenden and Sorensen, 1985a) and medial zone of sandstone is feldspathic east of Ogden Valley, where mapped and described as argillite member of Maple Canyon Formation by Crittenden (1972) and Sorensen and Crittenden (1979); thickness uncertain, but appears to be about 600 feet (180 m) thick on west flank of Grizzly Peak in the Mantua quadrangle and about 1000 feet (300 m) thick between Ogden Canyon and North Ogden divide. In Ogden Valley typically non-resistant and tan weathering such that gray to green to dark-gray fresh color is seldom seen except in cut slopes and excavations. This unit is prone to slope failures.

Citations, tables, and/or figures noted above are not provided herein, but are in Coogan and King (2016).

Norwood Formation bedrock in the area has average dips of about 30 to 45 degrees, although this unit has local depositional variations that may produce lower and higher dips within a relatively short distance (Jon King, Utah Geological Survey, verbal communication, February 29, 2016). Figure 2 shows one field measurement reportedly in Norwood Formation bedrock about 2,500 feet north of the site that shows a strike/dip of N49°W 40° NE. Two additional measurements inferred from photo interpretation are in Norwood Formation east and northeast of the site and reported in GIS data in Coogan and King (2016). These measurements show strikes of N33°W and N17°W and dips of 33° and 17° to the northeast (respectively).

Seismotectonic Setting

The property is located at the western margin of Ogden Valley, a roughly 40-square mile back valley described by Gilbert (1928) as a structural trough similar to Cache and Morgan Valleys to the north and south, respectively. The back valleys of the northern Wasatch Range are in a transition zone between the Basin and Range and Middle Rocky Mountains provinces (Stokes, 1977, 1986). The Basin and Range is characterized by a series of generally north-trending elongate mountain ranges, separated by predominately alluvial and lacustrine sediment-filled valleys and typically bounded on one or both sides by major normal faults (Stewart, 1978). The boundary between the Basin and Range and Middle Rocky Mountains provinces is the prominent, west-facing escarpment along the Wasatch fault zone at the base of the Wasatch Range. Late Cenozoic normal faulting, a characteristic of the Basin and Range, began between about 17 and 10 million years ago in the Nevada (Stewart, 1980) and Utah (Anderson, 1989) portions of the province. The faulting is a result of a roughly east-west directed, regional extensional stress regime that has continued to the present (Zoback and Zoback, 1989; Zoback, 1989). The back valleys are morphologically similar to valleys in the Basin and Range, but exhibit less structural relief (Sullivan and others 1988).

Ogden Valley occupies a structural trough created by up to 2,000 feet of vertical displacement on normal faults bounding the east and west sides of the valley. The Ogden Valley southwestern margin fault (aka West Ogden Valley fault; Black and others, 2003) is shown on Figure 2 (dotted line) trending northwestward near the eastern site boundary. The most recent movement on this fault is pre-Holocene (Sullivan and others, 1986). Western GeoLogic (2006) excavated one trench across the presumed fault location slightly southeast of the Project. This trench reportedly exposed a sequence of latest Pleistocene to Holocene-age alluvium and colluvium displaying no evidence for active faulting.

The site is also situated near the central portion of the Intermountain Seismic Belt (ISB). The ISB is a north-south-trending zone of historical seismicity along the eastern margin of the Basin and Range province which extends for approximately 900 miles from northern Arizona to northwestern Montana (Sbar and others, 1972; Smith and Sbar, 1974). At least 16 earthquakes of magnitude 6.0 or greater have occurred within the ISB since 1850, with the largest of these events the M_S 7.5 1959 Hebgen Lake, Montana earthquake. However, none of these events have occurred along the Wasatch fault zone or other known late Quaternary faults in the region (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest of these events to the site was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake and south of the town of Snowville.

Lake Bonneville History

Lakes occupied nearly 100 basins in the western United States during late-Quaternary time, the largest of which was Lake Bonneville in northwestern Utah. The Bonneville basin consists of several topographically closed basins created by regional extension in the Basin and Range (Gwynn, 1980; Miller, 1990), and has been an area of internal drainage for much of the past 15 million years. Lake Bonneville consisted of numerous topographically closed basins, including the Salt Lake and Cache Valleys (Oviatt and others, 1992). Portions of Ogden Valley were inundated by Lake Bonneville at its highstand, and sediments from Lake Bonneville are mapped in the Project area on Figure 2.

Timing of events related to the transgression and regression of Lake Bonneville is indicated by calendar age estimates of significant radiocarbon dates in the Bonneville Basin (Oviatt, 2015). Approximately 30,000 years ago, Lake Bonneville began a slow transgression (rise) to its highest level of 5,160 to 5,200 feet above mean sea level. The lake rise eventually slowed as water levels approached an external basin threshold in northern Cache Valley at Red Rock Pass near Zenda, Idaho. Lake Bonneville reached the Red Rock Pass threshold and occupied its highest shoreline, termed the Bonneville beach, around 18,000 years ago. During the transgression and highstand, major drainages that emanate from within the Wasatch Range (such as the Weber River) formed large deltaic complexes in the lake at their canyon mouths. Headward erosion of the Snake River-Bonneville basin drainage divide then caused a catastrophic incision of the threshold and the lake level lowered by roughly 360 feet in fewer than two months (Jarrett and Malde, 1987; O'Conner, 1993). The site would be above the elevation of the highest (Bonneville) shoreline.

Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline between about 16,500 and 15,000 years ago. Climatic factors then caused the lake to regress rapidly from the Provo shoreline, and by about 13,000 years ago the lake had eventually dropped below historic levels of Great Salt Lake. Drainages that fed Lake Bonneville began downcutting through stranded deltaic complexes and near-shore deposits as the lake receded from the Provo shoreline. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Great Salt Lake then experienced a brief transgression around 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990).

SITE CHARACTERIZATION

Empirical Observations

On June 30, 2016, Bill D. Black of Western GeoLogic conducted a reconnaissance of the property. Weather at the time of the site reconnaissance was clear and sunny with temperatures in the 80's (°F). The site is at the western margin of Ogden Valley on east- to northeast-facing slopes overlooking Ogden Valley. Native vegetation consists mainly of trees and brush. A substantial area of the site had previously been cleared of vegetation to facilitate access and the proposed development. No active streams were observed crossing the Project, and no bedrock outcrops or evidence of ongoing or recent slope instability was also observed. Slopes at the site have a steepness of from about 2.5:1 on the west to about 4:1 (horizontal to vertical) on the east. No other evidence of geologic hazards was observed.

Air Photo Observations

High-resolution orthophotography from 2012 (Figure 3B) and 1-meter bare earth DEM LIDAR from 2011 available from the Utah AGRC (Figure 3A) were reviewed to obtain information about the geomorphology of the Project area. The site is at the western margin of Ogden Valley on east- to northeast-facing slopes overlooking Pineview Reservoir. One slope failure is evident on the air photos about 400 feet northwest of the site. This failure reportedly occurred around April-May 2006. The existing paved street was reportedly installed in 2009, although it is possible that this slide was caused by grading activity. The failure toe has been removed and buttressed with a retained rock wall. An unnamed ephemeral drainage appears to have crossed the slide area, which now follows the scarp base to the northeast, cuts across the left-lateral margin of the slide, and then crosses the road (Figures 3A-B). Below the road, the drainage re-enters its former course and proceeds downslope to the east. No other geologic hazards were evident at the site or in the area on the photos.

Subsurface Investigation
One trench and three walk-in test pits were excavated at the property between June 30 and July 2, 2016 to evaluate subsurface conditions. Figure 4 is a site plan at a scale of one inch equals 60 feet (1:720) showing the site boundaries, surveyed topography, the proposed home location and footprint, locations of the trench and test pits, and approximate locations of the borings conducted by GSH. Figures 5 and 6A-C are logs of the trench and test pits at a scale of 1 inch equals five feet (1:60). Due to the length of the trench and scale, Figure 5 occupies four 11"x17" sheets (A-D). The trench and test pit locations were measured using a hand-held GPS unit and by trend and distance methods from known points. Trench logging generally followed methodology in McAlpin (1996). The trench and test pit exposures were also digitally photographed at 5-foot intervals to document subsurface conditions. The photos are not provided herein, but are available on request. No complications were encountered that substantially impacted the subsurface investigation, except for groundwater seepage in test pit TP-1, which caused this test pit to rapidly fill with water to a depth of several feet during and following the logging.

The trench at the site was excavated generally along the north site boundary and extended an overall N34°E for a total distance of 247 feet (Figure 4). The trench exposed a sequence of inclined bedrock units of the Tertiary Norwood Formation in which the modern A-horizon soil and a Bt to Bw horizon was forming. The exposed bedrock sequence showed strikes ranging from N40°W to N42°W and dips of from 37° to 42° to the northeast (Figures 5A-D), which appears similar to nearby measurements (discussed above). Unit descriptions are provided on Figure 5D. No evidence of landsliding was exposed in the trench, except for one suspect iron-oxide stained crack near station 1+61 feet (Figure 5C) that may be related to slow slope creep. One seep was also observed near station 0+67 feet (Figure 5B), although this seep was weak and only caused a muddy area in the trench floor.

Test pit TP-1 at the site (Figures 4 and 6A) exposed a sequence of alluvium and colluvium in which the A- and B-horizon soils were forming. The lowermost unit in this test pit appeared to be a shallow slump deposit, whereas the overlying unit (1b) appeared to be a mix of slope colluvium (Figure 6A). No source area for this slump was evident on Figures 3A-B, suggesting it was either small or has been eroded away (and therefore is old). Test pit TP-2 (Figures 4 and 6B) exposed a sequence of colluvium overlying tuffaceous conglomerate and claystone bedrock of the Norwood Formation. We infer the latter correlates to unit 1h in the trench (Figure 5B), although no overlying conglomerate unit was observed in the trench and may reflect a lateral variation between the trench and TP-1. Such variations are commonly found in the Norwood Formation. Test pit TP-3 (Figures 4 and 6C) exposed a sequence of tuffaceous conglomerate and sandstone that we infer correlates to units 1b and 1c in the trench (Figure 5A), although the measured strike/dip in TP-3 differed slightly (N44°W 29°NE.

Cross Section

Figure 7 shows a cross section across the slope at the site at a scale of 1 inch equals 30 feet with no vertical exaggeration. The profile location is shown on Figure 4. Units and contacts are inferred based on the subsurface data discussed above. We use an overall dip of 40 degrees for contacts within the Norwood Formation. Presumed existing groundwater levels are also indicated based on the GSH field logs for the borings, although we note that future levels may fluctuate seasonally and in response to landscape irrigation.

GEOLOGIC HAZARDS

Assessment of potential geologic hazards and the resulting risks imposed is critical in determining the suitability of the site for development. Table 1 below shows a summary of the geologic hazards reviewed at the site, as well as a relative (qualitative) assessment of risk to the Project for each hazard. A "high" hazard rating (H) indicates a hazard is present at the site (whether currently or in the geologic past) that is likely to pose significant risk and/or may require further study or mitigation techniques. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal risk. Moderate-risk hazards may also require further studies or mitigation. A "low" hazard rating (L) indicates the hazard is not present, poses little or no risk, and/or is not likely to significantly impact the Project. Low-risk hazards typically require no additional studies or mitigation. We note that these hazard ratings represent a conservative assessment for the entire site and risk may vary in some areas. Careful selection of development areas can minimize risk by avoiding known hazard areas.

Table 1. *Geologic hazards summary.*

Hazard	H	M	L	...Hazard Rating
Earthquake Ground Shaking	X			
Surface Fault Rupture			X	
Liquefaction and Lateral-spread Ground Failure			X	
Tectonic Deformation			X	
Seismic Seiche and Storm Surge			X	
Stream Flooding			X	
Shallow Groundwater		X		
Landslides and Slope Failures	X			
Debris Flows and Floods			X	
Rock Fall			X	
Problem Soil		X		

Earthquake Ground Shaking
Ground shaking refers to the ground surface acceleration caused by seismic waves generated during an earthquake. Strong ground motion is likely to present a significant risk during moderate to large earthquakes located within a 60 mile radius of the project area (Boore and others, 1993). Seismic sources include mapped active faults, as well as a random or "floating" earthquake source on faults not evident at the surface. Mapped active faults within this distance include the East and West Cache fault zones; the Brigham City, Weber, Salt Lake, and Provo segments of the Wasatch fault zone; the East Great Salt Lake fault zone; the Morgan fault; the West Valley fault zone; the Oquirrh fault zone; and the Bear River fault zone (Black and others, 2003).

The extent of property damage and loss of life due to ground shaking depends on factors such as: (1) proximity of the earthquake and strength of seismic waves at the surface (horizontal motions are the most damaging); (2) amplitude, duration, and frequency of ground motions; (3) nature of foundation materials; and (4) building design (Costa and Baker, 1981). Assuming 2012/2015 IBC design codes, a site class of D (stiff soil), and a risk category of II, USGS calculated uniform-hazard and deterministic ground motion values with a 2% chance of exceedance in 50 years are as follows:

Table 2. *Seismic hazards summary.*
(Site Location: 41.27688° N, - 111.82975° W)

S_S	*0.927g*
S_1	*0.317g*
S_{MS} (F_a x S_S)	*1.047g*
S_{M1} (F_v x S_1)	*0.559g*
S_{DS} (2/3 x S_{MS})	*0.698g*
S_{D1} (2/3 x S_{M1})	*0.373g*
Site Coefficient, F_a	*=1.129*
Site Coefficient, F_v	*=1.767*

Given the above information, earthquake ground shaking is a high risk to the site. The hazard from earthquake ground shaking can be adequately mitigated by prudent design and construction.

Surface Fault Rupture
Movement along faults at depth generates earthquakes. During earthquakes larger than Richter magnitude 6.5, ruptures along normal faults in the intermountain region generally propagate to the surface (Smith and Arabasz, 1991) as one side of the fault is uplifted and the other side down dropped. The resulting fault scarp has a near-vertical slope. The surface rupture may be expressed as a large singular rupture or several smaller ruptures in a broad zone. Ground displacement from surface fault rupture can cause significant damage or even collapse to structures located on an active fault.

The nearest active fault to the site is the Weber segment of the WFZ about 6.1 miles to the west, and no evidence of active surface faulting is mapped or was evident at the site. Based on this, the hazard from surface faulting is rated as low. The Ogden Valley southwestern margin fault (Black and others, 2003) is near the eastern site boundary (Figure 2, dotted line), however the most-recent movement on this fault is believed to be middle to late Quaternary. Western GeoLogic (2006) found no evidence for active (Holocene-age) faulting in one trench excavated across the presumed fault location slightly southeast of the site.

Liquefaction and Lateral-spread Ground Failure
Liquefaction occurs when saturated, loose, cohesionless, soils lose their support capabilities during a seismic event because of the development of excessive pore pressure. Earthquake-induced liquefaction can present a significant risk to structures from bearing-capacity failures to structural footings and foundations, and can damage structures and roadway embankments by triggering lateral spread landslides. Earthquakes of Richter magnitude 5 are generally regarded as the lower threshold for liquefaction. Liquefaction potential at the site is a combination of expected seismic (earthquake ground shaking) accelerations, groundwater conditions, and presence of susceptible soils.

No soils likely susceptible to liquefaction were observed in the trench and test pit exposures at the site, or were evident in the borings conducted by GSH. Based on this, the hazard from liquefaction and lateral spreading is rated as low.

Tectonic Deformation
Tectonic deformation refers to subsidence from warping, lowering, and tilting of a valley floor that accompanies surface-faulting earthquakes on normal faults. Large-scale tectonic subsidence may accompany earthquakes along large normal faults (Lund, 1990). Tectonic subsidence is believed to mainly impact those areas immediately adjacent to the downthrown side of a normal fault. Western GeoLogic (2006) previously identified the site as having a low risk from tectonic deformation given the lack of active faults in the site area.

Seismic Seiche and Storm Surge
Earthquake-induced seiche presents a risk to structures within the wave-oscillation zone along the edges of large bodies of water, such as the Great Salt Lake. Given the elevation of the subject property and distance from large bodies of water, the risk to the subject property from seismic seiches is rated as low.

Stream Flooding
Stream flooding may be caused by direct precipitation, melting snow, or a combination of both. In much of Utah, floods are most common in April through June during spring snowmelt. High flows may be sustained from a few days to several weeks, and the potential for flooding depends on a variety of factors such as surface hydrology, site grading and drainage, and runoff.

No active drainages cross the site or were evident, and based on this the hazard from stream flooding should be low. However, site hydrology and runoff should be addressed in the civil engineering design and grading plan for the Project given the substantial impact that groundwater may have on slope stability.

Shallow Groundwater
No springs are shown on the topographic map for the site or were reported or observed. However, groundwater seeps were observed in the trench and TP-1 at the site, and borings B-2 and B-3 encountered groundwater at depths of 22 and 32 feet (respectively). We anticipate groundwater to be around 35 feet bgs in the upper (western) part of the site and gradually shallow to around 10 feet bgs in the lower (eastern) part. Given this and that substantial slope cuts may be required for the proposed development; we rate the risk from shallow groundwater as moderate.

Landslides and Slope Failures
Slope stability hazards such as landslides, slumps, and other mass movements can develop along moderate to steep slopes where a slope has been disturbed, the head of a slope loaded, or where increased groundwater pore pressures result in driving forces within the slope exceeding restraining forces. Slopes exhibiting prior failures, and also deposits from large landslides, are particularly vulnerable to instability and reactivation.

The site is in an area mapped as being underlain by mass-movement deposits. One small slide is evident on air photos to the north of the property, although no evidence for recent or ongoing slope instability was observed at the site. Except for possible shallow slump deposits in TP-1 and a crack suggestive of possible slope creep in the trench (discussed above), no landslide deposits or deformation was also observed in the trench or test pits. The exposed stratigraphy in the trench and test pits appear to show a fairly consistent sequence of tuffaceous bedrock across the site. This evidence, and the general correspondence between measured strike/dip measurements in the exposures and nearby measurements (discussed above), suggests that the geologic mapping on Figure 2, which shows the site in Quaternary mass-movement deposits, is inaccurate.

Although air photo evidence and the subsurface information from the trench and test pits do not indicate any existing landslides at the site, slopes at the property are steep and in landslide-prone bedrock, and a small landslide is also nearby in similar slopes. Given this, we rate the hazard from landsliding as high. We recommend stability of the slopes be evaluated in a geotechnical engineering evaluation prior to building based on site specific data and subsurface information included in this report. Recommendations for reducing the risk from landsliding should be provided if factors of safety are determined to be unsuitable. The stability evaluation should take into account possible perched groundwater and fluctuating seasonal levels, and care should also be taken that site grading does not destabilize slopes in this area without prior geotechnical analysis and grading plans. Water and improper slope cuts appear to be significant factors in slope instability in the site area. Therefore, it is critical that proper drainage be maintained, and that all cuts are engineered and retained properly.

Debris Flows

Debris flow hazards are typically associated with unconsolidated alluvial fan deposits at the mouths of large range-front drainages, such as those along the Wasatch Front. Debris flows have historically significant damage in the Wasatch Front area. No evidence for debris-flow channels, levees, or other debris-flow features was observed at the site or on air photos. Based on the above, we rate the existing risk from debris flows at the site as low.

Rock Fall

No bedrock outcrops were observed at the site or in higher slopes that could present a source area for rock fall clasts. Based on the above, we rate the hazard from rock falls as low.

Swelling and Collapsible Soils

Surficial soils that contain certain clays can swell or collapse when wet. Given the subsurface soil conditions observed at the site, it is possible that clayey interbeds may be present in the subsurface that could pose a moderate risk from problem soils. A geotechnical engineering evaluation should therefore be performed to address soil conditions and provide specific recommendations for site grading, subgrade preparation, and footing and foundation design.

CONCLUSIONS AND RECOMMENDATIONS

Earthquake ground shaking and landslides are identified as geologic hazards posing a high relative risk to the Project. Shallow groundwater and problem soils also pose a moderate risk. The following recommendations are provided to reduce risk from these hazards and for proper site development:

- ***Excavation Inspection*** - This report does not reflect subsurface variations that may occur laterally away from exploration trenches and test pits. The nature and extent of such variations may not become evident until the course of construction, and are sometimes sufficient to necessitate structural or site plan changes. Thus, we recommend that we inspect the building footing or foundation excavation to recognize any differing conditions that could affect the performance of the planned structure.

- ***Geotechnical Investigation*** - A design-level geotechnical engineering study should be conducted prior to construction to: (1) address soil conditions at the site for use in foundation design, site grading, and drainage; (2) provide recommendations regarding building design to reduce risk from seismic acceleration; (3) evaluate and provide recommendations regarding shallow groundwater and subsurface drainage; and (4) evaluate stability of slopes at the site, including providing recommendations for reducing the risk of landsliding if the factors of safety are deemed unsuitable, based on the geologic characterizations provided in this report and site-specific geotechnical data. The stability evaluation should account for possible perched groundwater and seasonal fluctuations.

- ***Excavation Backfill Considerations*** - The trench and test pits may be in areas where structures could subsequently be placed. However, backfill may not have been replaced in the excavations in compacted layers. The fill could settle with time and upon saturation. Should structures be located in an excavated area, no footings or structure should be founded over the excavations unless the backfill has been removed and replaced with structural fill, if the fill is to support a structure.

- ***Availability of Report*** - The report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. This report should be referenced for information on technical data only as interpreted from observations and not as a warranty of conditions throughout the site. The report should be submitted in its entirety, or referenced appropriately, as part of any document submittal to a government agency responsible for planning decisions or geologic review. Incomplete submittals void the professional seals and signatures we provide herein. Although this report and the data herein are the property of the client, the report format is the intellectual property of Western Geologic and should not be copied, used, or modified without express permission of the authors.

LIMITATIONS

This investigation was performed at the request of the Client using the methods and procedures consistent with good commercial and customary practice designed to conform to acceptable industry standards. The analysis and recommendations submitted in this report are based upon the data obtained from site-specific observations and compilation of known geologic information. This information and the conclusions of this report should not be interpolated to adjacent properties without additional site-specific information. In the event that any changes are later made in the location of the proposed site, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or approved in writing by the engineering geologist.

This report has been prepared by the staff of Western GeoLogic for the Client under the professional supervision of the principal and/or senior staff whose seal(s) and signatures appear hereon. Neither Western GeoLogic, nor any staff member assigned to this investigation has any interest or contemplated interest, financial or otherwise, in the subject or surrounding properties, or in any entity which owns, leases, or occupies the subject or surrounding properties or which may be responsible for environmental issues identified during the course of this investigation, and has no personal bias with respect to the parties involved.

The information contained in this report has received appropriate technical review and approval. The conclusions represent professional judgment and are founded upon the findings of the investigations identified in the report and the interpretation of such data based on our experience and expertise according to the existing standard of care. No other warranty or limitation exists, either expressed or implied.

The investigation was prepared in accordance with the approved scope of work outlined in our proposal for the use and benefit of the Client; its successors, and assignees. It is based, in part, upon documents, writings, and information owned, possessed, or secured by the Client. Neither this report, nor any information contained herein shall be used or relied upon for any purpose by any other person or entity without the express written permission of the Client. This report is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of Western GeoLogic.

In expressing the opinions stated in this report, Western GeoLogic has exercised the degree of skill and care ordinarily exercised by a reasonable prudent environmental professional in the same community and in the same time frame given the same or similar facts and circumstances. Documentation and data provided by the Client, designated representatives of the Client or other interested third parties, or from the public domain, and referred to in the preparation of this assessment, have been used and referenced with the understanding that Western GeoLogic assumes no responsibility or liability for their accuracy. The independent conclusions represent our professional judgment based on information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by the Client or their representative has been assumed to be correct and complete. The conclusions presented are based on the data provided, observations, and conditions that existed at the time of the field exploration.

It has been a pleasure working with you on this project. Should you have any questions, please call.

Sincerely,
Western GeoLogic, LLC

Bill. D. Black, P.G.
Senior Engineering Geologist

Reviewed by:

Craig V. Nelson, P.G.
Principal Engineering Geologist

ATTACHMENTS

Figure 1. Location Map (8.5"x11")
Figure 2. Geologic Map (8.5"x11")
Figure 3A. 2011 LIDAR Image (8.5"x11")
Figure 3B. 2012 Air Photo (8.5"x11")
Figure 4. Site Plan (8.5"x11")
Figures 5A-D. Trench Log (four 11"x17" sheets)
Figures 6A-C. Test Pit Logs (three 8.5"x11" sheets)
Figure 7. Cross Section (11"x17")

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Western Geologic Project No. 4083

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REFERENCES

Anderson, R.E., 1989, Tectonic evolution of the intermontane system--Basin and Range, Colorado Plateau, and High Lava Plains, *in* Pakiser, L.C., and Mooney, W.D., editors, Geophysical framework of the continental United States: Geological Society of America Memoir 172, p. 163-176.

Arabasz, W.J., Pechmann, J.C., and Brown, E.D., 1992, Observational seismology and evaluation of earthquake hazards and risk in the Wasatch Front area, Utah, *in* Gori, P.L. and Hays, W.W., editors, Assessment of Regional Earthquake Hazards and Risk along the Wasatch Front, Utah: Washington, D.C, U.S. Geological Survey Professional Paper 1500-D, Government Printing Office, p. D1-D36.

Avery, Charles, 1994, Ground-water hydrology of Ogden Valley and surrounding area, eastern Weber County, Utah and simulation of ground-water flow in the valley-fill aquifer system: Utah Department of Natural Resources, Technical Publication no.99, 84 p.

Black, B.D., Hecker, Suzanne, Hylland, M.D., Christenson, G.E., and McDonald, G.N., 2003, Quaternary fault and fold database and map of Utah: Utah Geological Survey Map 193DM, CD-ROM.

Coogan, J.C., and King, J.K., 2001, Progress Report--Geologic Map of the Ogden 30' X 60' Quadrangle, Utah and Wyoming, year 3 of 3: Utah Geological Survey Open-File Report 380, scale 1:100,000, 31 p. pamphlet.

____, 2016, Interim Geologic Map of the Ogden 30' x 60' Quadrangle, Box Elder, Cache, Davis, Morgan, Rich, and Summit Counties, Utah, and Uinta County, Wyoming: Utah Geological Survey Open-File Report 653DM, scale 1:100,000, 141 p. with appendices.

Earthtec Testing & Engineering, 2006, Geotechnical Study—Pineview at Radford Hills. Huntsville, Utah: unpublished consultant's report prepared for Titan Development, ETE Job No. 06-0020, 14 p. with test pit logs, soil testing, and slope stability analyses.

Gilbert, G.K., 1928, Studies of Basin and Range Structure: U.S. Geological Survey Professional Paper 153, 89 p.

Gwynn, J.W. (Editor), 1980, Great Salt Lake--A scientific, historical, and economic overview: Utah Geological Survey Bulletin 166, 400 p.

Jarrett, R.D., and Malde, H.E., 1987, Paleodischarge of the late Pleistocene Bonneville flood, Snake River, Idaho, computed from new evidence: Geological Society of America Bulletin, v. 99, p. 127-134.

Lund, W.R. (Editor), 1990. Engineering geology of the Salt Lake City metropolitan area, Utah: Utah Geological and Mineral Survey Bulletin 126, 66 p.

McCalpin, J.P., 1996, Paleoseismology: San Diego, California, Academic Press Inc., Volume 62 of the International Geophysical Series, 588 p.

Miller, D.M., 1990, Mesozoic and Cenozoic tectonic evolution of the northeastern Great Basin, *in* Shaddrick, D.R., Kizis, J.R., and Hunsaker, E.L. III, editors, Geology and Ore Deposits of the Northeastern Great Basin: Geological Society of Nevada Field Trip No. 5, p. 43-73.

O'Connor, J.E., 1993, Hydrology, hydraulics, and geomorphology of the Bonneville flood: Geological Society of America Special Paper 274, 83 p.

Oviatt, C.G., 2015, Chronology of Lake Bonneville, 30,000 to 10,000 yr B.P.: Quaternary Science Reviews, v. 110 (2015), p. 166-171.

Oviatt, C.G., Currey, D.R., and Sack, Dorothy, 1992, Radiocarbon chronology of Lake Bonneville, Eastern Great Basin, USA: Paleogeography, Paleoclimatology, Paleoecology, v. 99, p. 225-241.

Sbar, M.L., Barazangi, M., Dorman, J., Scholz, C.H., and Smith, R.B., 1972, Tectonics of the Intermountain Seismic Belt, western United States--Microearthquake seismicity and composite fault plane solutions: Geological Society of America Bulletin, v. 83, p. 13-28.

Smith, R.B., and Arabasz, W.J., 1991, Seismicity of the Intermountain Seismic Belt, *in* Slemmons, D.B., Engdahl, E.R., Zoback, M.D., and Blackwell, D.D., editors, Neotectonics of North America: Geological Society of America, Decade of North American Geology Map v. 1, p. 185-228.

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

Stewart, J.H., 1978, Basin-range structure in western North America, a review, *in* Smith, R.B., and Eaton, G.P., editors, Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 341-367.

____, 1980, Geology of Nevada: Nevada Bureau of Mines and Geology Special Publication 4.

Stokes, W.L., 1977, Physiographic subdivisions of Utah: Utah Geological and Mineral Survey Map 43, scale 1:2,400,000.

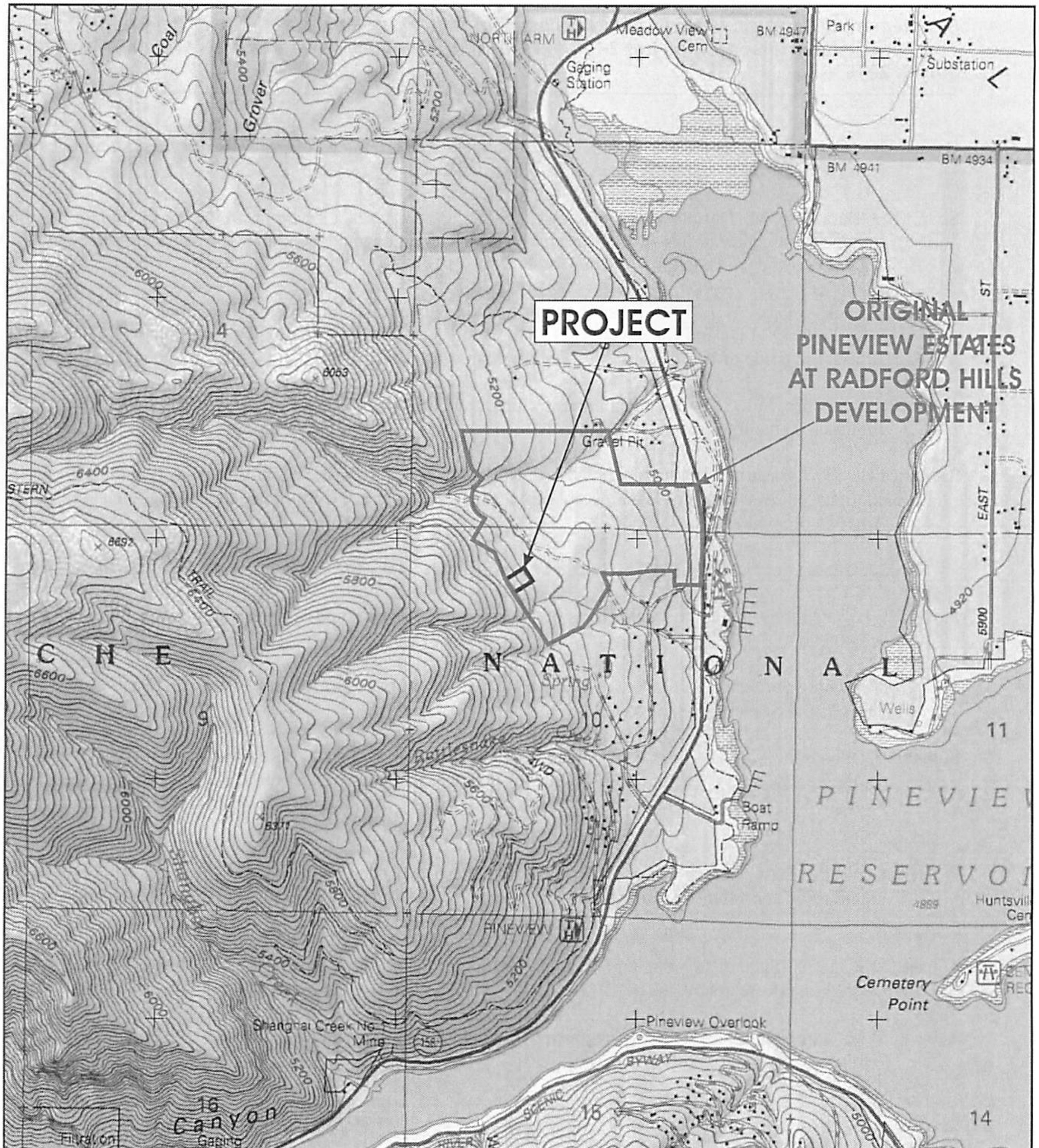
____, 1986, Geology of Utah: Salt Lake City, University of Utah Museum of Natural History and Utah Geological and Mineral Survey, 280 p.

Sullivan, J.T., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1986, Regional seismotectonic study for the back valleys of the Wasatch Mountains in northeastern Utah: Denver, Colorado, U.S. Bureau of Reclamation, Seismotectonic Section, Division of Geology, Engineering and Research Center, unpublished report, 317 p.

Western GeoLogic, 2006, Geologic Hazards Evaluation--Pineview Estates at Radford Hills, Weber County, Utah: unpublished consultant's report prepared for Earthtec Testing & Engineering, 15 p. with trench and test pit logs.

Zoback, M.L., 1989. State of stress and modern deformation of the northern Basin and Range province: Journal of Geophysical Research, v. 94, p. 7105-7128.

Zoback, M.L. and Zoback, M.D., 1989. Tectonic stress field of the conterminous United States: Boulder, Colorado, Geological Society of America Memoir, v. 172, p. 523-539.



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Huntsville, 1998;
Project location NW1/4, Section 10, T6N, R1E (SLBM).

WESTERN GEOLOGIC

N W E S

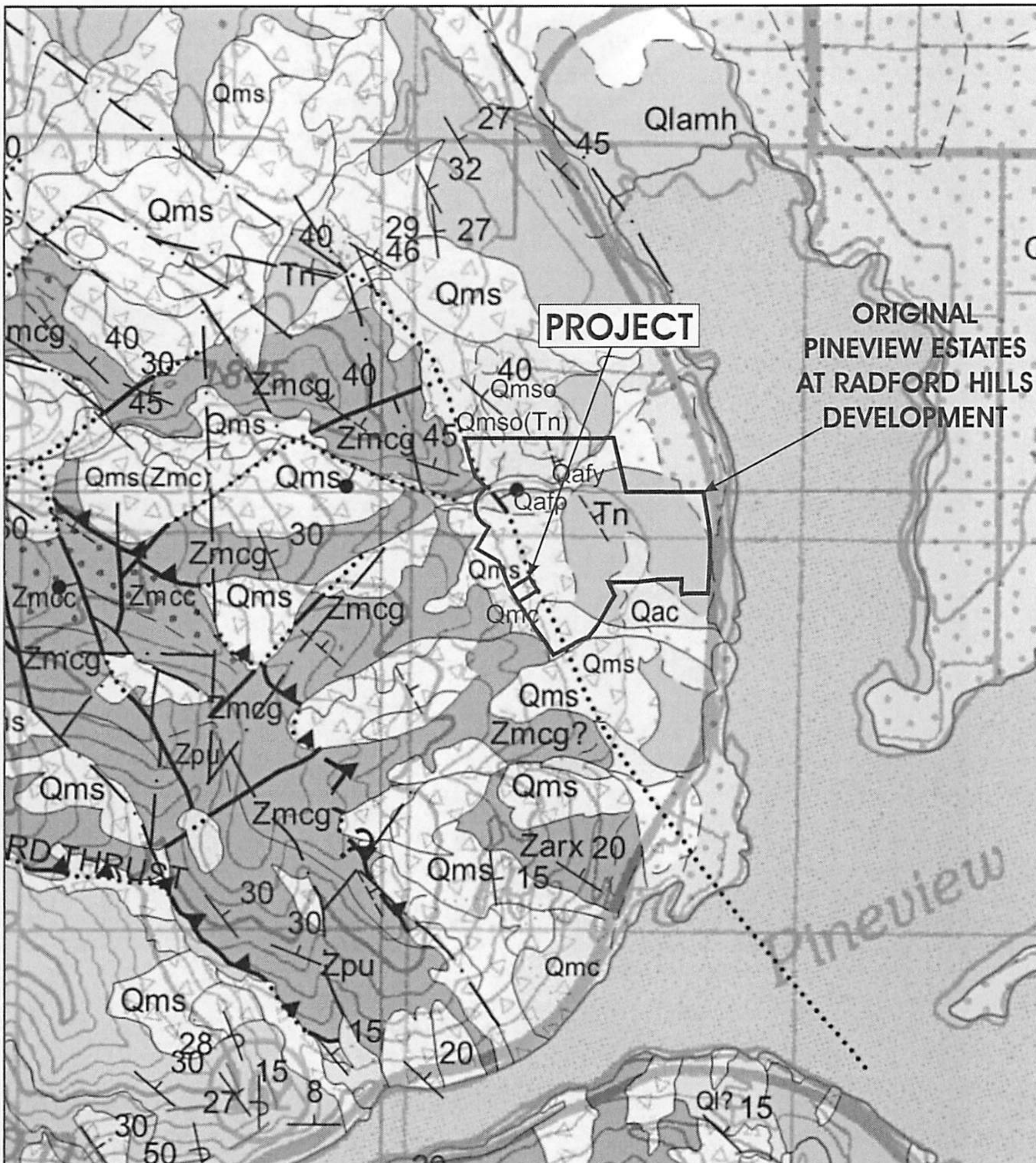
0 1000 2000 feet

Scale 1:24,000
(1 inch = 2000 feet)

LOCATION MAP

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 1



Source: Coogan and King (2016); original map scale 1:100,000. See text for explanation of nearby surficial geologic units.

WESTERN GEOLOGIC

N S W E

0 1000 2000 feet

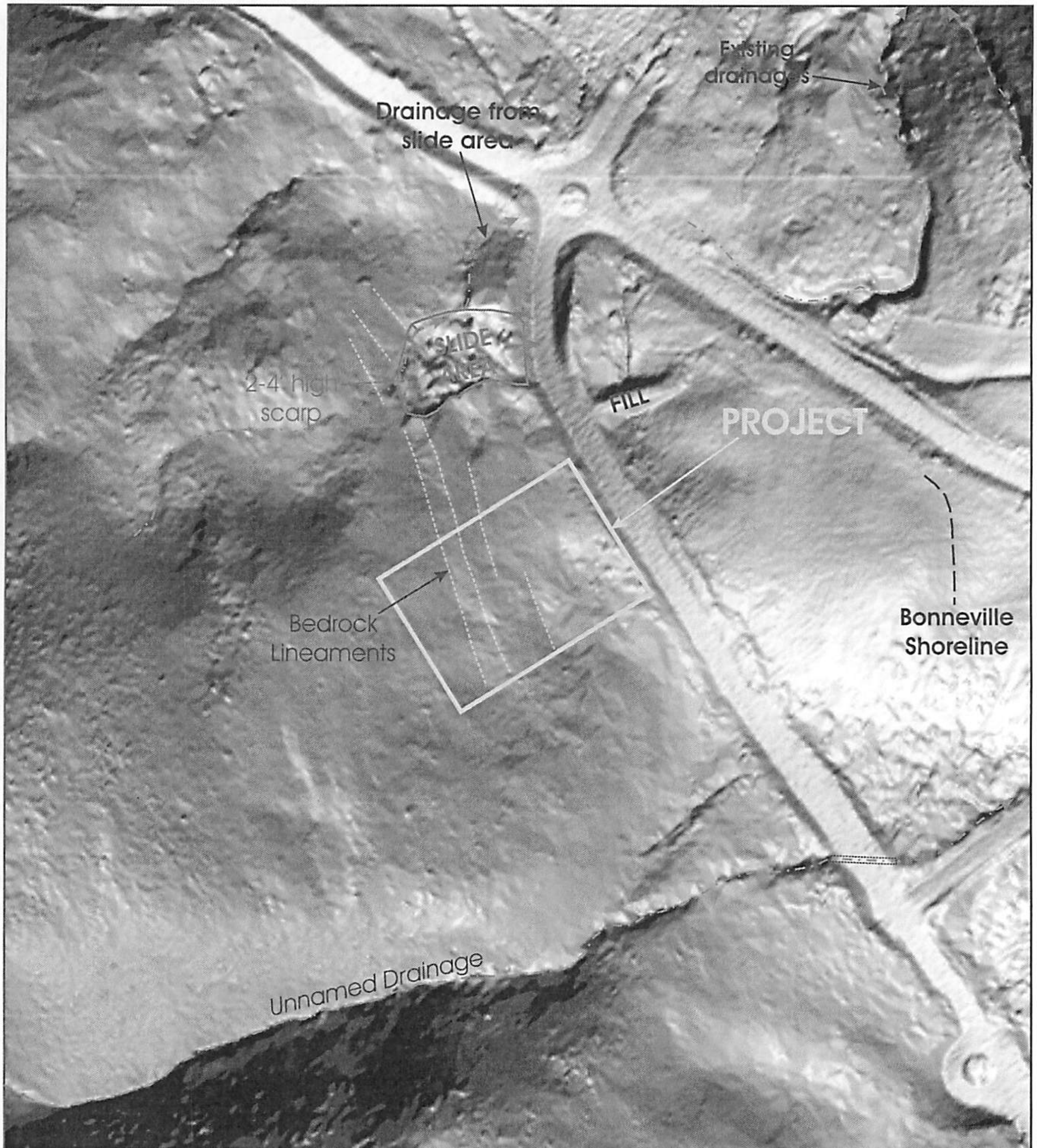
Scale 1:24,000
(1 inch = 2000 feet)

GEOLOGIC MAP

GEOLOGIC HAZARDS EVALUATION

The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 2



Source: Utah AGRC, 1-meter LIDAR Bare Earth DEM, 2011.

WESTERN GEOLOGIC

N W E S

0 100 250 feet

Scale 1:2,400
(1 inch = 200 feet)

2011 LIDAR IMAGE

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 3A

Source: Utah AGRC, High Resolution Orthophoto, 6-inch resolution, 2012.

N
W E
S

0 100 250 feet

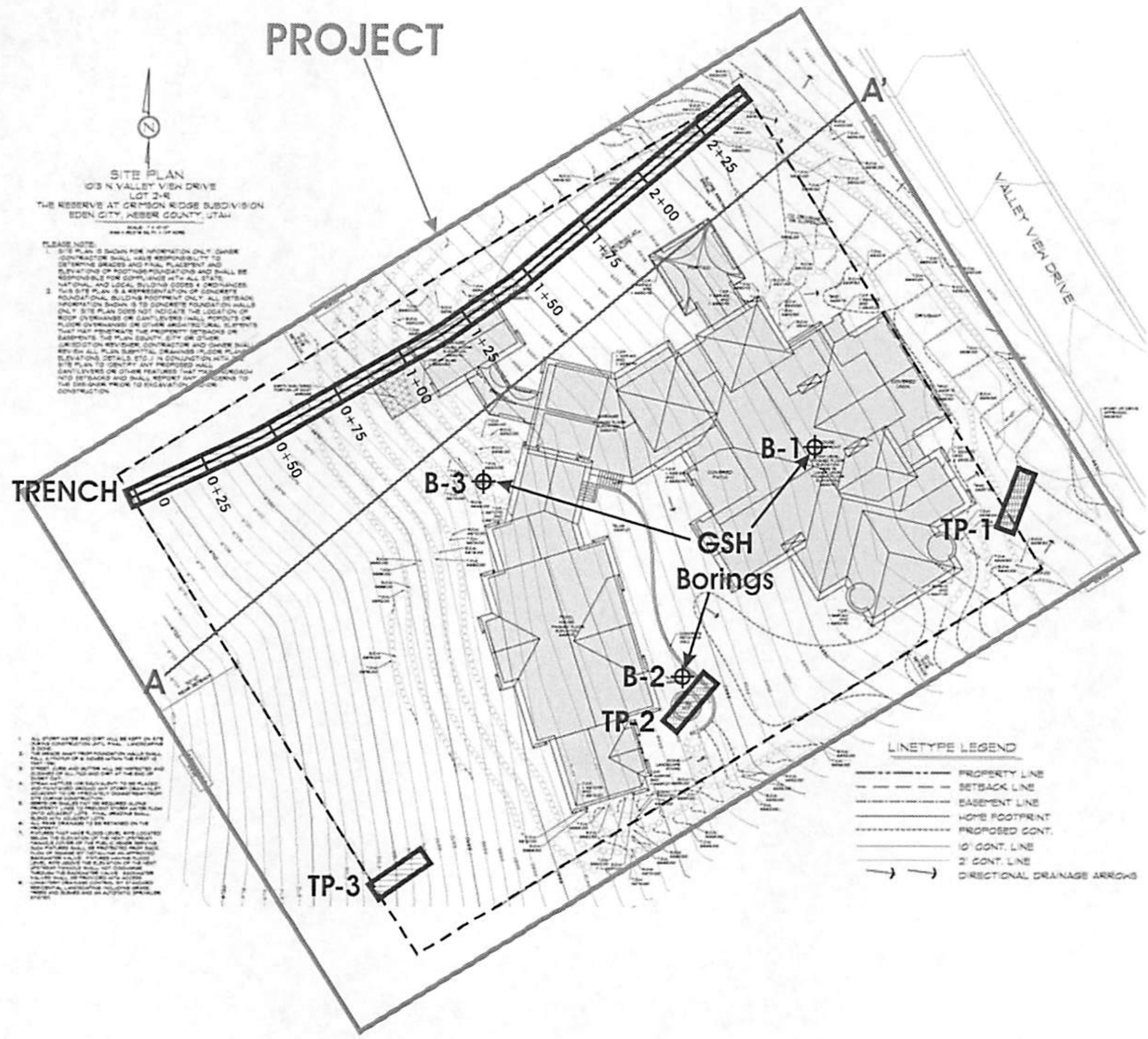
Scale 1:2,400
(1 inch = 200 feet)

WESTERN GEOLOGIC

2012 AIR PHOTO

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 3B



N
W E
S

0 30 60 feet

Scale 1:720
(1 inch = 60 feet)

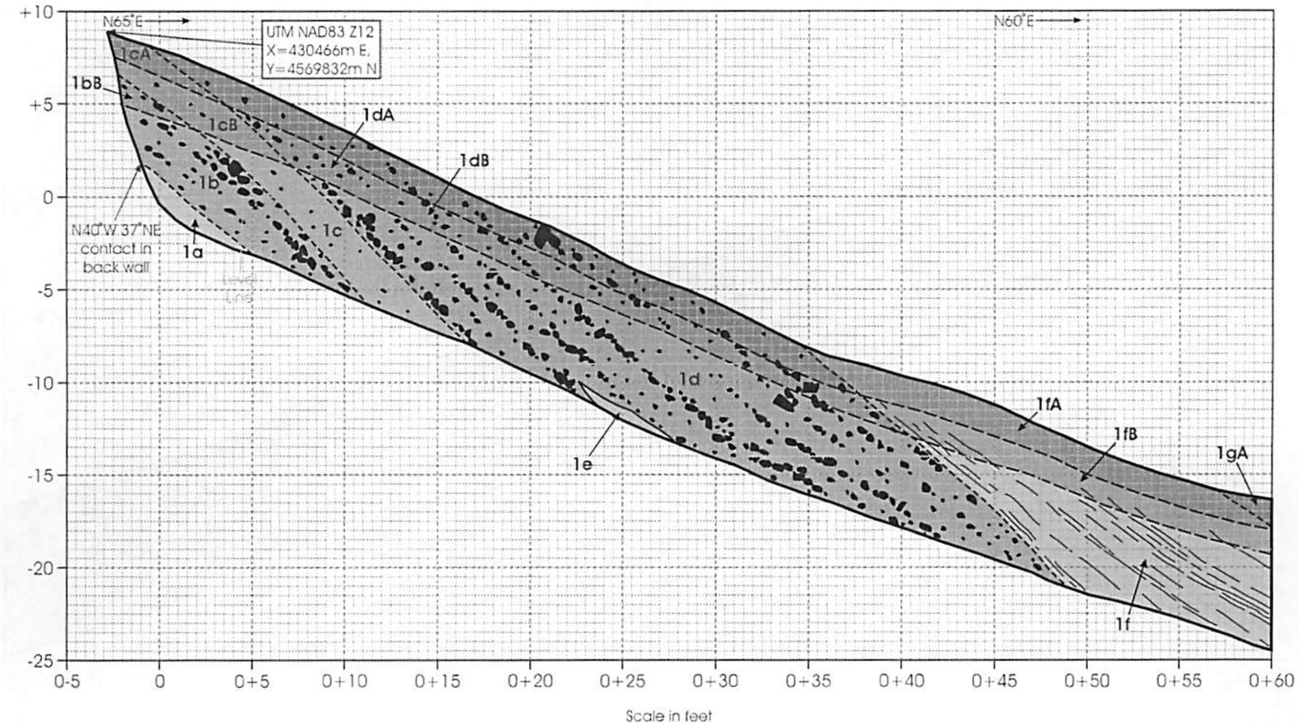
WESTERN GeoLogic

SITE PLAN

GEOLOGIC HAZARDS EVALUATION

The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 4



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Trench logged by Bill D Black, P.G.
on June 1-2, 2016

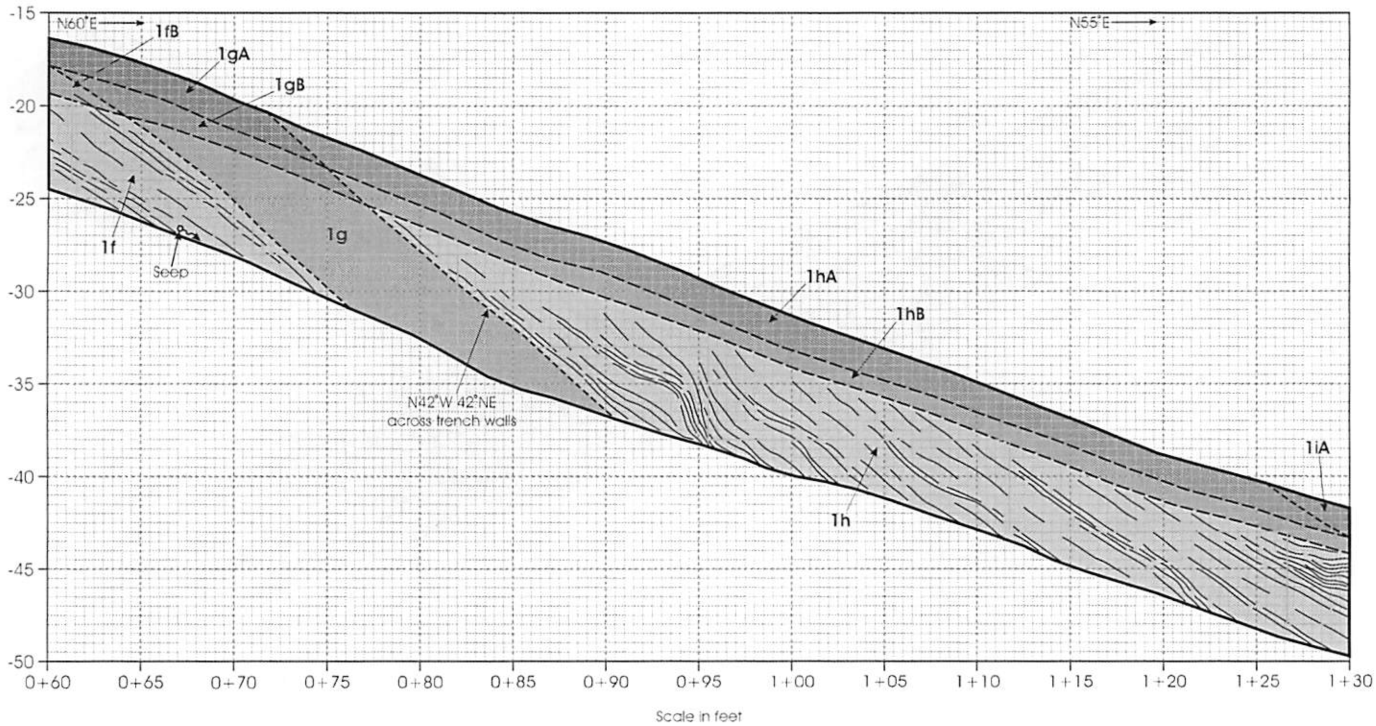
See Figure 5d for unit descriptions

TRENCH LOG, SHEET 1

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 5A

WESTERN GeoLogic



WESTERN GEOLOGIC

See Figure 5d for unit descriptions

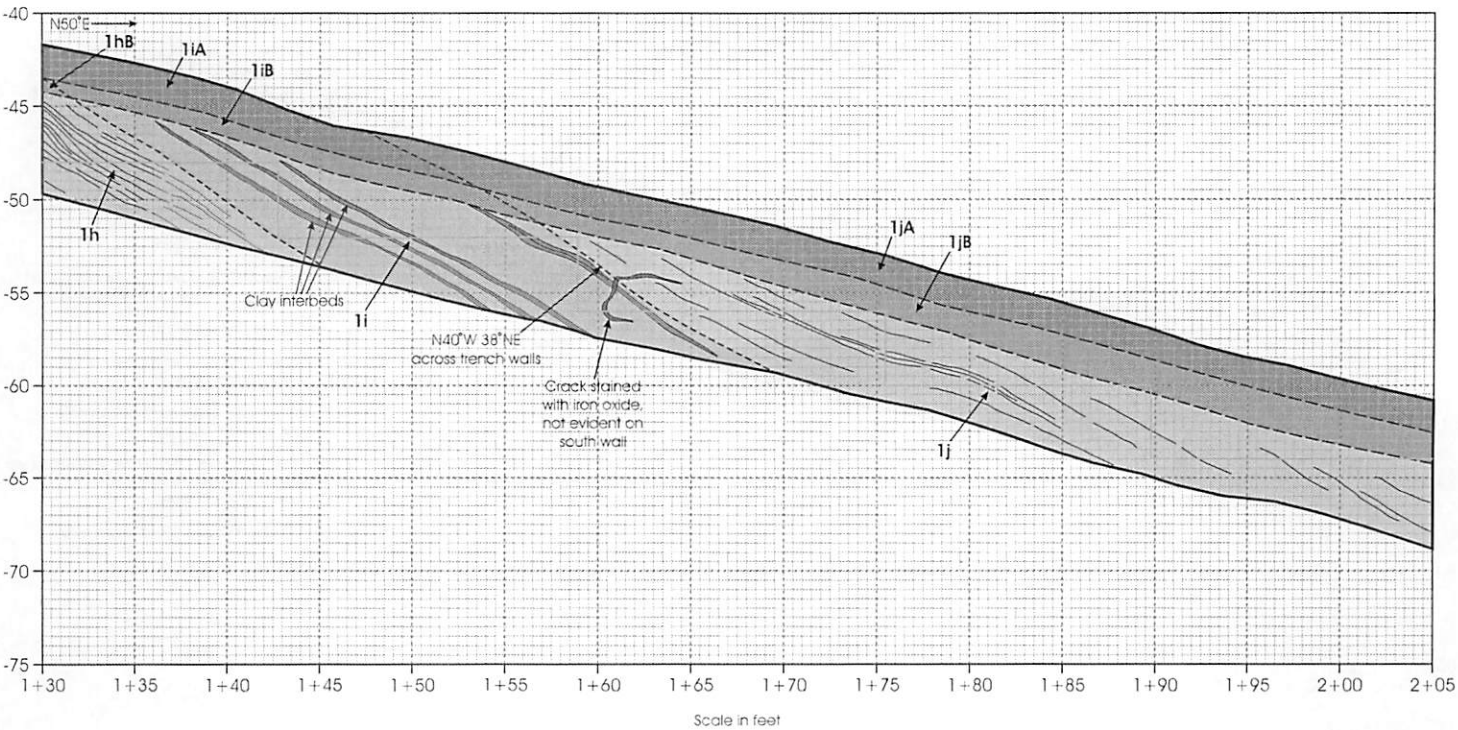
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Trench logged by Bill D Black, P.G.
on June 1-2, 2016

TRENCH LOG, SHEET 2

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 5B



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Trench logged by Bill D Black, P.G.
on June 1-2, 2016

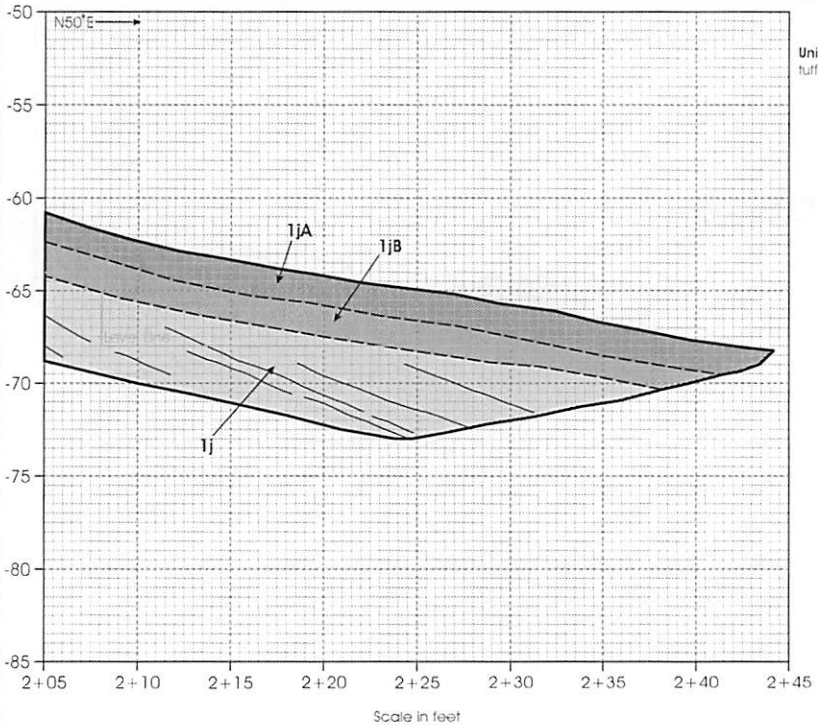
See Figure 5d for unit descriptions

WESTERN GeoLogic

TRENCH LOG, SHEET 3

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 5C



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - sequence of moderate to high density, poorly to well bedded, tuffaceous bedrock units striking northwestward and dipping to the northeast.

1a. Pale-olive-brown clayey sand to sandy clay (SC/CL); likely weathered tuffaceous sandstone.

1b. Reddish-olive-brown sandy gravel to gravelly sand with clay and cobbles (GW/SW); likely weathered tuffaceous conglomerate.

1bB. Vertisol B horizon formed in unit.

1c. Olive-orange clayey sand with trace gravel (SC); likely weathered tuffaceous sandstone.

1cA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1cB. Vertisol B horizon formed in unit.

1d. Reddish-brown gravelly sand to sandy gravel with cobbles and rare boulders (GW/SW); likely weathered tuffaceous conglomerate.

1dA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1dB. Vertisol B horizon formed in unit.

1e. Discontinuous interbed in unit 1d comprised of yellowish-olive sandy lean to fat clay (CL/CH).

1f. Pale-olive to pale-reddish-brown sandy clay (CL/CH); likely weathered tuffaceous sandy claystone.

1fA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1fB. Vertisol B horizon formed in unit.

1g. Olive-reddish-brown clayey sand (SC); likely weathered tuffaceous sandstone.

1gA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1gB. Vertisol B horizon formed in unit.

1h. Pale-brown lean to fat clay (CL/CH) with carbonate stringers; likely weathered claystone.

1hA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1hB. Vertisol B horizon formed in unit.

1i. Olive clayey sand (SC) with interbeds of reddish-brown lean to fat clay (CL/CH); likely weathered tuffaceous sandstone; fractured in places and with zones of iron-oxide staining.

1iA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1iB. Vertisol B horizon formed in unit.

1j. Very-pale-brown to pale-olive sandy clay to silt (CL/ML) with stage III-IV carbonate; likely weathered tuffaceous claystone to siltstone.

1jA.Organic-enriched, root-penetrated, A-horizon soil formed in unit.

1jB. Vertisol B horizon formed in unit.

TRENCH LOG, SHEET 4

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

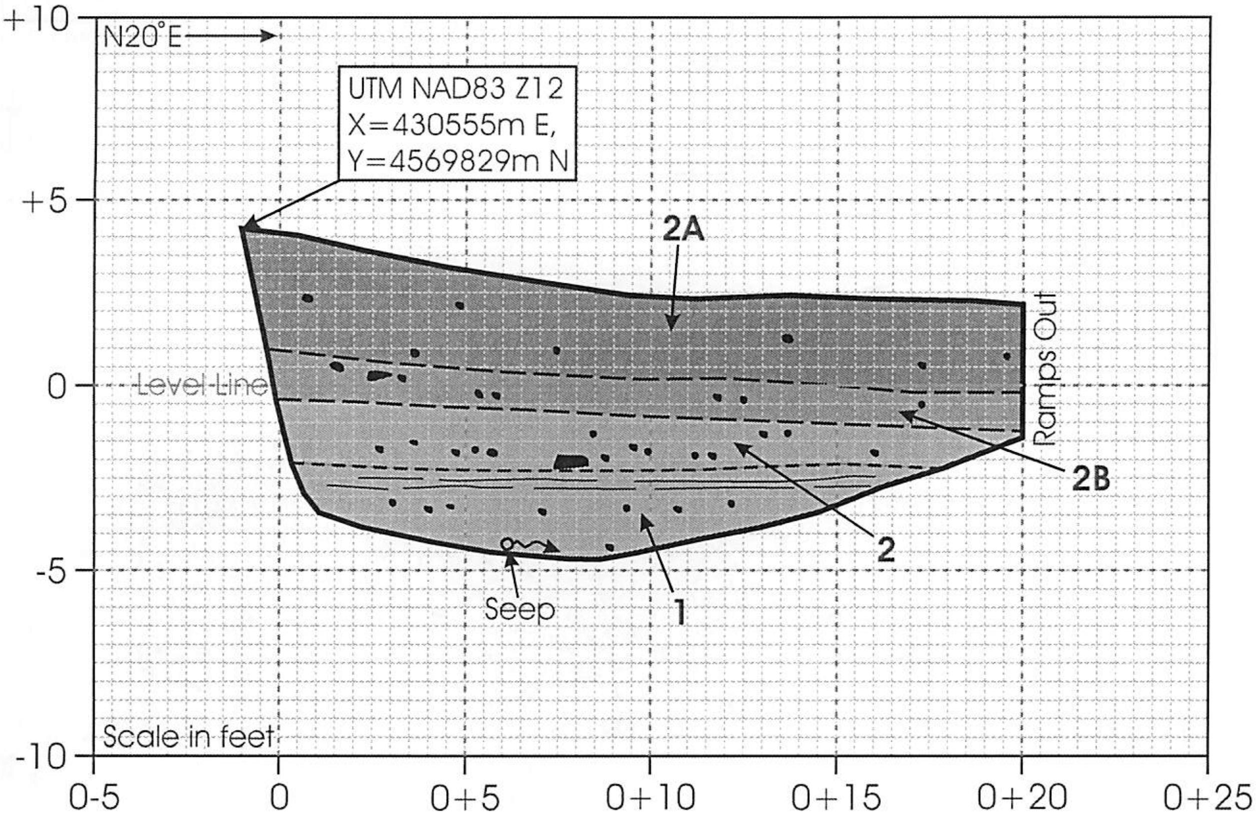
FIGURE 5D

SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Trench logged by Bill D Black, P.G.
on June 1-2, 2016

WESTERN GEOLOGIC

See Figure 5d for unit descriptions



UNIT DESCRIPTIONS

Unit 1. *Latest Pleistocene to Holocene Alluvium and Colluvium* - Reddish-brown to gray, moderate to high density, poorly bedded to massive, bedded, sandy clay (CL) with gravel; topset lean to fat clay lense; likely shallow slump deposits.

Unit 2. *Holocene Alluvium and Colluvium* - Reddish-brown to dark-brown, moderate density, massive, sandy clay with gravel and trace cobbles (CL); likely slope colluvium.

2A. Organic-rich, very-dark-grayish-brown, root penetrated, A-horizon soil formed in unit.

2B. B-horizon soil formed in unit.

WESTERN GEOLOGIC

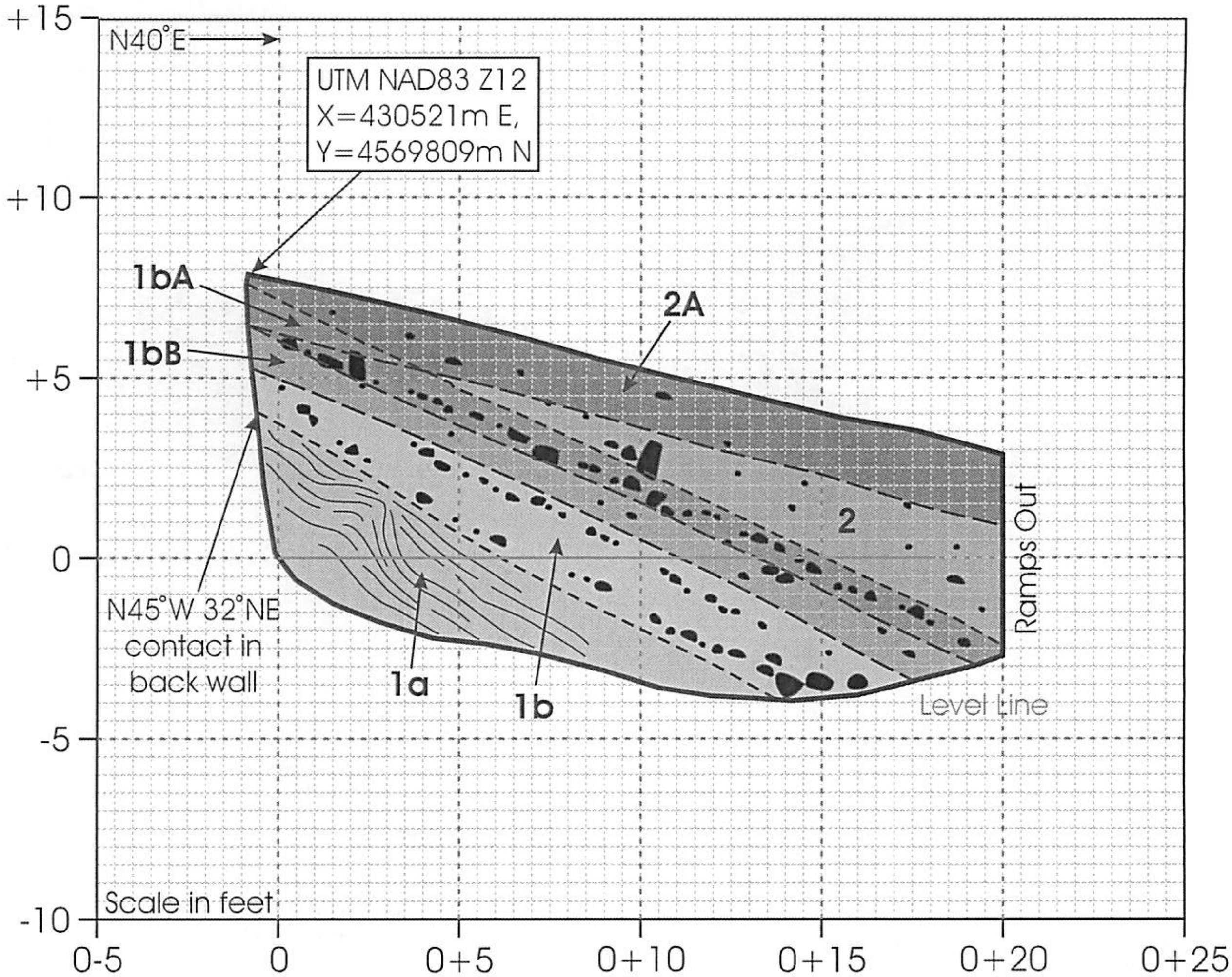
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Logged by Bill D. Black, P.G.
on May 31, 2016
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 1 LOG

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 6A



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Sequence of weathered, poorly to well-bedded, moderate to high density, tuffaceous claystone, sandstone, and conglomerate.

1a. Claystone to sandstone comprised of sandy clay to clayey sand (CL-CH/SC), iron-oxide staining along bedding; likely corresponds to unit 1h in trench (Figure 5).

1b. Conglomerate comprised of reddish-brown clayey sand with gravel, cobbles, and trace boulders (SC).

1bA. Paleosol A horizon formed in unit.

1bB. B-horizon soil formed in unit.

Unit 2. *Holocene Alluvium and Colluvium* - Reddish-brown to dark-brown, moderate density, massive, sandy clay with gravel and trace cobbles (CL); clasts with stage II carbonate, mainly quartzite.

2A. Organic-rich, very-dark-grayish-brown, root penetrated, A-horizon soil formed in unit.

WESTERN GEOLOGIC

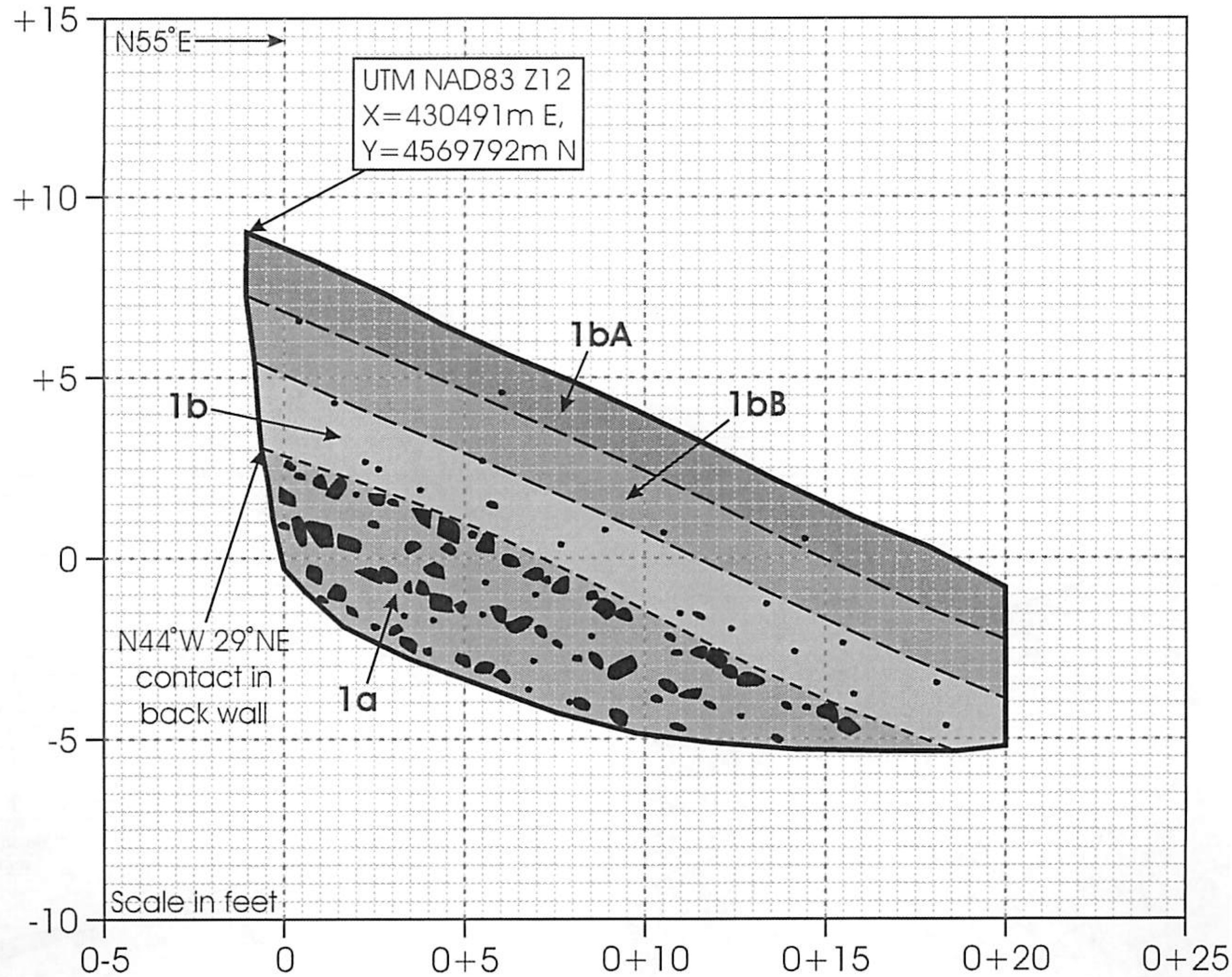
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Logged by Bill D. Black, P.G.
on May 31, 2016
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 2 LOG

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 6B



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Sequence of weathered, moderate density, poorly bedded, tuffaceous conglomerate and sandstone.

1a. Tuffaceous conglomerate comprised of reddish-brown clayey gravelly sand to sandy gravel (SC/GW) with cobbles and trace boulders.

1b. Highly weathered tuffaceous sandstone (?) comprised of clayey sand with gravel (SC).

1bA. Modern A-horizon soil formed in unit.

1bB. B-horizon soil formed in unit.

WESTERN GEOLOGIC

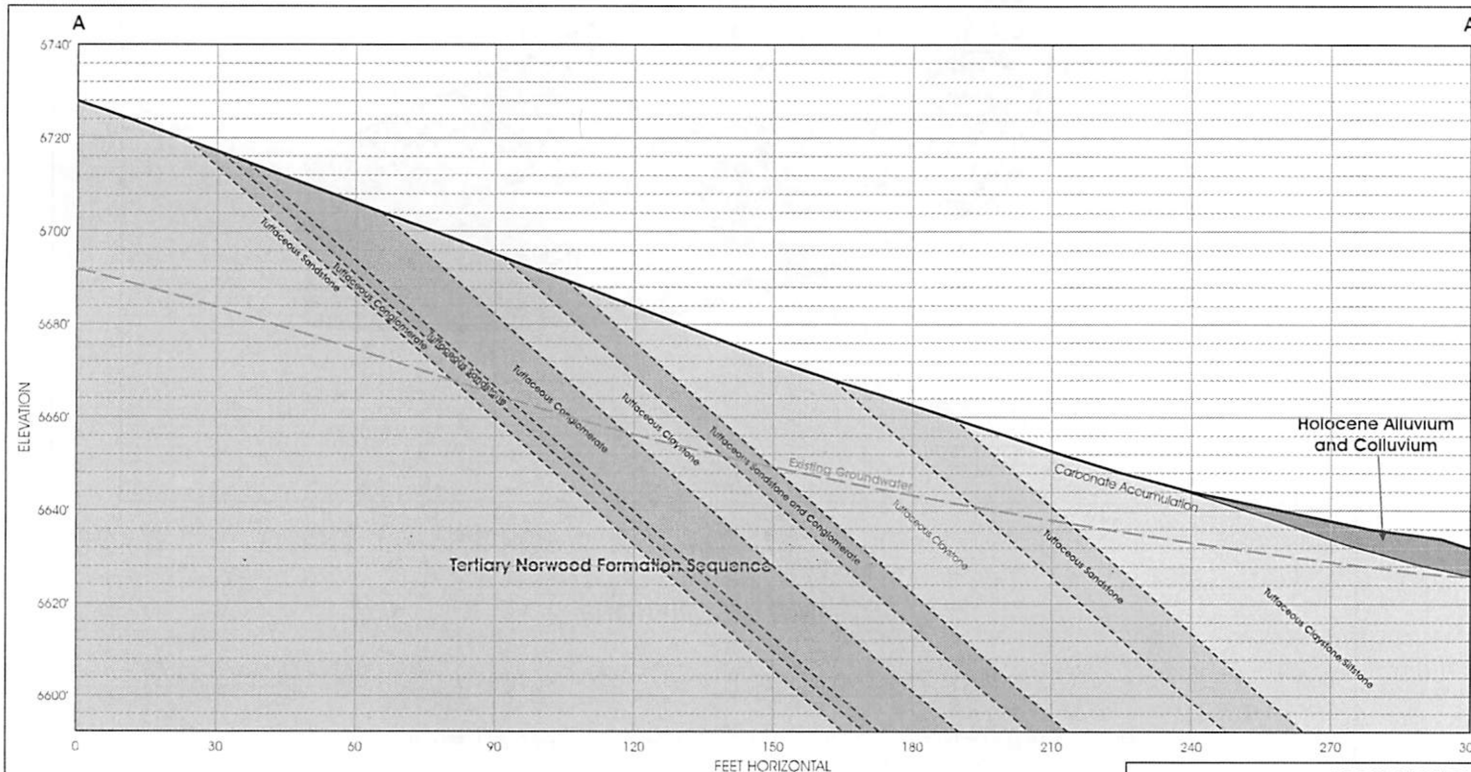
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Logged by Bill D. Black, P.G.
on May 31, 2016
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 3 LOG

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 6C



SCALE: 1 inch = 20 feet
No vertical exaggeration
Contacts based on subsurface data and are inferred in unexplored areas and at depth

CROSS SECTION

GEOLOGIC HAZARDS EVALUATION
The Reserve at Crimson Ridge, Lot 2-R
1013 North Valley View Drive
Liberty, Weber County, Utah

FIGURE 7