REPORT

GEOLOGIC HAZARDS RECONNAISSANCE

PROPOSED AREA 1 MIXED-USE DEVELOPMENT

POWDER MOUNTAIN RESORT

WEBER COUNTY, UTAH

Prepared for

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August 28, 2012

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SUBJECT: Geologic Hazards Reconnaissance
Proposed Area 1 Mixed-Use Development
Powder Mountain Resort
Weber County, Utah

Dear Mr. Begelman:

This report presents results of a reconnaissance-level engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for the proposed Powder Mountain Resort Area 1 Mixed-Use Development in Weber County, Utah (Figure 1 – Project Location). The project is located about 7.5 miles north of Huntsville, Utah and is in all or portions of Sections 5-8, Township 7 North, Range 2 East; and Sections 1 and 12, Township 7 North, Range 1 East. The project area encompasses a total of about 1,058 acres.

PURPOSE AND SCOPE

The purpose and scope of this investigation is to identify and interpret surficial geologic conditions at the project and identify potential risk from geologic hazards, particularly from slope instability. This investigation is intended to: (1) provide preliminary geologic information and assessment of geologic conditions; (2) identify potential geologic hazards that may be present and qualitatively assess their risks to the intended project; and (3) provide recommendations for additional site- and hazard-specific studies or mitigation measures as may be needed based on our findings.

This report is intended to be a reconnaissance-level tool to assist with project planning, and reduce and minimize impacts from high-risk geologic hazards. The following services were performed in accordance with the above stated purpose and scope:

- A site reconnaissance of the project area conducted by an experienced certified engineering geologist to assess the site setting and look for adverse geologic conditions;
- Review of readily-available geologic maps and reports;

- Review of high-resolution aerial photography provided by Summit; and
- Evaluation of available data and preparation of this report, which presents the results of our study.

The engineering geology section of this report was prepared in general accordance with the Guidelines for Preparing Engineering Geologic reports in Utah (Utah Section of the Association of Engineering Geologists, 1986).

HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the Huntsville and Browns Hole Quadrangle show the Project straddles a subsidiary drainage basin (Lefty's Canyon) east of upper South Fork Wolf Creek. Two small ponds are shown on Figure 1 in the southeast part of the project in Section 8, Township 7 North, Range 2 East associated with an unnamed spring area at the head of Lefty's Canyon. A small, spring-fed drainage flows southwestward through the canyon bottom to South Fork Wolf Creek, which in turn flows southward into Ogden Valley. Depth to groundwater at the site is unknown, but likely varies from near surface to substantially greater than 50 feet. Based on topography, we anticipate groundwater in the area flows into Lefty's Canyon through bedrock and unconsolidated colluvium, and then downstream to the southwest toward South Fork Wolf Creek. Canyon bottoms and areas at the head of Lefty's Canyon likely have shallowest groundwater levels.

Groundwater depths in the project area likely fluctuate 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 or on top of less-permeable bedrock layers. Fracture flow would likely be dominant in areas of Paleozoic sedimentary bedrock; whereas surface water at ridge tops underlain by Wasatch Formation bedrock may perch and daylight where gently dipping bedrock layers meet steep slopes.

GEOLOGY

Structural Setting

The site is located near the northern 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 most recent movement on these faults is pre-Holocene (Sullivan and others, 1986).

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.

Surficial Geology

Geology of the project area is shown on Figure 2 at a scale of 1:12,000 (1 inch equals 1,000 feet), based on air photo and field observations and mapping by Coogan and King (2001). Due to the scale of the mapping and size of the project area, Figure 2 covers one 11 inch x 17 inch sheet. UTM NAD83 coordinates for the project corners are provided on Figure 2 to facilitate georeferencing. Figure 2 shows surficial geology of the project area consists of various Cambrian-age bedrock units (grouped together as unit Cr), Tertiary bedrock of the Wasatch Formation (unit Tw), and Pleistocene- to Holocene-age colluvial, landslide, and alluvial deposits (units Qmso, Qms, Qm, and Qa; Figure 2). Coogan and King (2001) map numerous bedrock faults in the project area that are Cenozoic in age, including thrust faults of the Willard thrust. These bedrock faults are not shown on Figure 2 because they are not pertinent to our evaluation.

Coogan and King (2001) describe geologic units at the site and in the vicinity (from youngest to oldest in age) as follows:

> **Qal** – ***Stream alluvium and floodplain deposits (Holocene)***. Sand, silt, clay, and gravel in channels and floodplains; locally includes muddy, organic overbank and oxbow lake deposits; composition depends on source area; 0 to 20 feet (0-6 m) thick.
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> **Qm** – ***Mass-movement deposits, undivided (Holocene and Pleistocene)***. Includes slides, slumps, and flows, as well as colluvium, talus, and alluvial fans that are mostly debris flows; mostly mapped where several types of deposits cannot be mapped separately; composition depends on local sources; 0 to 40 feet (0-12 m) thick.

> **Qms, Qmso** – ***Landslide and slump deposits (Holocene and Pleistocene)***. Poorly sorted clay- to boulder-sized material; locally includes flow deposits; generally characterized by hummocky topography, head and internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with age; thickness highly variable. Suffix o denotes a probable Pleistocene age.
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> **Tw** – ***Wasatch Formation (Eocene and uppermost Paleocene)***. Typically red-weathering conglomerate, as well as sandstone, siltstone, and mudstone; clasts usually rounded and from Precambrian and Paleozoic rocks; basal conglomerate dominated by locally derived clasts - lower Paleozoic carbonates in the Maples area, and Precambrian crystalline rocks and Cambrian Tintic Quartzite west of Strawberry Creek; thickness uncertain, about 560-foot (170 m) thickness exposed west of Strawberry Creek, additional estimated (partially exposed) 750-foot (230 m) thickness east of creek may be fault repetition; thickness varies due to relief on basal erosional surface. Queried Wasatch is light-gray to brownish-gray, variably cemented conglomerate that forms knobs on east margin of Snow Basin quadrangle, with Norwood apparently draped over the knobs; contains highly fractured, white quartzite (bleached Tintic) blocks; mapped as Tintic by Eardley (1944). The nearest Tintic exposures are about 2.5 to 3.5 miles (4-5.6 km) east in the Durst Mountain quadrangle.
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> **Cr** – ***undivided Cambrian bedrock (lower to upper Cambrian)***. Sequence of Paleozoic sedimentary rock units locally including: St. Charles Formation (light- to medium-gray cliff-forming dolomite, calcareous sandstone, and sandy dolomite); Nounan Dolomite (medium- to light-gray cliff-forming dolomite); Bloomington Formation (olive-brown to orange-brown silty argillite, interlayered with gray- to orange-gray, thin- to medium-bedded, silty limestone, flat-pebble conglomerate, oncolitic limestone, and oolitic limestone); Ophir Formation (generally highly deformed brown to olive-gray argillite with some intercalated medium-gray silty limestone beds, light- to medium-gray ledge-forming micritic limestone, and brown to olive-gray micaceous to silty argillite and slate); Blacksmith Dolomite (medium-gray, coarsely crystalline, cliff- and ridge-forming dolomite); Ute Formation (gray limestone and minor gray to light-gray dolomite above and below interbedded gray to dark-gray limestone with wavy silt layers, and olive-gray micaceous shale and argillite); and Geertsen Canyon Quartzite (mostly buff quartzite).

Two strike and dip measurements were made in the project area in Sections 5 and 6, Township 7 North, Range 2 East (Figures 2). Both measurements were in exposed Cambrian-age sedimentary rock; no exposures of Wasatch Formation bedrock were observed in the project area, which generally appeared weathered at the surface. Measured bedding strikes ranged between N2°W to N40°W, with dips of from 11° to 24° to the southwest. The western bedrock exposure showed three joint sets trending N5°W, N90°E, and S56°W, with northwest, south, and southwest dips of 85°, 75°, and 66° (respectively, Figure 2). Wasatch Formation bedrock in the project area appears to dip gently to the northwest to southeast generally crosswise or into the slopes in Lefty's Canyon. Coogan and King (2001) show three strike and dip measurements in the

Wasatch Formation in the project area, though these outcrops were not observed: (1) N54°E 1° NW in the north part of the project, (2) N17°E 6°SE in the northeast part of the project, and (3) N3°E 5°SE in the east part of the project. The mapped landslides in Lefty's Canyon appear to be sourced in the Wasatch Formation, and could involve rotational slip on gently tilted, clayey bedrock layers where groundwater can perch.

Lake Bonneville and Glacial 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 is a regional, topographically closed basin comprised of several conjoined smaller basins created by crustal extension in the Basin and Range (Gwynn, 1980; Miller, 1990); the basin has been an area of internal drainage for much of the past 15 million years (Oviatt and others, 1992). Sediments from Lake Bonneville are not mapped in the project area, but are found in Ogden Valley to the south.

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 (Donald Currey, University of Utah; written communication to the Utah Geological Survey, 1996; and verbal communication to the Utah Quaternary Fault Parameters Working Group, 2004). Approximately 32,500 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, after about 18,000 years ago. The lake remained at this level until 16,500 years ago, when headward erosion of the Snake River-Bonneville basin drainage divide 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). Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline. 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. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Great Salt Lake then experienced a brief transgression between 12,800 and 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).

Landsliding in the project area possibly initiated in Pleistocene time following retreat of glacial ice in the region after the Pinedale glacial advance. The Pinedale glacial advance was the last major glaciation to appear in the Rocky Mountains in the United States. The Pinedale glacial advance lasted from approximately 30,000 to 10,000 years ago, was at its greatest extent between 23,500 and 21,000 years ago, and was composed of mountain glaciers that partly merged (to the east in Wyoming) into the Cordilleran Ice Sheet. Glaciers in Little Cottonwood and Bells Canyons advanced into eastern Salt Lake Valley from the Wasatch Range between 26,000 and 18,000 years ago (Personius and Scott, 1992). This is locally termed the Bells Canyon glacial advance, which is correlative to the Pinedale in Utah.

SITE CHARACTERIZATION

The project area is in the Wasatch Range about 7.5 miles north of Huntsville, which is in the east-central part of Ogden Valley in Weber County, Utah. The project generally consists of lightly to heavily forested south-, west-, and north-facing slopes overlooking Lefty's Canyon. The north portion of the project is along the ridge crest at the boundary between Weber and Cache Counties; the east, southeast, and south portions of the project are along the ridge between Lefty's Canyon and unnamed canyons to the east, southeast, and south; and the west portion of the Project is on west-facing slopes overlooking South Fork Wolf Creek.

Empirical Observations

On the 16th and 17th of August, 2012, Mr. Bill D. Black of Western GeoLogic conducted a reconnaissance of the project area and immediate vicinity. Given the large size of the project, steep slopes, and lack of road access, not all areas were directly accessed or observed. A photographic record of the site reconnaissance is included in the attachments with this report.

The project straddles Lefty's Canyon, a west-facing subsidiary drainage basin of South Fork Wolf Creek. A small spring-fed drainage flows through the base of the canyon to the southwest, and was observed to be flowing at a very low level at the time of our reconnaissance. Native vegetation in the project area consists of grasses, sagebrush, and other low brush, with mature aspen and pine trees in slope areas overlooking the canyon. North-facing slopes in the project area were generally heavily vegetated. The project area ranges in elevation between about 7,850 and 8,900 feet, with the highest points along the north boundary of the project and the lowest points in the bottom of Lefty's Canyon in the southwest part. Slopes bounding Lefty's Canyon below ridge crest areas steepen into the drainage bottom, and range between an overall roughly 2.5:1 (horizontal:vertical) to 5:1 gradient.

Slopes in Lefty's Canyon are mantled by a mixture of slope colluvium from surficial erosion, small shallow-seated slumps, and talus (unit Qm, Figure 2). The colluvial veneer appeared thin near the ridge tops and likely thickens downslope into the canyon bottom. Unit Qm is generally found only in slopes steeper than about 5:1. Several landslides were observed in the project area in the south-facing slope below the ridge crest in the north part of the project, and in slopes near the head of Lefty's Canyon. The landslides are in areas mapped as unit Qm or Tw (Figure 2). The landslides include older landslides (map unit Qmso) with subdued morphology, and younger slides (map unit Qms) with typical hummocky morphology (Figure 2). Given the morphology, we believe the older slides are of Pleistocene age, and the younger slides are of Holocene to latest Pleistocene age. The older slides appeared to be eroded rotational and translational failures. The younger slides appeared to be smaller, including shallow-seated slumps. One younger slide was observed in the north part of the project in Sections 5 and 6, Township 7 North, Range 2 East (Figure 2) at the toe of an older failure, and may have initiated from differential downslope creep or a smaller reactivation of the older upslope slide. A younger slide (unit Qms) was also observed in unit Qm associated with the spring area at the head of Lefty's Canyon in Section 8, Township 7 North, Range 2 East

(Figure 2) that appeared to be an ongoing failure. The head area of the slide appeared very hummocky and marked by discontinuous low scarps, whereas the toe in the canyon bottom was prominently bulged from ongoing deformation. Several smaller slides were observed in unit Qm west of the spring-area, and appeared to be slumps in thickened, marginally stable colluvium mantling the canyon bottom slopes.

Air Photo Observations

High-resolution aerial photography provided by Summit was reviewed to obtain information about the geomorphology of the project area. Figure 3 is an annotated air photo for the project area at a scale of 1:12,000 (1 inch equals 1,000 feet), based on our field observations (discussed above), and prior mapping by Coogan and King (2001) and Elliot and Harty (2010). Due to the scale and size of the project area, Figure 3 covers one 11 inch x 17 inch sheet. Figure 3 is at the same scale and registered to Figure 2. Figure 3 shows slopes bounding Lefty's Canyon are dominated by mixed slope colluvium and mass wasting deposits, including several Pleistocene- to Holocene-age landslides. These features are discussed in the Empirical Observations Section above. Ridge top areas are generally underlain by bedrock, whereas slopes overlooking Lefty's Canyon are mantled by colluvium. In the west part of the project, the bedrock forms a series of alternating light and dark bands of Paleozoic sedimentary rock layers. Bedrock in the north, east, and south parts of the project is less evident, but appears to form faint layers that wrap around Lefty's Canyon. These areas would be underlain by Wasatch Formation. A talus chute is evident in the southwest-facing slope near the head of Lefty's Canyon. This area appears suggestive of either a shallow rockslide or a rock-fall runout zone from upslope Wasatch Formation bedrock to the northeast and east. No other geologic hazards are evident on the air photos.

GEOLOGIC HAZARDS

Assessment of potential geologic hazards and the resulting risks imposed is critical in determining the suitability of the project area for development. The discussion below provides a summary of site observations and geologic hazards reviewed for the project area, as well as a relative (qualitative) assessment of risk to the project for each hazard. A "high" hazard rating (H) indicates a hazard that is present at the site (whether currently or in the geologic past), is likely to pose significant risk to the project, and/or may require further study or mitigation techniques. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal risk, only impacts portions of the project, and/or only poses a risk to certain project development plans. 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.

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. Nearest active fault to the site is the Weber section of the Wasatch fault zone about 8.5 miles to the southwest (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). Peak ground, 0.2 second spectral, and 1.0 second spectral accelerations (percent of gravity, %g) at the site with 10% and 2% probabilities of exceedance in 50 years are estimated in Frankel and others (2002) as follows:

41.363022° N, -111.760474° W	**10% PE in 50yr**	**2% PE in 50yr**
PGA	17.79	36.09
0.2 sec SA	43.02	88.16
1.0 sec SA	14.44	32.85

Given the above information, earthquake ground shaking is a high risk to the subject site. The hazard from earthquake ground shaking can be adequately mitigated by design and construction of homes in accordance with appropriate building codes. The project geotechnical engineer, in conjunction with the developer, should confirm and evaluate the seismic ground-shaking hazard and provide appropriate seismic design parameters as needed.

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 either as a large, singular scarp, or several smaller ruptures comprising a fault zone. Ground displacement from surface fault rupture can cause significant damage or even collapse to structures located across a rupture zone.

No active faults are mapped at the project or evident on air photos, and no evidence for faulting was observed during the site reconnaissance. Given this, the existing risk from surface faulting in the project area is low. Nearest active fault to the site is the Weber section of the Wasatch fault zone about 8.5 miles to the southwest (Black and others, 2003).

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.

Sandy soils possibly susceptible to liquefaction are not likely present in the project area given the mapped colluvial veneers and bedrock. Given the above, we rate the hazard from liquefaction 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). No active faults are mapped in the project area, and therefore the risk from tectonic deformation 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 or similar large lakes or reservoirs. No large bodies of water are in the project area. Given the above, the risk to the project 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.

The project area straddles Lefty's Canyon, a subsidiary drainage basin of South Fork Wolf Creek. A small, spring-fed stream flows through the canyon bottom. The creek was flowing at a very low level at the time of our reconnaissance, though flows may be slightly higher during spring snow melt. No other active drainages cross the site. Given the above, we rate the risk from stream flooding as moderate for canyon bottom areas, and low everywhere else. Site hydrology and runoff should be addressed in the civil engineering design for the development.

Shallow Groundwater
Groundwater in the project area is likely locally and seasonally variable. Areas in and adjacent to the creek and spring area at the head of Lefty's Canyon likely have shallowest levels. Groundwater elsewhere may be at substantial depth. Given the above, we rate the risk from shallow groundwater as moderate, however we do not anticipate that shallow groundwater will pose a significant constraint to the project. Evaluation of and recommendations regarding shallow groundwater should be provided in the project geotechnical engineering evaluation.

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.

Slopes bounding Lefty's Canyon below ridge crest areas steepen into the drainage bottom, and range between an overall roughly 2.5:1 (horizontal:vertical) to 5:1 gradient. The slopes are mantled by mixed slope colluvium, slumps, and talus (unit Qm, Figure 2). The colluvial veneer appeared thin near the ridge tops and likely thickens downslope into the canyon bottom. Unit Qm is generally found only in slopes steeper than about 5:1. Several landslides are in the project area in the south-facing slope below the ridge crest in the north part of the project, and in slopes near the head of Lefty's Canyon. The landslides are in areas mapped as unit Qm or Tw (Figure 2). The landslides include older Pleistocene landslides (map unit Qmso) with subdued morphology, and younger Holocene to late Pleistocene slides (map unit Qms) with typical hummocky morphology (Figures 2 and 3). The older slides appeared to be eroded rotational and translational failures. The younger slides appeared to be smaller, including shallow-seated slumps. Landsliding in the area has likely been ongoing since Pleistocene time, possibly following the Pinedale (Bells Canyon) glacial advance. A combination of clayey surficial colluvium, weathered Wasatch Formation bedrock, unstable landslide deposits, and/or perched groundwater appears to be the likely cause for the failures. Landslides in the project area may be slow moving failures, such as the failure at the spring area, which appears to be ongoing.

All the above evidence suggests slopes bounding Lefty's Canyon have marginal stability and the risk from landslides in the project area is high. Landslide risk can be minimized by avoiding mapped landslides and steep slopes in the project area, particularly at a planning level. Mapped colluvial and landslide areas in the project area appear to be in slopes steeper than 20%. We therefore recommend that stability of slopes be evaluated in a site-specific geotechnical engineering evaluation prior to construction for any development in slope areas exceeding 20%. Recommendations for reducing the risk from landsliding should be provided if factors of safety are determined to be unsuitable. Groundwater is a significant contributor to slope instability, and stability evaluations should conservatively assume near-surface conditions. Care should also be taken that site grading does not destabilize slopes in the project area without prior geotechnical analysis and grading plans, and that proper drainage is maintained.

Development of steeper slope areas, and some areas in mapped landslides adjacent to the ridge crest, may be feasible if shallow bedrock can be encountered and proved stable in the geotechnical evaluation. This would likely require drilling, and may also require expensive structural mitigation techniques to reduce risk from slope instability (such as drilled piers), as deemed necessary by the project geotechnical engineer. If drilling is conducted, the borings should be carefully logged to note discontinuities such as clay gouge zones or abrupt lithologic changes that may indicate weak bedrock zones.

Debris Flows

A debris flow is a fast moving, liquefied landslide of unconsolidated, saturated debris that can carry material ranging in size from clay to boulders, and may entrain a large amount of woody debris. Debris flows typically form when unconsolidated sediments become saturated and unstable on a steep slope or mountain stream channel, accelerate downhill by gravity, and entrain further debris as they scour steep mountain channels. Debris from a flow is deposited when velocities fall, such as in channel margins, pulse surges, and gentler slope areas below a critical threshold. 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 in Utah.

No evidence of debris-flow features such as channels or levees, or debris flow deposits, was observed on air photos or during our reconnaissance. However, the project is in an area where debris flows may initiate. Deposition from such a flow would be in canyon bottom areas less than about a 15% gradient. Such areas are found only at the south edge of the project, and further downstream to the southwest. Given all the above, we rate the risk from debris flows as low.

Rock Fall

Cliff areas possibly posing a risk from rock falls are found mainly in the western part of the project. Given the above, we rate the risk from rock falls as moderate. However, a talus chute suggestive of either a prehistoric rockslide or a rock-fall runout zone was observed in the eastern part of the project below an area of weathered Wasatch Formation. These areas would have a high risk from rock falls, as well as canyon bottom areas below steep slopes.

Radon

Radon comes from the natural (radioactive) breakdown of uranium in soil, rock, and water and can seep into homes through cracks in floor slabs or other openings. The project is located in an area of "Moderate" radon-hazard potential (Black, 1993). A moderate potential indicates that indoor radon concentrations would likely be between 2 and 4 picocuries per liter of air. However, actual indoor radon levels can be affected by non-geologic factors such as building construction, maintenance, and weather. Indoor testing following construction is the best method to characterize the radon hazard and determine if mitigation measures are required.

Swelling and Collapsible (Problem) Soils

Surficial soils that contain certain clays can swell or collapse when wet. Given the geologic mapping (Figure 2) and surficial soils observed at the site, soils susceptible to swelling or collapse may be present. We anticipate that most bedrock areas will have only a shallow veneer of surficial soil, however colluvial and landslide areas may have deeper, possibly clay-rich soils. We therefore rate the risk from swelling and collapsible soils as moderate. A geotechnical engineering evaluation should be performed prior to construction to address soil conditions and provide specific recommendations for site grading, subgrade preparation, and structural and footing design.

Volcanic Eruption

No active volcanoes, vents, or fissures are mapped in the region. Based on this, no volcanic hazard likely exists in the project area and the risk to the project is low.

CONCLUSIONS AND RECOMMENDATIONS

Geologic hazards posing a high risk to the project are earthquake ground shaking and landslides. Moderate risk hazards include stream flooding, shallow ground water, rock falls, indoor radon, and problem soils. Except for earthquake ground shaking, not all hazards are present in every area of the project. The risk may vary, as discussed above.

The following recommendations are provided:

- ***Seismic Design*** - The structures should be designed and constructed to current seismic standards to reduce the potential ground-shaking hazard.

- ***Geotechnical Investigation*** - A design-level geotechnical engineering study should be conducted prior to design and construction to: (1) address soil conditions at the project for use in footing design, site grading, and drainage; (2) provide recommendations to reduce risk from seismic acceleration; and (3) evaluate and address potential shallow groundwater issues as warranted. Landslide risk can be minimized by avoiding mapped landslides and steep slope areas at the project. We recommend structures be placed outside of mapped landslides, though these areas may be developable if future studies can demonstrate that bedrock is shallow and slopes are stable under static and dynamic conditions. We recommend that a slope stability evaluation be performed for any development on slopes steeper than 20%, including providing recommendations for reducing the risk from landsliding if static or dynamic factors of safety are unsuitable. Groundwater should conservatively be assumed to be at near-surface levels to represent seasonal alpine conditions.

- ***Other Investigations*** – Risk from stream flooding should be addressed in the civil engineering design for the project, in accordance with all applicable local government development guidelines, for any structures located in the canyon bottom. Risk from rock falls can be minimized by avoiding placing structures below steep slopes with bedrock outcrops, and in talus or runout zones. Risk from radon can be determined by indoor testing following construction.

- ***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

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ATTACHMENTS

Photographic Record of Site Reconnaissance
Figures 1. Location Map
Figures 2. Geologic Map
Figures 3. Air Photo

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Photographic Record of Site Reconnaissance
Proposed Powder Mountain Area 1 Mixed-Use Development
Weber County, Utah

East view of head of Lefty's Canyon

North view from south side of Lefty's Canyon

North view of south-facing slopes and northern Qmso landslide area

Typical weathered Wasatch Formation slope

Piping from spring area in Lefty's Canyon

Spring area in Lefty's Canyon

Photographic Record of Site Reconnaissance
Proposed Powder Mountain Area 1 Mixed-Use Development
Weber County, Utah

East view of toe of spring area landslide

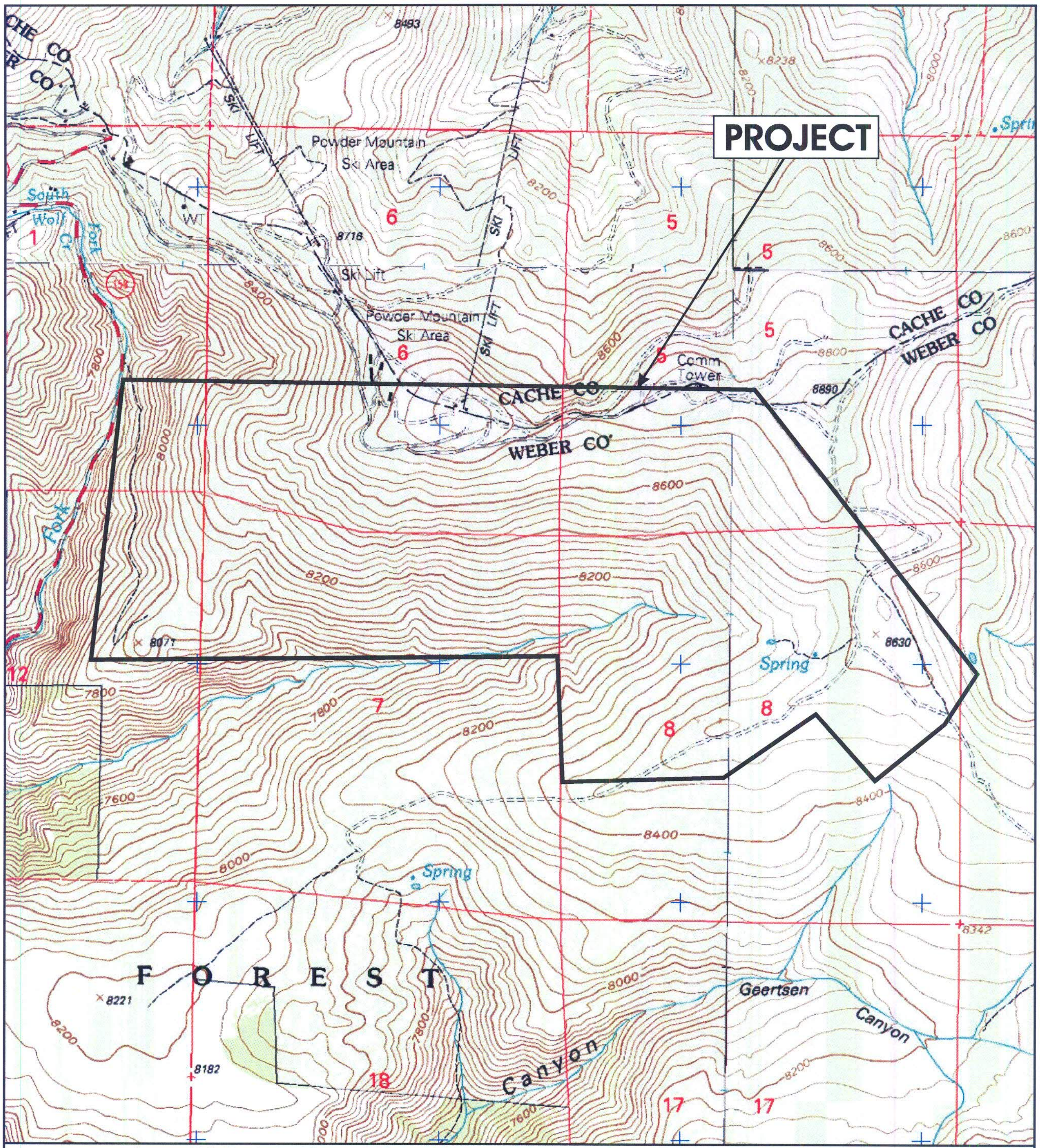
Creek in Lefty's Canyon

Right-lateral margin of spring area landslide

Qms landslide area in Lefty's Canyon

Cambrian sedimentary bedrock exposure

Cambrian sedimentary bedrock exposure



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, UT - Huntsville and Browns Hole, 1998.

WESTERN GEOLOGIC

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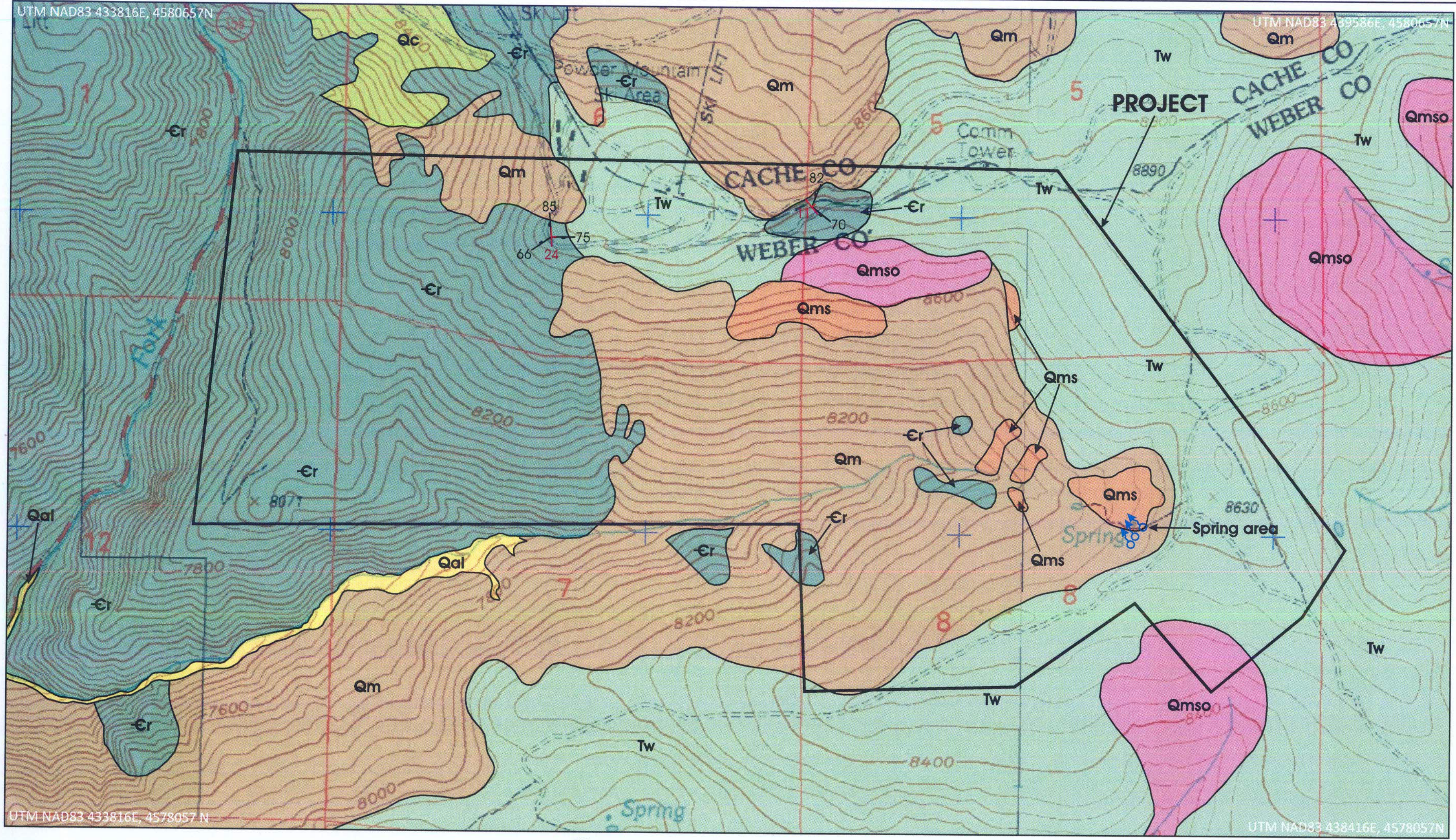
0 1000 2000 feet
Scale 1:24,000
(1 inch = 2000 feet)

LOCATION MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Geologic Hazards Reconnaissance
Proposed Area 1 Mixed-Use Development
Powder Mountain Resort
Weber County, Utah

FIGURE 1



WESTERN GEOLOGIC

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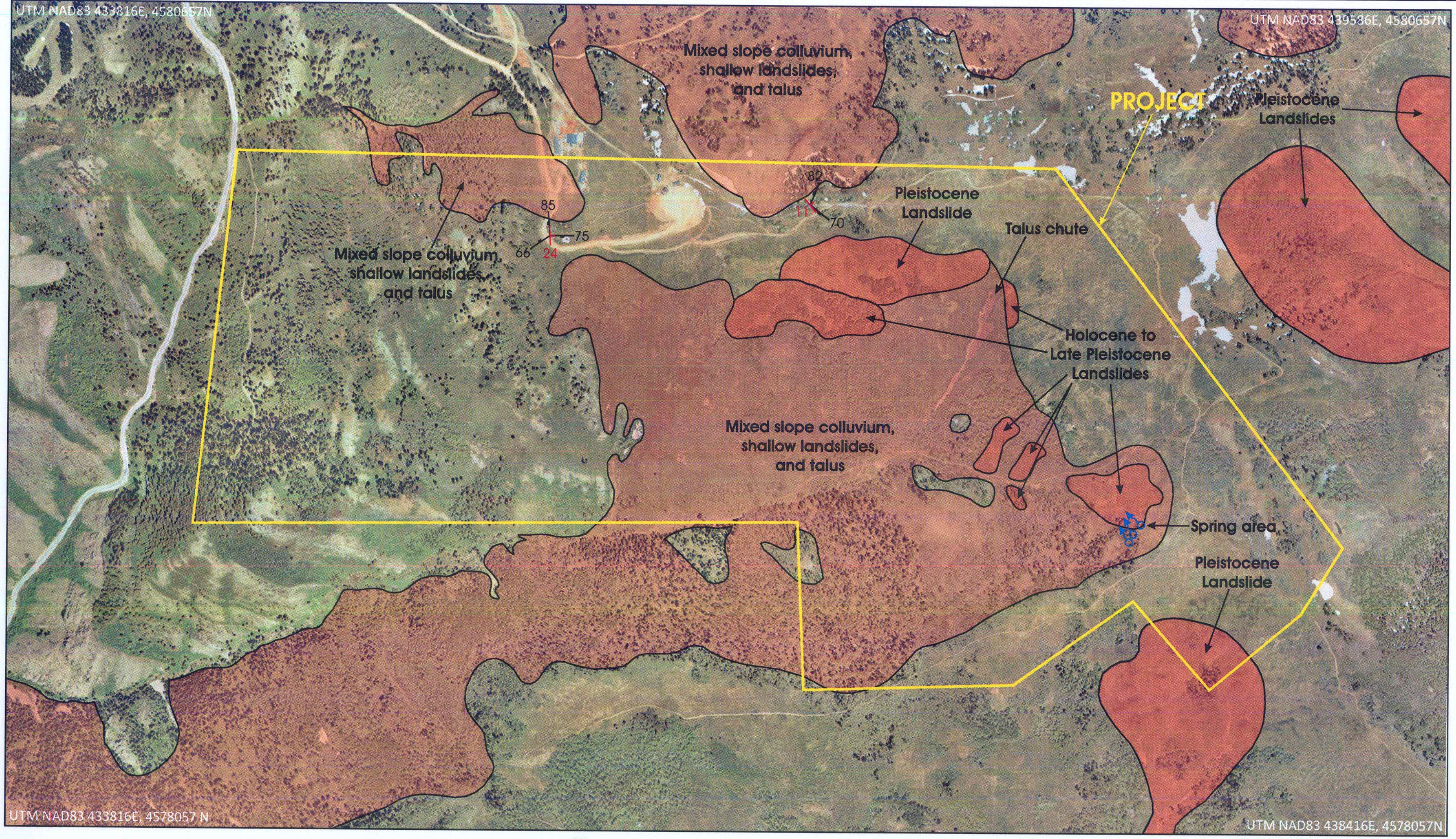
0 500 1000 feet
Scale 1:12,000
(1 inch = 1000 feet)

Source: modified from Coogan and King (2001) based on air photo evidence and field observations. See text for explanation of geologic units.

GEOLOGIC MAP

GEOLOGIC HAZARDS RECONNAISSANCE
Proposed Area 1 Mixed-Use Development
Powder Mountain Resort
Weber County, Utah

FIGURE 2



WESTERN GEOLOGIC

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Scale 1:12,000
(1 inch = 1000 feet)

Source: air photo base from High Resolution SID imagery provided by Summit Engineering; landslide mapping modifed from Coogan and King (2001) and Elliot and Harty (2010 based on air photo evidence and field observations.

AIR PHOTO

GEOLOGIC HAZARDS RECONNAISSANCE
Proposed Area 1 Mixed-Use Development
Powder Mountain Resort
Weber County, Utah

FIGURE 3