# REPORT

# GEOLOGIC HAZARDS EVALUATION

## POWDER MOUNTAIN WEST LOT 42-R

## 6706 ASPEN DRIVE (6675 NORTH)

## EDEN, WEBER COUNTY, UTAH

***Prepared for***

GSH Geotechnical
1596 West 2650 South, Suite 107
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July 21, 2016

***Prepared by***

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July 21, 2016

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**SUBJECT:** Geologic Hazards Evaluation
Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

Dear Mr. Harris:

This report presents results of an engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for lot 42-R in the Powder Mountain West subdivision in Eden, Utah (Figure 1 – Project Location). The Project is identified as Weber County Assessor's parcel number 22-110-0011 (6706 East 6675 North). The site is on south- to southeast-facing slopes in the Wasatch Range at Powder Mountain Ski Area, and is in the SE1/4 Section 36, Township 8 North, Range 1 East (Salt Lake Base Line and Meridian; Figure 1). Elevation of the property ranges from about 8,264 feet to 8,308 feet above sea level. It is our understanding that the current intended site use is for development of a single-family residential home.

## 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 three test pits at the site on July 1, 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.

## HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the James Peak Quadrangle shows the Project is slightly north of the head of South Fork Wolf Creek about 0.83 miles southeast of James Peak. South Fork Wolf Creek flows southward into Ogden Valley. Depth to groundwater at the site is unknown, but is likely greater than 50 feet. No springs are shown at the site or in the area on Figure 1 or were observed during our reconnaissance. Groundwater depth at the Project likely fluctuates seasonally from snowmelt, and also locally depending on bedrock flow patterns. Groundwater from snowmelt likely infiltrates through surficial colluvium, and then flows through bedrock fractures. Based on topography, we anticipate groundwater in the area to flow to the southeast into the South Fork Wolf Creek drainage basin and then into Ogden Valley further south.

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). The site would be in a recharge area for the valley-fill aquifer.

## GEOLOGY

### Surficial Geology

The site is located in steep mountainous terrain in the Wasatch Range about 3.5 miles northeast of Ogden Valley near the divide between the Wellsville and Wolf Creek drainage basins. This divide marks the boundary between Weber and Cache Counties (to the south and north, respectively). The Wasatch Range is a major north-south trending mountain range that marks the eastern boundary of the Basin and Range physiographic province (Stokes; 1977, 1986); Ogden Valley is a sediment-filled intermontane valley within the Wasatch Range.

Surficial geology of the site is mapped by Coogan and King (2016; Figure 2) as Neoproterozoic (Precambrian-age) bedrock of the Mutual Formation. Coogan and King (2016) describe surficial geologic units in the site area on Figure 2 as follows:

> ***Qct*** - *Colluvium and talus, undivided (Holocene and Pleistocene)*. Unsorted clay- to boulder-sized angular debris (scree) at the base of and on steep, typically partly vegetated slopes; shown mostly on steep slopes of resistant bedrock units; 6 to 30 feet (2-9 m) thick.
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> ***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).

Wasatch Formation (Eocene and upper Paleocene) – Typically red to brownish-red sandstone, siltstone, mudstone, and conglomerate with minor gray limestone and marlstone locally (see Twl); lighter shades of red, yellow, tan, and light gray present locally and more common in uppermost part, complicating mapping of contacts with overlying similarly colored Norwood and Fowkes Formations; clasts typically rounded Neoproterozoic and Paleozoic sedimentary rocks, mainly Neoproterozoic and Cambrian quartzite; basal conglomerate more gray and less likely to be red, and containing more locally derived angular clasts of limestone, dolomite and sandstone, typically from Paleozoic strata, for example in northern Causey Dam quadrangle; sinkholes indicate karstification of limestone beds; thicknesses on Willard thrust sheet likely up to about 400 to 600 feet (120-180 m) in Sharp Mountain, Dairy Ridge, and Horse Ridge quadrangles (Coogan, 2006a-b), about 1300 feet (400 m) in Monte Cristo Peak quadrangle, about 1100 feet (335 m) in northeast Browns Hole quadrangle, about 2200 feet (670 m) in southwest Causey Dam quadrangle, about 2600 feet (800 m) at Herd Mountain in Bybee Knoll quadrangle, and about 1300 feet (400 m) in northwest Lost Creek Dam quadrangle, estimated by elevation differences between pre-Wasatch rocks exposed in drainages and the crests of gently dipping Wasatch Formation on adjacent ridges (King); thickness varies locally due to considerable relief on basal erosional surface, for example along Right Fork South Fork Ogden River, and along leading edge of Willard thrust; much thicker, about 5000 to 6000 feet (1500-1800 m), south of Willard thrust sheet near Morgan. Wasatch Formation is queried (Tw?) where poor exposures may actually be surficial deposits. The Wasatch Formation is prone to slope failures. Other information on the Wasatch Formation is in Tw descriptions under the heading “Sub-Willard Thrust - Ogden Canyon Area” since Tw strata are extensive near Morgan Valley and cover the Willard thrust, Ogden Canyon, and Durst Mountain areas.

Along the South Fork Ogden River, Wasatch strata are mostly pebble, cobble, and boulder conglomerate with a matrix of smaller gravel, sand, and silt in the Browns Hole quadrangle, and coarse-grained sandstone to granule conglomerate as well as siltstone and mudstone to the east in the Causey Dam quadrangle; note thinning to east away from source area. The Wasatch weathers to boulder-covered dip (?) slopes north of the South Fork Ogden River, for example in Evergreen Park. Along the South Fork, the Wasatch Formation is separated from the underlying Hams Fork Member of the Evanston Formation by an angular unconformity of a few degrees, with the Hams Fork containing less siltstone and mudstone than the Wasatch and having a lighter color.

The Herd Mountain surface is developed on the Wasatch Formation at elevations of 7600 to 8600 feet (2300-2620 m) in the Bybee Knoll quadrangle and in remnants in the Huntsville, Browns Hole, and Sharp Mountain quadrangles. The origin of this boulder-strewn surface is debated (see Eardley, 1944; Hafen, 1961; Mullens, 1971). Eardley’s (1944) Herd Mountain surface is flat lying or gently east dipping, about the same as the underlying Wasatch Formation, and is strewn with quartzite boulders to pebbles that King thinks are residual and colluvial deposits of uncertain age that were derived from the Wasatch Formation. The other characteristic of this surface is the presence of pimple mounds and, given the elevations of greater than about 7500 feet (2300 m), possible periglacial patterned ground. Photogrammetric dips on the Wasatch Formation under the surface are nearly flat (<3°) and an apparent angular unconformity is present in the Wasatch since dips on older Wasatch strata are greater than 3 degrees. King mapped this unconformity as a marker bed, but Coogan does not agree that this is an unconformity.

***Cbk, Cbk?*** - *Blacksmith Formation (Middle Cambrian)*. Typically, medium-gray, very thick to thick-bedded, dolomite and dolomitic limestone with tan-weathering, irregular silty partings to layers; weathers to lighter gray cliffs and ridges; 250 to 760 feet (75-230 m) thick in our map area. The Blacksmith Formation on the leading edge of the Willard thrust sheet thickens southward from 600 feet (180 m) along Sugar Pine Creek in the Dairy Ridge quadrangle, to about 760 feet (230 m) in the northwestern Horse Ridge quadrangle (Coogan, 2006a-b). To the south and west, the Blacksmith is about 500 feet (150 m) thick near Causey Dam (Mullens, 1969), with a 530-foot (161 m) thickness reported at the Baldy Ridge section (Rigo, 1968, aided by Mullens) in the Causey Dam or Horse Ridge quadrangle. Farther west, the Blacksmith is reportedly 409 feet (125 m) thick in the Sharp Mountain area (Hafen, 1961) and is about 250 feet (75 m) thick near the South Fork Wolf Creek in the Huntsville quadrangle (Coogan this report); still farther west, this unit is reportedly about 700 to 800 feet (210-245 m) thick near Mantua (Williams, 1948; Ezell, 1953; Sorensen and Crittenden, 1976a). So the thickness of the Blacksmith Formation is low in the Huntsville quadrangle and thickens to north, west, and east, and thickens southward on leading edge of thrust sheet.

The Blacksmith to the north of our map area is about 475 feet (144 m) thick in the Porcupine Reservoir quadrangle (Rigo, 1968; Hay, 1982), about 450 feet (137 m) thick near the Blacksmith Fork River (Maxey, 1958), and 410 feet (125 m) thick in Blacksmith Fork Canyon (Hay, 1982). The Blacksmith thickness in the Browns Hole area is uncertain due to poorly exposed Cambrian strata. Laraway's (1958) Blacksmith contacts are not those of Crittenden (1972) or our mapping (see also Hodges member above); so his reported 730-foot (220 m) thickness is suspect. Laraway's (1958) report of Bolaspidella and Ehmaniella trilobite fossils in his Blacksmith is also problematic because these fossils are characteristic of the Bloomington and Ute Formations, respectively (Maxey, 1958). Also, Laraway's description of covered intervals in typically cliff-forming Blacksmith imply a fault repetition of the Ute or his measuring at least 986 feet (300 m) of Ute (see Ute description for comparison) and less than 403 feet (123 m) of Blacksmith; further, Crittenden's (1972) large thicknesses (~1300 or less likely 1150 feet [~400 or <350 m]) and mixed carbonates above Ute shale on his lithologic column imply fault repetition(s). Our Blacksmith-Bloomington contact is above a non-resistant Ute interval that overlies a resistant cliffy interval in the Ute. This makes the Ute about 700 feet (215 m) thick on Crittenden's (1972) lithologic column, and the Blacksmith and lower Bloomington about 650 feet (200 m) thick on his column. Finally, Crittenden's (1972) lithologies are not like what Laraway (1958) reported in his measured section.

***Cu, Cu?*** - *Ute Formation (Middle Cambrian)*. Interbedded gray thin- to thick-bedded limestone with tan-, yellowish-tan-, and reddish-tan-weathering, wavy, silty layers and partings, and olive-gray to tan-gray, thin-bedded shale and micaceous argillite; and minor, medium-bedded, gray to light-gray dolomite; sand content in limestone increases upward such that calcareous sandstone is present near top of formation; mostly slope and thin ledge former; base less resistant (more argillaceous) than underlying Langston Formation; Zacanthoides, Kootenia, Bathyuriscus, and Peronopsis sp. trilobite fossils reported by Rigo (1968, USGS No. 5960-CO) in Causey Dam quadrangle; estimate 450 to 1000 feet (140-300 m) thick and thinnest on leading edge of Willard thrust sheet.

The thickness range for the Ute Formation is based on multiple studies. It is reportedly 600 to 700 feet (180-210 m) thick west of Sharp Mountain (see Ezell, 1953; Crittenden, 1972; Deputy, 1984), and though a 840-foot (256 m) thickness was reported north of our map area in the Porcupine Reservoir area (Rigo, 1968), the Ute only looks about 600 feet (180 m) thick on the Porcupine Reservoir map of Berry (1989). The Ute is reportedly 1090 and 1380 feet (330 and 420 m) thick in the Sharp Mountain area (Hafen, 1961; Rigo, 1968, respectively), but these thicknesses are suspect since the Ute is thinner to the north, east, and west. We suspect that Hafen (1961) used dips that were too steep (~30 degrees vs ~16.5 degrees) so the real Ute thickness is about 620 feet (190 m) where he measured his section; we do not know what Rigo (1968) measured. North of our map area in the Hardware Ranch quadrangle, Deputy (1984) measured 681 feet (207.6 m) of Ute. To the east, the Ute is about 450 feet (137 m) thick in the Horse Ridge and Dairy Ridge quadrangles (Coogan, 2006a-b) and 515 feet (157 m) thick at the Baldy Ridge section (Rigo, 1968) in the Horse Ridge quadrangle. The thickest Ute may be near the South Fork Wolf Creek in the Huntsville quadrangle, where Coogan estimates a 1000-foot (300 m) thickness, 1150 feet (350 m) thick if steeper dip, while King estimates the Ute is about 1100 feet (335 m) thick, based on a higher Ute-Langston contact than Coogan picked. Rigo (1968) reported 1370 feet (418 m) of Ute near the South Fork Wolf Creek, but his contacts are not used on our map. To the south in the Browns Hole quadrangle, about 700 feet (210 m) of mixed shale and limestone was shown by Crittenden (1972) and his depiction is likely derived from the 659 feet (201 m) of Ute reported by Laraway (1958) along the South Fork Ogden River; this is about what Laraway (1958) mapped. But Crittenden (1972) did not map the Ute-Blacksmith contact; further, see problems above under Blacksmith Formation.

The Ute Formation as first mapped in the James Peak, Mantua, and Huntsville quadrangles was too thick because Coogan mapped the lower shale in the Langston Formation as the entire Langston, not realizing the base of the Ute is a shale above the upper carbonate (typically dolomite) of the Langston. He did this because the upper carbonate is not distinct in these quadrangles, like it is to the west in the Mount Pisgah quadrangle and to the east in the Sharp Mountain quadrangle. The same problem exists locally in the Sharp Mountain quadrangle. Though King revised the present map to place the upper Langston carbonate in the Langston, problems with this contact and Ute and Langston Formation thicknesses may persist.

Just north of our map area in the Wellsville Mountains, Maxey (1958) reported Ehmaniella(?) sp. and Glossopleura sp. trilobites in and at the base of the Ute Formation, respectively, making it Middle Cambrian. Deiss (1938) and Berry (1989) reported Ehmaniella sp. trilobites north of our map area near the Blacksmith Fork River.

***Cl, Cl?*** - *Langston Formation (Middle Cambrian)*. Upper part is gray, sandy dolomite and limestone that weathers to ledges and cliffs; middle part is yellowish- to reddish-brown to gray weathering, greenish-gray, fossiliferous shale and lesser interbedded gray, laminated to very thin-bedded, silty limestone (Spence Shale Member); basal part is light-brown-weathering, ledge forming gray limestone and dolomite with local poorly indurated tan, dolomitic sandstone at bottom; basal part that is less resistant (Naomi Peak Member) is present at least in northwest part of our map area; conformably overlies Geertsen Canyon Quartzite; 200 to 400 feet (60-120 m) thick. Designated “Formation” rather than “Dolomite” due to the varied lithologies.

The thickness of the Langston Formation is based on several studies. North of the map area, 410 feet (125 m) of Langston was measured along the upper Blacksmith Fork River in the Hardware Ranch quadrangle by Buterbaugh (1982). The Langston is 270 feet (80 m) thick in the Sharp Mountain area (Hafen, 1961) and to the east it is about 200 to 250 feet (60 to 75 m) thick in the Horse and Dairy Ridge quadrangles (Coogan, 2006a-b); the 85-foot (26 m) thickness reported at the Baldy Ridge section (Rigo, 1968) in the Horse Ridge quadrangle is likely incorrect. The 170 feet (50 m) of dolomite reported near Browns Hole (Crittenden, 1972) is likely only the basal dolomite of the Langston Formation; Laraway (1958) probably measured 120 feet (37 m) of this basal dolomite and 298 feet (91 m) of Langston along the South Fork Ogden River in the Browns Hole quadrangle. Laraway’s (1958) reported 398-foot (121 m) Langston thickness is likely an error, since he measured and mapped about 300 feet (90 m) of Langston. Near the South Fork Wolf Creek in the Huntsville quadrangle, the Langston is about 300 feet (90 m) thick (Coogan’s measurements), but King used a higher contact on our map making the Langston about 390 feet (120 m) thick. Farther west the Langston is about 400 to 460 feet (120-140 m) thick (see Ezell, 1953; Maxey, 1958; Rigo, 1968; Buterbaugh, 1982).

Just north of the map area near the Blacksmith Fork River, the Langston trilobite fauna (Glossopleura zone) is Middle Cambrian in age (Maxey, 1958), and near Brigham City, the fauna (Glossopleura trilobite zone in Spence Shale, Albertella trilobite zone in Naomi Peak) is earliest Middle Cambrian in age (Maxey, 1958; Jensen and King, 1996, table 2).

***Cgc, Cgc?*** - *Geertsen Canyon Quartzite (Middle and Lower Cambrian and possibly Neoproterozoic)*. In the west mostly buff (off-white and tan) quartzite, with pebble conglomerate beds; pebbles are mostly rounded light colored quartzite; contains cross bedding, and pebble layers and lenses; colors vary from tan and light to medium gray, with pinkish, orangish, reddish, and purplish hues; outcrops darker than these fresh quartzite colors; cliff forming; some brown-weathering, interbedded micaceous argillite and quartzite common at top and mappable locally; pebble to cobble conglomerate lenses more abundant in middle part of quartzite, and basal, very coarse-grained arkose locally; near Huntsville, total thickness about 4200 feet (1280 m), including upper argillite about 375 feet (114 m) thick and basal coarse-grained arkose (arkosic to feldspathic quartzite) about 300 to 400 feet (90-120 m) thick (Crittenden and others, 1971). Overall seems to be thinner near Browns Hole. Called Prospect Mountain Quartzite and Pioche Shale (argillite at top) by some previous workers.

Upper and lower parts of Crittenden and others (1971; Crittenden, 1972; Sorensen and Crittenden, 1979) are not mappable outside the Browns Hole and Huntsville quadrangles, likely because the marker cobble conglomerate and change in grain size and feldspar content reported by Crittenden and others (1971) is not at a consistent horizon; quartz-pebble conglomerate beds are present in most of the Geertsen Canyon Quartzite.

To the east on leading margin of Willard thrust sheet, the Geertsen Canyon is thinner, an estimated 3200 feet (975 m) total thickness (Coogan, 2006a-b), and may be divided into different members, though informal members to west and east are based on conglomerate lenses near member contact and feldspathic lower member (see Crittenden and others, 1971; Coogan, 2006a-b).

Lower part in west (Cgcl, Cgcl?) is typically conglomeratic and feldspathic quartzite (only up to 20% feldspar reported by Crittenden and Sorensen, 1985a, so not an arkosic), with 300- to 400-foot (90-120 m), basal, very coarse-grained, more feldspathic or arkosic quartzite; 1175 to 1700 feet (360-520 m) thick (Crittenden and others, 1971; Crittenden, 1972; Sorensen and Crittenden, 1979) and at least 200 to 400 feet (60-120 m) thinner near Browns Hole (compare Crittenden, 1972 to Sorensen and Crittenden, 1979). Unit queried where poor exposures may actually be surficial deposits.

***Zm, Zm?*** *- Mutual Formation (Neoproterozoic).* Grayish-red to purplish-gray, medium to thick-bedded quartzite with pebble conglomerate lenses; also reddish-gray, pink, tan, and light-gray in color and typically weathering to darker shades than, but at least locally indistinguishable from, Geertsen Canyon Quartzite; commonly cross-bedded and locally feldspathic; contains argillite beds and, in the James Peak quadrangle, a locally mappable medial argillite unit; 435 to 1200 feet (130-370 m) thick in Browns Hole quadrangle (Crittenden, 1972) and thinnest near South Fork Ogden River (W. Adolph Yonkee, Weber State University, verbal communication, 2006); thicker to northwest, up to 2600 feet (800 m) thick in Huntsville quadrangle (Crittenden and others, 1971) and 2556 feet (780 m) thick in James Peak quadrangle (Blau, 1975); may be as little as 300 feet (90 m) thick south of the South Fork Ogden River (King this report); absent or thin on leading edge of Willard thrust sheet (see unit Zm?c); thins to south and east.

***Zi, Zi?*** *- Inkom Formation (Neoproterozoic).* Overall gray to reddish-gray weathering, poorly resistant, psammite and argillite, with gray-weathering meta-tuff lenses in lower part; upper half dominantly dark green, very fine-grained meta-sandstone (psammite) with lower half olive gray to lighter green-gray, greenish gray-weathering, laminated, micaceous meta-siltstone (argillite); lower greenish-weathering part missing near South Fork Ogden River and the Inkom is less than 200 feet (60 m) thick; in Mantua quadrangle, Inkom typically 300 feet (90 m) thick, and is only less than 200 feet (60 m) thick where faulted (King this report); 360 to 450 feet (110-140 m) thick northeast of Huntsville (Crittenden and others, 1971), and absent on leading edge of Willard thrust sheet (Coogan, 2006a); location of "pinch-out" not exposed.

***Zcc, Zcc?*** *- Caddy Canyon Quartzite (Neoproterozoic).* Mostly vitreous, almost white, cliff-forming quartzite; colors vary and are tan, light-gray, pinkish-gray, greenish-gray, and purplish-gray, that are typically lighter shades than the Geertsen Canyon Quartzite; 1000 to 2500 feet (305-760 m) thick in west part of our map area, thickest near Geertsen Canyon in Huntsville quadrangle (Crittenden and others, 1971; Crittenden, 1972); 1500 feet (460 m) thick near South Fork Ogden River (Coogan and King, 2006); thinner, 725 to 1300 feet (220-400 m) thick, and less vitreous on leading edge of Willard thrust sheet. Lower contact with Kelley Canyon Formation is gradational with brownish-gray quartzite and argillite beds over a few tens to more than 200 feet (3-60 m) (see Crittenden and others, 1971). Where thick, this gradational-transitional zone is what is mapped as the Papoose Creek Formation. Near Geertsen Canyon, this transition zone is 600 feet (180 m) thick and was mapped with and included in the Caddy Canyon Quartzite by Crittenden and others (1971, figure 7), and in the Caddy Canyon and Kelley Canyon Formations by Crittenden (1972, see lithologic column).

***Zkc, Zkc?*** *- Kelley Canyon Formation (Neoproterozoic).* Dark-gray to black, gray to olive-gray-weathering argillite to phyllite, with rare metacarbonate (for example basal meta-dolomite); grades into overlying Caddy Canyon quartzite with increasing quartzite; gradational interval mapped as Papoose Creek Formation (Zpc); 1000 feet (300 m) thick in Mantua quadrangle (this report), where Papoose Creek Formation is mapped separately, and reportedly 2000 feet (600 m) thick near Huntsville (Crittenden and others, 1971, figure 7), but only shown as about 1600 feet (500 m) thick to Papoose Creek transition zone by Crittenden (1972). The Kelley Canyon Formation is prone to slope failures.

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

Figure 2 shows two strike and dip measurements in Mutual Formation bedrock in the area that shallow eastward: (1) N5° E 68° SE about 600 feet west of the site, and (2) N11° E 8° SE about 1,100 feet to the northeast. Two thrust faults are also mapped trending through the Mutual Formation to the north of the site, and bounding the unit to the south. These thrusts mark the leading edge of the Willard Thrust sheet.

**Seismotectonic Setting**

The site is located slightly south of the divide between Ogden and Cache Valleys, which are to the south and north, respectively. Cache Valley is a major sediment-filled, north-south-trending intermontane valley flanked by the Bear River Range to the east and the Wellsville Mountains to the west. Ogden Valley is a roughly 40 square-mile back valley within the Wasatch Range described by Gilbert (1928) as a structural trough similar to Cache and Morgan Valleys to the north and south, respectively. Both valleys 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).

Ogden and Cache 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 vertical displacement on normal faults bounding the east and west sides of the valley. The most recent movement on these faults is pre-Holocene (Sullivan and others, 1986). Cache Valley is a similar structural trough, and is bounded by the active West Cache fault zone at the base of the Malad Range and Wellsville Mountains on the west, and the East Cache fault zone at the base of the Bear River Range on the east. The most-recent, large-magnitude surface faulting earthquake on the West Cache fault zone occurred between 4,400 and 4,800 years ago (Black and others, 2000), whereas the most-recent event on the East Cache fault zone occurred about 4,000 years ago (McCalpin, 1994).

No active faults (those with evidence for Holocene activity) are mapped at the Project. However, the Project is 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.

# SITE CHARACTERIZATION

## Empirical Observations

On July 1, 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 70's (°F). The site is in Powder Mountain Ski Area near the divide between Ogden and Cache Valleys to the north and south, respectively. Slopes at the site are steep and generally dip toward the south at an overall gradient of about 2.5:1 (horizontal:vertical). Native vegetation consists mainly of aspen trees, brush, weeds, and grasses. West of the site an area of low-relief quartzite bedrock was observed above (north of) Aspen Drive. This bedrock area bounds the eastern side of a south-trending swale vegetated only by grasses and low brush. The bedrock was observed to extend further northward above the upper loop of Alpine Drive. No bedrock outcrops were evident directly upslope of the site, no evidence of ongoing or recent slope instability, landslides, rockfalls, or other geologic hazards was observed.

## Air Photo Observations

Aerial photography from 2014 available from the Utah AGRC (Figure 3) was reviewed to obtain information about the geomorphology of the Project area. No LIDAR coverage was available. No geologic hazards were evident at the site or in adjacent areas on the photo. Several areas of low-relief quartzite bedrock are evident to the west of the site that bound the eastern and western sides of a shallow swale formed either by avalanches or surface drainage from the bedrock areas. The swale trends downslope to the south toward the head of South Fork Wolf Creek.

## Subsurface Investigation

Three walk-in test pits were excavated at the property on July 1, 2016 to evaluate subsurface conditions. Figure 4 is a site plan at a scale of one inch equals 30 feet (1:360) showing the site boundaries, surveyed topography, the proposed home location and footprint, and locations of the test pits. Figures 5A-C are logs of the test pits at a scale of 1 inch equals five feet (1:60). All three test pits exposed a similar sequence of slope colluvium in which the modern A-horizon was forming, overlying weathered quartzite bedrock that caused backhoe refusal at depths of 4.7 to 6.1 feet. We anticipate the bedrock refusal depths to be approximately the thickness of the weathered C profile. No strike and dips could be measured to the limited exploration depths, but bedrock layers were observed in test pit TP-2 (Figure 5B) dipping toward the east at about 45 degrees and a clayey argillite layer was observed in the east wall of TP-1 that dipped slightly to the south. No evidence of groundwater or geologic hazards was observed.

## Cross Section

Figure 6 shows a cross section across the slope at the site at a scale of 1 inch equals 10 feet with no vertical exaggeration. The profile location is shown on Figure 4. The upper elevation of the profile is not in an area of surveyed topography, thus we interpolated this elevation based on the difference in digital elevation between the northwest and southwest site corners, and the surveyed elevation of the southwest site corner. Units and contacts are inferred based on the subsurface data discussed above. The cross section shows the site is underlain by a surficial veneer of slope colluvium overlying quartzite bedrock of the Mutual Formation, which would dip slightly to the south and away from the viewer at around 45-50 degrees.

## 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 B (rock), 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: 41.38035° N, - 111.78527° W)*

| | |
|---|---|
| **$S_S$** | *0.858g* |
| **$S_1$** | *0.287g* |
| **$S_{MS}$ ($F_a$ x $S_S$)** | *0.858g* |
| **$S_{M1}$ ($F_v$ x $S_1$)** | *0.287g* |
| **$S_{DS}$ (2/3 x $S_{MS}$)** | *0.572g* |
| **$S_{D1}$ (2/3 x $S_{M1}$)** | *0.191g* |
| **Site Coefficient, $F_a$** | *=1.000* |
| **Site Coefficient, $F_v$** | *=1.000* |

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 8.6 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.

### 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 test pit exposures at the site, and given that bedrock is shallow no susceptible soils are likely present. 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. The site is not on the downthrown side of any active faults, and therefore the risk from tectonic subsidence is low.

**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 the hazard from stream flooding is low. However, site hydrology and runoff should be addressed in the civil engineering design and grading plan for the Project to ensure that proper drainage is maintained.

**Shallow Groundwater**
No springs are shown on the topographic map for the site or were reported or observed, and no evidence for shallow groundwater was observed in the test pit exposures to the depth explored. It is likely that groundwater flow in the site vicinity is dominated by fracture flow through bedrock, although given the sites alpine location it is possible that shallow groundwater may occur seasonally following snowmelt in the colluvial veneer. However, we do not anticipate shallow groundwater to pose a significant site constraint and rate the risk as low.

## 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.

No landslides are mapped at the site or in the area, and no evidence for landslides or ongoing slope instability was observed at the site during our reconnaissance. However, slopes at the site are steep. We therefore rate the risk from landslides as moderate. 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 shallow groundwater from seasonal fluctuations, and care should also be taken that site grading does not destabilize slopes in this area without prior geotechnical analysis and grading plans.

## 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. The outcrops to the west and northwest are low in relief and currently appear incapable of generating significant rockfalls.

## Swelling and Collapsible Soils

Surficial soils that contain certain clays can swell or collapse when wet. Given the subsurface conditions observed at the site, bedrock appears shallow and the surficial colluvium appeared sandy. The bedrock may contain intermittent indurated clay (argillite) layers, such as observed in TP-3 (Figure 5C), although no such layers were observed in TP-2. We note that this layer would be at considerable depth beneath the proposed home given the bedrock dip and distance of the home from TP-3. However, a geotechnical engineering evaluation should be performed to confirm soil conditions and provide specific recommendations for site grading, subgrade preparation, and footing and foundation design.

## CONCLUSIONS AND RECOMMENDATIONS

Earthquake ground shaking is identified as the only geologic hazard posing a high relative risk to the Project. The risk from slope failures is also rated as moderate given that slopes at the site are steep. 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 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; and (3) 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 seasonal groundwater fluctuations.

- ***Excavation Backfill Considerations* -** The 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 3. Air Photo (8.5”x11”)
Figure 4. Site Plan (8.5”x11”)
Figures 5A-C. Test Pit Logs (three 8.5”x11” sheets)
Figure 6. Cross Section (11”x17”)

## 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., Giraud, R.E., and Mayes, B.H., 2000, Paleoseismic investigation of the Clarkston, Junction Hills, and Wellsville faults, West Cache fault zone, Cache County, Utah: Utah Geological Survey Special Study 98, 23 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., 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.

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

McCalpin, J.P., 1994, Neotectonic deformation along the East Cache fault zone, Cache County, Utah: Utah Geological Survey Special Study 83, 37 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.

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.

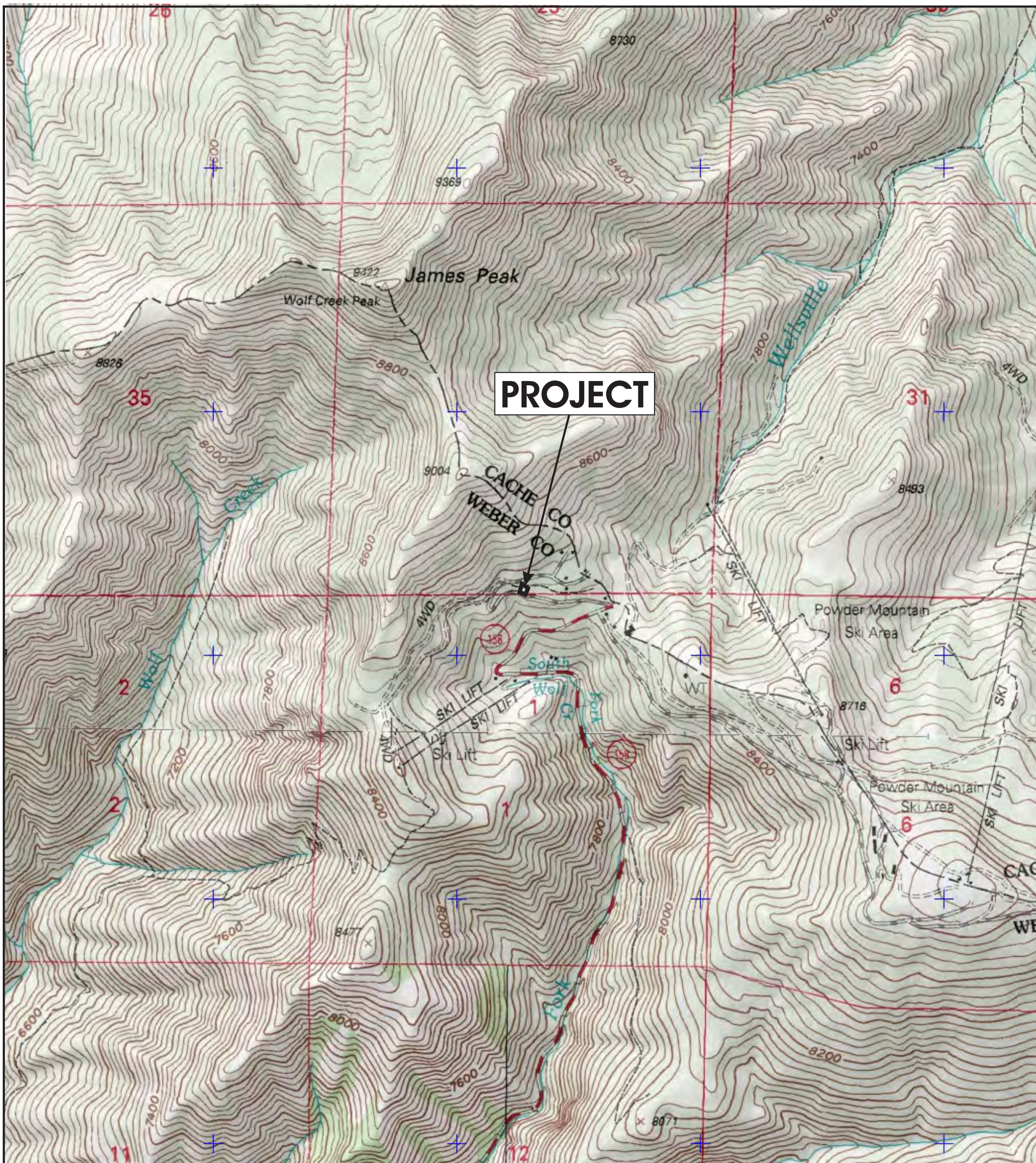
Stokes, W.L., 1977, Physiographic subdivisions of Utah: Utah Geological and Mineral Survey Map 43, scale 1:2,400,000.

____, 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.

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 - James Peak, 1998;
Project location SE1/4, Section 36, T8N, R1E (SLBM).

0 1000 2000 feet

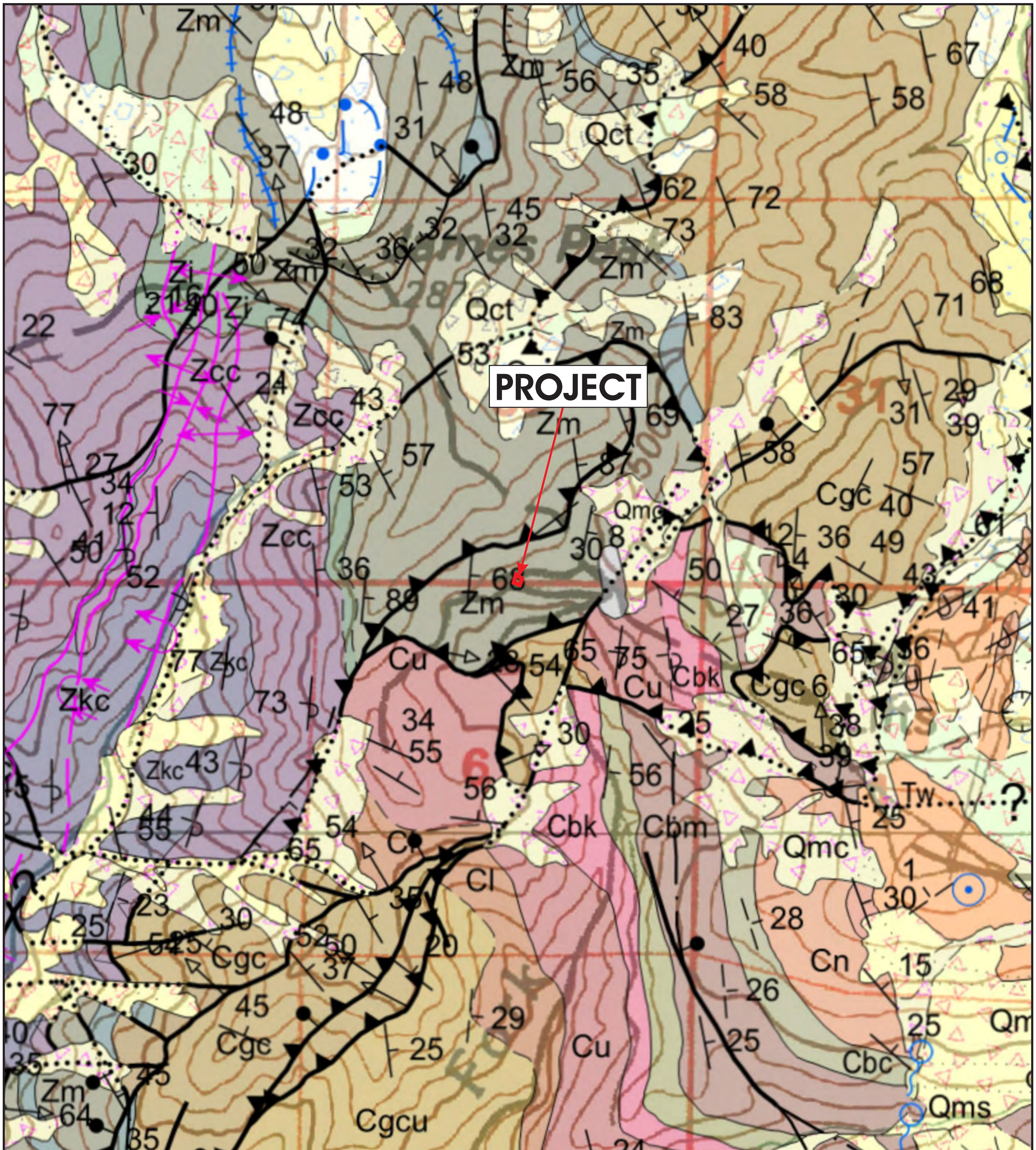
Scale 1:24,000
(1 inch = 2000 feet)

## LOCATION MAP

### GEOLOGIC HAZARDS EVALUATION

Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, 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.

# GEOLOGIC MAP

## GEOLOGIC HAZARDS EVALUATION

Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

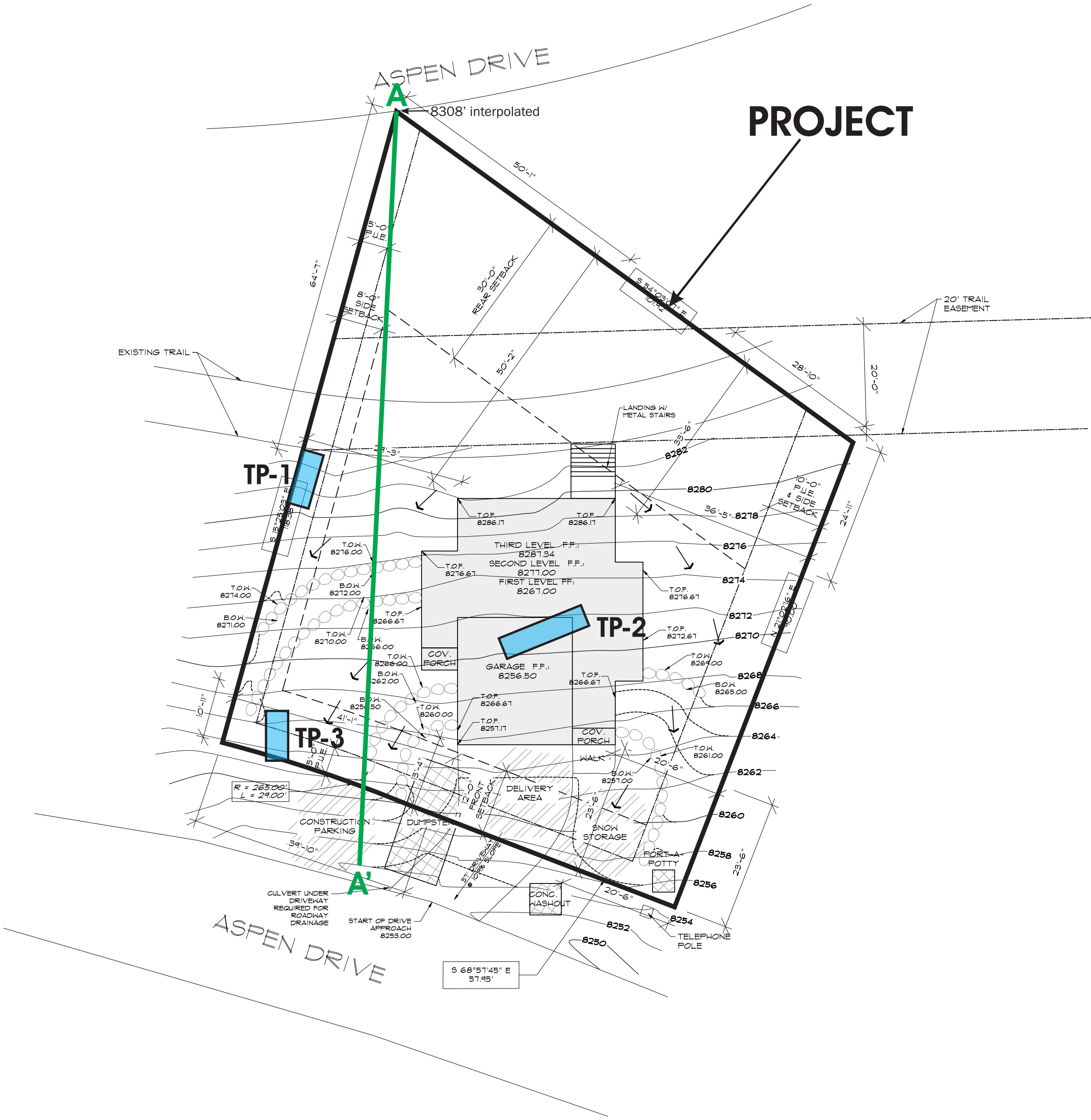
**FIGURE 2**

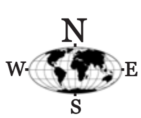
WESTERN GeoLogic

N W E S

0 1000 2000 feet

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




0 15 30 feet

Scale 1:360
(1 inch = 30 feet)

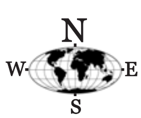
## SITE PLAN

## GEOLOGIC HAZARDS EVALUATION

Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

**FIGURE 3**


Source: Utah AGRC, NAIP, 1 meter resolution, 2014.




0 100 200 feet

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

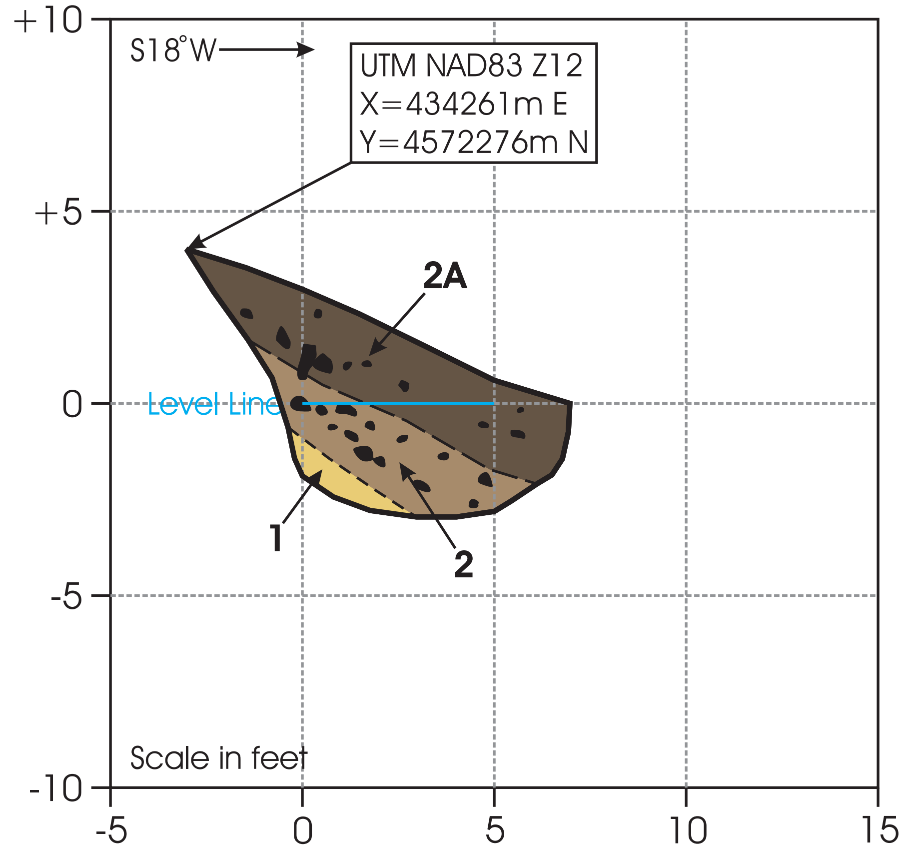
## AIR PHOTO

### GEOLOGIC HAZARDS EVALUATION

Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

**FIGURE 4**

WESTERN GEOLOGIC




**UNIT DESCRIPTIONS**

**Unit 1.** *Precambrian Mutual Formation* - Weathered, dense, massive, buff-colored quartzite; caused backhoe refusal at about 4.7 feet deep.

**Unit 2.** *Holocene Slope Colluvium* - Likely slope wash comprised of organic-enriched, brown to dark brown, root-penetrated, moderate density, massive, sand with silt, gravel, and cobbles; clasts subangular quartzite with stage II carbonate.

**2A.** Modern A-horizon soil formed in unit 2.

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

Logged by Bill D. Black, P.G.
on July 1, 2016
Reviewed by
Craig V. Nelson, P.G.

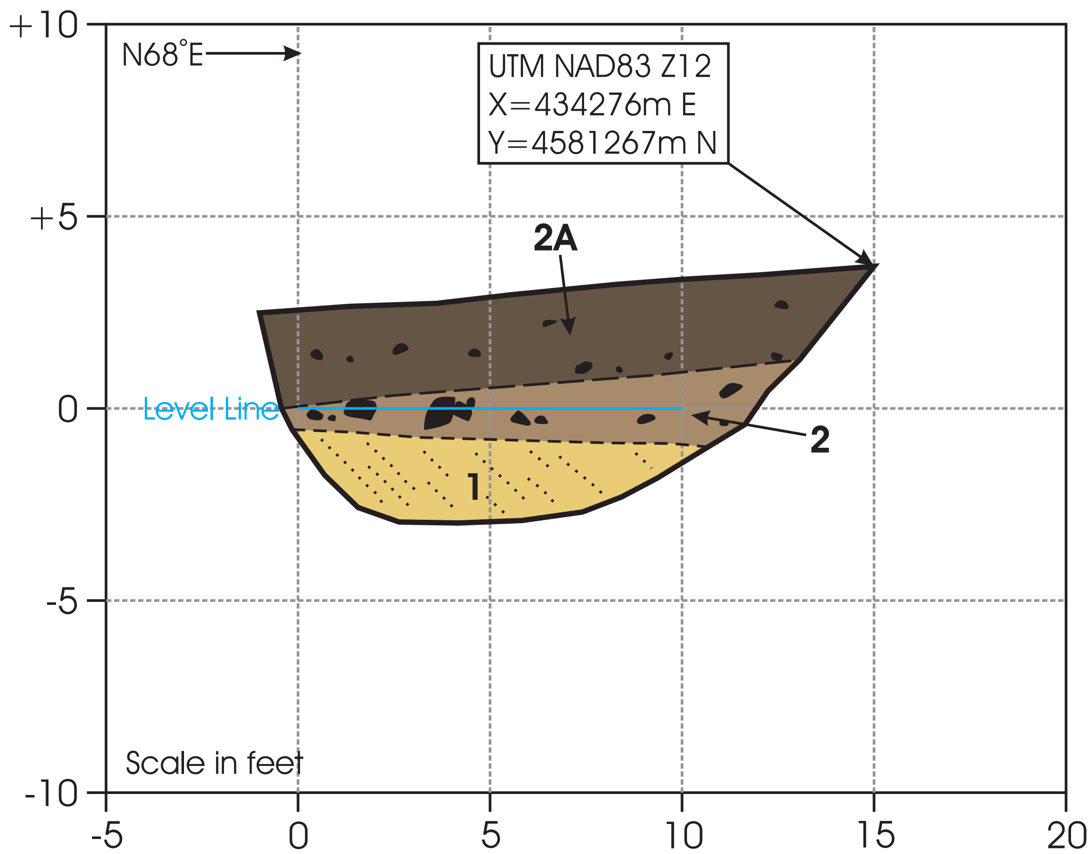
WESTERN GEOLOGIC

**TEST PIT 1 LOG**

**GEOLOGIC HAZARDS EVALUATION**

Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

**FIGURE 5A**




**UNIT DESCRIPTIONS**

**Unit 1.** *Precambrian Mutual Formation* - Weathered, dense, poorly bedded, orange- to buff-colored quartzite; caused backhoe refusal at about 5.8 feet deep; bedding dips to east at about 45 degrees, but strike could not be confidently measured due lack of exposure depth.

**Unit 2.** *Holocene Slope Colluvium* - Likely slope wash comprised of organic-enriched, brown to dark brown, root-penetrated, moderate density, massive, sand with silt, gravel, and cobbles; clasts subangular quartzite with stage II carbonate.

**2A.** Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

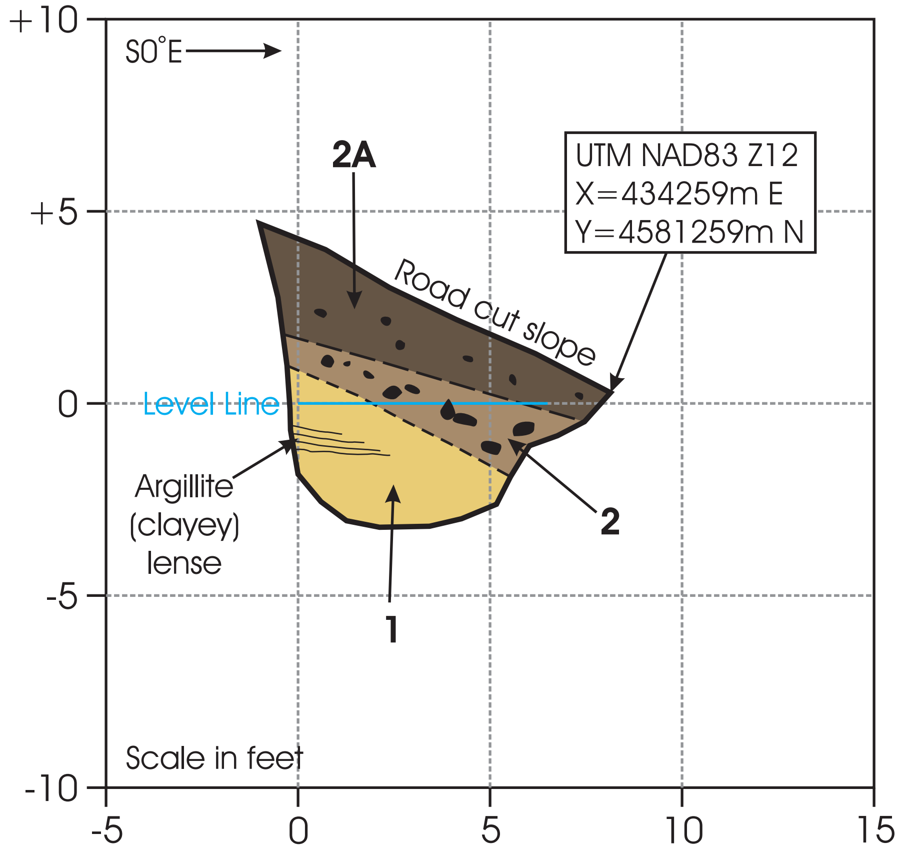
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
North Wall Logged, West to East

Logged by Bill D. Black, P.G.
on July 1, 2016
Reviewed by
Craig V. Nelson, P.G.

**TEST PIT 2 LOG**

**GEOLOGIC HAZARDS EVALUATION**
Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

**FIGURE 5B**




**UNIT DESCRIPTIONS**

**Unit 1.** *Precambrian Mutual Formation* - Weathered, dense, massive, buff-colored quartzite with discontinuous argillate (indurated clay) lense; caused backhoe refusal at about 6.1 feet deep.

**Unit 2.** *Holocene Slope Colluvium* - Likely slope wash comprised of organic-enriched, brown to dark brown, root-penetrated, moderate density, massive, sand with silt, gravel, and cobbles; clasts subangular quartzite with stage II carbonate.

**2A.** Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

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

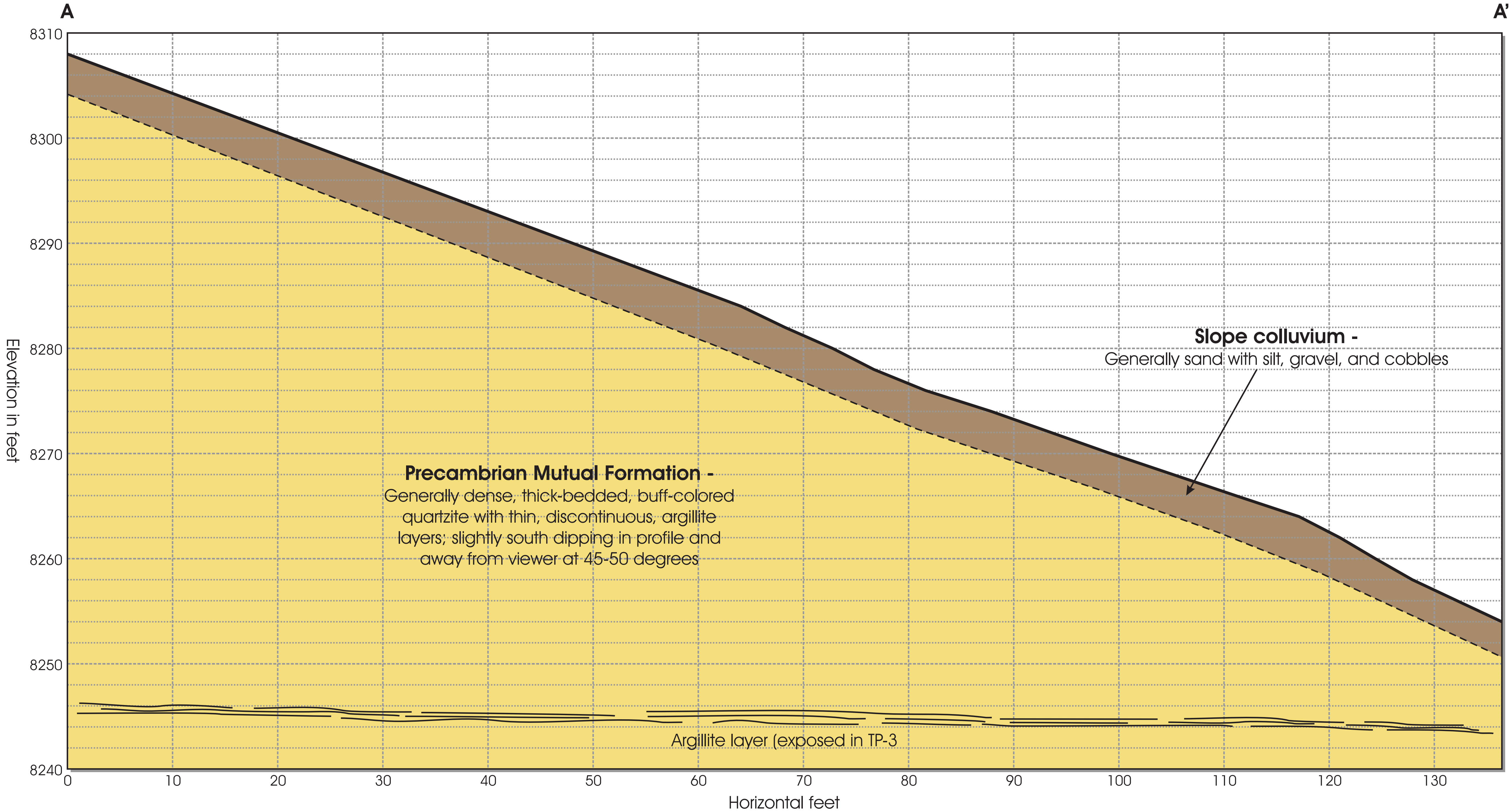
Logged by Bill D. Black, P.G.
on July 1, 2016
Reviewed by
Craig V. Nelson, P.G.

**TEST PIT 3 LOG**

**GEOLOGIC HAZARDS EVALUATION**

Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

**FIGURE 5C**




WESTERN GEOLOGIC

SCALE: 1 inch = 10 feet
No vertical exaggeration
Contacts based on subsurface data and are inferred in unexplored areas and at depth

## CROSS SECTION

**GEOLOGIC HAZARDS EVALUATION**
Powder Mountain West Lot 42-R
6706 Alpine Drive (6675 North)
Eden, Weber County, Utah

**FIGURE 6**