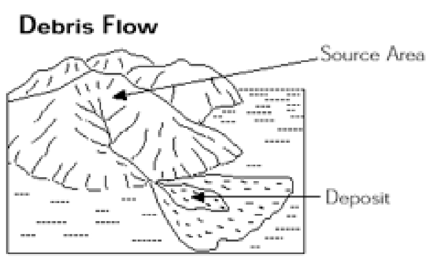
Landslides

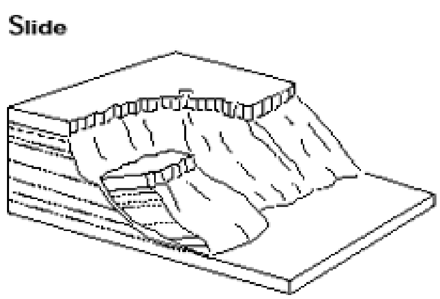
Profiling Hazard Event

Landslides are a "down slope movement of a mass of rock, earth, or debris". Landslides, often referred to as mass wasting or slope failures and are one of the most common natural disasters (Cruden 36). Slope failures can vary considerably in shape, rate of movement, extent, and impact on surrounding areas. Slope failures are classified by their type of movement and type of material. The types of movement are classified as falls, slides, topples, and flows. "The types of material include rock, debris (coarse grained soil) and earth (fine grained soil)" (Eldredge 17). "Types of slope failures then are identified as rock falls, rock slides, debris flows, debris slides, and so on" (Eldredge 17). Slope failures occur because of an increase in the driving forces (weight of slope and slope gradient) or a decrease in the resisting forces (friction, or the strength of the material making up a slope). "Geology (rock type and structure), topography (slope gradient), water content, vegetative cover, and slope aspect are important factors of slope stability" (Eldredge 18).

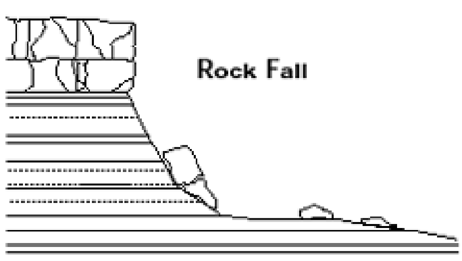
Figure 2F-1 Three Common Types of Landslides in Utah



Debris flows consist of sediment-water mixtures that flow down a streambed or hillside, commonly depositing sediment at canyon mouths in fan like deposits known as alluvial fans.



Slides are down slope movements of soil or rock on slopes.



Rock falls consist of rock(s) falling from a cliff or cut slope and are very common in the canyon country of southern Utah.

Conditions That Make Slopes More Susceptible to Landslides

- Discontinuities: faults, joints, bedding surfaces.
- Massive materials over soft materials.
- Orientations of dip slope: bedding planes that dip out of slope.
- Loose structure and roundness.
- Additional weight to the head of a slide, such as: rain, snow, landslides, mine waste piles, buildings, leaks from pipes, sewers, and canals, construction materials, and fill materials.
- Ground shaking: earthquakes or vibrations.
- Increase in lateral spread caused by mechanical weathering.
- Removal of lateral support.
- Human activities: cut and fill practices, quarries, mine pits, road cuts, lowering of reservoirs.
- Removal of underlying support: under cutting of banks in a river.
- Increase in pore water pressure: snow melt, rain, and irrigation.
- Loss of cohesion.

Landslide History

In the United States, it is estimated that the total dollar losses from landslides are between one and two billion dollars ($1.6 billion and $3.2 billion, year 2000 dollars). This figure is a conservative estimate, as there is no uniform method or overall agency that keeps track of or reports landslide losses. Landslides result in extremely high monetary losses in other countries, but there is no overall estimate as to the exact amount.

In Utah, the most current documented yearly losses from damaging landslides are from 2001, which exceeded $3 million, including the costs to repair and stabilize hillsides along state and federal highway (Ashland, 2003). Total landslide dollar losses are hard to determine for past events because a standard for documenting them does not exist. Several state and local agencies track landslide losses with inconsistent formats, often resulting in several different totals for a single event. The recurrent or ongoing movement at very slow rates of some slides results in widespread, but typically limited, damage. This movement causes damage cumulatively over several years. Francis Ashland, of the Utah Geologic Survey discusses landslide damages in Utah as well as the difficulties of accruing accurate post movement loss numbers. His work “The Feasibility of Collecting Accurate Landslide-Loss Data in Utah, Open File Report 410” is found in appendix J of this plan.

Thistle Slide

In 1983, the town of Thistle was destroyed by floodwaters when the Thistle landslide created a natural dam and subsequent reservoir, blocking roads and rail line. The Marysvale branch of the railroad was never reopened, leaving a large area of central Utah without rail service. Thistle resulted in Utah's first presidential disaster declaration and became the most costly landslide in United States history. Three reports have been issued estimating the cost of the landslide between $200 million and $337 million dollars ($467.7 million and $788.2 million in 2013 dollars).

Heather Drive Landslide

In 2001, this landslide destroyed three houses in Layton City and forced the relocation of three others. Landslide movement also severed underground utility service to the houses. Total dollar losses for this event have been estimated by various sources to be between $519,800 and $1,092,000 ($684,130 and $1,437,226 in 2013 dollars). This landslide is a partial reactivation of a prehistoric landslide in silt and clay sediments of ancient Lake Bonneville. Lake Bonneville sediments in the Layton area are prone to landslides.

Santaquin Mollie Fire Debris Flow

In August of 2001, the 8,000+ acre Mollie Fire burned an area of the Wasatch Range known as Dry Mountain above the city of Santaquin. The bench development area of Santaquin City is located no more than 50 yards from the edge of the fire perimeter on an alluvial fan. The Mollie wildfire caused watershed damaged and elevated the debris flow risk. At approximately 6:45 p.m. on Thursday, September 12, 2002, after nearly a week of intense thunderstorms, the charred earth of the ironically named Dry Mountain produced 10 debris flows. These flows did major damage to several houses and resulted in significant cleanup costs.

Buckley Draw—Springville Fire

The Springville fire started on June 30, 2002, at 7:19 p.m. and burned a total of 2,207 acres above dozens of homes. This burned area heightened the debris flow risk to those homes on the alluvial fans below. At the April 29, 2003 neighborhood meeting, the debris flows in Santaquin were contrasted with the conditions at the Buckley Draw. Plans for trench construction were discussed. A flag notification system and evacuation plan was put in place. A website with updated hazard information, a phone 'hot line' with an updated message, and a notification procedure alerting the Neighborhood Chair of any changes in the hazard level were implemented. A practice evacuation drill was held on Saturday, May 10, 2003.

The 1,500 feet long trench/deflection dike was completed on July 28, 2003, by Provo City in conjunction with the NRCS and their Emergency Watershed Protection program. At approximately 3:00 a.m. on September 10, 2003, four separate debris flows were triggered. The newly finished trench routed the second largest flow. The trench finished "in the nick of time" worked as designed, preventing property loss and potential life loss. It is difficult to predict total amount of damage prevented by the trench, but at a minimum the deflection dike prevented damage equal to its construction cost. The spreader fences in the debris run-out field distributed the runoff materials and completely contained this debris flow.

Kanab Creek Landslide

On March 12, 2005, at approximately 5:30 p.m., a 100 ft. long by 60 ft. high vertical stream-cut along Kanab Creek failed. This landslide occurred within the city limits of Kanab, killing one boy and partially burying two children. This earth-fall-type landslide was most likely the result of long-term gravitational effects on over-steepened, unconsolidated material in the arroyo walls (Lund, 2005).

Provo Rock Fall

On May 12, 2005, at 5:00 p.m., a rock fall destroyed a guest house located in Provo. No fatalities resulted from the rock fall. The rock measured 7 x 5.1 x 4.5 feet and weighed approximately 13 tons. The rock fall is believed to have resulted from a series of significant storms that passed through the Provo area between May 10-12, in which approximately 3.7 inches of mixed rain and snow fell on the area. It was raining at the time of the rock fall (Giraud, 2005).

South Weber Landslide

Around 9:30 p.m. on Sunday, April 9, 2006, a rapidly moving landslide in South Weber broke through the back wall of a house at 7687 South 1650 East, injuring a child inside. The landslide started on a steep slope near a pond in a gravel pit atop a bluff behind the house. Subsequent investigation found evidence of subsurface water flow from the pond to the slope.

Water seepage and saturation of materials atop the bluff likely triggered the landslide, but the steep slope, the weight of fill placed on the top of the slope, and weak underlying geologic materials were contributing factors. Also, a major rain and snow storm on April 4 -6 dropped approximately 2 inches of water, likely causing surface and subsurface water levels to rise. After the landslide, the pond was drained to reduce further sliding. The 1650 East landslide and a similar one nearby that demolished a barn and blocked South Weber Drive (State Route 60) in 2005, demonstrate the destructive nature of rapidly moving landslides and the risk of building at the base of steep slopes.

The rapidly moving landslide that slammed into this house at 7687 South 1650 East, South Weber, broke through the back wall and injured a child inside.

Sunset Drive and Beechwood Drive Landslides

Homeowners along Sunset Drive in Layton recognized in mid-April of 2006 that the Sunset Drive landslide had reactivated. In 1998, landslide movement damaged seven lots and resulted in a house being condemned and demolished. The 2006 movement affected six lots, including two homes. The house at 1843 East Sunset Drive straddles the main scarp, and landslide movement had removed support from beneath part of the foundation. Layton City building inspectors found the house unsafe for occupancy due to structural damage, and it may be moved off the landslide to another location. UGS geologists measured a 4- to 8-foot increase in ground-water levels in and around the landslide between March 16 and April 17, which apparently triggered movement. The 2006 peak ground-water level is a threshold that can be used to predict future landslide movement.

The Beechwood Drive landslide occurred a quarter-mile south of the Sunset Drive landslide and reactivated at about the same time. The Beechwood Drive landslide is a reactivation of a pre-existing landslide with no documented historical movement. The landslide main scarp cuts across the back of five lots and has damaged landscaping in backyards. The landslide also affected the upper part of the proposed Beechwood subdivision phase 6 development. Both the Sunset and Beechwood Drive landslides show how prone some slopes in Layton are to landslide movement.

Creekside Drive Landslide

In 2005, three landslides formed in the Creekside Drive area of Mountain Green in Morgan County, in a northeast-facing slope underlain by pre-existing landslide deposits. In 2006, the three landslides reactivated, and two new landslides formed nearby.

Continued movement of the largest of the five landslides forced the evacuation of a severely damaged house at the top of the slide, and damaged two others.

Landslide movement left this concrete driveway slab suspended in the air in the Creekside Drive area, Mountain Green.

Damage also occurred to Creekside Drive and utilities beneath the road, disrupting the power and water to the affected subdivision.

Despite favorable subdivision-wide and lot-specific geotechnical studies, landsliding occurred within only a few years of development on the pre-existing landslide deposits. Stabilization of the landslides, particularly the largest one, will likely prove costly and technically challenging.

Sherwood Hills Landslide

The Sherwood Hills landslide in northern Provo is one of several in northern Utah that has undergone repeated movement over the past 25 years. Damage to houses and roads caused by renewed landslide movement was first documented in the early 1980s. The landslide has been systematically monitored since May 1999 when Provo City established survey points on the slide and began using high-precision Global Positioning System survey techniques to measure movement. The survey results suggest that the landslide remained active even during the drought years between 1999 and 2004.

With the return of wetter-than-normal conditions in 2005, the rate and area of landslide movement increased. By 2006, three houses in the upper part of the landslide had been abandoned, including one built in 2000, and a road had been severely damaged. Some data suggest that landslide movement is continuous, slowing in the summer to an undetectable rate, and increasing in the late winter and early spring as groundwater levels rise during the snowmelt. The continuing losses due to movement illustrate the potential high costs, both public and private, associated with development on large, pre-existing landslides.

City Creek Canyon Landslides

A cluster of historical landslides is visible from the hairpin turn in Bonneville Boulevard in lower City Creek Canyon in Salt Lake City. Movement of the largest and most damaging of these landslides has been monitored since June of 1998 by the UGS and the Salt Lake City surveyor. Since then, the toe of the landslide has moved about 24 feet, and the main scarp has offset the ground surface by about the same amount. Like most recurrently active landslides in northern Utah, movement typically occurs between March and June as ground-water levels rise following the snowmelt. Four houses at the top of the slide are threatened, and efforts to protect one house have cost in excess of $300,000. In 2006 the landslide reactivated again, moving about 2 feet despite drier-than-normal conditions in Salt Lake City.

Landsliding in Northern Utah

Locally wet conditions in northern Utah have caused some landslides to reactivate along with other types of shallow slope failures. Areas with active landslides in early 2009 include Ogden Valley in eastern Weber County, western Morgan County, southeastern Davis County, and Spanish Fork Canyon in Utah County. Examples include: reactivation or acceleration of persistently moving historical landslides, minor movement of landslides in highway cut slopes, local highway embankment and rock-wall failures, and local shallow slides on steep slopes in pre-existing landslides.

Above-normal precipitation in southeastern Davis County has caused an increase in the rate of movement of the Springhill landslide in North Salt Lake, resulting in additional damage to houses, roads, and buried utilities. The landslide has moved persistently since the late 1990s, severely damaging three houses since 1998. Damaging landsliding has also occurred in Ogden Valley and the Snowbasin area of eastern Weber County.

Snowmelt-induced landsliding occurred in the front yard of a house in the foothills of Ogden Valley, where saturated fill soil slid onto a driveway that crossed the slope. Reactivation of pre-existing landslides crossed by State Route 226 (near Snowbasin ski resort) is causing minor damage to the highway in several locations. In addition, embankment failures along the edge of the highway are causing road cracks and pavement settlement.

Landsliding coincident with the snowmelt was detected at several other sites this year, including minor movement of the Frontier Drive landslide in Morgan County, a small landslide in a highway cut slope in Spanish Fork Canyon, Utah County, and a new small slide in a local steep slope in the head of the Sage Vista Lane landslide in Cedar Hills, Utah County. Several landslides that occurred in generally south-facing slopes, including an embankment failure along US-6/89 in Spanish Fork Canyon, may have been caused by relatively rapid snowmelt. For the most part, no damage has resulted from these landslides.

Provo Rock Fall

Around 11:30 a.m. on April 11, 2009, a rock fall impacted the area of 1500 North and 1550 East in Provo, Utah.

One rock fall boulder damaged the outside of a playhouse located at 1522 North 1550 East, and another, larger boulder severely damaged a vacant house at 1496 North 1550 East.

Boulder that damaged the vacant house at 1496 North 1550 East, Provo. Boulder is estimated to be 4x5x4 feet. Photo courtesy of the Provo Fire Department.

This rock fall occurred one lot north of the May 12, 2005 "Y" Mountain rock fall. The rock fall occurred shortly after a storm on April 8-9 that dropped 1.5 inches of precipitation in less than 18 hours at the Cascade Mountain Snotel site, 3 miles southeast of the rock-fall source area. Impact craters (bounce marks) evident on the slope above the houses indicate several rocks traveled downslope. The rocks traveled an estimated one mile downslope, and likely achieved high velocities as they bounced and rolled.

At 1496 North 1550 East, a boulder bounced over the back fence and into the back of the house. Inside the house, the boulder damaged the ceiling and crashed through a wall, before falling through the floor and into the garage door.

The source for the rock fall in both 2005 and 2009 is a cliff band in the Mississippian Deseret Limestone on "Y" Mountain, about 2,600 vertical feet above the houses.
Numerous large rocks from prehistoric and historical rock-fall events are scattered throughout the neighborhood and on the hillside above, indicating that these lots are in a high rock-fall hazard area. Although the occurrence of this rock fall does not necessarily indicate a heightened rock-fall hazard under present conditions, rock falls are possible in this area at any time and typically occur with no warning, often during and following storms, periods of snowmelt, and earthquakes.

Rockville Rock Fall

The rock, estimated to be about 21 x 17 x 17 feet and weighing about 450 tons, slid and fell from the upper slope of Rockville Bench, began to roll downslope, collided with a large stationary boulder at the base of the slope, and shattered into numerous smaller fragments that damaged several outbuildings, two cars, and a house. Although people were home at the time, no one was injured. The rock fall occurred shortly after a protracted storm event on February 5-9, 2010 that produced 1.38 inches of rain at the Zion Canyon RAWS station, 4.5 miles northeast of Rockville.

The rock fell/rolled 280 vertical feet and a slope distance of 500 feet before colliding with the other boulder. Debris ejected from the impact measured up to 9 feet in long dimension and traveled an additional 180 feet. The rock fall originated from the Shinarump Conglomerate Member of the Triassic Chinle Formation that caps Rockville Bench, although the event occurred in two stages. The rock originally detached from the Shinarump ledge, traveled about 40 feet, and came to rest on a steep slope formed on the upper red member of the Moenkopi Formation, where it remained high on the slope for at least 17 years.

The rainstorm prior to the rock fall likely caused material beneath the rock to erode and caused the rock to slide and then fall over a 12-foot ledge and roll down the remainder of the slope. This rock fall occurred less than 2000 feet west of where another large rock fall severely damaged a home in Rockville in October 2001. A second large talus (rock already detached from its source area) boulder remains high on the slope and appears to be analogous to the boulder that moved. Numerous large boulders from prehistoric and historical rock falls are present along the base of Rockville Bench, indicating several homes there are in a high-rock-fall hazard area. Although the occurrence of this rock fall does not necessarily indicate a heightened rock-fall hazard under present conditions, rock falls are possible in this area at any time and typically occur with no warning, often during and following storms, periods of freeze-thaw, and earthquakes.

Another rock fall occurred in Rockville on December 12, 2013. A massive boulder the size of a tractor came loose at the top of a cliff near Zions National Park and tumbled down the mountain, crushing a home and killing two people inside. The Utah Geological Survey contributes a week of severe weather, a lot of freeze-thaw, and a lot of moisture to the movement of the boulders.

Source: ksl.com

Springhill Landslide

The Utah Geological Survey (UGS) has been monitoring conditions at the Springhill landslide in North Salt Lake, Davis County since 1998. In the late 1990s, residents in the Springhill area of North Salt Lake, Davis County began noticing cracking and other distress related to relatively minor movement of the landslide. By 1998, a house at 160 Springhill Drive that straddled the northern boundary of the landslide was severely damaged and condemned. Relatively severe distress also occurred to several houses along Valley View Drive (formerly 350 East) and Springhill Circle.

Little movement or damage occurred during a dry period between 1999 and 2004, but the rate of movement accelerated during the 2005 wet year. Since 2005, the amount of movement each year has increased, except in 2007 (a dry year), resulting in an increased amount of damage and distress, particularly to houses in the upper and lower parts of the landslide and to Springhill Drive.

UGS Aerial Springhill Landslide

The Springhill landslide is about 720 feet long and about 290 feet wide where it is crossed by Springhill Drive. The local relief (change in elevation) is about 150 feet and the average slope of the landslide is approximately 21 percent (the ground rises 21 feet over a distance of 100 feet). The depth of the landslide varies along its length. Along the northern edge of Springhill Circle, the landslide is about 48 feet deep and likely deeper than 70 feet beneath Springhill Drive. The landslide is shallower along its southern edge, and in the head and toe.

The City of North Salt Lake worked with DEM and FEMA in obtaining PDM and HMGP grants to purchase the properties affected by this landslide. As of 2013 the houses in the affected area of the landslide have been demolished and North Salt Lake is working on turning the area into open space.

St. George Rock Fall

At around 3:00 AM on January 19, 2013, a 12 x 9 foot boulder dislodged from Foremaster Ridge and crashed into a resident's house seriously injuring a woman who was sleeping on her bed. The cause of the rock fall has been attributed to a severe water leak associated with a house atop the ridge. An estimated 40,000 gallons of water leaked into the sandstone rock on Foremaster Ridge.

<u>Bingham Canyon Landslides</u>

Two landslides occurred in 2013 in Rio Tinto's Bingham Canyon Mine. The first landslide occurred on April 10, 2013 at 9:30 PM. This landslide was calculated to have moved around 65-70 million cubic meters of dirt and rock adown the side of the mining pit. This April landslide is considered to be historically the largest landslide in the United States that is not connected to volcanism. Officials at the mine anticipated the slide and took precautions. On September 11, 2013, a second landslide occurred, but was smaller than the landslide in April. The September landslide caused the evacuation of 100 workers. No injuries occurred during either landslide.

Assessing Vulnerability by Jurisdiction

According to the USGS, landslides are a widespread geological hazard that can occur in all 50 states. Urban development in and along hillside areas increase the number of people threatened by landslide events each year. Many factors contribute to overall landslide vulnerability; including local weather, soil moisture, duration and intensity of precipitation, wildfire history, and development pressure. Typically, landslides result from other natural disasters such as earthquakes, volcanoes, wildfires, and floods. Table 2F-1 illustrates how many square miles per county are in high or moderate landslide susceptible areas. Data for assessing landslide vulnerability was provided by UGS.

A map was created to show the hazard ranking of the landslide hazard for each county as reported in the LHMPs (Figure 2F-2). The hazard ranking is calculated from a combination of severity (categorized from 0-3) and frequency (categorized from0-3). This ranking is located in the LHMPs. The SHMPC added all of the counties rankings from their plans, for a ranking from 0-6 to be scored. The map highlights the highest at risk counties (a rank of 6 or 5) whose population growth rates are 1.5% (the state average) or greater. This is designed to mark areas of rapid growth and development by county that are the highest risk to landslides as reported in LHMPs.

Table 2F-2 shows the squares miles of land in each county that are located in High, Moderate or Low landslide susceptibility areas. Table 2F-1 ranks the counties by square mileage of land located within high or moderate landslide susceptibility areas. San Juan County has the most square miles in high and moderate landslide susceptible areas; this is due to the fact that it is the largest county in Utah. It is also one of the least developed counties in Utah with greater than 80% of the county belonging to the federal government, this is reflected in the map figure 2F-2 that shows how county rank hazards, San Juan ranked landslide very low. Table 2F-3 shows the estimated dollar amount of potential building loss due to landslides, San Juan has not reported any amount. This could be because they do not have the means to collect this data combined with that there is minimal development in the county.

Greater detail and data is needed in the LHMP's to better understand statewide vulnerability for landslides.

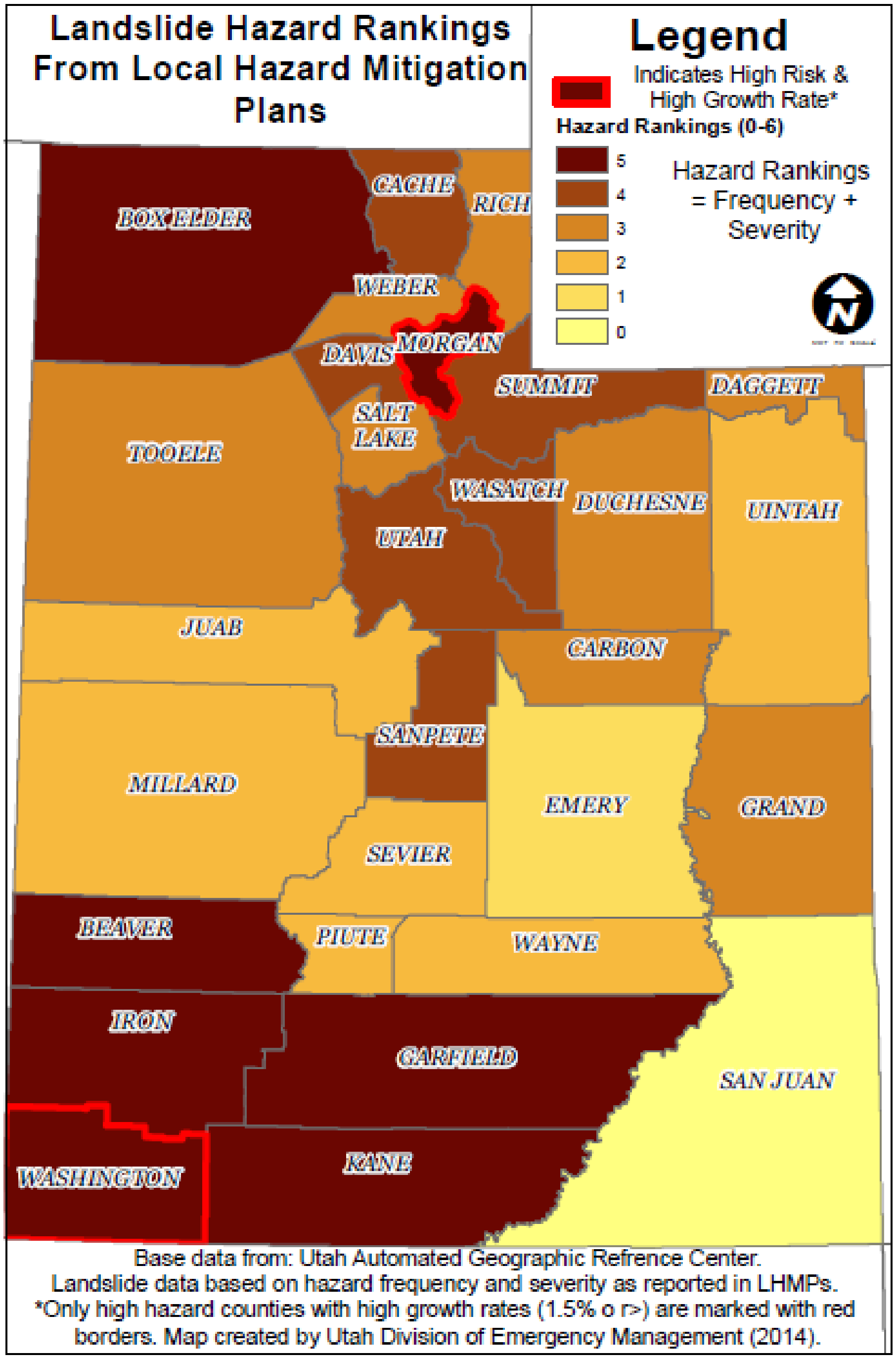
Table 2F-1 Area of square miles per county with high or moderate landslide risk

Rank	County	Areas within High or Moderate Landslide Susceptibility Areas (square miles)
1	San Juan	2512.3
2	Kane	1680.5
3	Grand	1537.9
4	Uintah	1367.1
5	Millard	1187.8
6	Washington	1108
7	Utah	1076.7
8	Summit	1035.8
9	Box Elder	1010.8
10	Tooele	938.3
11	Carbon	818.4
12	Juab	803.6
13	Wayne	785.4
14	Sanpete	783.6
15	Iron	758.7
16	Wasatch	717.91
17	Beaver	625.6
18	Sevier	587.4
19	Cache	563.5
20	Morgan	449.3
21	Piute	361.7
22	Salt Lake	321.6
23	Daggett	312.2
24	Rich	263.9
25	Weber	261.8
26	Garfield	197.5
27	Emery	128.02
28	Duchesne	104.6
29	Davis	104
Total		**23,815.66**

Table 2F-2 Summary of Landslide Susceptibility per County by Hazard Category

County Name	High Hazard (square miles)	Moderate Hazard (square miles)	Low Hazard (square miles)	Extremely Low Hazard (square miles)
Beaver	46.6	579	236.1	1365.4
Box Elder	46.6	579	236.1	1365.4
Cache	10.8	552.7	161.2	365.3
Carbon	7.1	811.3	219.4	407.3
Daggett	8.7	303.5	165.5	195.7
Davis	15.4	89	14.6	16.9
Duchesne	15.4	89.2	14.6	167.6
Emery	2.02	126	143.1	175.3
Garfield	3.7	193.8	223.5	1763.1
Grand	17.2	1520.7	547.9	1508.6
Iron	20.5	738.2	333	1906.5
Juab	15.2	788.4	211.4	1999.5
Kane	42	1638.5	672.9	1530.9
Millard	13.1	1174.7	396.9	4524.1
Morgan	25.7	423.6	92.3	46.7
Piute	65.9	295.8	121.6	211.7
Rich	1.2	262.7	227.3	449.4
Salt Lake	1.63	320	25	373.9
San Juan	102.6	2409.7	1287.8	3765.9
Sanpete	100.9	682.7	254.8	463.1
Sevier	149.7	437.7	317.2	458.5
Summit	80.1	955.7	417.9	348.1
Tooele	1.3	937	233.2	5396.4
Uintah	32.4	1334.7	906.2	2068.1
Utah	21.1	1055.6	195	591.3
Wasatch	9.51	708.4	247.3	160.1
Washington	28.1	1079.9	423.2	792.9
Wayne	48.7	736.7	323.6	1239.9
Weber	15	246.8	61.9	237.2

Figure 2F-2 County Rankings for Landslide Hazard from LHMPs



Estimating Potential Losses by Jurisdiction

The following tables were developed using information and data from local hazard mitigation plans. Counties are ranked by number of structures in counties and the replacement costs. Per capita loss estimates were also calculated, ranked and mapped.

The map figure 2F-2 highlights Morgan and Washington Counties. These two counties have ranked landslides risk at a 5 and both have exceeds the state's average growth rate.
Salt Lake, Weber, Davis and Utah Counties rank low for landslide susceptibility areas. This is due to their smaller geographic areas. Davis County is the smallest County in the state yet ranks third in estimated dollar amounts of potential building loss because of the development and population. These six counties have the majority of damage causing landslides and are of particular interest to the state when looking for landslide mitigation measures.

Table 2F-3 and figure 2F-3 show estimated losses to facilities. These figures are directly from the LHMP's, some of which did not report any figures. The table and map show the greatest potential losses are located in the greatest populated areas. Kane, Summit and Morgan Counties potential losses appear higher when looked at per capita, this is due to their low population and high landslide risk. Morgan and Summit Counties are mountainous counties with communities of higher wealth. People live and work in these counties for the view and to be in the mountains which often leads to building on slopes and in landslide areas. As reported in the map on figure 2F-3 and table 2F-4, Kane County ranks the highest with per capita loss of structures susceptible to landslides. While some of this can be attributed to their low population, this finding was unexpected and will be a subject for further analysis.

The percentage of change of vulnerable structures in landslide areas is of concern as shown in Table 2F-5 Change in Landslide Vulnerable Structures. These numbers are self-reported by each county and located in the LHMP's. Some counties data is severely lacking, while other counties have updated their data from previous plans. The SHMPC determined the extreme percentage of change in structures is due to better building data while a reasonable percentage of it is due to population growth.

An example would be Juab County; they had a population growth of 17% between their planning updates and reported a -50% structures vulnerable to landslides. The SHMPC determined they did not move buildings out of landslide risk areas but have used better data on locating structures. Kane County shows a 7242% increase of structures vulnerable to landslides while they had a 14.1% population growth over the same period. These numbers lead the SHMPC to determine that a smaller percentage of new structures in landslide areas is reasonable while the greater percentage change is due to better data.
As LHMP's are updated and the data used in the plans become better, the SHMP will better reflect vulnerability throughout the state.

Table 2F-3 Landslide Loss Estimates for Buildings from LHMPs

Loss Estimates for Buildings (From LHMPs) Utah Statewide Landslide Risk 2014		
County – Number of Structures	**Number of Structures in Areas of Moderate or Greater hazard**	**Replacement Costs of Residential Units and Annual Sales of Commercial Units (inflation adjusted)**
Salt Lake	30,388	$6,690,896,906
Weber	17,609	$4,195,363,723
Davis	11,839	$2,434,741,693
Utah	11,753	$1,883,430,984
Washington	2,823	$967,146,700
Summit	3,054	$577,665,948
Morgan	1,356	$295,761,335
Kane	881	$227,878,899
Cache	1,099	$209,087,058
Iron	881	$194,175,540
Wasatch	757	$102,817,095
Tooele	391	$61,232,726
Sevier	553	$53,171,309
Garfield	182	$45,895,089
Box Elder	441	$41,710,530
Grand	97	$25,907,258
Beaver	285	$23,881,934
Duchesne	253	$21,623,213
Carbon	97	$8,149,076
Piute	92	$7,371,550
Uintah	66	$5,640,838
Wayne	17	$1,362,134
Daggett	13	$1,025,607
Juab	1	$101,492
Sanpete	1	$101,492
Emery	0*	$0
Millard	0*	$0
Rich	0*	$0
San Juan	0*	$0
State Total	**84929**	**$18,076,140,130**

*Figures from the latest Local Hazard Mitigation Plans (the recent UBAOG and SEALG plans were included) Updated in 2014. *None reported*

Figure 2F-3 Per Capita Estimated Loss to Facilities for Landslides from LHMPs

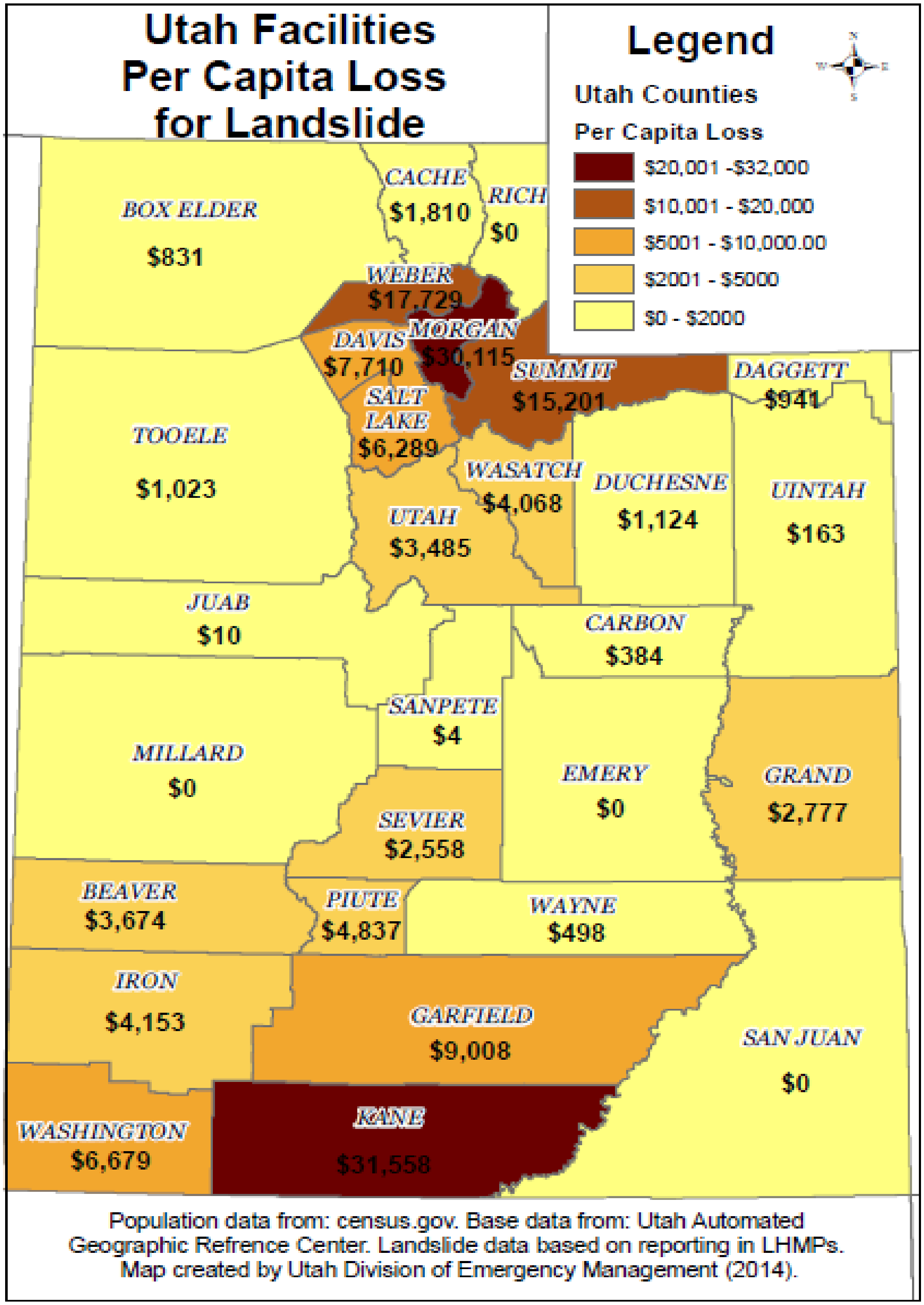


Table 2F-4 Ranked Per Capita Loss of Structures Susceptible to Landslides

Rank	County	Per Capita Loss to Structures Susceptible to Landslides (from LHMPs)	2011-2012 Population Growth Rates
1	Kane	$31,557.80	-0.3%
2	Morgan	$30,115.20	1.9%
3	Weber	$17,728.89	1.1%
4	Summit	$15,200.54	1.5%
5	Garfield	$9,007.87	-1.5%
6	Davis	$7,709.54	1.3%
7	Washington	$6,678.77	2.3%
8	Salt Lake	$6,289.37	1.5%
9	Piute	$4,836.98	0.5%
10	Iron	$4,153.49	0.2%
11	Wasatch	$4,068.26	3.8%
12	Beaver	$3,673.58	-0.4%
13	Utah	$3,484.58	2.0%
14	Grand	$2,777.36	0.6%
15	Sevier	$2,558.28	-0.6%
16	Cache	$1,809.96	0.8%
17	Duchesne	$1,123.63	2.0%
18	Tooele	$1,022.76	1.0%
19	Daggett	$940.92	-6.0%
20	Box Elder	$831.37	-0.02%
21	Wayne	$497.67	-0.9%
22	Carbon	$383.56	-0.5%
23	Uintah	$163.39	4.1%
24	Juab	$9.81	0.1%
25	Sanpete	$3.64	-0.3%
26	Emery	$0	-0.3%
27	Millard	$0	-0.3%
28	Rich	$0	-2.2%
29	San Juan	$0	1.1%

Table 2F-5 Change in Landslide Vulnerable Structures

Percent Change in Number of Structures in Landslide Risk Areas LHMPs 2004 - 2014		
County	**Percentage of Change**	**2004-2012 Population Growth Rate**
Kane	7242%	14.1%
Beaver	1936%	3.3%
Wayne	1600%	6.3%
Washington	927%	31.4%
Salt Lake	465%	12.8%
Iron	392%	22.6%
Summit	164%	15.7%
Davis	114%	19.1%
Morgan	100%	10.3%
Tooele	100%	21.8%
Garfield	100%	23.5%
Wasatch	68%	32.7%
Weber	12%	8.9%
Piute	12%	12.4%
Sanpete	0%	1.7%
Sevier	0%	16.3%
Carbon	0%	9.9%
Grand	0%	11.6%
Daggett	0%	7.3%
Uintah	0%	29.4%
Duchesne	-3%	26.4%
Box Elder	-14%	12.2%
Cache	-18%	16.2%
Utah	-35%	27.2%
Juab	-50%	17.0%
Using LHMPs from 2004 and the most current LHMP		
Counties not listed do not have updated data on number of structures in landslide risk areas		
It is difficult to discern if change is due to growth or with better/different data for each county		

Development Trend Impacts

Landslide events do not typically affect large areas of populations like earthquakes or drought can; however, they can have a devastating impact on the local level. In 2013, one rockfall in St. George injured a person in their house and another rockfall in Rockville killed two people also in their home. St. George is located in a high growth rate county that saw a 4.6% population growth rate from 2010-2012. The Springhill Landslide in North Salt Lake, which had a 2.4% growth rate from 2010-2012, led to the demolishment of several homes through PDM and HMGP grants.

Based on the landslide vulnerability analysis displayed in Figure 2F-5, the areas of highest vulnerability are along the Wasatch Front and the southwestern corner of the state. Vulnerability is tied to population and these two areas are the highest populated areas in the state and have seen the highest growth in the last several years. Of the 50 fastest growing cities (> 5000) in Utah, 39 of them are in the two highest landslide vulnerability areas.

Some communities like Rockville have built their homes in high landslide susceptibility areas and will continue to experience the threat of rockfalls. Several of Salt Lake County's developing areas are near or on landslide risk areas such as South Mountain. Developers are building homes up high along the benches of the Wasatch Front, closer to potential landslide high risk areas. This has been a trend for several years.

Many cities in Utah, Davis, Weber and Morgan Counties have had high growth and continue to develop in landslide risk areas. Some such as Salt Lake County and Layton have ordnances in place to reduce development in high risk areas. The UGS and DEM continue to work with communities in developing and adopting hillside development ordinances.

After wildfires, the potential for debris flows can cause havoc on some communities. The fastest growing city in Utah, Saratoga Springs, with a growth rate of 18.7% from 2010-2012, saw a devastating debris flow in August of 2012 that damaged several homes. The debris flow was the result of heavy rains that hit an area that had been previously scorched by wildfire. Just north of Saratoga Springs, the third fastest growing city, Herriman, had a large wildfire in 2012. One year later the city began a reseeding effort to help mitigate against the threat of debris flows. As the benches continue to be high growth areas, debris flows, rockfalls, and landslides may continue to be a big problem.

Assessing Vulnerability by State Facilities

State facilities data was provided by the Utah Division of Risk Management. The data presented in this shape file was complied with the help of several state agencies and entities. The state-owned facilities shape file was overlaid on top of the 2006 Utah Geological Survey landslide susceptibility shape file. Using ESRI ArcMap GIS, landslide susceptibility areas were clipped from a county shape files for each Utah County. The "select by location" option was then utilized in order to determine how many vulnerable state facility structures exist per county.

Table 2F-6 Total Number of State Owned Facilities in Landslide Susceptibility Areas

County Name	Facilities in Landslide Susceptibility Areas			
	Low	Moderate	High	Total
Beaver	0	22	0	22
Box Elder	1	10	2	13
Cache	0	67	27	94
Carbon	9	34	0	43
Daggett	9	9	0	18
Davis	0	42	0	42
Duchesne	12	72	0	84
Emery	4	37	0	41
Garfield	11	14	0	25
Grand	0	10	0	10
Iron	66	8	0	74
Juab	2	0	0	2
Kane	3	22	0	25
Millard	0	9	0	9
Morgan	0	43	0	43
Piute	0	2	0	2
Rich	5	50	0	55
Salt Lake	1	99	0	100
San Juan	24	27	0	51
Sanpete	0	50	0	50
Sevier	1	44	0	45
Summit	26	54	0	80
Tooele	11	4	0	15
Uintah	0	9	0	9
Utah	1	40	0	41
Wasatch	79	66	0	145
Washington	39	73	0	112
Wayne	0	0	0	0
Weber	4	13	8	25
Overall Total	**308**	**930**	**37**	**1275**

Table 2F-7 Ranked Total Number of State Owned Facilities in Landslide Susceptibility Areas

Rank	County	Total State Facilities in Landslide Susceptibility Areas	2011-2012 Population Growth Rates
1	Wasatch	145	3.8%
2	Washington	112	2.3%
3	Salt Lake	100	1.5%
4	Cache	94	0.8%
5	Duchesne	84	2.0%
6	Summit	80	1.5%
7	Iron	74	0.2%
8	Rich	55	-2.2%
9	San Juan	51	1.1%
10	Sanpete	50	-0.3%
11	Sevier	45	-0.6%
12	Carbon	43	-0.5%
13	Morgan	43	1.9%
14	Davis	42	1.3%
15	Emery	41	-0.3%
16	Utah	41	2.0%
17	Garfield	25	-1.5%
18	Kane	25	-0.3%
19	Weber	25	1.1%
20	Beaver	22	-0.4%
21	Daggett	18	-6.0%
22	Tooele	15	1.0%
23	Box Elder	13	-0.02%
24	Grand	10	0.6%
25	Millard	9	-0.3%
26	Uintah	9	4.1%
27	Juab	2	0.1%
28	Piute	2	0.5%
29	Wayne	0	-0.9%

Estimating Potential Losses by State Facilities

Approximate current values for state owned facilities were provided by the Utah Division of Risk Management. ESRI GIS software was used to determine which state-owned facilities are within high or moderate landslide susceptibility areas. The current values of those facilities within high or moderate landslide susceptibility areas were then summed in order to determine the total estimated current value of at-risk facilities for each county.

The per capita loss for each county was also determined and put into a table. The per capita loss for every county was ranked from the highest to lowest amount. The population growth percentage estimates from 2011-2012 were put next to the per capita loss amounts to highlight areas of great per capita loss and recent population growth. A map was also created to visualize the potential per capita loss.

Analyzing Tables 2F-6 and 2F-7, and the State Facility Landslide by County maps in Appendix R, State facilities in Cache County are of the greatest risk with 27 buildings in the High hazard zone. Weber County only has 25 buildings at risk but 8 of those are in the high hazard zone. Wasatch, Washington and Salt Lake Counties all have 100 or more buildings in landslide susceptibility areas but zero of those buildings are in the high hazard zones. DEM will work Risk Management and DFCM in obtaining greater detail on the facilities located in landslide susceptibility areas.

Table 2F- 8 Total Insured Value of State Owned Facilities in Landslide Susceptibility Areas (ranked by insured value)

County Name	State Facilities in Landslide Susceptibility Areas	Insured Value of State Facilities in Landslide Susceptibility Areas	2011-2012 Population Growth Rates
Salt Lake	100	$765,347,771	1.5%
Washington	112	$207,773,840	2.3%
Cache	94	$195,210,067	0.8%
Sanpete	50	$162,924,172	-0.3%
Weber	25	$102,530,030	1.1%
Duchesne	84	$96,635,918	2.0%
Iron	74	$82,659,448	0.2%
Utah	41	$62,592,265	2.0%
San Juan	51	$45,355,589	1.1%
Wasatch	145	$40,889,334	3.8%
Davis	42	$39,105,405	1.3%
Carbon	43	$32,136,292	-0.5%
Summit	80	$26,930,862	1.5%
Tooele	15	$20,517,516	1.0%
Emery	41	$17,551,295	-0.3%
Garfield	25	$17,164,396	-1.5%
Kane	25	$10,641,743	-0.3%
Daggett	18	$10,603,193	-6.0%
Box Elder	13	$8,702,602	-0.02%
Rich	55	$8,524,128	-2.2%
Sevier	45	$6,957,395	-0.6%
Morgan	43	$4,399,821	1.9%
Millard	9	$1,999,983	-0.3%
Grand	10	$1,984,550	0.6%
Beaver	22	$1,643,934	-0.4%
Juab	2	$1,339,512	0.1%
Uintah	9	$548,059	4.1%
Piute	2	$115,740	0.5%
Wayne	0	$0	-0.9%
Total	**1275**	**$1,972,784,860**	

Figure 2F-4 Per Capita Loss to State Facilities for Landslides

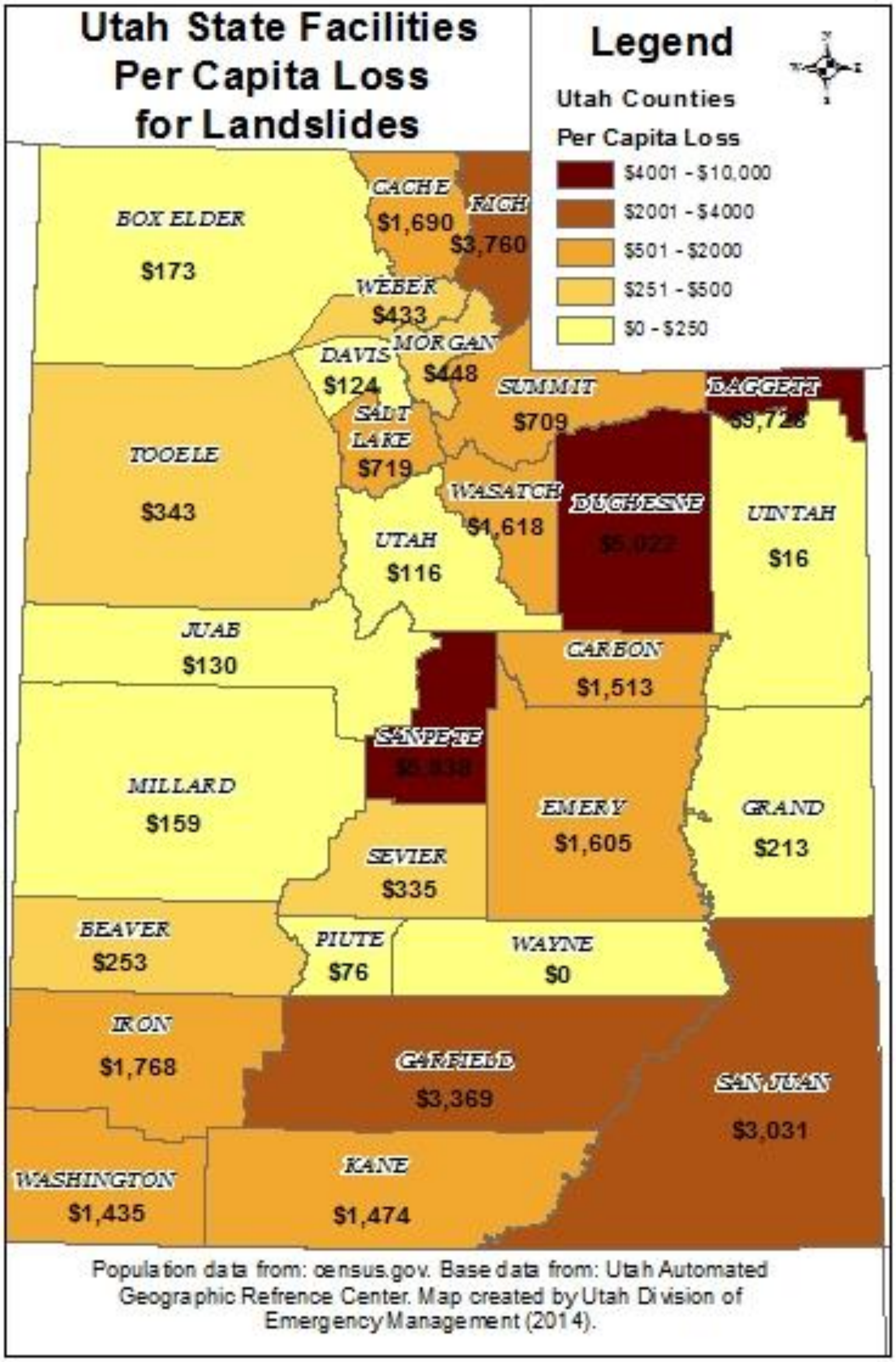


Table 2F-9 Ranked State Facilities per Capita Loss to Landslides

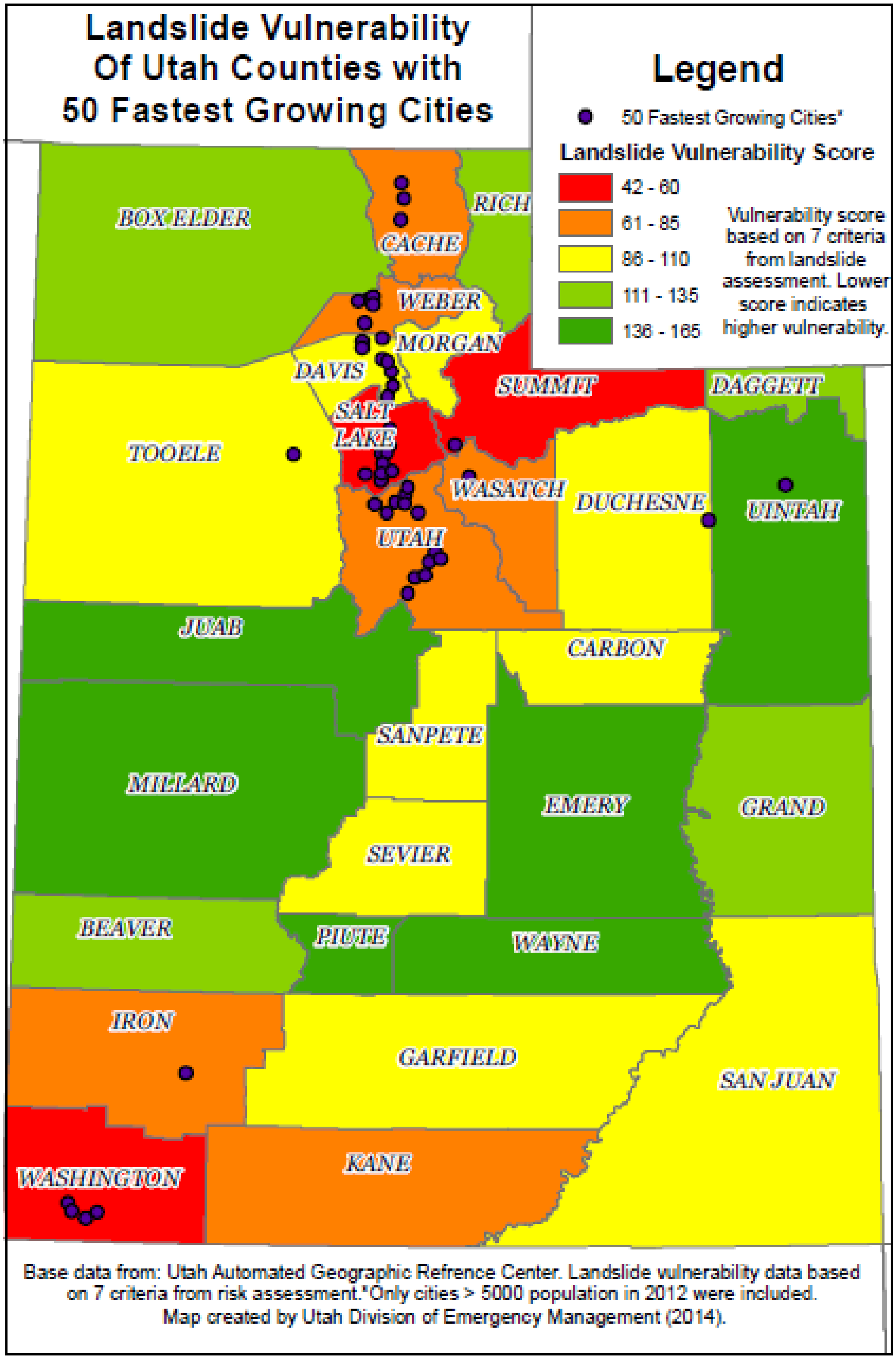
Rank	County	State Facilities Per Capita Loss to Landslides	2011-2012 Population Growth Rates
1	Daggett	$9,728	-6.0%
2	Sanpete	$5,838	-0.3%
3	Duchesne	$5,022	2.0%
4	Rich	$3,760	-2.2%
5	Garfield	$3,369	-1.5%
6	San Juan	$3,031	1.1%
7	Iron	$1,768	0.2%
8	Cache	$1,690	0.8%
9	Wasatch	$1,618	3.8%
10	Emery	$1,605	-0.3%
11	Carbon	$1,513	-0.5%
12	Kane	$1,474	-0.3%
13	Washington	$1,435	2.3%
14	Salt Lake	$719	1.5%
15	Summit	$709	1.5%
16	Morgan	$448	1.9%
17	Weber	$433	1.1%
18	Tooele	$343	1.0%
19	Sevier	$335	-0.6%
20	Beaver	$253	-0.4%
21	Grand	$213	0.6%
22	Box Elder	$173	-0.02%
23	Millard	$159	-0.3%
24	Juab	$130	0.1%
25	Davis	$124	1.3%
26	Utah	$116	2.0%
27	Piute	$76	0.5%
28	Uintah	$16	4.1%
29	Wayne	$0	-0.9%

Table 2F-10 Landslide Vulnerability of Utah Counties*

Rank	County	Vulnerability Score
1	Washington	42
2	Salt Lake	51
3	Summit	58
4	Iron	66
5	Cache	67
6	Kane	68
7	Wasatch	69
8	Weber	74
9	Utah	78
10	Morgan	88
11	Davis	92
11	Duchesne	92
12	Garfield	100
13	Sanpete	101
14	San Juan	102
15	Carbon	104
16	Tooele	107
17	Sevier	108
18	Beaver	114
19	Grand	119
20	Box Elder	120
21	Daggett	126
22	Rich	132
23	Emery	141
24	Uintah	148
25	Millard	151
26	Piute	152
27	Juab	159
28	Wayne	163

*Based on 7 criteria from landslide risk assessment.

Figure 2F-5 Landslide Vulnerability of Utah Counties with 50 Fastest Growing Cities



Utah Landslide Vulnerability Analysis

A vulnerability analysis was performed based on 7 criteria contained in Tables 2F-1 Area of square miles per county with high or moderate landslide risk, 2F-3 Landslide Loss Estimates for Buildings, 2F-4 Ranked Per Capita Loss of Structures Susceptible to Landslides, 2F-7 Total Number of State Owned Facilities in Landslide Susceptibility Areas, 2F-8 Total Insured Value of State Owned Facilities in Landslide Susceptibility Areas, and 2F-9 Ranked State Facilities per Capita Loss to Landslides and figure 2F-3 Per Capita Estimated Loss to Facilities for Landslides.

Each of the criteria was ranked from 1 to 29 for each county (see Table 2F-9 as an example). The ranking numbers were combined for each county and the totals were ranked from 1 to 29 to determine a vulnerability ranking. Counties with the same vulnerability score receive the same ranking number. The counties with the lowest total ranking number would indicate the highest overall vulnerability to hazards. For example, if a county ranked 1 for each of the criteria it would receive a vulnerability ranking of 7. Table 2F-10 and Figure 2F-5 list the results of the analysis. This analysis does not represent the likelihood of landslides impacting a county, but the vulnerability of a county to landslides based on the 7 criteria.

The analysis indicates that the regions of highest landslide vulnerability are along the Wasatch Front and the southwestern corner of the state. The top 11 counties identified on Table 2F-10 are of the greatest concern. The other 18 counties have a landslide risk and do have landslides; the top 11 though have the greatest population, the greatest risk and a track record of having destructive landslides. Better data on structures in landslide areas, as well as better data of landslides throughout the state, is needed to have a better determination of statewide risk.