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Full Length Research Paper

Geomorphic and hazard vulnerability assessment of recent residential developments on landslide-prone terrain: The case of the Traverse Mountains, Utah, USA

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Homeowners who live near or on steep slopes of the Traverse Mountains along the Wasatch front in southern Salt Lake City, Utah (USA) are at risk where development of "master-planned communities" has been permitted on known landslide deposits since 2001. Some of the largest landslides in the state of Utah are being modified as road construction and residential development progresses. This paper reviewed the setting of the landslide-prone areas and used Geographic Information Systems (GIS) spatial tools to assess the value of local developments built on mapped slide features. Dataset overlays were compiled to determine the vulnerability of residences, and to quantify potential monetary loss from a future landslide event. The key elements at risk include property, as well as the population, economic activities, and public services of a given region. An initial conservative figure calculated for the vulnerability of residents owning property exceeds $500 million for the Traverse Mountains region of Draper City, based on 2007 property values recorded at the Salt Lake County Assessors Office. In developing this area, the failure to consider existing and potential hazards has caused a myriad of tensions among local government officials, planners, financiers, state regulators, consultants, developers, realtors, and homeowners.

Key words: Landslide, slope stability, vulnerability, Utah, geopolitics, GIS.

INTRODUCTION

Within the Salt Lake Valley of northern Utah, USA (Figure 1) economic and population growth places demands on land access, use and development (Biek, 2005a). As residential development encroaches the benches of the Wasatch Front and the Traverse Mountains, engineering solutions are increasingly implemented to tame the hilly terrain. As the demand for a "home with a view" escalates, and people live on higher slopes and in more remote locales and larger homes, the potential for damage, destruction, and loss of life due to natural hazards grows. Since 2001, development pressure and rezoning efforts in Utah have escalated, and permits are being issued to build new roads and houses on active portions of known landslides. Many of the hill slopes in northern Utah are susceptible to slope instabilities and many areas contain landslides and/or are comprised of landslide-prone geologic materials (Harty, 1991; Machette, 1992; Giraud and Shaw, 2007). In the area of Salt Lake City, various slope instability events have occurred in recent times, including rockfall, debris flow, debris flood, rotational and translational slumps, and earth flows (e.g., Nelson and Lund, 1990).

Investigations conducted by the Utah Geological Survey (hereafter, UGS) have examined the stability of recently active earth flows, debris flows and slides, and assessed the "lessons learned." A key observation reported in a UGS technical report by Christensen and Ashland (2006) is that Quaternary landslides mapped in northern Utah typically remain near a threshold of instability, such that slight increases in groundwater levels

Abbreviations: UGS, Utah geological survey; **GIS,** geographic information systems; **LVL,** Little Valley Landslide.

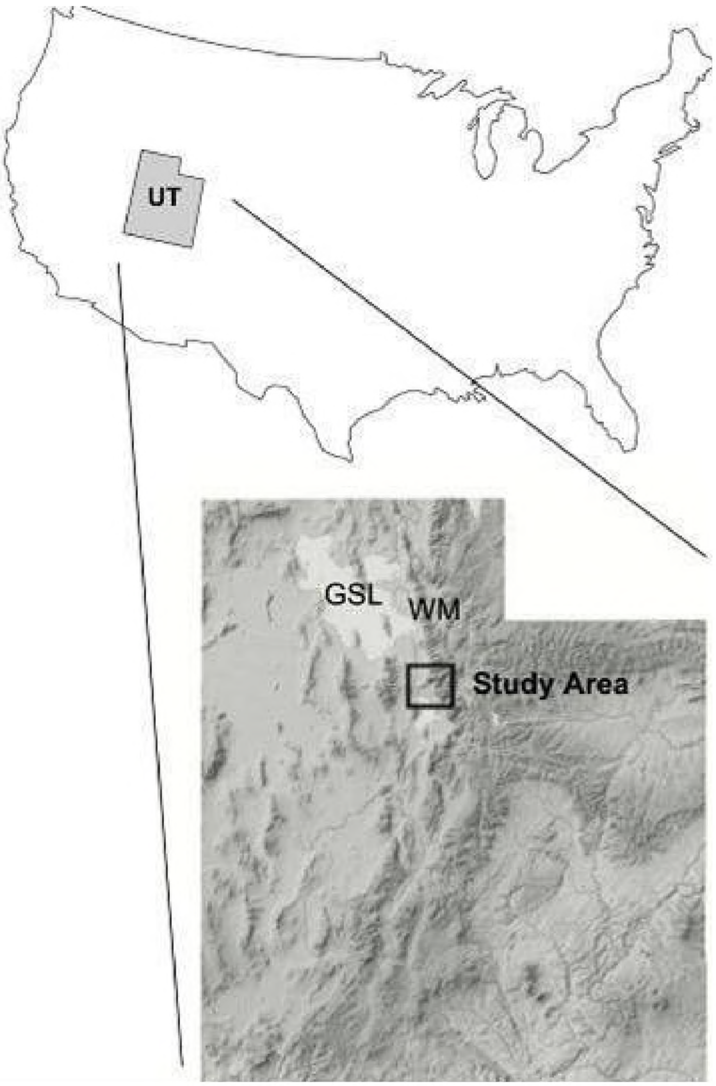

Figure 1. The study area located in the state of Utah, USA. The inset map shows the topography and the location of the Great Salt Lake (GSL), the Wasatch Mountains (WM) and the Study Area (labeled box) in the Traverse Mountains.

can induce further movement downslope. Christensen and Ashland (2006) noted that the safety of many Utah landslides is conditional; however, various geotechnical-engineering analyses have found that “dormant” or “inactive” landslide deposits (following the definitions of Cruden and Varnes, 1996) are adequately stable for development to progress. In their report, Christensen and Ashland (2006) demonstrated that historical landslide behavior in Utah contradicts some of the geologic evidence that is often cited to demonstrate the stability of pre-existing landslides, such as subdued geomorphic expression and natural buttressing of flows by high relief terrain (Crozier, 1986; Dikau et al., 1996). Ideally, accurate slope stability assessments inform the decisions of government agencies, environmental consultants, and developers. Various stakeholders may hold different opinions about a landscape and its suitability for development, but the law does specify some planning protocols, zoning and safety considerations. In Utah, the housing code specifies some standards related to residential siting, and home sites must adhere to specific setback distances from known geological hazards such as faults. Nevertheless, geotechnical engineering design can follow the Utah code for a single residence without considering the terrain elements such as landslide scarps within the larger neighborhood. Hence, a home can be designed to conform to code - and still not be sited with a safe minimum setback distance above and below a mapped geologic hazard such as a fault or a landslide. Through analyses of historical landslide datasets the

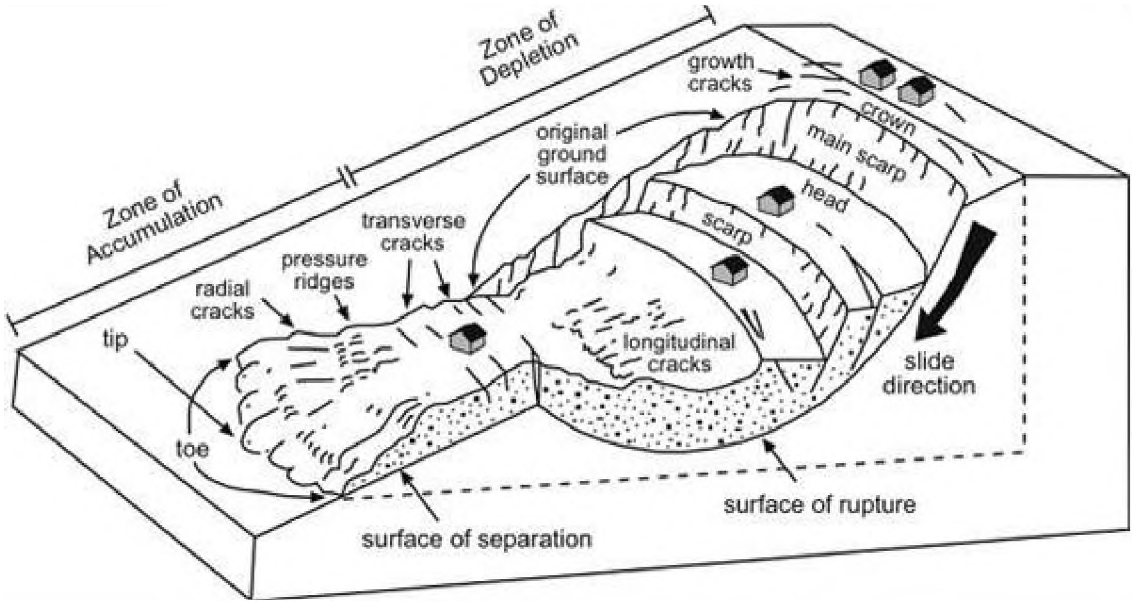

Figure 2. Basic geomorphic anatomy of a landslide in cross-section, redrawn from Crudden and Varnes (1996). Common housing site locations are depicted on terrace treads within the slide, which is a gravity-driven downslope movement of a mass of rock, debris, or materials such as soil and vegetation. Dashed lines indicate the topographic rise and the run-out length. Setback is the distance between the homesite and the geomorphic feature or hazard.

report by Christensen and Ashland (2006) demonstrated that Utah codes may be insufficient because damaging deformation can occur downslope beyond the toe of a landslide, and because landslides can enlarge upslope beyond a setback based on main- scarp stability. The report by Christensen and Ashland (2006) recommended that local conditions and multiple failure types should be considered in estimating effective run-out distances and setbacks from the base of slopes (Figure 2).

A majority of the recorded historical landslide losses in Utah are from reactivated pre-existing landslides (Anderson et al., 1984; Ashland, 2003a). Although landslide-related losses happen every year, and can occur during drought years (Ashland, 2005a), northern Utah has experienced three periods of significantly above-normal precipitation and related landslide losses during the following years: 1983 - 1984, 1997 - 1998, and 2005 - 2006 (Ashland, 2003a). Significant landslide losses occurred in the benchmark 1983 - 84 years (Wieczorek et al., 1989), mainly due to the Thistle landslide, which was the costliest landslide in U.S. history, amounting to more than $200 million in 1983 dollars (Kaliser, 1983; Anderson et al., 1984; Milligan, 2005). Estimated landslide losses in 2005 - 2006 exceeded $10 million (Christensen and Ashland, 2006).

One of the largest landslide deposits mapped by the Utah Geological Survey is the Little Valley Landslide (Figure 3), which is located in Draper City within the Traverse Mountains. The Little Valley Landslide is among the largest complex landslides or earth flows in the state of Utah (Biek, 2005 b, c, and d; Ashland, 2008 a, b) and is currently being developed. The Little Valley Landslide has been active since the Pleistocene, and is comparable in spatial scale to the 1983 Thistle Landslide, which displaced 21×10^6 m^3 of material into the Spanish Fork Canyon in central Utah (Anderson et al., 1984; Milligan, 2005). The Thistle Landslide engulfed a small town, dammed a river system and decimated a significant transportation corridor comprised of two major highways and an important rail line junction. However, there was no loss of life due to the rapid evacuation of the sparse local population (50 people). Retrospective landslide-loss evaluation by Ashland (2003a) found that direct costs of the Thistle landslide were known within a year of the event, but there were more substantial indirect costs (e.g., lifelines, transportation corridors, sewerage and communication networks, remediation, stabilization, etc) that accrued during the five-year period following the landslide disaster.

Incomplete and unreliable loss-estimations for the Thistle Landslide were widely publicized by the media, owing to a lack of accurate landslide-loss and cost data in local jurisdiction agencies and tax assessors at the county, state, and federal level. To improve the reliability of loss estimates after such an event, Ashland (2003a) recommended implementation of a Geographic Information Systems (GIS) approach for statewide landslide-loss estimation based on assessment of landslide susceptibility and vulnerability, or the amount of building inventory at risk as derived from median property values and

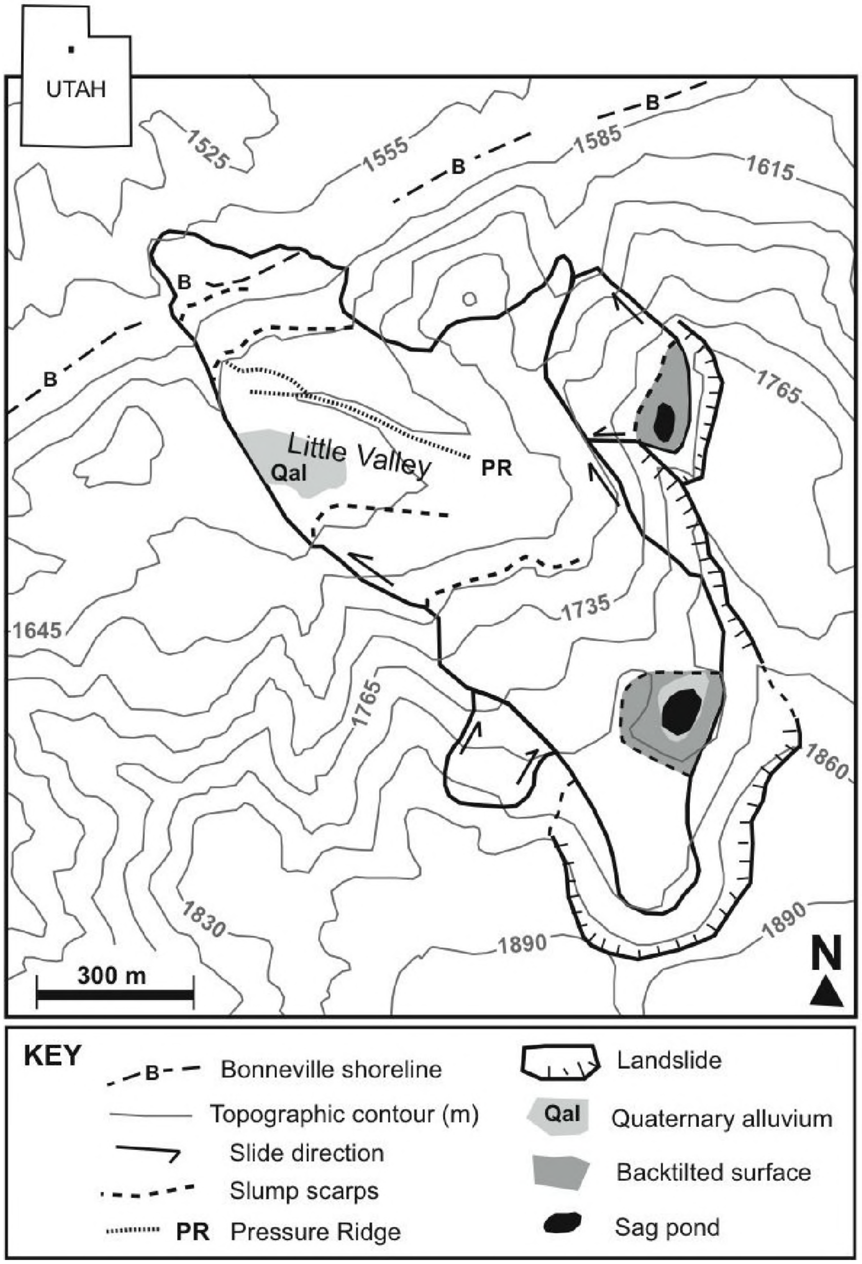

Figure 3. Map of the Little Valley Landslide deposit, modified from Biek (2005a) and Ashland (2008b). Dashed lines indicate the major lobes and crest lines of the back tilted surfaces. Note two prominent rotational landslide blocks: one in the eastern part of the head and another along the east flank of the slide. Each is characterized by a back-tilted surface partly buried by pond deposits. Today, sag ponds still remain in the upslope parts of the rotated blocks. The toe of the landslide deposited into Lake Bonneville deposits dating to the ancient high stand of Great Salt Lake ~16,000-18,000 BP. A pressure lobe of the LVL is naturally buttressed.

and other factors.

OBJECTIVE

This paper assesses the potential effects of landslide activity in the Traverse Mountains, where developments of "master-planned communities" have been permitted on landslide deposits since 2001 (Figures 4 and 5).

Governmental datasets and field observations are thoroughly reviewed and compiled in a new GIS for vulnerability assessment. The present analysis includes

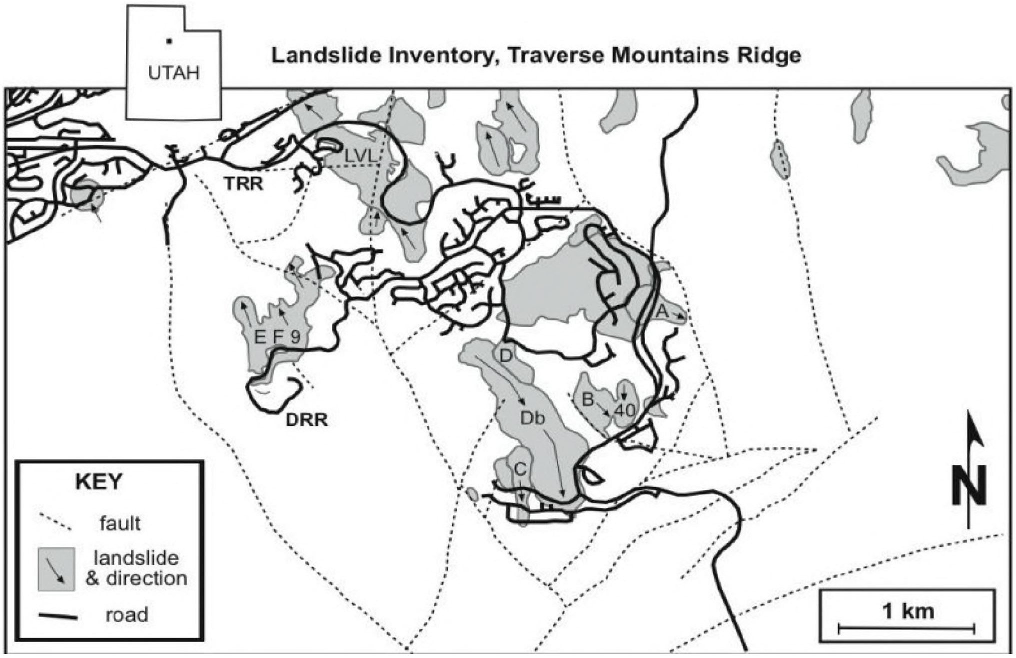

Figure 4. Landslide deposits in the Traverse Mountains region, after those mapped by the Utah Geological Survey (Biek 2005a, b, c and d), with labels as recorded in the UGS landslide inventory. Arrows denote the direction of slip. LVL=Little Valley Landslide. Connector roads are labeled: DRR=Deer Ridge Road; TRR=Traverse Ridge Road. Most of the faults depicted in the map are normal.

Figure 5. "Google Earth™ image of the Traverse Mountains study area as mapped in Figure 4. The Steep Mountain scarp is apparent along the left side of the image. TRR: Transverse Ridge Road; DRR: Deer Ridge Road".

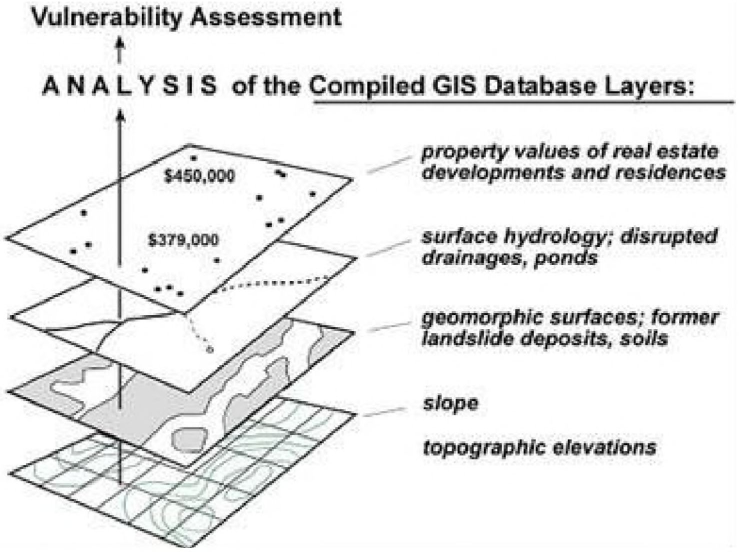

Figure 6. Datasets in the GIS compilation were analyzed and a vulnerability assessment was generated.

the reactivation of the Little Valley Landslide (LVL), which could have potentially devastating effects due to its upslope position and proximity to the populated urban corridor in Salt Lake Valley.

This paper has four main goals: (1) to provide an overview of the geological setting of the mapped landslides and developed landslide-prone areas in the region of the Traverse Mountains near Draper City; (2) to document the specific natural factors influencing landslide activity in this region, and discuss the anthropogenic activities that may impact slope stability; (3) to assess key components of risk and calculate a metric of vulnerability by compiling available information for predicting potential monetary loss in this region; and (4) to discuss some of the sociopolitical issues influencing development, environmental management, and regional planning in the southern part of Salt Lake Valley.

DATASETS AND METHODOLOGICAL APPROACH

- Field-based observations complemented an extensive review of available reports on the environment, geology and hazards of the Traverse Mountains.
- Using the ESRI software package ArcGIS version 9.2, a Geographic Information System (GIS) was built for landslide-prone areas in the Traverse Mountain area (Figure 6). Geologic maps were digitized from primary sources and records from the State of Utah government, and additional data layers were compiled from observations. Field-checking of landslide features was performed and Cartesian coordinates were verified with a hand-held GPS device. The derived geomorphically-classified polygons were rasterized and combined with the digital elevation model (DEM).
- Layers were built to consider the value of property and built structures as recorded by the Salt Lake County Assessors Office for the 2007 Tax Year. Property values for the southern annexed portion of the region in Draper City that is located within Utah County could not be included in the assessment because those records were not compiled digitally. Cadastral data were compiled in a GIS layer to develop estimates for the potential total risk value in US dollars, after the occurrence of a landslide disaster event.
- Analysis of the GIS layers followed basic methods (Burrough and McDonnell, 2000) and used tools in the software. A main goal was to demonstrate the association of houses sited on vulnerable geomorphic settings.
- Assessment of the vulnerability metric considered the value of land and built structures in terrain components related to landslides, including: 1) those homes built in and on the UGS mapped landslide deposits and toe areas; 2) built home sites within the headcut and scarp regions of the UGS mapped landslides; and 3) residential areas adjacent to or downslope of known slides.
- To assess landowner and resident perceptions and opinions, more than 50 homeowners in Draper were informally interviewed, and an additional 208 Utah residents were canvassed using a simple poll-survey. Qualitative survey questions focused on perceptions of landscape attributes, risk elements, safety, the role of the government and real estate law.

OVERVIEW OF THE STUDY AREA AT RISK

The traverse mountains geographic setting

Northern Utah is a high relief region located at the junction of the Rocky Mountain and Great Basin physiographic provinces, with slopes ranging from slight (1 to 5%) to great (5 to 100%). Salt Lake Valley has the Wasatch Mountains along its eastern border, and the Oquirrh Mountains to the west. The east-west oriented Traverse Mountains extend from the Wasatch Front as a structural salient expressed between the Salt Lake and Provo segments of the Wasatch fault (Hecker and Harty, 1990). The modern topographic relief has developed over the past 20 million years as a result of extension and magmatism following Late Tertiary mountain building (that is, the Sevier and Laramide mountain-building periods) (Machette, 1992; and Biek, 2005a, d).

In general, the local basement of the Traverse Mountains includes rocks belonging to the Pennsylvanian-Mississippian Oquirrh Group, which includes clastics and carbonates associated with a shallow marine and shelfal sequence, as well as highly fractured

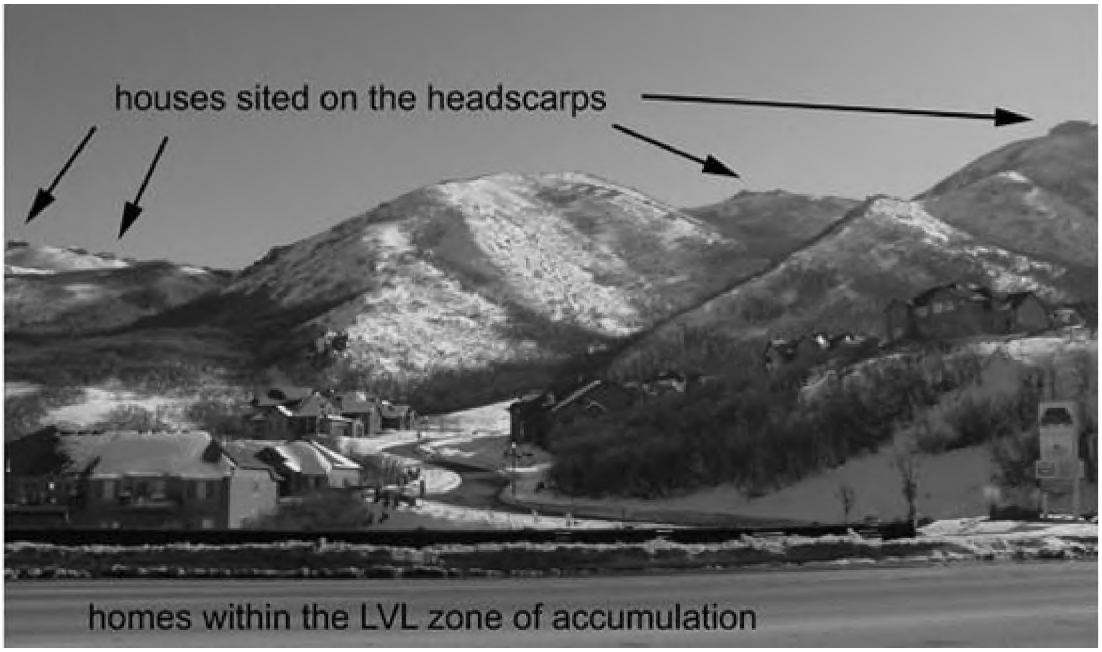

Figure 7. Looking southeast from the Traverse Ridge Road toward the development in the Little Valley located in the accumulation zone of the LVL. The homes in the foreground are sited on the hummocky topography created by LVL deposits. Houses apparent along the ridgeline are sited on terraces in the head scarp positions of the landslide.

fractured orthoquartzites (Stokes, 1986). A 300 m thick sequence of Middle Tertiary volcanics unconformably overlies the palaeozoic sequence. Tuffs, breccias, lava flows and volcaniclastics making up the tertiary section are deeply weathered and have been locally hydrothermally altered and cross-cut by rhyolitic dikes and plugs (Biek, 2005c). The region is quite extensively fractured and faulted; a series of normal faults strike roughly north-south throughout the region (Figure 4). Highly plastic soils mantle the region (CMT Engineering Laboratories, 2007). Landslide deposits are made up of a heterogeneous, poorly sorted mix of clay and coarse materials, including large blocks (house-sized) of displaced volcanic rock.

There are currently several landslides mapped in the Traverse Mountains. On Utah Geological Survey (UGS) maps, some of the largest slides have been labelled with letters or numbers. The UGS have begun to develop a landslide inventory for the region, and have made geomorphic observations and acquired some radiocarbon ages to develop a partial reconstruction of the movement of landslides on the Traverse Mountains over time (e.g., Biek, 2005 d). The Little Valley Landslide (hereafter, abbreviated LVL) is the best studied of these landslide features. For example, CMT Engineering Laboratories (2007) studied the local soils, and Tingey and others (2007) conducted airborne LiDAR (Light Detection and Ranging) and geophysical surveys in the region of the LVL. Other data for the LVL have been discussed in reports by Ashland (2008 a, b).

The LVL is a very large and complex slide-earth flow, and its geomorphic expression is rather subdued, with a small bowl-like valley, hummocky topography and some chaotic bedding apparent within the zone of accumulation (Figure 7). The LVL appears to be a deep-seated slide and consists of several stacked lobes and two rotational blocks in the head region and along its eastern flank. The slide extends ~ 1770 m downslope from between the ridgeline of the Traverse Mountains, and within the Little Valley area, the landslide debris spans a maximum width ~550 m. Local geomorphic evidence (e.g., observations of bent trees, displaced poles, disrupted drainages, deformed soils) suggests ongoing movement of the slide downslope. Radiocarbon dates on organic samples collected at depths exposed by stratigraphic trenches through the displaced sediments suggest that the initial rupture of the LVL occurred at least ~29,000 yr ago (Ashland, 2008b).

Materials making up the LVL toe appear to have run out ~100 m to the northwest into the Lake Bonneville shoreline terrace (Oviatt et al., 1992), which is a prominent and well-dated physiographic feature in the region. The emplacement of toe materials in the area past the range-bounding fault along north end of the Traverse Mountains (aka, the Steep Mountain fault) thus occurred around ~17,000 years ago; this is some of the evidence that the slide may have been activated by earthquake activity during the Pleistocene. There is additional radiocarbon-dated evidence that the LVL slide was active episodically ~13000, ~11000, ~7000 and ~4700 years ago (Tingey et al., 2007; Ashland, 2008b), but event duration and the precise rate of movement is not well constrained. It appears that the LVL overlies even older landslide deposits that make up the hummocky landscape downslope, upon which a golf course has been built. Deep-seated (ruptures at depths >10 m) landslides have been mapped throughout the Traverse Mountains. Each slide mapped on Figure 4 is best viewed as a complex earth movement, with multiple lobes at various scales of observation, indicating a coalescence of failure planes. The net vectors of mass movement indicating displacement are always downhill, but deformation may proceed at different rates and compass directions. On the ground, the recognition of landslides in the Traverse Mountains takes a trained eye, since the natural terrain elements have been disrupted by development and built structures.

Factors affecting landslides in the Traverse Mountains

Generally speaking, landslides occur when the downslope weight of the mass along a slope exceeds the strength of the material along the slip surface. When the driving force (downslope weight) exceeds the resisting force (internal material strength), the material comprising the slope will move. According to Griffiths (1999), landslide casual factors can be classified into preparatory factors and triggering factors. Preparatory or predisposing factors make the slope susceptible to movement without actually initiating the downslope movement, while the triggering factors initiate or perpetuate movement. Triggering factors include any external stimulus that produces an immediate change in the stress-strain relationships in the slope, resulting in movement (Wieczorek, 1996). "Triggers" known to have caused or reactivated landslides in Utah include heavy rainfall or snowmelt, earthquake shaking, erosion, or human activities (Wright and Rathje, 2003; Ashland, 2003b).

There have been several baseline studies, environmental impact assessments and other consultant reports commissioned in association with the development of the Traverse Mountains (e.g., Delta Geotechnical Consultants, 1997; CMT Engineering Laboratory, 2007). Additional geological studies were conducted by the state (e.g., Utah Geological Survey), who found that the prior occurrence of previous landslides in a given area is paramount in predicting high potential for additional landslides in an area. This is to say that slope instabilities usually reoccur in locations of former landslides. Hence, predicting the likelihood of future landslide occurrences requires an understanding of conditions and processes controlling past landslides in the area of interest, including: (1) geological setting, (2) groundwater conditions, (3) geomorphological conditions, (4) hydroclimatic factors, (5) seismic activity, (6) weathering, and (7) anthropogenic factors. Table 1 summarizes observations of factors affecting slope stability in the Traverse Mountains.

In the Traverse Mountains, "the development footprint" since 2001 is emerging as one of the key factors that compromises slope stability. Human activities and hillslope modifications associated with development have altered the landscape significantly, and these can further predispose slope movements. Excavation of materials from the slope or crest (crown area) of a landslide deposit tends to reduce resisting force. Road building efforts (e.g., grading, cutting, and filling activities) have obscured the landslide topography across the region, and have reworked materials from all portions of multiple landslides. Road development has required significant engineering efforts, including excavation, fill removal and movement, and drainage modification. Efforts to regrade existing slopes have altered the resisting strength of slope materials (Figure 8). Vegetation removal and the emplacement of nonporous asphalt roads have redirected the pre-existing natural drainage systems. Constructed roads and corridors experience the heavy traffic of construction equipment, trucks and haulers, which create artificial vibrations that, can reduce cohesive material strengths. Removal of toe material from a landslide can promote slope instabilities along the path of the slope (Figure 9). A significant amount of landslide toe materials has been removed for the development of roads within the region. Construction and road grading has removed geologic materials from the toe portions of at least eight different landslides within the Traverse Mountains region (Figure 10).

Loading the crest or crown area of a former landslide is another factor that can promote slope instability. Development of the Traverse Mountains has placed additional water weight (that is, subterranean water tanks) and new buildings in the crestal positions at various localities along terraces above the headscarps of known landslide deposits. Figure 11 shows homes built above the head scarp of the LVL. Homeowner activities can influence slope stabilities. For example, extensive irrigation and lawn watering activities by residents can enhance water runoff and soil pore water contents that can reduce the resisting force of slope materials. Leaky mains or burst utility pipes, as well as emergency situations such as water from fire mitigations, sudden flashflood storm events, rapid snowmelt, or backed-up sewerages can also lubricate slope materials, and enhance downslope mass movements (Ashland, 2003b).

Defining and assessing hazard vulnerability and risk

Areas with a potential susceptibility have some likelihood of a potentially damaging landslide occurring within a given area, and vulnerability is the potential to experience adverse impacts on the local population, property, economic activity, public services, etc (Alexander, 1999). Risk is the expected degree of loss due to a particular landslide phenomenon. Barnett et al. (2008) provides a thorough review of these various terms and discusses the applications of vulnerability indices. Vulnerability is commonly assessed as a monetary measure of damages experienced when elements at risk are affected by a hazardous process or event (Wisner and Luce, 1993; Blaikie et al., 1994; Wisner et al., 2005). Elements at risk may include the population, properties, economic activities, and public services of a given region (Alexander, 2004). Vulnerability is commonly estimated in monetary terms of cost associated with damage repairs or replacements after damages are accrued (Committee on the Review of the National Landslide Hazards Mitigation Strategy of the National Research Council 2004; Galli and Guzzetti, 2007).

Vulnerability to landslides is not a standardized analysis, especially compared to earthquake and volcano vulnerability metrics (Glade and Crozier, 2004; Zimbelman et al., 2003). For landslides, calculated economic measures often consider monetary equivalences to the complete loss of the assets or total destruction of all assets or elements at risk within an investigated area (e.g., Carrara et al., 1991). Less tangible elements of the political, social, and psychological and community vulnerabilities are more difficult to assess (Blaikie et al., 1994). Despite some limitations, however, vulnerability analyses may be beneficial for assessing risk components, measuring the robustness or the fragility of elements, and considering exposure to, or protection from a potentially damaging event (e.g., Fedeski and Gwilliam, 2007; Committee on the Review of the National Landslide Hazards Mitigation Strategy of the National Research Councils, 2004). Vulnerability assessments can also inform citizens and policymakers (Godschalk et al., 1999) and guide regional planners and regulators (e.g., Erley and Kockelman, 1981; Olshansky, 1998), preferably in advance of a disaster event.

RESULTS AND DISCUSSION

Assessment of monetary vulnerability

The GIS-based assessment of regional vulnerability in the Traverse Mountains generated a monetary estimate of $500 million for the development area of 14.5 square kilometers (~3600 acres), which includes the subdivision SunCrest. Only built dwellings with assessed property values on file for the 2007 tax year were considered. This $500 million vulnerability metric is a conservative figure, because the rate of residential development in the region is high, and it outpaced the recording of valuations. Furthermore, the figure does not consider any statistics in regards to vulnerable infrastructure. In the event of a disaster, for example, if the roads were destroyed, there would be additional high costs for repairs and/or replacement. Based upon 2007 estimates reported in the local Salt Lake City News and in reports (CMT Engineering Laboratories 2007), the estimates to repair the

Table 1. Observations in regards to landslide causality in traverse mountains

Geological predispositions	
a. Weak substrate materials	Bedrock and soils are weak (Ashland 2008a).; basal slip surfaces or glide surfaces most commonly form within local Tertiary volcanic rocks (Biek, 2005a, b).
b. Sensitive materials	Expansive clays present (CMT Laboratories 2007).
c. Weathered materials	Can be said of most of the hillslope materials.
d. Jointed, sheared, fissured or fractured materials and other structural discontinuities	Orthogonal joint sets present. Geologic substrate and bedrock intensely fractured. Deformed soils. (Ashland 2008a).
e. Faults	Several mapped in area (Ashland 2008a and b); fig. 4
f. Soil instabilities	Soils are thinly developed & compressible (CMT 2007).
g. Permeability contrasts present	Poor drainage apparent; sag ponds develop on clay-rich areas along back-tilted surfaces within the LVL. Permability problems present (CMT Laboratories 2007).
h. Contacts of geologic units	N/A, but could be problem at stratigraphic depth.
i. Contrast in stiffness or plasticity	Present (CMT Laboratories 2007)
j. Former failure plane or prior landslide	Several mapped by Biek 2005 a-c, Ashland 2008 a and b.
Morphological causalities	
a. Slope and upslope hillslope steepness	Slopes >15 degrees across the region. UGS maps.
b. Tectonic uplift	Active uplift is ongoing across the Rocky Mountains.
c. Isostatic rebound	Uplift due to crustal thinning, and unloading since Lake Bonneville time (Crittendon1963, Bills and others 2002)
d. Erosion of slope and toe areas	Road construction along LVL caused extensive modifications Figs. 7, 8, 9
e. Erosion of lateral margins	Road construction esp Traverse Ridge Road, and foundation preparation. Fig. 8b.
f. Subterranean erosion (solution, piping)	None noticed but there could be karstic dissolution of subsurface limestone units of the Oquirrh formation
g. Deposition loading on slope or along crest	Housing developments placed through all areas of landslides. Figs. 7, 8B, 10, 11
h. Vegetation removal (construction, forest fire, drought)	Extensive removal of plants across the region, due to construction and road building.
Physical triggers	
a. Intense rainfall	e.g., rainfall triggered initiation of '84 Thistle Landslide
b. Rapid snowmelt	Does occur.
c. Exceptional precipitation	1983-84, 1997-98, and 2005-06 (Ashland 2003a).
d. Storms: flash floods, sheetflow	Can occur.
e. Seismic: Earthquake shaking, fault rupture, mass movement	Estimates of the maximum magnitude of Wasatch Fault earthquake ~7.0 to 7.5 on the Richter scale once every 300-400 years (Solomon and others 2004). Draper Heights landslide (Ashland 2008a).
f. Snow and Ice: freeze-thaw weathering	Region endures harsh winters.
g. Clay-rich expansive soils: shrink and swell weathering	Has contributed to documented road problems. including failure, fig. 11 (CMT Laboratories 2007).

existing damaged roads amount to around $10 million (Gehrke, 2008a). The $500 million figure for vulnerability does not capture this or any other costs associated with replacing damaged local roads, sewers, and other public works.

Like any natural hazard, issues of risk assessment and mitigation are complex (Hungr et al., 2005). While the vulnerability of developments on pre-existing landslides is high and may be viewed as a potential "time bomb ticking," certain areas could remain stable for many years, until slopes become unstable and the landslides reactivate. The decisions that place people and property in harm's way are often not considered until a disaster strikes. This paper outlines some of the core issues involved with the residential developments on mapped landslide deposits in the Traverse Mountains in Utah.

Potential effects of slope hazard events

Reactivation of mapped landslides would likely impact

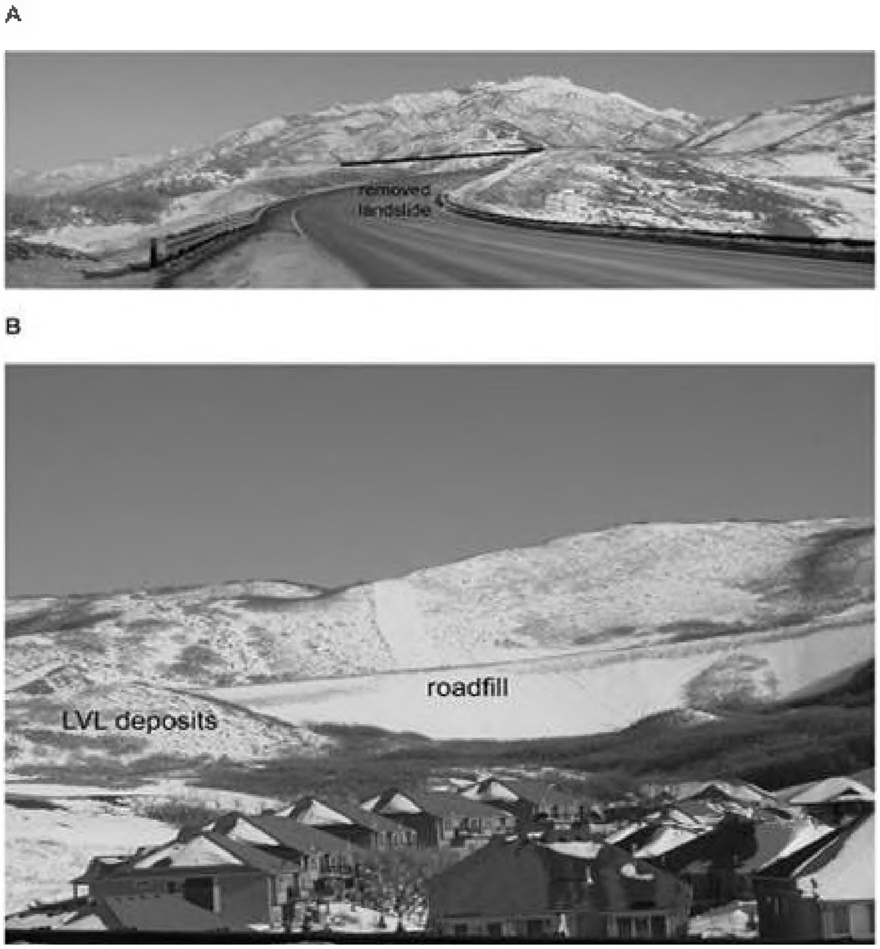

Figure 8. A -- Photograph showing where LVL deposits were removed to construct the primary connector road to the mountainous region. Construction of Traverse Ridge Road involved extensive modification of the landscape. Deposits were removed from the toe area and there was extensive grading of topography within the LVL zone of accumulation. B -- Looking east from the "valley bowl" within the LVL zone of accumulation, towards the Traverse Ridge Road, which is the main access road that snakes up the mountain at a 10% grade. Road building has eroded the lateral margins of the slide deposit. Hummocky terrain is present between the houses and the road fill.

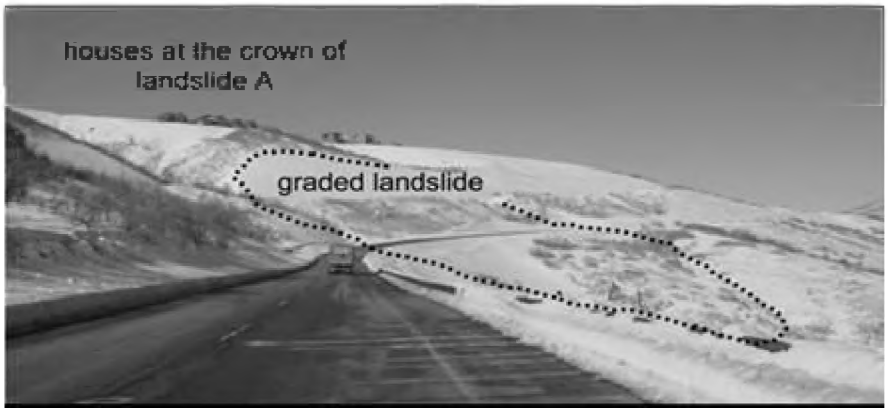

Figure 9. Looking due north along the Traverse Ridge Road, where road construction and grading efforts have deforested the natural environment and altered much of the topography created by deposits of landslide A. Houses have been built at the crown of Landslide A, in a domain that lies within another, larger landslide deposit. Garbage truck for scale.

Figure 10. Southwest view along Traverse Ridge Road, near the landslide 40 -landslide B area. Road construction through the region has removed a significant amount of landslide material. Homes have been built in the down slope region.

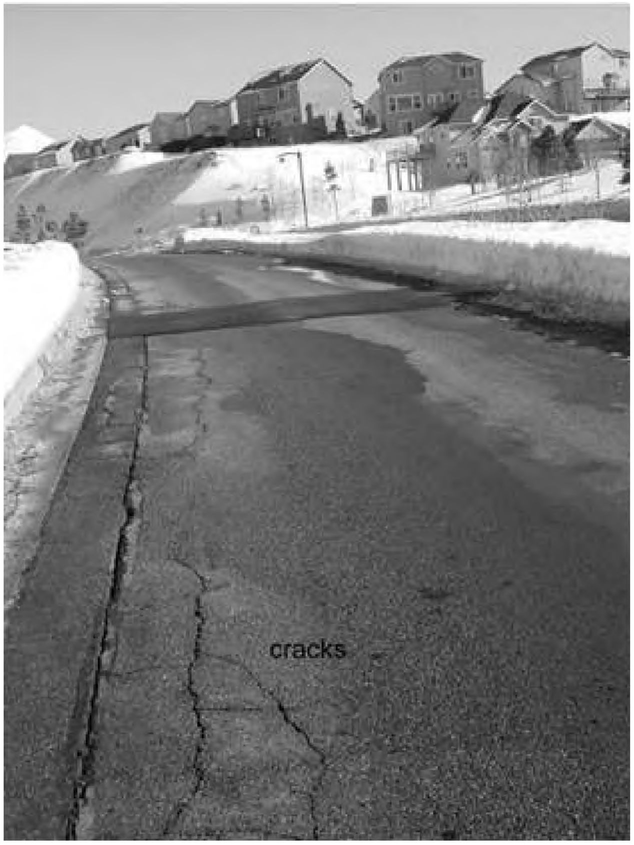

Figure 11. In the background, houses have been built upon a terrace above a head scarp. In the foreground, radial growth cracks indicate that local failure zones are setting up in the asphalt along Deer Ridge Road where the road runs along the ridge top, which is the crown of the LVL. For reference, the LVL is to the left of the photograph taken.

the roads in the Traverse Mountains, by deforming them or pushing debris materials over them such that they are blocked. This would impact transportation corridors and evacuations from the residential developments, since there are few roads or other transportation options available. Traverse Ridge Road is the primary collector and it is the major route in and out. In the event of an emergency, there is a strong possibility for vehicular traffic problems and bottlenecking delays. The estimated Average Annual Daily Traffic (AADT) for Traverse Ridge Road and Deer Ridge Drive is 5,300 with 11% medium truck and 5% heavy truck. The estimated equivalent single axle loads (ESALs) for the roadways are approximately 2.53 million (CMT Engineering Laboratories, 2007).

The population at risk

People at risk of experiencing slope failure in the Traverse Mountain landscape, amount to hundreds of households (US Census Bureau Population Division, 2008). While the area was slated for development of 3000 homes, it is estimated that home occupancy in the developed parts on Traverse Mountain landslide deposits is presently at 1/3 capacity. Residents of developments in the region are typically more affluent than the average inhabitant of Salt Lake Valley. Since 2005, home prices within the SunCrest subdivision in the Traverse Mountains have ranged from $220,000 to >$2 million, with a home median value estimate ~$390,696 in 2006, and ~$410,134 in 2007 (www.zillow.com). The median price range of houses in Salt Lake City Metropolitan Area is lower; a recent figure is $229,900 for December 2008 (Salt Lake Board of Realtors, 2008).

Risk perceptions by the population

An informal survey of local homeowners interviewed door-to-door, at public community functions, and at open houses suggests that most residents in the Traverse Mountains believe there is very little risk of a landslide affecting their home or property. Most people think that landslide hazard is low because building on risky terrain is regulated and laid out in a logical manner. More than 70% of the people casually surveyed in northern Utah (n= 208) think that the US law in regards to landslides is adequate to protect them from harm. A casual survey of comments posted on websites regarding related news stories and on community blogspaces (http://www.deseretnews.com/, http://www.sltrib.com/, http://suncrestresidents.blogspot.com/) suggest that many citizens who are self-identified as living in these developments believe they are quite safe. There is a prevailing feeling that it is more hazardous to live along the Wasatch Fault or in a liquefaction-prone zone down in the Salt Lake Valley, as compared to living in developments located in the Traverse Mountains.

Aspects of vulnerability at the personal level

Lack of accurate, accessible information about geologic hazards and vulnerability to landslides in residential zones delimits citizens' ability to determine personal risk elements (Olshansky and Rogers, 1987; Harmsworth and Raynor, 2004). For both citizens and governments, access to accurate Earth Science information and its wise use are key elements for planning and disaster abatement (Christenson, 2003). Various government agencies and the Utah Geological Survey has developed a number of informational brochures on local hazards (e.g., Eldredge, 1996; Solomon, 2001), most of which are available online, and many of which address the Traverse Mountains region.

Ironically, a geologic-hazards monument and sign that explained and mapped out vulnerable areas in the Traverse Mountains and Draper City was met with great resistance during 2008 (Gehrke, 2008b). The Salt Lake Tribune reported that residents worried their property values would plunge if the city publicized the negative aspects of the mountaintop community, causing property taxes elsewhere to jump. Some residents suggested "if the city was adopting such an open policy, it should erect signs detailing how many sex offenders live in certain ZIP codes and one near the prison warning people to watch out for escaped convicts" (Gehrke, 2008b).

Utah real estate law

In the state of Utah, the law does not stipulate disclosure of flood, environmental conditions, or hazards in real estate transactions, whereas regulations in Oregon, Washington, and California require disclosure. As such, Utah sellers (and probably developers) remain protected from lawsuits by the tradition of *caveat emptor*, better known as the "buyers beware" clause. This passage is a distillation of a longer phrase, "*caveat emptor, qui ignorare non debuit quod jus alienum emit,*" which roughly translates from Latin to: "let a purchaser, who ought not to be ignorant of the amount and nature of the interest which he is about to buy, exercise proper caution." The logic behind *caveat emptor* is that while the seller might know more about the problems of a property, the buyer should be more knowledgeable about what would satisfy the needs of the buyer as compared to the seller, who may have different standards (Nanda, 2006). However, a strict interpretation of *caveat emptor* places buyers in a rather vulnerable position with regards to hidden defects in the property. Lacking a full investigation or experience, buyers have no way to learn the real condition of a property, and no protection from "lemons" (Lefcoe, 2004). The *caveat emptor* tradition has remained a standard practice in real estate long after its abandonment in other sectors. United States courts began to reject *caveat emptor* around 1900, finding in favor of implied warranties for goods that were "sold by description and not inspected before sale." Car manufacturers, for example, were one of the first sectors to develop warranties, largely due to the court cases they faced (Englin, 2006).

Concerning real estate transactions within the United States, legislation varies by state and seller disclosure is not legally mandated in many places. While the primary purpose of disclosure from a realtor's perspective is protection against litigation, Stern (2005) holds that disclosure will "reduce informational asymmetries, create better matches between buyers and sellers, and increase the fairness of transactions." A key benefit of disclosure is to reduce the information gap between the seller and the buyer, which can benefit the buyer rather than the selling agent. The rationale of consumer protection legislation, including disclosure, is based on the assumption that humans are generally "risk-adverse" and makes rational decisions using the knowledge the person has about each issue and its alternatives (Palm, 1981; Guthrie, 2006). According to these assumptions, if a buyer is presented with a disclosure form, then he/she will choose to buy, if the option is available with the least risk and best-sounding argument. In terms of natural hazard disclosure, a buyer would attempt to avoid buying property in a hazard area or take actions to lessen the potential hazard (Nanda and Ross, 2008). Providing information about the location of a hazard zone allows a buyer to make a rational choice, and enables the buyer to make choices about whether to buy property within the zone or to taking mitigation measures upon purchase of the property (Hendricks, 2002). In spite of this logic, some studies have suggested that people may prefer to tolerate risks rather than avoid them. One classic study conducted in the late 1970's evaluated the impact of earthquake disclosure requirements on home buying choices in California, and concluded that disclosure legislation did not have much impact on buyer behaviors (Palm, 1981). Studies indicate that when disclosure happens during the late stages of a transaction, the buyer is less likely to back out of the situation or place a high value on the information (Hendricks, 2002). Recent studies by Jenkins-Smith et al. (2002), Stern (2005), Englin (2006), and Wiley and Zumpano (2008) have reviewed the dynamics of natural hazard disclosure by sellers in real estate transactions. Nanda (2008) analyzed 21 years of real estate transactions from 50 US states and found that the average seller may be able to fetch a higher price (about three to four percent) for a residence by furnishing a state-mandated seller's property condition disclosure statement to the buyer. However, property disclosure statements are not routinely required across the US and current (that is, 2009) law surrounding real estate transactions in the state of Utah does not require disclosure.

CONCLUSIONS AND GEOPOLITICAL IMPLICATIONS

Because real estate law in Utah does not require disclosure of natural hazard events (e.g., former landslides or floods), buyers must shoulder the responsibility of assessing the potential vulnerability of an area for hazards. Although geologic maps and reports are available for regions in Utah, most potential buyers are not likely to refer to them in the process of their decision-making. Current zoning is likely inadequate to avoid hazards in landslide-prone areas of the Traverse Mountains. The degree to which extensive hillslope modification and development activities have affected stability in the study region can only be assessed when surface reactivation or another deep-seated landslide event occurs.

Initial estimates for the hazard vulnerability in the developments analyzed within the Salt Lake County portion of the Traverse Mountains can be partially assessed in monetary terms. Initial estimates indicated the vulnerability is in excess of $500 million as based on the 2007 property values on record. Much of the vulnerability will be borne by the individual homeowners affected. This initial estimate for vulnerability does not figure in any damages to infrastructures such as the roads or other public works (affected sewerage, emergency management, pipelines, electrics, utilities etc), which could amount to several additional millions of dollars in repairs. As such, landslides affecting the Traverse Mountains could eclipse the costs accrued by the 1983 Thistle Landslide.

Landslide vulnerability in Utah is dominantly predicated by the location of former slides, which are likely to reoccur on existing planes of weakness in the landscape. Reactivation is largely dependent on slope, material, and water saturation, which is most prevalent during the snowmelt runoff and late summer/fall months. Officially monitoring these parameters in known vulnerable regions is a best practice for environmental management and regional planning (e.g., Reid et al., 1999). At present, the Traverse Mountains region is under-monitored for weather and slope stability conditions, and there are no local stations that measure snow and rain accumulations such as the US government's SNOTEL program (http://www.wcc.nrcs.usda.gov/snotel/Utah/utah.html).

City and county engineers wanted Terrabrook, the primary developer, to install inclinometers and piezometers to measure and monitor ground movement in the region, but an agreement was reached that three of the $10,000 instruments could go in after construction was completed (Swinyard, 2005). However, no monitoring instruments were installed, because the Dallas-based developers of the SunCrest subdivision declared bankruptcy in April 2008 prior to the completion of the slated construction (Palmer, 2008 a, b, c, d, Sanchez, 2008 a, b, Toomer-Cook, 2008). After the loans were defaulted, the project was bought by Zions Bank for $52.3 million in July 2008, and most activities have been indefinitely suspended (Smart, 2009).

Geopolitics, complexities and lawsuits continue to plague the development of the Traverse Mountain. A newspaper article by Gehrke (2008) outlines some of the issues and discusses how the failure to properly anticipate and mitigate potential hazards and associated complications caused a myriad of tensions and problems among local government officials, planners, financiers, state regulators, consultants, developers, realtors, and homeowners. At present, many stakeholders face difficulties - the original developers who sought the permits to develop on the mapped landslides have defaulted on $58 million in loans, and since 2008 a bank owns the property deed for an unfinished development (Gehrke, 2008). Roads have begun to fail and are continuing to degrade because much of the soil is unstable (CMT Engineering Laboratories, 2007; Gehrke, 2007); retaining walls are breaking, and house foundations are cracking.

The real estate market has collapsed, with some construction projects having been abandoned midstream, and about 2/3 of the residences remaining vacant. Zions, the holding bank of the property, conducted a long and futile search for a new investor to take over the development project (Meyers, 2008). New investors may have been daunted by the prospect of inheriting problems, and the complications of meeting the more specific codes specified in the Draper City Geologic Hazard Ordinances (2007), which was enacted in December 2007 (Sanchez, 2009). In June 2009, Zions bank filed a $25 million lawsuit against the city of Draper for mismanagement of the site (Smart, 2009). It seems clear that this bank-owned “master-planned community” developed on top of one of Utah’s largest landslide deposits faces an unstable and litigious future.

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REFERENCES

Alexander ED (1999). Vulnerability. In Alexander ED, Fairbridge RW (eds), Encyclopedia of Environ. Sci. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 663–664.

Alexander ED (2004). Vulnerability to landslides. In: Glade T, Anderson MG, Crozier MJ (eds) Landslide risk assessment. John Wiley Publishers, New York, New York, pp. 175–198.

Anderson LR, Keaton JR, Saarinen TF, Wells WG (1984). The Utah landslides, debris flows, and floods of May and June 1983-1984: Washington, D.C., National Academy Press, p. 96.

Ashland FX (2003a). The feasibility of collecting accurate landslide loss data in Utah: Utah Geological Survey Open-File Report 410, p. 25.

Ashland FX (2003b). Characteristics, causes, and implications of the 1998 Wasatch Front landslides, Utah: Utah Geological Survey Special Study 105, p. 49.

Ashland FX (2008a). Reconnaissance of the Draper Heights Landslide and other possible earthquake-induced, shallow disrupted soil and rock slides in Draper, Utah. Utah Geol. Survey Open File Re. 519. p. 14.

Ashland FX (2008b). Reconnaissance of the Little Valley Landslide, Draper, Utah: Evidence for possible late Holocene, earthquake induced reactivation of a large pre-existing landslide. Utah Geol. Survey Open File Rep. 520. p. 20.

Barnett J, Lambert S, Fry I (2008). The Hazards of Indicators: Insights from the Environmental Vulnerability Index. Annals Assoc. Am. Geogr. 98: 102-119.

Biek RF (2005a). The Traverse Mountains: New Geologic Maps and Explosive Suburban Growth: Utah Geol. Survey, Survey Notes 37: 1-19.

Biek RF (2005b). Geologic map of the Jordan Narrows quadrangle, Salt Lake and Utah Counties, Utah: Utah Geol. Survey Map 208, scale 1:24,000.

Biek RF (2005c). Geologic map of the Lehi quadrangle and part of the Timpanogos Cave quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 210, scale 1:24,000.

Biek RF (2005d) UGS (Utah Geological Survey) Landslide Inventory Traverse Ridge. p. 1.

Bills BG, Wambeam TJ, Currey DR (2002). Geodynamics of Lake Bonneville. In" Great Salt Lake, an overview of change. DNR/UGS Special Publication, pp. 7-32.

Blaikie P, Cannon T, Davis I, Wisner B (1994) At risk - Natural hazards, people’s vulnerability and disasters. Routledge, London and New York, p. 284.

Burrough P, McDonnell R (2000). Principles of Geographical Information Systems. Oxford University Press.

Carrara A, Cardinali M, Detti R, Guzzetti F, Pasqui V, Reichenbach P (1991). GIS techniques and statistical models in evaluating landslide hazard. Earth Surface Processes Landforms, 16: 427–445.

Christenson GE (2003). Life along the fault: Reducing risk in Utah. Geotimes. available online at http://www.geotimes.org/apr03/feature_utah.html.

Christenson GE, Ashland FX (2006) Assessing the stability of landslides – Overview of lessons learned from the historical landslides in Utah. Utah Geological Survey Technical Report, p. 17. http://geology.utah.gov/online/techrpt/lessons_learned.pdf.

Committee on the Review of the National Landslide Hazards Mitigation Strategy of the National Research Council (2004). Partnerships for Reducing Landslide Risk: Assessment of the National Landslide Hazards Mitigation Strategy. Washington, DC: The National Academies Press, p. 144. available online at http://www.nap.edu/catalog.php?record_id=10946.

CMT Engineering Laboratories (2007). Geotechnical Engineering Investigation/Pavement Evaluation, Suncrest Subdivision, Draper, Utah: CMT Engineering Project No. 2864 Report prepared for Draper City, 1020 East Pioneer Rd., Draper, Utah on Nov. 26, 2007. 175.

Crittenden MD Jr (1963). New data on the isostatic deformation of Lake Bonneville. USGS Professional Paper 454-E: 31-35.

Crozier MJ (1986). Landslides: Causes, Consequences & Environment. Croom Helm, London, England, p. 252.

Crudden DM, Varnes DJ (1996). Landslide types and processes. In: Turner AK, Schuster RL (eds) Landslides, investigation and mitigation: Washington, D.C., National Research Council, Transportation Res. Board, Special Rep. 247, pp. 36-75.

Delta Geotechnical Consultants (1997). Geotechnical study – proposed Traverse Ridge Road alignment 2, Draper, Utah: Salt Lake City, Utah unpublished consultant’s report, p. 24.

Dikau R, Brundsen D, Schrott L, Ibsen ML (eds.) (1996). Landslide recognition. Identification, movement and causes, John Wiley Publishers, Chichester, England, p. 251.

Draper City (2007). Title 9 Land Use and Development Code for Draper City, Chapter 9-19 Geologic Hazards Ordinance (enacted 12/11/2007), online at www.draper.ut.us.

Eldredge SN (1996). Homebuyers guide to earthquake hazards in Utah: Utah Geological Survey Public-Information Series 38, p. 27.

Englin KS (2006). Fully Disclosed: Natural Hazard Disclosure in Real Estate Transactions. Masters Thesis, Dept. Plann. Public Policy

Manage., University of Oregon, p. 78.

Erley D, Kockelman WJ (1981). Reducing Landslide Hazards: A Guide for Planners. Chicago, Illinois: American Planning Association, Planning Advisory Service Report No. 359.

Fedeski M, Gwilliam J (2007). Urban sustainability in the presence of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology. Landscape and Urban Planning 83: 50-61.

Galli M, Guzzetti F (2007). Vulnerability to landslides in Umbria, central Italy. Environ. Manage., 40:649–664.

Gehrke S (2007). Report finds fault in roads at SunCrest. The Salt Lake Tribune 11/29/2007.

Gehrke S (2008a). SunCrest neighbors say Draper responsible for problems. The Salt Lake Tribune 4/25/2008.

Gehrke S (2008b). A sign of the times in Draper: Residents being told of geologic hazards. The Salt Lake Tribune 2/23/2008.

Giraud RE, Shaw LM (2007). Landslide Susceptibility Map of Utah: Utah Geological Survey Map 228DM, 1:500,000, p. 12.

Glade T, Crozier MJ (2004), Landslide Hazard and Risk – Concluding Comment and Perspectives. In: Glade T, Anderson MG, Crozier MJ (eds) Landslide risk assessment. John Wiley Publishers, New York, pp, 767–772,

Godschalk DR, Beatley T, Berke P, Brower DJ, Kaiser EJ, Bohl CC, Matthew GRM (1999). Natural Hazard Mitigation; Recasting Disaster Policy and Planning. Washington, D.C.: Island Press.

Griffiths JS (1999). Proving the occurrence and cause of a landslide in a legal context. Bull. Eng. Geol. Environ. 58:75-85.

Guthrie C (2006). Law, Information, and Choice: Capitalizing on Heuristic Habits of Thought. In: Gigerenzer, G and Engel, C (Eds) Heuristics and the Law, Cambridge, MA, The MIT Press, p. 425-438.

Harmsworth G, Raynor B (2004). Cultural consideration in landslide perception. In: Glade T, Anderson MG, Crozier MJ (eds) Landslide risk assessment. John Wiley Publishers, New York, New York, pp. 219-284.

Harty KM (1991). Landslide map of Utah: Utah Geological and Mineral Survey Map 133, 1:500,000, p. 28.

Hecker S, Harty KM (1990). Geologic setting. In: Lund, W (ed) Engineering geology of the Salt Lake City Metropolitan Area, Utah. Utah Geol. Mineral Survey Bull. 126: 10-18.

Hendricks DP (2002). Silence is golden: The case for mandatory disclosure of coastal hazards and land-use restrictions by residential sellers in North Carolina. North Carolina Central Law Rev. 25: 96-124.

Hungr O, Fell R, Couture R, Eberhardt E (2005). Landslide risk management: proceedings of the International Conference on Landslide Risk Management, Vancouver, Canada, 31 May-3 June 2005. Taylor & Francis, London, p. 776.

Jenkins-Smith HC, Silva CL, Berrens RP, Bohara A (2002). Information disclosure requirements and the effect of soil contamination on property values. J. Environ. Plann. Manage. 45:323-339.

Kaliser BN (1983). Geologic hazards of 1983. Survey Notes. Utah Geological and Mineral Survey, Salt Lake City, Utah, pp. 3-8.

Lefcoe G (2004). Property Condition Disclosure Forms: How the Real Estate Industry Eased the Transition From Caveat Emptor to 'Seller Tell All.' Real Property, Probate, Trust J., 39:193-250.

Machette MN (1992). Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah. USGS Miscellaneous Investigation Series Map I-2095 1:50,000 scale.

Meyers DW (2008). Zions Bank boots Draper – "Divorce" action may stem from feud over roadwork. The Salt Lake Tribune 12/26/2008.

Milligan M (2005). Thistle Landslide revisited, Utah County, Utah. Utah Geological Survey GeoSights article, Survey Notes 37: 2.

Nanda A (2006). Property Condition Disclosure Law: Does 'Seller Tell All' Matter in Property Values?: University of Connecticut Department of Economics Working Paper Series, Paper 2005-47R, 42 p.

Nanda A (2008). Property Condition Disclosure Law: Why Did States Mandate 'Seller Tell All'?: J. Real Estate Fin. Econ. 37: 131-146.

Nanda A, Ross SL (2008). The Impact of Property Condition Disclosure Laws on Housing Prices: Evidence from an Event Study using Propensity Scores: University of Connecticut Department of Economics Working Paper Series, Paper 2008-39R, p. 32.

Nelson CV, Lund WR (1990). Geologic Hazards and Constraints in Lund, WR (ed) Engineering Geology of the Salt Lake City Metropolitan Area, Utah. Utah Geol. Mineral Survey Bull. 126: 26-36.

Olshansky RB and Rogers JD (1987). Unstable Ground: Landslide Policy in the United States. Ecology Law Quarterly 3: 201-267.

Olshansky RB (1998). Regulation of hillside development in the United States. Environ. Manage.,22: 383-392.

Oviatt CG, Currey DR, Sack D (1992). Radiocarbon chronology of Lake Bonneville, eastern Great Basin, USA. Palaeogr. Palaeoclimatol. Palaeoecol., 99: 225-241.

Palm R (1981). Public Response to Earthquake Hazard Information. Annals Assoc. Am. Geogr. 71: 389-399.

Palmer R (2008a). SunCrest fails to meet loan obligations. Deseret Morning News 3/6/2008.

Palmer R (2008b). SunCrest developer surrenders, hopes to sell in June. Deseret News 4/14/2008.

Palmer R (2008c). Sale of SunCrest nears resolution. Deseret News 11/19/2008.

Palmer R (2008d). Zions cuts all banking ties with Draper. Deseret News12/26/2008.

Reid ME, LaHusen RG, Ellis WL (1999). Real-Time Monitoring of Active Landslides. Reston, Virginia: U.S. Geological Survey, U.S. Geological Survey Fact Sheet 091-99.

Salt Lake Board of Realtors (2008). December 29, 2008 press release: Home sales fall but median price rises. Online at: http://www.slrealtors.com/pdfs/pr_081229.pdf.

Sanchez JW (2008a). Draper, developers seek a deal to salvage project. The Salt Lake Tribune 10/28/2008.

Sanchez JW (2008b). Draper hopes to salvage SunCrest Deal – A developer has canceled an agreement to take over the housing project. The Salt Lake Tribune 12/18/2008.

Smart C (2009). Zions Bank sues Draper over failed SunCrest: Court ? $25M suit alleges city's mismanagement led to development's bankruptcy. The Salt Lake Tribune 6/29/2009.

Solomon BJ (2001). Using Geologic-Hazards Information to reduce risks and losses – a guide for local governments. Utah Geological Survey Public Information Series 75, p. 6.

Solomon BJ, Storey N, Wong I, Silva W, Gregor N, Wright D, McDonald G (2004). Earthquake-hazards scenario for a M7 earthquake on the Salt Lake City segment of the Wasatch fault zone, Utah: Utah Geol. Surv. Special Study 111DM, p. 59.

Stern S (2005). Temporal Dynamics of Disclosure: The Example of Residential Real Estate Conveyancing. Utah Law Rev.57: 57-95.

Stokes WL (1986). Geology of Utah. Utah Geological Survey Miscellaneous Publication, Utah Museum of Natural History, Salt Lake City, Utah, USA, p. 280.

Swinyard K (2005). Open space, growth keys in Draper race - Mayoral candidates Pugh, Smith clash over development. Deseret Morning News 11/3/2005.

Tingey BE, McBride JH, Thompson TJ, Stephenson WJ, South JV, Bushman, M (2007). Study of a prehistoric landslide using seismic reflection methods integrated with geological data in the Wasatch Mountains, Utah, USA. Eng. Geol. 95: 1-29.

Toomer-Cook J (2008). Settlement in SunCrest case proposed: Deal gives unsecured creditors a fraction of what they're owed. Deseret News 8/29/2008.

United States Census Bureau Population Division (2008). Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2000 to July 1, 2007 - 2007 Population Estimates. Report Number CBSA-EST2007-01 (CSV). Washington, D.C.: US Government Press.

Wieczorek GF, Lips EW, and Ellen SD 1(989) Debris flows and hyperconcentrated floods along the Wasatch Front, Utah, 1983 and 1984. Assoc. Eng. Geol. Bull. 26: 191-208.

Wieczorek GF (1996). Landslide Triggering Mechanisms, in Landslides: Investigation and Mitigation. In: Turner AK and Schuster RL (eds). Transportation Res. Board, Nat. Res. Council, Special Report 247. Washington., D.C.: National Academy Press. pp. 76-90.

Wiley JA, Zumpano LV (2008). The Real Estate Brokerage Market and the Decision to Disclose Property Condition Defects. Real Estate Econ. 36: 693-716.

Wisner B, Luce HR (1993). Disaster vulnerability: scale, power and daily life. Geo. J. 30:127–140

Wisner B, Blaikie PM, Cannon T (2005). At risk: natural hazards, people vulnerability and disasters. Routledge Publisher, London, England, p. 492.

Wright SG, Rathje EM (2003). Triggering Mechanisms of Slope Instability and Their Relationship to Earthquakes and Tsunamis. Pure and Appl. Geophys. 1865-1877.

Zimbelman D, Watters RJ, Bowman S, Firth I (2003). Quantifying Hazard and Risk Assessments at Active Volcanoes. AGU-EOS 84: 213, 216-217.