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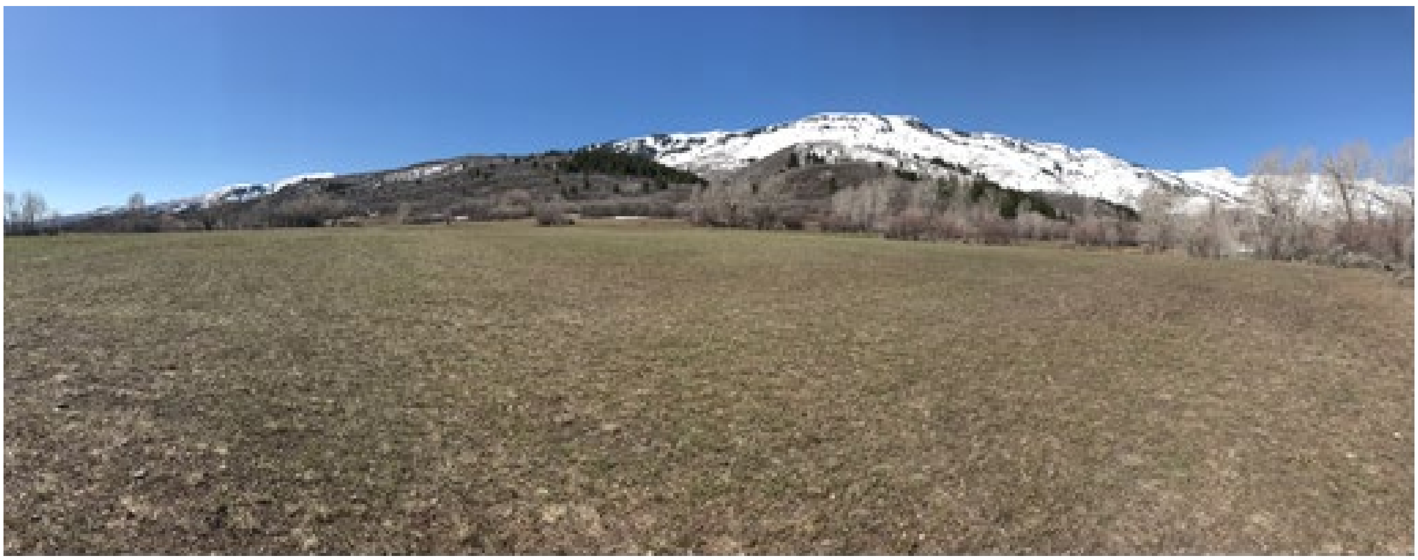

# Geologic Hazards Screening Assessment
# Lot 1 Moqui Balls Subdivision
# Liberty, Utah 84310
# Parcel # 22-004-0166

GeoStrata Job No. 1460-001

May 6, 2019
Prepared for:

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Prepared by:

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## APPENDICES

## 1.0 EXECUTIVE SUMMARY

The purpose of this investigation and report is to assess the 8 acre proposed single-family residential lot located at approximately 2503 East 5100 North in Liberty, Utah for the presence of geologic hazards that may impact the planned development of the site. The work performed for this report was performed in accordance with our proposal, dated April 8, 2019

The surface fault rupture hazard that would potentially impact the subject site was assessed as part of our study. No active surface fault ruptures are located near the subject site. Given our field and office investigations, the surface fault rupture hazard within the subject site is considered low and it is considered unlikely that surface fault rupture will impact the proposed development. It is the opinion of GeoStrata that surface fault rupture hazard should not preclude development at the subject lot.

The tectonic deformation hazard that would potentially impact the site was assessed as part of our study. No active faults are reported or mapped within or adjacent to the subject site. It is the opinion of GeoStrata that the tectonic deformation hazard within the subject site is considered low and it is considered unlikely that tectonic deformation will impact the proposed development. It is the opinion of GeoStrata that the tectonic deformation hazard should not preclude development at the subject site.

The liquefaction hazard that would potentially impact the site was assessed as part of our study. The site is located in an area currently designated as having a “Very Low” liquefaction potential. The near-surface soils are not considered to be susceptible to liquefaction. It is the opinion of GeoStrata that liquefaction hazard should not preclude development at the subject site.

The rockfall hazards within the subject site were assessed as part of our study. No rockfall or talus deposits are located within or immediately adjacent to the subject lot. Our field investigation revealed no indications that the subject lot has been subjected to previous rockfall. Therefore, the rockfall hazard within the subject site is considered low and it is considered unlikely that rockfall will impact the proposed development. It is the opinion of GeoStrata that rockfall hazard should not preclude development at the subject site.

The landslide, slump and creep hazards that would potentially impact the site were assessed as part of this study. No Holocene age Landslide deposits are mapped as underlying the subject site or within the vicinity of the subject site. No hummocky topography was observed within the subject site during our review. It is the opinion of GeoStrata that the landslide, slump and creep hazard within the subject site is considered low and it is considered unlikely that landslide, slump and/or creep will impact the proposed development.

Slope stability of the subject site was not assessed as part of this geological hazard assessment. The subject site was observed to be relatively flat (Plate 2 Topographic Map). The possibility that development of the site could negatively affect slope stability within the subject site is increased if development is planned for areas of the site with slopes steeper than approximately 3 horizontal: 1 vertical.

The snow avalanche hazard that would potentially impact the site was assessed as part of this study. No evidence of prior snow avalanche was observed within the subject site. It is the opinion of GeoStrata that the snow avalanche hazard within the subject site is considered low and it is considered unlikely that this hazard will impact the proposed development. It is the opinion of GeoStrata that snow avalanche hazard should not preclude development at the subject site.

The alluvial-fan flooding hazard that would potentially impact the site was assessed as part of this study. Based on the most recent published geologic maps, no Holocene age alluvial fan deposit is mapped within or adjacent to the subject site. Given our field and office investigations, the alluvial fan flooding hazards within subject site is considered low and it is considered unlikely that debris flows will impact the proposed development. It is the opinion of GeoStrata that alluvial fan flooding hazard should not preclude development at the subject lot.

The shallow groundwater hazard that would potentially impact the site was not assessed and is out of the scope of this study. Seasonal fluctuations in precipitation, surface runoff from adjacent properties, or other on or offsite sources may increase moisture conditions; groundwater conditions can be expected to rise several feet seasonally depending on the time of year. Due to the presence of nearby streams, it is possible that shallow groundwater could pose a hazard to habitable structures with basements or crawlspaces. Since shallow groundwater was not assessed as part of this study, a separate geotechnical study including subsurface exploration would be needed to assess this hazard.

The stream flooding hazard that would potentially impact the site was assessed as part of this study. Cobble Creek flows northwest-southeast through the northern portion of the subject site. No construction of habitable structures should occur within the area identified as a High

Flooding Hazard, unless the civil engineer develops proper site grading and drainage plans. It should be noted that all FEMA regulations should be complied with by the design civil engineer. Given our field and office investigations, the stream flooding hazard within the subject lot is considered low to moderate and it is considered unlikely that stream flooding will impact the proposed development as long our recommendations for avoidance of the flood area is followed. It is the opinion of GeoStrata that stream flooding hazard should not preclude development at the subject lot. Proper site grading and drainage plans should be developed for the subject site as a part of the civil engineering design for the lot.

The canal flooding hazard that would potentially impact the site was assessed as part of this study. No canals were observed or are mapped within or adjacent to the subject site. Given our field and office investigations, the canal flooding hazard within the subject lot is considered low and it is considered unlikely that canal flooding will impact the proposed development. It is the opinion of GeoStrata that canal flooding hazard should not preclude development at the subject lot.

The dam failure hazard that would potentially impact the site was assessed as part of this study. two man made reservoirs are located approximately 850 feet southwest and up-gradient of the subject site. Based on the topography of the subject site and surrounding area, the distance of the Two man made reservoirs from the subject site, and the size of the two man made reservoirs, the dam failure hazard within the subject lot is considered low to moderate. It is our recommendation that the potential for dam failure flooding hazards within the subject site should be considered by the project civil engineer. This hazard should be mitigated by the project civil design engineer through the engineering and development of appropriate grading and drainage plans for the proposed residence. It is the opinion of GeoStrata that dam failure hazard should not preclude development at the subject lot.

The problem soils hazard is out of the scope of this study. Based on our review of published geologic maps and our field observations, the subject site is underlain by fine-grained clayey soils with sand and gravel. No laboratory testing was performed on these soils as part of this study and therefore this hazard was not assessed as part of this study. In order to understand soil properties for use in the design of footing and foundation elements such as bearing capacity, lateral loading, and settlement potential, a site specific geotechnical study would need to be conducted for the project.

The radon gas hazard is out of the scope of this study. The radon gas hazard within the subject site is considered high. A high radon gas potential indicates that the indoor radon gas levels are likely to be greater than 4 picocuries per liter (pCi/L). Indoor testing following construction is recommended for determining radon gas levels and mitigation methods needed.

The karst and sink holes hazards is out of the scope of this study. The karst and sink holes hazards within the subject site are considered low and it is unlikely that karst and sink holes hazards will impact the proposed development.

**NOTICE: The scope of services provided within this report are limited to the assessment of the subsurface conditions for the proposed development. This executive summary is not intended to replace the report of which it is part and should not be used separately from the report. The executive summary is provided solely for purposes of overview. The executive summary omits a number of details, any one of which could be crucial to the proper application of this report.**

# 2.0 INTRODUCTION

## 2.1 PURPOSE AND SCOPE OF WORK

The purpose of this investigation and report is to assess the 8 acre proposed single-family residential lot located at approximately 2503 East 5100 North in Liberty, Utah for the presence of geologic hazards that may impact the planned development of the site. The geologic hazards considered for this site are presented in Table 2 of this report. The work performed for this report was performed in accordance with our proposal, dated April 8, 2019. Our scope of services included the following:

- Review of available references and maps of the area.
- Stereographic aerial photograph interpretation of aerial photographs covering the site area.
- Review of 2016 0.5 meter LiDAR obtained from the State of Utah AGRC.
- Geologic reconnaissance and field mapping of the site by an engineering geologist to observe and document pertinent surface features indicative of geologic hazards.
- Evaluation of our observations combined with existing information and preparation of this written report with conclusions and recommendations regarding possible surface rupture hazards or any other geologic hazards observed to affect the site.

The recommendations contained in this report are subject to the limitations presented in the Limitations section of this report.

## 2.2 PROJECT DESCRIPTION

The subject site is located in the northwest portion of Ogden Valley in Liberty, Utah. The subject site is currently comprised of a relatively flat and undeveloped single-family residential building lot. The parcel immediately west of the subject site is occupied by an established single family residence whereas the other adjoining parcels are currently undeveloped. Proposed development, as currently planned, will consist of a single family residential structure as well as associated roadways, driveways, utilities and landscape areas. It is our understanding that the general area of the subject lot was first developed in the 1960's. The subject site is shown on the Site Vicinity Map and Topographic Map included in the Appendix of this report (Plate 1; Plate 2).

# 3.0 METHODS OF STUDY

## 3.1 OFFICE INVESTIGATION

To prepare for the investigation, GeoStrata reviewed pertinent literature and maps listed in the references section of this report, which provided background information on the local geologic history of the area and the locations of suspected or known geologic hazards (Elliot and Harty, 2010; Black and others, 2003; Crittenden and Sorensen, 1985; Sorensen and Crittenden, 1979; Coogan and King, 2016). The geologic hazards considered for this site include landslide, alluvial fan flooding/debris flow, rock fall, surface fault rupture and stream flooding. A stereographic aerial photograph interpretation was performed for the subject site using a set of stereo aerial photographs obtained from the UGS as shown in Table 1.

| Source | Photo Number | Date | Scale |
|---|---|---|---|
| USFS | ELK_2-44 | June 25, 1963 | 1:15,840 |
| USFS | ELK_2-45 | June 25, 1963 | 1:15,840 |

**Table 1: Aerial Stereosets.**

GeoStrata also conducted a review of 2016 0.5 meter LiDAR data obtained from the State of Utah AGRC to assess the subject site for visible lineations or other geologic related geomorphology. The LiDAR data was used to create hillshade imagery that could be reviewed for assessment of geomorphic features related to geologic hazards (Plate 3).

## 3.2 FIELD INVESTIGATION

An engineering geologist investigated the geologic conditions within the general site area. A field geologic reconnaissance was conducted to observe existing geologic conditions and to assess existing geomorphology for surficial evidence of geologic hazards. During our fieldwork we conducted site observations to assess geologic hazards that might impact the subject lots. We used our field observations to confirm the observations made during our office research and to observe any evidence of geologic hazards that were not evident in our office research but which could be observed in the field.

# 4.0 GEOLOGIC CONDITIONS

## 4.1 GEOLOGIC SETTING

The site is located in Liberty, Utah at an elevation between approximately 5,360 feet above mean sea level in the northwestern portion of Ogden Valley. Outcroppings of Proterozoic age sedimentary bedrock indicative of a coastal environment with fluctuating sea levels are visible in the northern portion of Ogden Valley. After their formation, these sedimentary beds were then exposed to folding and uplift related to the collision between North America and Farallon plates during what is referred to as the Sevier Orogeny which lasted from the Cretaceous to early Tertiary. The Willard Thrust fault, one of the largest faults in the Sevier mountain belt, bounds the western side of Ogden Valley. Volcanism during the Tertiary gave rise to the deposition of Norwood Tuff which is prevalent in the in the southern portion of Ogden Valley and along knolls or foothills in the central portion of the valley. Transition from thrust faulting to Basin and Range extension occurred during the Cenozoic. As a result, the Ogden Valley is a northwest trending structural basin or fault graben flanked by two uplifted blocks, the Wasatch Range on the west and unnamed flat-topped mountains to the east (King and others 2008). The Wasatch Range is the easternmost expression of pronounced Basin and Range extension in north-central Utah (Stokes, 1986).

The near-surface geology of the Ogden Valley is dominated by lake sediments which were deposited within the last 30,000 years during the high stand of the Lake Bonneville Cycle when water inundated Ogden Canyon and formed a small lake in Ogden Valley (Scott and others, 1983; Hintze, 1993; Leggette and Taylor, 1937; King and others, 2008). As the lake receded, streams began to incise large deltas that had formed at the mouths of major canyons along the Wasatch Range and the unnamed flat-topped mountains bounding the eastern margins of Ogden Valley. The eroded material was then deposited in shallow lakes and marshes in the basin and in a series of recessional deltas and alluvial fans. Sediments toward the center of the valley are predominately deep-water deposits of clay, silt and fine sand whereas sediments closer to the mountain fronts are shallow-water deposits of coarse sand and gravel. However, these deep-water deposits are in places covered by a thin post-Bonneville alluvial cover.

## 4.2 SITE GEOLOGY

Bedrock exposures, located to the west of the subject site, are mapped as the mudstone member of the Perry Canyon Formation (ZYpm) as illustrated on Plate 5 Site Vicinity Geologic Map and

Plate 6 Site Vicinity 30x60 Geologic Map. This unit is described as gray and green-weathering, black, non-foliated argillite and sandy argillite, and slate that grades into black chloritoid and pyrite-bearing schist (Coogan and King, 2016). The extent of this bedrock unit varies between the Interim Geologic Map of the Ogden 30’ X 60’ Quadrangle (Coogan and King, 2016) and the Geologic Map of the North Ogden Part of Ogden and Plain City Quad (Crittenden and Sorensen, 1985). Coogan and King (2016) delineate the eastern edges of the mudstone member of the Perry Canyon Formation as a coalescence of several landslide deposits (Qms) with ages ranging from Holocene to upper and potentially middle Pleistocene (Plate 6). The near surface soils primarily underlying the subject site as mapped by Crittenden and Sorensen (1985) are identified as Holocene Alluvial Fan Deposits (Qf) whereas Coogan and King (2016) further divide this unit into upper Pleistocene Lake Bonneville-age alluvium (Qab) and alluvial fan deposits (Qafpb). Lastly, a concealed east dipping fault is located trending northwest near the southwest corner of the subject site.

## 5.0 GENERALIZED SITE CONDITIONS

### 5.1 SURFACE CONDITIONS

As stated previously, the project site is located within the northwestern extent of Ogden Valley in Liberty, Utah. The subject site is situated on a relatively flat undeveloped 8 acre parcel within Weber County (Plate 2 Topographic Map). Cobble Creek flows northwest-southeast through the northernmost portion of the subject site. The area surrounding Cobble Creek is densely vegetated with large brush and tall mature trees. The remainder of the subject site is open and vegetated with tall grasses. Based on our review of the site, this area was previously used for agricultural purposes. As indicated to GeoStrata by the Client, the proposed structure will be located in this area of the site. No structures were observed within the subject property. The property to the west of the subject site is an established single-family residential lot. The other adjoining parcels are currently undeveloped.

## 6.0 GEOLOGIC HAZARDS

Geologic hazards can be defined as naturally occurring geologic conditions or processes that could present a danger to human life and property. These hazards must be considered before development of the site. There are several hazards that if present at the site should be considered in the design of habitable structures and other critical infrastructure. The hazards considered for this site are presented on Table 2 and discussed in the following sections of this report.

| Hazard | Hazard Rating* | | | | | Further Study Recommended |
|---|---|---|---|---|---|---|
| | Not Applicable | Not Assessed | Low | Moderate | High | |
| Ground Shaking | | | X | | | |
| Surface Fault Rupture | | | X | | | |
| Tectonic Deformation | | | X | | | |
| Liquefaction | | | X | | | |
| Rock Fall and Topple | | | X | | | |
| Landslide | | | X | | | |
| Slump | | | X | | | |
| Creep | | | X | | | |
| Avalanche | | | X | | | |
| Debris Flow | | | X | | | |
| Hyperconcentrated Flow | | | X | | | |
| Stream Flow | | | X | | | |
| Shallow Groundwater | | X | | | | E |
| Stream Flooding | | | X | | X | E |
| Canal Flooding | X | | | | | |
| Dam Failure | | | X | X | | E |
| Problem Soils | | X | | | | E |
| Radon | | X | | | | |
| Karst and Sink Hole | | X | | | | |

**Table 2: Summary of Geologic Hazards.**

Table 2 shows the summary of the geologic hazards assessed and not assessed at the subject site. A hazard rating of "Not Assessed" are hazards this report does not consider and no inference is made as to the presence or absence of the hazard at the site. A hazard rating of "Low" indicates that no evidence was found to indicate that the hazard is present, hazard not known or suspect to be present. A hazard rating of "Moderate" indicates that the hazard may exist, but the evidence is equivocal, based only on theoretical studies, or was not observed and further study is necessary as noted. A hazard rating of "High" indicates that that evidence is strong that the hazard exists and mitigation measures should be taken. If a hazard is assessed to potentially impact the site then further studies may be recommended. The following are the recommended studies and the letter designation associated with those studies: "E" – geotechnical/engineering, "H" – hydrologic, "A" – avalanche, "G" – additional detailed geologic hazard study out of the scope of this study.

## 6.1 EARTHQUAKE GROUND SHAKING HAZARD

During the event of an earthquake, seismic waves radiate outward from the initial point of rupture and dissipate with distance. The ground shakes as the seismic waves displace the ground both vertically and horizontally. Ground shaking can cause significant damage to and potentially collapse structures and can also trigger landslides, avalanches and liquefaction. The type of soil a seismic wave travels through can amplify or dampen the effects of ground shaking.

Seismic hazard maps depicting probabilistic ground motions and spectral response have been developed for the United States by the U.S. Geological Survey as part of NEHRP/NSHMP (Frankel et al, 1996). These maps have been incorporated into both *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (FEMA, 1997) and the *International Building Code* (IBC) (International Code Council, 2015). Spectral responses for the Maximum Considered Earthquake ($MCE_R$) are shown in the table below. These values generally correspond to a two percent probability of exceedance in 50 years (2PE50) for a "firm rock" site. To account for site effects, site coefficients which vary with the magnitude of spectral acceleration are used. Based on our field and office investigations, it is our opinion that this location is best described as a Site Class D which represents a "stiff soil" profile. The spectral accelerations are shown in the table below. The spectral accelerations are calculated based on the site's approximate latitude and longitude of 40.358480° and -111.885523° respectively and the U.S. Seismic Design Maps web based application. Based on the IBC, the site coefficients are $F_a$=1.07 and $F_v$= 1.64. From this procedure the peak ground acceleration (PGA) is estimated to be 0.435g.

| Site Location:<br>Latitude = 40.358480 N<br>Longitude = -111.885523 W | Site Class D Site Coefficients:<br>Fa = 1.07<br>Fv = 1.64 |
|---|---|
| **Spectral Period (sec)** | **Response Spectrum Spectral Acceleration (g)** |
| 0.2 | $S_{MS}=(F_a*S_s=1.07*1.083) = 1.16$ |
| 1.0 | $S_{M1}=(F_v*S_1=1.64*0.382) = 0.63$ |
| [a] IBC 1613.3.4 recommends scaling the $MCE_R$ values by 2/3 to obtain the design spectral response acceleration values; values reported in the table above have not been reduced. | |

**Table 3: $MCE_R$ Seismic Response Spectrum Spectral Acceleration Values for IBC Site Class D[a].**

Based on the above information, it is the opinion of GeoStrata that the earthquake ground shaking hazard within the subject site should not preclude development at the subject site. The seismic data provide above should be used by the project geotechnical and structural engineers for proper site and structural design. GeoStrata recommends that a licensed structural engineer provide proper structural designs for proposed residential structures which account for and mitigate this hazard. It is the opinion of GeoStrata that earthquake ground shaking hazard should not preclude development at the subject site.

## 6.2 SURFACE FAULT RUPTURE HAZARD

Movement along faults within the crustal rocks beneath the ground surface generates earthquakes. During large magnitude earthquakes (Richter magnitude 6.5 or greater) along the normal faults in the intermountain region, fault ruptures can propagate to the ground surface resulting in a surface fault rupture (Smith and Arabasz, 1991). The fault scarp formed during a surface fault rupture event along a normal fault is generally nearly vertical. A surface rupture fault may be comprised of a larger single surface rupture or several smaller surface ruptures across a fault zone. For all structures designed for human occupancy, a surface rupturing fault is considered active if it has experienced movement in approximately the past 10,000 years (Christenson and others, 2003).

Based on review of published geologic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 2016 0.5 meter LiDAR and our field observations, no active surface ruptures are located near the subject site (Plate 7 UGS Quaternary Fault Map). The nearest fault is the Ogden Valley North Fork Fault. This fault is Quaternary in age with an undetermined reoccurrence interval and a slip rate of less than 0.2 mm/yr (Black and others, 2003). This fault is trending northwest and located along the southwestern property boundary of the subject site. The nearest reported active fault is the Weber section of the Wasatch Fault Zone which is located approximately 3 miles west of the subject site. Given our field and office investigations, the surface fault rupture hazard within the subject site is considered low and it is considered unlikely that surface fault rupture will impact the proposed development. It is the opinion of GeoStrata that surface fault rupture hazard should not preclude development at the subject lot.

## 6.3 TECTONIC DEFORMATION

Subsidence is a hazard associated with warping, lowering and tilting of a valley floor accompanying surface ruptures on normal faults (Robinson, 1993). Inundation along the shores of lakes and reservoirs and the rise of groundwater levels are the main hazards associated with subsidence. Structures that require gentle gradients or horizontal floors such as waste water treatment plants and sewer lines may be adversely affected by tectonic subsidence. Because subsidence may occur over very large areas, it is not generally practical to avoid the use of potentially affected land except in narrow areas of hazard due to lakeshore inundation (Keaton, 1987; Robison, 1993). According to Gary Christenson (UGS, personal communication 2001), tectonic subsidence is not typically assessed for subdivision development unless the development is located within an area of potential lake flooding.

Based on published geological maps, no active faults are reported or mapped within or adjacent to the subject site. It is the opinion of GeoStrata that the tectonic deformation hazard within the subject site is considered low and it is considered unlikely that tectonic deformation will impact the proposed development. It is the opinion of GeoStrata that the tectonic deformation hazard should not preclude development at the subject site.

## 6.4 LIQUEFACTION

Certain areas within the intermountain region possess a potential for liquefaction during seismic events. Liquefaction is a phenomenon whereby loose, saturated, granular soil deposits lose a significant portion of their shear strength due to excess pore water pressure buildup resulting from dynamic loading, such as that caused by an earthquake. Among other effects, liquefaction can result in densification of such deposits causing settlements of overlying layers after an earthquake as excess pore water pressures are dissipated. The primary factors affecting liquefaction potential of a soil deposit are: (1) level and duration of seismic ground motions; (2) soil type and consistency; and (3) depth to groundwater.

Based on our review of the *Liquefaction Special Study Areas, Wasatch Front and Nearby Areas, Utah* compiled by Christenson and others, 2008, the site is located in an area currently designated as having a "Very Low" liquefaction potential. "Very Low" liquefaction potential indicates that there is less than a 5 percent probability of having an earthquake within a 100-year period that will be strong enough to cause liquefaction. The surface soils we observed during our field investigation are not considered to be susceptible to liquefaction. A liquefaction analysis was beyond the scope of this geologic hazards assessment; however, if the owner wishes to have greater understanding of the liquefaction potential of the soils at greater depths, a liquefaction analysis should be completed at the site. It is the opinion of GeoStrata that liquefaction hazard should not preclude development at the subject site.

## 6.5 ROCKFALL AND TOPPLE

Rockfalls are the fastest moving mass movement that predominantly occurs in mountains where a rock source exists along steep slopes and cliffs greater than 35 degrees. Rockfalls are a result of a loss of support from beneath the rock mass that can be caused by freeze/thaw action, rainfall, weathering and erosion, and/or strong ground shaking resulting from seismic activity. Rockfalls result in the collection of rock fall material, referred to as talus, at the base of the slope. The presence of talus indicates that a rockfall hazard has occurred and may still be present at the site.

Based on review of published geologic maps, our stereographic aerial photograph interpretation and our field observations, no rockfall or talus deposits are located within or immediately adjacent to the subject lot. Our field investigation revealed no indications that the subject lot has been subjected to previous rockfall. Therefore, the rockfall hazard within the subject site is considered low and it is considered unlikely that rockfall will impact the proposed development. It is the opinion of GeoStrata that rock fall hazard should not preclude development at the subject site.

## 6.6 LANDSLIDE, SLUMP, CREEP

There are several types of landslides that should be considered when evaluating geologic hazards at a site with moderately to steeply sloping terrain. These include shallow debris slides, deepseated earth or rock slumps and earth flows. Landslides, slumps, creep and other mass movements can develop on moderate to steep slopes where the slope has been altered or disturbed. Movement can occur at the top of a slope that has been loaded by fill placement, at the base of a slope that has been undercut, or where local groundwater rises resulting in increased pore pressures within the slope. Slopes that exhibit prior failures and large landslide deposits are particularly susceptible to instability and reactivation.

Based on our review of published geologic maps, hillshades derived from 2016 0.5 meter LiDAR, our stereographic aerial photograph interpretation and our field observations, no Holocene age Landslide deposits are mapped as underlying the subject site or within the vicinity of the subject site. No hummocky topography was observed within the subject site during our review. It is the opinion of GeoStrata that the landslide, slump and creep hazard within the subject site is considered low and it is considered unlikely that landslide, slump and/or creep will impact the proposed development.

Slope stability of the subject site was not assessed as part of this geological hazard assessment. The subject site was observed to be relatively flat (Plate 2 Topographic Map). The possibility that development of the site could negatively affect slope stability within the subject site is increased if development is planned for areas of the site with slopes steeper than approximately 3 horizontal: 1 vertical.

## 6.7 AVALANCHE

An avalanche is a rapid flow of snow down a hill or mountainside. A snow avalanche can be a hazard in high alpine settings with slopes generally between 35 degrees and 45 degrees that accumulate appreciable amounts of snow. There are three types of avalanches: slough, dry slab and wet slab. Sloughs typically occur right after a heavy snowfall event. This type of slide occurs from a single point and accumulates snow as it moves downslope. Dry slabs are the most common type of avalanche and are the result of a fracture that occurs along a weak layer within the snowpack. Dry slabs can travel upwards of 80 mph removing trees and structures in its path. Wet slabs are triggered when percolating water dissolves bonds and decreases the strength of the weak snow layer. This type of slab can travel up to 20 mph. Several factors that influence a snow avalanche include weather, temperature, slope steepness, slope orientation, wind direction and wind loading, terrain, vegetation, and snowpack conditions. Snow avalanche hazard could affect access and snow removal on roads as well as the safety of habitable structures and critical facilities.

Based on review of our stereographic aerial photograph interpretation and our field observations, no evidence of prior snow avalanche was observed within the subject site. It is the opinion of GeoStrata that snow avalanche hazards should not preclude development within the subject lot.

## 6.8 ALLUVIAL FAN FLOODING

Alluvial fan flooding is a potential hazard that may exist in areas containing Holocene alluvial fan deposits. This type of flooding typically occurs as a stream flows, hyperconcentrated flows and debris flows consisting of a mixture of water, soil, organic material, and rock debris with variations in sediment-water concentrations transported by fast-moving water flows. Stream flows contains approximately less than 20% sediment by volume and involves sediment transport by entrained and suspended sediment load (Bowman and Lund, 2016). Unconfined stream flows are referred to as sheetfloods which are spread over and occur in the distal areas of the alluvial fan. Hyperconcentrated flows are alluvial fan flows with 20 to 60% sediment by volume whereas debris flows contain greater than 60% sediment by volume.

Alluvial fan flooding can be a hazard on or below alluvial fans or in stream channels above alluvial fans. Precipitation (rainfall and snowmelt) is generally viewed as an alluvial fan flood "trigger", but this represents only one of the many factors that contribute to alluvial fan flooding hazard. Vegetation, root depth, soil gradation, antecedent moisture conditions and long term climatic cycles all contribute to the generation of debris and initiation of alluvial fan flooding. Events of relatively short duration, such as a fire, can significantly alter a basin's absorption of storm water and snowmelt runoff and natural resistance to sediment mobilization for an extended period of time. These factors are difficult to quantify or predict and vary not only between different watersheds, but also within each sub-area of a drainage basin. In general, there are two methods by which alluvial fan flooding can be mobilized: 1) when shallow landslides from channel side-slopes are conveyed in existing channels when mixed with water and 2) channel scour where debris is initially mobilized by moving water in a channel and then the mobilized debris continues to assemble and transport downstream sediments.

Based on review of published geologic maps, a Holocene age alluvial fan deposit is mapped within the subject site (Plate 5 Site Vicinity Geologic Map). However, the more updated geologic map that covers the subject site (Coogan and King, 2016) does not indicate that the subject site is located within or near a Holocene age alluvial fan deposit (Plate 6 Site Vicinity 30x60 Geologic Map). Furthermore, based on our review of stereographic aerial photographs and hillshades derived from 2016 0.5 meter LiDAR, no active alluvial fans are located within or near the subject site. Given our field and office investigations, the alluvial fan flooding hazards within subject site is considered low and it is considered unlikely that debris flows will impact the proposed development. It is the opinion of GeoStrata that alluvial fan flooding hazard should not preclude development at the subject lot.

## 6.9 SHALLOW GROUNDWATER

Shallow groundwater flooding is a hazard that can cause the flooding of excavated areas where the depth of excavation exceeds the depth of the local water table. Shallow groundwater flooding should be considered when designing habitable structures that are planned to have basements or crawlspaces within areas of potential shallow groundwater.

Shallow groundwater assessment is out of the scope of this study. Seasonal fluctuations in precipitation, surface runoff from adjacent properties, or other on or offsite sources may increase moisture conditions; groundwater conditions can be expected to rise several feet seasonally depending on the time of year. Due to the presence of nearby streams, it is possible that shallow groundwater could pose a hazard to habitable structures with basements or crawlspaces. Since shallow groundwater was not assessed as part of this study, a separate geotechnical study including subsurface exploration would be needed to assess this hazard.

## 6.10 STREAM FLOODING HAZARD

Stream flooding can be caused by precipitation, snowmelt or a combination of both. Throughout most of Utah floods are most common in spring during the snowmelt. High flows in drainages can last for a few hours to several weeks. Factors that affect the potential for flooding at a site include surface water drainage patterns and hydrology, site grading and drainage design, and seasonal runoff.

Based on review of published topographic maps, review of stereographic aerial photographs and our field observations, Cobble Creek flows northwest-southeast through the northern portion of the subject site (Plate 8 Hydrology Map). No construction of habitable structures should occur within the area identified as a High Flooding Hazard, unless the civil engineer develops proper site grading and drainage plans. It should be noted that all FEMA regulations should be complied with by the design civil engineer. Given our field and office investigations, the stream flooding hazard within the subject lot is considered low to moderate and it is considered unlikely that stream flooding will impact the proposed development as long our recommendations for avoidance of the flood area is followed. It is the opinion of GeoStrata that stream flooding hazard should not preclude development at the subject lot. Proper site grading and drainage plans should be developed for the subject site as a part of the civil engineering design for the lot.

## 6.11 CANAL FLOODING

High runoff in a short period of time can lead to canal water breaching their banks and flooding the surrounding area. Failure of the canal embankments or a blockage in the canal could also lead to flooding surrounding the canal.

Based on review of published topographic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 2016 0.5 meter LiDAR and our field observations, no canals were observed or are mapped within or adjacent to the subject site. Given our field and office investigations, the canal flooding hazard within the subject lot is considered low and it is considered unlikely that canal flooding will impact the proposed development. It is the opinion of GeoStrata that canal flooding hazard should not preclude development at the subject lot.

## 6.12 DAM FAILURE

Dams are structures that store water and diverge and impound water upstream. Most dams have a spillway where water flow from the reservoir is controlled and hydroelectric power is produced. Failure in dams can occur from a collapse or a breach in the structure most commonly due to extended periods of high runoff.

Based on our review of topographic quadrangles and our field investigation, two man made reservoirs are located approximately 850 feet southwest and up-gradient of the subject site (Plate 1 Site Vicinity Map; Plate 2 Topographic Map; Plate 8 Hydrology Map). Based on the topography of the subject site and surrounding area, the distance of the two man made reservoirs from the subject site, and the size of the two man made reservoirs, the dam failure hazard within the subject lot is considered low to moderate. It is our recommendation that the potential for dam failure flooding hazards within the subject site should be considered by the project civil engineer. This hazard should be mitigated by the project civil design engineer through the engineering and development of appropriate grading and drainage plans for the proposed residence. It is the opinion of GeoStrata that dam failure hazard should not preclude development at the subject lot.

## 6.13 PROBLEM SOILS

Problem soils include collapsible soils and expansive soils. Collapsible soils are low density and typically dry soils that decrease in volume when exposed to water. This type of problem soil typically occurs in alluvial fan flooding deposits, dry loess or eolian deposits or unconsolidated colluvium deposits (Owens and Rollins, 1990). Expansive soils are soils that undergo an increase in volume upon wetting and typically include fine grained soils such as clay.

The problem soils hazard is out of the scope of this study. Based on our review of published geologic maps and our field observations, the subject site is underlain by fine-grained clayey soils with sand and gravel. No laboratory testing was performed on these soils as part of this study and therefore this hazard was not assessed as part of this study. In order to understand soil properties for use in the design of footing and foundation elements such as bearing capacity, lateral loading, and settlement potential, a site specific geotechnical study would need to be conducted for the project.

## 6.14 RADON

Radon is a naturally occurring odorless, tasteless and colorless gas that is released during the breakdown of uranium in well drained permeable soils and uranium rich rocks which include granite, metamorphic rocks, black shales, and some volcanic rocks (Sprinkel and Solomon, 1990). Radon gas moves freely in the air and can also dissolve in water which can potentially migrate through cracks and open spaces in rock, soils, and foundations as well as utility pipes.

The radon gas hazard is out of the scope of this study. Based on our review of the *Radon Hazard Potential Map of the Ogden Valley, Weber County, Utah* compiled by Solomon, 1996, the radon gas hazard within the subject site is considered high. A high radon gas potential indicates that the indoor radon gas levels are likely to be greater than 4 picocuries per liter (pCi/L). Indoor testing following construction is recommended for determining radon gas levels and mitigation methods needed.

## 6.15 KARST AND SINK HOLES

A karst is a type of underground drainage terrain that is the result of dissolution of soluble bedrock such as limestone, carbonate rock, salt beds or other types of rocks that are easily dissolved by groundwater circulating through them. The most common type of hazard that forms within a karst terrain is subsidence or collapse of soils, these are referred to as sink holes. Sink holes can be a few feet to hundreds of acres wide and 1 to 100 feet deep and can form slowly or collapse suddenly.

Based on our review of published geologic maps, the karst and sink holes hazards within the subject site are considered low and it is unlikely that karst and sink holes hazards will impact the proposed development. It is the opinion of GeoStrata that karst and sink hole hazards should not preclude development at the subject lot.

## 7.0 GEOLOGIC HAZARDS SUMMARY AND CONCLUSIONS

It is the opinion of GeoStrata that the geologic hazards that we assessed in this study that could impact the subject site or that have not been assessed as a part of this study but which could impact the subject site include: shallow groundwater, stream flooding, dam failure hazard, problem soils and radon gas. Below is a summary of each geologic hazard and GeoStrata's recommendation for mitigation:

- Shallow groundwater hazard within the subject site was not assessed as part of this study. Seasonal fluctuations in precipitation, surface runoff from adjacent properties, or other on or offsite sources may increase moisture conditions; groundwater conditions can be expected to rise several feet seasonally depending on the time of year. Due to the presence of nearby streams, it is possible that shallow groundwater could pose a hazard to habitable structures with basements or crawlspaces. Since shallow groundwater was not assessed as part of this study, a separate geotechnical study including subsurface exploration would be needed to assess this hazard.

- Stream flooding hazard within the subject site was assessed as part of this study. A drainage is located as trending northwest-southeast through the northern portion of the subject site (Plate 8 Drainage Map). No construction of habitable structures should occur within the area identified as a High Flooding Hazard, unless the civil engineer develops proper site grading and drainage plans. It should be noted that all FEMA regulations should be complied with by the design civil engineer. Given our field and office investigations, the stream flooding hazard within the subject lot is considered low to moderate and it is considered unlikely that stream flooding will impact the proposed development as long our recommendations for avoidance of the flood area is followed. It is the opinion of GeoStrata that stream flooding hazard should not preclude development at the subject lot. Proper site grading and drainage plans should be developed for the subject site as a part of the civil engineering design for the lot.

- Dam failure hazard within the subject site was assessed as part of this study. Two man made reservoirs are located approximately 850 feet southwest and up-gradient of the subject site. Based on the topography of the subject site and surrounding area, the distance of the two man made reservoirs from the subject site, and the size of the two man made reservoirs, the dam failure hazard within the subject lot is considered low to moderate. It is our recommendation that the potential for dam failure flooding hazards within the subject site should be considered by the project civil engineer. This hazard should be mitigated by the project civil design engineer through the engineering and development of appropriate grading and drainage plans for the proposed residence. It is the opinion of GeoStrata that dam failure hazard should not preclude development at the subject lot.

- Problem soils hazard within the subject site was not assessed as part of this study. The subject site is underlain by fine-grained clayey soils with sand and gravel. No laboratory testing was performed on these soils as part of this study and therefore this hazard was not assessed as part of this study. In order to understand soil properties for use in the design of footing and foundation elements such as bearing capacity, lateral loading, and settlement potential, a site specific geotechnical study would need to be conducted for the project.

- Radon gas hazard within the subject site is considered high. Indoor testing following construction is recommended for determining radon gas levels and mitigation methods if needed.

It is the opinion of GeoStrata that these hazards should not preclude the development of the subject site, assuming that these recommendations given above will be followed.

# 7.0 CLOSURE

## 7.1 LIMITATIONS

The conclusions and recommendations contained in this report, which include professional opinions and judgments, are based on the information available to us at the time of our evaluation, the results of our field observations and our understanding of the proposed site development. If any conditions are encountered at this site that are different from those described in this report, our firm should be immediately notified so that we may make any necessary revisions to recommendations contained in this report. In addition, if the scope of the proposed development changes from that described in this report, our firm should also be notified.

All services were completed in accordance with the current standard of care and generally accepted standard of practice at the time and in the place our services were completed. No other warranty, expressed or implied, is made. Development of property in the immediate vicinity of geologic hazards involves a certain level of inherent risk. It is impossible to predict where geologic hazards will occur. New geologic hazards may develop and existing geologic hazards may expand beyond their current limits.

All services were performed for the exclusive use and benefit of the above addressee. No other person is entitled to rely on GeoStrata's services or use the information contained in this letter without the express written consent of GeoStrata. We are not responsible for the technical interpretations by others of the information described or documented in this report. The use of information contained in this report for bidding purposes should be done at the Contractor's option and risk.

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