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Kittitas County Critical Areas Ordinance – Geologically Hazardous Areas

BEST AVAILABLE SCIENCE REVIEW AND CONSIDERATIONS FOR CODE UPDATE

Prepared for: August 2012

Kittitas County

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1.0 INTRODUCTION

Washington State's Growth Management Act (GMA) (RCW 36.70A) requires counties and cities to adopt development regulations that identify and protect the functions and values of critical areas, as well as protect human life and safety. Geologically hazardous areas (GHAs), one of five types of "critical areas" identified by the GMA, are defined as: areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns (RCW36.70A.030[9]). As noted in the GMA implementing rules (WAC 365-190-120) an area that is susceptible to one or more of the following types of hazards must be classified as a geologically hazardous area:

- Erosion hazard;
- Landslide hazard;
- Seismic hazard; or
- Areas subject to other geological events such as coal mine hazards and volcanic hazards including: mass wasting, debris flows, rock falls, and differential settlement.

There are many types of geologically hazardous areas in Kittitas County. This paper provides an overview of the best available science pertaining to geologically hazardous areas in the County. The paper reviews the County's existing geologically hazardous areas regulations in Kittitas County Code (KCC) 17A.06 and offers considerations for how to incorporate the current scientific understanding of geologically hazardous areas into development standards and regulations in Kittitas County. Some geological hazards can be reduced or mitigated by engineering, design, or modified construction practices so that risks to public health and safety are minimized. When mitigation measures cannot reduce risks to acceptable levels, building in geologically hazardous areas should be avoided.

This paper was prepared as part of Kittitas County's effort to update its critical areas ordinance. The County may also use this information to update its shoreline master program under RCW 90.58. These two regulatory programs overlap, so the updates are being closely coordinated.

The County is also engaged in a separate multi-jurisdictional planning effort for hazard mitigation in accordance with Chapter 44 of the Code of Federal Regulations (44 CFR). The County, in partnership with many eligible local governments in Kittitas County, prepared the Kittitas County Hazard Mitigation Plan in 2011 to leverage hazard mitigation resources and to meet requirements of the federal Disaster Mitigation Act of 2000. The Plan contains detailed information on the nature, extent and implications of many types of geologic and non-geologic hazards in Kittitas County, and is incorporated here by reference.

2.0 OVERVIEW OF INVENTORY

Identification of geologically hazard areas requires analysis and understanding of surface and subsurface geology, soils, slopes, faults, watershed conditions, hydrology, streamflow records, and other landform features. Estimates of the rate and frequency of geologic change are also important because geologic processes form, modify, and erode the land surface over time. Many types of geologically hazardous areas can be identified using available geologic maps, soil surveys and/or various types of remote sensing tools such LIDAR, but precise identification, mapping and assessment of risk generally requires site-specific data and analyses.

Not all of the geologically hazardous areas in Kittitas County have been inventoried or mapped. The March 2012 Geologically Hazardous Area map (provided previously under separate cover) depicts steep slopes, landslide hazard areas, and seismic hazards (derived from the Washington Department of Natural Resources (WDNR) liquefaction susceptibility data) in Kittitas County. Inventory and mapping of channel migration zone hazard areas is currently underway in Kittitas County. Mine hazard areas have not been comprehensively inventoried or mapped.

3.0 GEOLOGICALLY HAZARDOUS AREAS IN KITTITAS COUNTY

Kittitas County is situated in central Washington on the eastern slopes of the Cascade Mountains between the Cascade Crest and the Columbia River in the Columbia River basin. The major geological features of Kittitas County are the Cascade and Wenatchee Mountains on the west and north portions, the south-central Yakima River Valley, and the Boylston and Saddle Mountains at the southeastern edge along the Columbia River. The far northern and southwestern areas of the County generally contain the steepest slopes with considerable areas that have slopes greater than 35 percent (Kittitas County, 2012). The eastern part of the County consists more of low, rolling to moderately steep glacial terraces and long, narrow valleys. The southeast section of the County is characterized by moderately steep to steep glacial terraces and steep, rough, broken mountain foothills.

Kittitas County lies within the Yakima Fold Belt subprovince of the Columbia Plateau (Lasmanis, 1991). Slope, geologic and soil conditions vary dramatically throughout the County and include steep mountain peaks, foothills, broad alluvial valleys, and near-desert areas. A simplified geologic sequence for this subprovince includes very old basement sedimentary rocks overlain by consolidated sedimentary rocks, Columbia River basalt flows interbedded with sedimentary layers, and relatively young unconsolidated (or weakly consolidated) materials (e.g., glacial deposits, lacustrine, loess, recent alluvium, etc.). Alpine and continental glaciers moved through this region helping to shape the mountains and deposit glacial materials on older formations.

The primary types of glacial deposits in the County are outwash and till (Lasmanis, 1991). Outwash consists of unconsolidated sand, gravel and rocks and results from runoff of melting glaciers. Outwash is usually loose and highly permeable. Glacial till, or hardpan, consists of unsorted clay, sand, grave, or rock that has been compacted by the weight of the glacial ice into a highly impervious, concrete-like material.

All of these geologic units have been influenced in some way by ongoing structural faulting and folding. Folding occurred in a north-south direction in association with tectonic activity and Cascade volcanism (Lasmanis, 1991). Structural basins formed by this ongoing faulting and folding have typically been filled with un- or weakly consolidated materials.

Three faults known as the Kittitas Valley faults are located within the County. These east-striking faults collectively show a right-stepping pattern in the broad, northwest-trending Kittitas Valley (Lidke, 2002). The Kittitas Valley coincides with a broad northwest-trending syncline that is expressed mostly in Miocene rocks of the Columbia Plateau Basalt Group (Lidke, 2002).

The County's Hazard Mitigation Plan classifies the probability of occurrence of certain hazards using a probability factor based on likelihood of annual occurrence as follows

- High—Hazard event is likely to occur within 25 years (Probability Factor = 3)
- Medium—Hazard event is likely to occur within 100 years (Probability Factor =2)
- Low—Hazard event is not likely to occur within 100 years (Probability Factor =1)
- No exposure—There is no probability of occurrence (Probability Factor = 0)

Using this system, probabilities for Kittitas County hazards are classified as follows (Kittitas County, 2012)[1]:

- Earthquake Hazard – High
- Landslide Hazard – High
- Avalanche Hazard – High
- Volcanic Hazard – Low

3.1 Erosion Hazard Areas

The GMA implementing rules (WAC 365-190-120) define erosion hazards as "areas likely to become unstable, such as bluffs, steep slopes, and areas with unconsolidated soils." Erosion hazard areas occur throughout Kittitas County. The USDA Soil Survey of Kittitas County (NRCS, 2010) describes characteristics associated with each soil type in the County including its level of probability for erosion. The erosion estimates, based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity, are expressed as K-factor (see Table 9 in the Kittitas County Soil Survey available at http://soils.usda.gov/survey/online_surveys/washington/WA637/KittitasWA.pdf).

K-Factor is one of six factors used to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water. Soils in Kittitas County exhibit a wide range of susceptibility to erosion. Erodability may be exacerbated in high gradient areas of the upper watersheds.

3.2 Landslide Hazard Areas

The GMA implementing rules (WAC 365-190-120) define landslide hazard areas as follows:

> Landslide hazard areas shall include areas potentially subject to landslides based on a combination of geologic, topographic, and hydrologic factors. They include any areas susceptible because of any combination of bedrock, soil, slope (gradient), slope aspect, structure, hydrology, or other factors.

Examples of these may include, but are not limited to the following:

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[1] The plan does not rate other types of geologic hazards such as channel migration hazards or mine hazards.

1. Areas of historic failures, such as:
    - Those areas delineated by the Natural Resource Conservation Service (NRCS) as having a “severe” limitation for building site development; or
    - Those areas mapped as class u (unstable), uos (unstable old slides), and urs (unstable recent slides) in the Department of Ecology Coastal Zone Atlas; or
    - Areas designated as quaternary slumps, earth-flows, mudflows, lahars, or landslides on maps published as the U.S. Geological Survey or Washington Department of Natural Resources (DNR) Division of Geology and Earth Resources.
2. Areas with all three of the following characteristics:
    - Slopes steeper than 15 percent;
    - Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock; and
    - Springs or groundwater seepage.
3. Areas that have shown movement during the Holocene epoch (from 10,000 years ago to the present) or which are underlain or covered by mass wastage debris of this epoch;
4. Slopes that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials;
5. Slopes having gradients steeper than 80 percent subject to rockfall during seismic shaking;
6. Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action, including stream channel migration zones;
7. Areas that show evidence of, or are at risk from snow avalanches;
8. Areas located in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows or catastrophic flooding; and
9. Any area with a slope of forty percent or steeper and with a vertical relief of ten or more feet except areas composed of bedrock. A slope is delineated by establishing its toe and top and measured by averaging the inclination over at least ten feet of vertical relief.

Slope stability depends on a number of complex variables (Montgomery et al., 1998). The geology, structure, and amount of groundwater in the slope affect slope failure potential, as do external processes (i.e., climate, topography, slope geometry, and human activity). Steeper areas have more landslides because of the greater slope, more active soil processes, and surface and subsurface water conditions (Thorsen, 1989). Slopes steeper than about 35 percent typically have more landslides and are classified as higher risk landslide hazard areas for clearing and grading. Slopes steeper than about 60 percent present an elevated slide risk with road building or tree cutting (Swanston, 1970; 1978; 1980; 1981; 1989; 1997).

The factors that contribute to slope movements include those that decrease the resistance in the slope materials and those that increase the stresses on the slope. Slope failure under static forces occurs when those forces initiating failure overcome the forces resisting slope movement. For example, a soil slope may be considered stable until it becomes saturated with water (e.g., during heavy rains or due to a broken pipe or sewer line). Under saturated conditions, the water pressure in the individual pores within the soil increases, reducing the strength of the soil. Cutting into the slope and removing the lower portion, or slope toe, can reduce or eliminate the slope support, thereby increasing stress on the slope.

Earthquake motions can induce significant horizontal and vertical dynamic stresses in slopes that can trigger failure. Earthquake-induced landslides can occur in areas with steep slopes that are susceptible to strong ground motion during an earthquake.

Other landslides occur when layers of bedrock, usually basalt flows, slide along planes of weakness. This is usually the result of undercutting along the flank of an anticlinal ridge where basalt and weakly resistant interbeds are tilted at a steep angle.

Although gravity acting on and over steepened slopes is the primary reason for a landslide, there are other contributing factors, including:

- Erosion by rivers or glaciers creates oversteepened slopes.
- Rock and soil slopes are weakened through saturation by snowmelt or heavy rains.
- Earthquakes create stresses that make weak slopes fail.
- Earthquakes of magnitude 4.0 and greater have been known to trigger landslides.
- Volcanic eruptions produce loose ash deposits, heavy rain, and debris flows.
- Excess weight from accumulation of rain or snow, stockpiling of rock or ore, from waste piles, or from human-made structures may stress weak slopes to failure.

According to available data, there have been three recorded landslide events in Kittitas County since 1960 and there are known landslide hazards along the Yakima River. Slopes in much of the western and northern portions of the County are 15 percent or greater. Slopes less than 15 percent are generally found in the river basins in the eastern portions of the County (Kittitas County, 2012). A study of the Swauk Creek watershed found that mass-wasting events (landslides) were common along the Columbia River Basalts in eastern Washington (Lillquist, 2001). Analysis discovered that slope failures covered approximately 38 percent of the Swauk watershed in Kittitas County. Translational slides were the most numerous, but complex slide-flows cover the most area. Slope failures were placed into four categories based on age: active, inactive-young, inactive-mature, and inactive-old. The majority of slope failures were found to be inactive-mature (occurring more than 6,880 years ago), with a minority of inactive-young (more than 5,930 years ago). Rockfall deposits cover approximately 29 percent of the watershed, range from inactive to active, and are typically found on top of previous slope failures in well-jointed Columbia River Basalts. Slope failures are typically associated with steep slopes, inclined beds, incompetent geologic units, streamcuts, road-cuts, and clear-cuts. In addition, extreme climatic events such as rain on snow events can activate slopes which were previously considered stable.

The DNR recently developed a statewide, GIS-based landslide inventory (DNR, 2010). Landslides occur due to the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Exposed rock slopes undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and deep-seated rotational slides. Debris flows consist of a loose mass of rocks and other granular material that, if saturated and present on a steep slope, can move downslope. Landslides may occur on slopes of 15 percent or less; however, the probability is greater on steeper slopes that exhibit old landslide features such as scarps, slanted vegetation, and transverse ridges. The rate of rock and soil movement can vary from a slow creep over many years to a sudden mass movement.

3.2.1 Channel Migration Hazard Areas

Channel migration is a type of landslide hazard associated with rapid stream bank erosion (WAC 365-190-120[6]). Kittitas County has many areas that are potentially unstable as a result stream channel migration including areas located in canyons, on active alluvial fans, and/or presently or potentially subject to inundation by debris flows or catastrophic flooding. Some of the areas at risk of channel migration include portions of the Teanaway River, North Fork Teanaway, Middle Fork Teanaway, Kachess River, Cabin Creek, Coleman Creek, Gold Creek, Coal Creek, Yakima River, Big Creek, Little Creek, Cle Elum River, Scatter Creek, Cooper River, Taneum Creek, Manastash Creek, South Fork Manastash Creek, Naneum Creek, and Wilson Creek (Personal Communication Patricia Olsen, Department of Ecology May 2012 and Christina Wollman Kittitas County, July 2012). The County is in the process of identifying and mapping channel migration areas, including avulsion hazard areas, as part of the Shoreline Master Program update.

3.2.2 Avalanche Hazard Areas

A snow avalanche is a type of slope failure that can occur whenever snow is deposited on slopes steeper than about 20 to 30 degrees. Some parts of western Kittitas County experience avalanche hazards (Kittitas County, 2012). There are two basic types of snow avalanches: point release and slab. A point release avalanche is the result of a small amount of cohesionless snow slipping out of place, moving downslope, and encountering additional cohesionless snow, such that the failure progresses and spreads out into a characteristic inverted V-shaped pattern. Point release events typically occur either within the cohesionless nearsurface layers of newly fallen snow or within the wet surface snow resulting from melt conditions. Point release events usually involve small volumes and generally present a small degree of hazard.

In contrast, slab release occurs when a cohesive cover of snow rests above a layer of lesser strength, along which the eventual sliding failure occurs when shear stress exceeds shear resistance. Slab release typically results from a complex series of events, often originating within a snow cover creeping downslope. Direct loads due to falling cornices, passage of humans through the starting zone, rockfalls, rain-on-snow events, or elastic waves from blasting or earthquakes can trigger slab avalanches.

Slab avalanches initiated within cohesive snow cover on slopes steeper than 25 degrees present the majority of avalanche hazards and are the main focus of defense and control measures. Failures occur when the shear load parallel to the slope exceeds the shear strength of supporting layers, and where the layer of cohesive snow, poorly anchored underneath, fractures as a continuous single unit. With relatively homogeneous snow properties, the fracture may spread for a great distance across a slope and may include a large volume of snow. Fractures may extend as much as several feet into the snow cover. Prediction of slab avalanches is difficult because the location of initial failure is frequently well below the surface, within the layers that accumulated weeks or months earlier. Slab avalanches present a significant hazard due to difficulty of prediction, in addition to their potential for release over large areas. The hazard to activity and structures in the avalanche run-out zone is high due to the large volumes of snow that can be activated by a slab release. Wet snow avalanches present additional problems due to their high mobility and erratic run-out style. Also important is the rapid mass movement of water-saturated snow, known as a slush flow.

Avalanches occur frequently each year and kill one to two people annually in the Northwest (about 25 to 35 deaths annually in the U.S.). Avalanches have killed more people in Washington than any other hazard during the past century. In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide. Avalanches have killed over 200 people in Washington since 1900 and 47 people between 1985 and 2009 (Kittitas County, 2012). This exceeds the death toll of earthquakes and floods combined.

Avalanche-prone areas can be delineated with some accuracy, since under normal circumstances avalanches tend to run down the same paths year after year, although exceptional weather conditions can produce avalanches that overrun normal path boundaries or create new paths. At lower elevations of the Cascades, the avalanche season begins in November and continues until the last remnants of snow have melted in early summer. In the high alpine regions, the hazard continues year-round. Hundreds of thousands of avalanches are thought to occur each year in the Cascades.

3.3 Seismic Hazard Areas

The GMA implementing rules define seismic hazard areas as "areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting" (WAC 365-190-120). Washington is situated at a convergent continental margin where the collisional boundary between two tectonic plates occurs. The Cascadia subduction zone, which is the convergent boundary between the North America plate and the Juan de Fuca plate, lies offshore of Washington, Oregon, and northern California. The two plates are converging at a rate of about 2 inches per year; in addition, the northward-moving Pacific plate is pushing the Juan de Fuca plate north, causing complex seismic strain to accumulate. Earthquakes are caused by the abrupt release of this slowly accumulated strain.

There are three types of earthquakes found in Washington: intraplate or Benioff-zone earthquakes, shallow crustal earthquakes, and subduction zone (interplate) earthquakes (DNR, 2012). Intraplate or Benioff-zone earthquakes occur in the subducting Juan de Fuca plate at depths of over 15 to 62 miles. As the Juan de Fuca plate subducts under the North America plate, earthquakes are caused by the abrupt release of slowly accumulated strain. Benioff-zone ruptures usually have dip-slip or normal faulting and produce no large aftershocks. These earthquakes are caused by mineral changes as the plate moves deeper into the mantle. Temperatures and pressure increase, and the minerals making up the plate alter to denser forms that are more stable at the increased temperature and pressure. The plate shrinks and stresses build up that pull the plate apart. Shallow crustal earthquakes occur within about 30 kilometers of the surface. Shallow crustal earthquakes are the primary mechanism for earthquakes in Kittitas County.

Subduction zone (interplate) earthquakes occur along the interface, between tectonic plates. Compelling evidence for great-magnitude earthquakes along the Cascadia subduction zone has recently been discovered. These earthquakes were potentially devastating (magnitude 8.0 to 9.0+) and recurred on average every 550 years. The recurrence interval, however, has apparently been irregular, as short as about 100 years and as long as about 1,100 years. The last of these great earthquakes occurred in Washington about 300 years ago. The USGS is currently conducting studies to further understand seismic risks in Eastern Washington which may be greater than previously recognized.

Areas considered to be at high risk of earthquake damage include surface deposits of manmade fill or partially decomposed organic material, filled wetlands, and areas of alluvial deposits subject to liquefaction. However, seismic risk is very complex and site conditions vary widely throughout the County. While some areas face a greater risk than others, all of Kittitas County is potentially at risk of significant earthquake damage.

Earthquakes can trigger large and sometimes disastrous landslides. Earthquakes can also weaken dams and levees. The County’s Hazard Mitigation Plan assesses risks of dam failure including failure associated with seismic events (Kittitas County, 2012).

Kittitas County is considered to be seismically active and while no major earthquake (magnitude 7 or more) has occurred in the last 300 years there is a potential for one to occur in the future. Damage from a seismic event would most likely result from ground shaking. Ground movement during an earthquake can vary depending on the overall magnitude, distance to the fault, focus of earthquake energy, and type of underlying geologic material. The composition of underlying soils, even those relatively distant from faults, can intensify ground shaking through amplification of ground movement and prolonging ground shaking. Secondary effects such as settlement, differential settlement, liquefaction, and lateral spreading are other seismic hazards associated with earthquake events.

3.3.1 Ground Shaking

An earthquake is an abrupt movement of the earth’s crust, caused by a sudden release of energy that has accumulated over time along a plane of movement known as a fault (USGS, 1997). Energy can be released through a sudden dislocation of fault blocks, triggered by volcanic activity, or through human made activities such as explosions. Dislocations of the crust expressed at the surface typically cause the most destruction. The crust may first bend and then, when the stress exceeds the strength of the rocks, break and snap to a new position. In the process of breaking, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake, along the surface and through the earth at varying speeds, depending on the material through which they move. The focal depth of an earthquake is the depth from the earth's surface to the region where an earthquake's energy originates (the focus).

The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth (USGS, 1997). The vibrations produced by earthquakes are detected, recorded, and measured by instruments called seismographs. Measurements by the seismograph, called a seismogram, reflect the changing intensity of the vibrations by responding to the motion of the ground surface beneath the instrument. From the data expressed in seismograms, scientists can determine the time, the epicenter, the focal depth, and the type of faulting of an earthquake, and can estimate how much energy was released.

The two general types of vibrations produced by earthquakes are surface waves, which travel along the earth's surface, and body waves, which travel through the earth. Surface waves usually have the strongest vibrations and probably cause most of the damage done by earthquakes (USGS, 1997). Body waves are of two types, compressional and shear. Both types pass through the earth's interior from the focus of an earthquake to distant points on the surface, but only compressional waves travel through the earth's molten core. The magnitude of an earthquake, usually expressed using the Richter scale, is a measure of the amplitude of the seismic waves. The moment magnitude of an earthquake is a measure of the amount of energy released—an amount that can be estimated from seismograph readings. The intensity, as expressed by the modified Mercalli scale, is a subjective measure that qualitatively describes how strong a shock was felt at a particular location. The Modified Mercalli (MM) intensity scale is commonly used to measure earthquake damage due to ground shaking. The MM values for intensity range from I (earthquake not felt) to XII (damage nearly total), and intensities ranging from IV to X could cause moderate to significant structural damage.[2] The intensities of an earthquake will vary over the region of a fault and generally decrease with distance from the epicenter of the earthquake.

Since 1971, a total of 33 recorded earthquakes of magnitude 3.0 or greater have occurred within the County ranging in magnitude from 3.0 to 4.3 (Kittitas County, 2012). Earthquakes of this magnitude are considered to be generally minor to light.

3.3.2 Settlement

Ground settlement can occur from immediate settlement, consolidation, shrinkage of expansive soil, and liquefaction (discussed below). Immediate settlement occurs when a load from a structure or placement of new fill material is applied, causing distortion in the underlying materials. This settlement occurs quickly and is typically complete after placement of the final load. Consolidation settlement occurs in alluvial deposits such as saturated clay from the volume change caused by squeezing out water from the pore spaces. Consolidation occurs over a period of time and is followed by secondary compression, which is a continued change in void ratio under the continued application of the load. Soils tend to settle at different rates and by varying amounts depending on the load weight or changes in properties over an area, which is referred to as differential settlement.

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid compaction and settling of subsurface materials (particularly loose, uncompacted, and variable sandy sediments above the water table) due to the rearrangement of soil particles during prolonged ground shaking. Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different amounts).

3.3.3 Liquefaction

Liquefaction is a transformation of soil from a solid to a liquefied state during which saturated soil temporarily loses strength resulting from the buildup of excess pore water pressure, especially during earthquake-induced cyclic loading. Soil susceptible to liquefaction includes loose to medium dense sand and gravel, low-plasticity silt, and some low-plasticity clay deposits that are saturated from a relatively shallow aquifer (generally less than 50 feet below ground surface). The depth to groundwater influences the potential for liquefaction, in that sediments need to be saturated to have a potential for liquefaction. Four kinds of ground failure commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength. These are described below.

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[2] The damage level represents the estimated overall level of damage that will occur for various MM intensity levels. The damage, however, will not be uniform. Not all buildings perform identically in an earthquake. The age, material, type, method of construction, size, and shape of a building all affect its performance

- Lateral spreading is the horizontal displacement of surficial blocks of sediments resulting from liquefaction in a subsurface layer that occurs on slopes ranging between 0.3 and 3 percent and commonly displaces the surface by several meters to tens of meters.

- Flow failures occur on slopes greater than 3 degrees and are primarily liquefied soil or blocks of intact material riding on a liquefied subsurface zone.

- Ground oscillation occurs on gentle slopes when liquefaction occurs at depth and no lateral displacement takes place. Soil units that are not liquefied may pull apart from each other and oscillate on the liquefied zone.

- The loss of bearing pressure can occur beneath a structure when the underlying soil loses strength and liquefies. When this occurs, the structure can settle, tip, or even become buoyant and "float" upwards. Liquefaction and associated failures could damage foundations, roads, underground cables and pipelines, and disrupt utility service.

The DNR recently produced *Preliminary Liquefaction Susceptibility and NEHRP Soil Type Maps for Washington State* (DNR, 2004).[3] A liquefaction susceptibility map presents an estimate of the susceptibility of the soils to liquefy as a result of earthquake shaking. The susceptibility is a measure of the physical characteristics of a soil column, such as grain texture, compaction, and depth of groundwater, which determine the propensity of the soil to liquefy during earthquake shaking. A liquefaction susceptibility map depicts the relative hazard in terms of high, moderate, or low liquefaction susceptibility, and cannot be used to directly predict the severity of permanent ground deformation resulting from liquefaction. Assessment of ground failure effects depends on local site conditions (e.g., slope steepness or the presence of free faces). The preliminary versions of the liquefaction susceptibility and NEHRP soil type maps are based on 1:100,000-scale geologic mapping.

The liquefaction susceptibility and NEHRP soil type maps are meant only as a general guide to delineate areas based on their potential for enhanced ground shaking. It is not a substitute for site-specific investigation to assess the actual ground conditions and potential for amplified ground shaking, as measured by the NEHRP soil type or other more quantitative analyses. Because the data used in producing this NEHRP soil type map is based on regional geologic mapping, this map cannot be used to make a final determination at any specific locality.

3.3.4 Surface Fault Rupture

Seismically induced ground rupture is defined as the physical displacement of surface deposits in response to an earthquake's seismic waves. The magnitude, sense, and nature of fault rupture can vary for different faults or even along different strands of the same fault. Ground rupture is considered more likely along active faults, which are faults that have experienced rupture within the last 11,000 years. There are no active faults located within Kittitas County and the three Kittitas Valley faults have not shown any definitive displacement within the last 1.6 million years (Lidke, 2002). Therefore, the likelihood of surface fault rupture occurring within the planning area is considered very low.

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[3] The National Earthquake Hazards Reduction Program (NEHRP) is a federal program that involves the relevant activities of four federal agencies, each of which has a distinct role in reducing earthquake risk.

3.4 Other Geologically Hazardous Areas

3.4.1 Volcanic Hazard Areas

Volcanic hazard areas as “areas subject to pyroclastic flows, lava flows, debris avalanche, inundation by debris flows, mudflows, or related flooding resulting from volcanic activity.” There are no active or dormant volcanoes located within Kittitas County; however Mount Rainer and Mount St. Helens are relatively near. Hazards to Kittitas County residents from these volcanoes are limited to ash deposition. The more devastating effects of volcanic activity, such as lava flows and lahars, would not affect Kittitas County because of intervening ridges.

3.4.2 Mine Hazards Areas

Mine hazard areas are underlain by abandoned mine shafts, secondary passages between shafts tunnels, or air vents. Mine hazards include subsidence, which is the uneven downward movement of the ground surface caused by underground workings caving in; contamination to ground and surface water from tailings and underground workings; concentrations of lethal or noxious gases; and underground fires. The location or extent of mine hazard areas in Kittitas County is unknown; however, historic coal and gold mining occurred historically in the Roslyn and Swauk Creek area, so there is a potential for mine hazards.

4.0 HUMAN ACTIVITY AND GEOLOGICALLY HAZARDOUS AREAS

Some geologic processes such as erosion and channel migration are easily influenced by human actions, while other events such as earthquakes or volcanoes occur at a scale or magnitude over which humans have limited control. Whether or not they are caused human actions, geologic events have a major effect on human health and safety and on the health of streams and other resources. Therefore, geologically hazardous areas present unique challenges for land use planning and development. This section describes some of the considerations important to land use planning in Kittitas County.

4.1 Erosion and Landslides Hazards

Erosion is a natural process that can be exacerbated by human activities such as vegetation clearing and grading. Erosion occurs when rainfall or accidental surface water discharges hitting a disturbed land surface cause soil particles to break away and move downslope. As water accumulates, it gains volume and energy and is able to mobilize ever larger soil particles. The eroded materials, which eventually get deposited on land or in streams, lakes or other waterbodies, can have a variety of detrimental effects on fish and wildlife and people. Eroded sediments can bury fish eggs or fill the spaces between gravel that support aquatic insects. Erosion can also impair water quality because sediments often transport nutrients such as phosphorus and other pollutants. Erosion often leads to stream channel in-fill and avulsion, blockage to fish passage, and loss of flood storage. Excessive soil erosion can lead to damage of building foundations and roadways.

Typically, erosion and landslide potential are increased with ground disturbing activities that expose soils to the effects of wind and water. Any type of soil can erode, but not all erosion is transported to adjacent properties or surface waters. Consequently, the proximity of ground disturbing activities to surface waters will often determine the type or level of risk associated with erosion and landslide hazard areas. Soils that are impermeable or minimally permeable generate surface water runoff and begin to erode sooner than very porous soils. Vegetation, the organic duff layer, small depressions, and soil density all minimize runoff and erosion.

People affect erosion and landslide hazard areas by clearing vegetation, grading and excavating soils, modifying drainage, and/or developing on steep slopes. Clearing and grading change the overall stability of a slope and often increase runoff, erosion, or landslide hazards down slope. Clearing and grading reduce interception of precipitation and remove the litter and loose surface soil layer (Konrad, 2000, 2003; Konrad and Burgess, 2001; Booth, 1990; Burgess et al. 1998). Removing vegetation, especially deep-rooted mature plants, reduces or removes the strength that roots provide to the soils on river banks and steep slopes (Bennett and Simon, 2004; Gray and Barker, 2004). Increased runoff is then concentrated directly into ditches, swales or other channels to creeks. The combined cumulative impact can lead to landslides if high risk areas are not avoided and adequate control measures are not provided and maintained.

4.1.1 Channel Migration Hazards

Stream and river channels change and move in balance to water, sediment, wood supply, and streambank conditions. The size of the stream, watershed conditions, valley bottom materials and conditions, gradient, degree and type of encroachment into the historic channel meander zone, and many other factors cumulatively create the potential for some rivers or streams to migrate or jump across the valley bottom (Rapp and Abbe, 2003). The natural tendency of channels to migrate is also influenced by increased runoff and/or bedload sediment supply from clearing, logging, roads, agriculture, and other actions in the surrounding watershed. When increased stormflow runoff is concentrated in creeks and rivers, it increases the frequency, magnitude, and duration of flood flows. This in turn causes changes in the rate and amount of incision, deposition, increased bank erosion, and related channel migration.

Migration rates are often further increased by clearing of trees along stream banks and in the channel migration zone. Dense streambank and overbank vegetation slows water velocity, leading to sediment deposition. When vegetation cover is removed or modified, erosion occurs (Bennett and Simon, 2004). Removal of trees and dense vegetation from the channel migration zone reduces the stream's ability to recruit woody material and reduces the quality, diversity and availability of in-stream habitat for fish and other aquatic species (Bolton and Shellberg, 2001).

People living near stream and river systems often attempt to control or mute these natural processes by armoring stream banks and/or constructing levees and other types of revetments to stop channel migration. People often assume that levees and other structures will protect them from channel migration hazards; however, when these control measures fail residents and property are at risk.

Although levees, bank armor, and other "river training" structures sometime do reduce or stop channel migration, these structures often reduce the quality and availability of instream and riparian habitats for fish and wildlife. River processes and aquatic habitat conditions depend on the ability of the river to change and form on its own. These functions are hampered by increased stormwater runoff, channel confinement and bank armoring, levees, or other projects designed to reduce channel migration. Bank protection projects often confine the channel and floods to a much smaller width, which can exacerbate channel changes, reduce the complexity of instream habitat, scour spawning beds, and cause other adverse ecological effects.

While it is important to protect the functions and values of stream corridors for water quality, quantity, and fish and wildlife habitat, it is also important to protect life and property from the natural hazards associated with the stream corridor. Alterations of stream corridors or natural drainage patterns expose areas to increased erosion that if not addressed can threaten the stability of building foundations, roads, bridges, or other developments or otherwise pose substantial risks to life and property.

Natural watershed and channel processes, forest management, roads, utilities, agriculture, and residential development can also reduce stability of valley wall slopes and streams upstream of alluvial fans. This in turn increases the natural tendency of floods to deposit sediment and change channels on alluvial fans. Clearing and excavation on alluvial fans can also alter channel migration and flooding areas. The soil strength, changes to rainfall-runoff response, and drainage patterns influence the degree and extent of instability and the subsequent occurrence of valley wall landslides and erosion. Landslides and erosion increase sediment supply and channel migration along the channel and on the alluvial fan, resulting in increased probability and magnitude of debris flows, large floods, and sediment deposition on the fan. Even moderate sized floods from an undisturbed basin can shift the main or side channels across most or all of an alluvial fan.

Not all portions of an alluvial fan are equally active at any given time, and it is difficult to identify or predict which area of an alluvial fan may be active. Relatively recent activity on one portion of a fan is no guarantee that other portions are inactive. For this reason, development on alluvial fans can be problematic and protective structures may be required to protect roads, bridges, and other structures. These measures are typically aimed at keeping the floods and debris flows on one portion of the fan.

Dredging is one means by which people often attempt to address alluvial fan hazards. Intermittent dredging following a moderate or large depositional event, or a number of smaller ones, does not guarantee adequate storage for the next flood; a large flood can still overwhelm the room provided for sediment storage, ultimately sending the floodwaters or channel in alternate directions across the fan.

Critical structures like bridges can be built to survive most floods, but it is often economically and technically impractical to build houses and other facilities to those standards. Consequently avoidance, limitations of the types of development, and buffers on the channel migration zone, (just the present channel location), can be used to reduce damage or losses in or near the channel migration zone of alluvial fans

4.1.2 Avalanche Hazards

Avalanches occur regularly in mountainous areas as result of weather and terrain factors such as rate of snowfall, temperature, slope, aspect, and ground cover (Kittitas County, 2012). Human actions typically do not have a direct influence on avalanche hazards, but people sometimes trigger avalanches intentionally (as a means of hazard mitigation) or unintentionally as a result of recreational activities. Most avalanche prone areas in the County are within the Mount Baker-Snoqualmie National Forest and other protected forests, so risks associated with human activity are low.

4.2 Seismic Hazards

The damage caused by seismic activity is dependent upon the intensity of the earthquake, its proximity to developed areas and population centers, the slope, thickness, consolidation, and moisture conditions of the surface and subsurface materials, and many other factors. Human actions have no influence on the likelihood of occurrence, timing, or severity of a seismic event. As a result, avoidance of high-risk hazard areas and adherence to the County building code standards are the main vehicles for reducing risks from seismic hazards.

5.0 REVIEW OF KITTITAS COUNTY GHA REGULATIONS

Kittitas County's existing critical areas code (KCC 17A) has minimal regulations for geologically hazardous areas and it is unclear how the existing regulations, as written, are administered or enforced. The code lacks many of the standard provisions found in most county codes for best management practices (BMP) related to setbacks and buffers, stormwater/drainage management, impact avoidance, environmental mitigation, and the like. The code states that areas identified as high risk geologic hazard areas such as cliffs or talus slopes may require specialized engineering to determine if the property is suitable for development purposes, but there are no details on the engineering requirements or suitability criteria a development proposal is required to meet.

KCC section 17A.06 indicates that the County has adopted the Uniform Building Code provisions for geologically hazardous areas. However this regulation appears to be superseded by the County's building code (KCC 14.04), which indicates that the International Building Code (IBC) rules and regulations (as adopted and amended by the Washington State Building Code Council pursuant to RCW 19.27) apply to the construction, alteration, removal, demolition, equipment, use and occupancy, location and maintenance of buildings and structures. The adoption of the 2009 International Building, Residential, Mechanical and Fire Codes and the 2009 Uniform Plumbing Code, with state amendments, became effective on July 1, 2010, along with amendments to the Washington State Energy Code. The IBC includes minimum seismic design requirements that consider probable seismic sources. Current code requirements recognize the effects of site-specific soil conditions and fundamental building response periods to structure seismic performance. The IBC also references many standards and documents that are enforced including the American Society of Civil Engineers (ASCE) Publication 7-05, *Minimum Design Loads for Buildings and Other Structures*.

The only other requirements for development in geologically hazardous areas in KCC 17A.06 are as follows:

- Natural resource based activities shall not be unduly restricted or prohibited in areas of known geologic hazards;
- The County shall enforce the policies contained within the Snoqualmie Pass Sub-Area Comprehensive Plan for avalanche hazard areas;
- Siting of structures on known mine hazard areas must be avoided; and
- Intentional disposal of volcanic ash fallout into any bodies of water shall not be allowed.

6.0 CONSIDERATIONS FOR CODE UPDATE

Geologically hazardous areas pose a potential threat to the health and safety of Kittitas County citizens when incompatible or poorly engineered commercial, residential, or industrial development is constructed in hazardous areas. Many geological hazards can be reduced or even eliminated through implementation of geotechnical engineering, design, and construction in accordance with current building code regulations, such that risks to human health and safety are considered acceptable. When technology cannot reduce risks to acceptable levels, building in geologically hazardous areas is best avoided.

Considering the limited nature of the existing regulations and the information presented above, there are several opportunities to improve the geologically hazardous areas section of KCC Title 17A to make it more consistent with scientific standards and commonly accepted management practices. Specific recommendations are as follows:

6.1 General Considerations

Kittitas County should revise the geologically hazardous areas designations to make them consistent with the GMA. This will ensure that all types of potentially hazardous areas are addressed during the development review process. Having accurate information about the location and extent of geologic hazards is critical for assessing and mitigating them. Many geologically hazardous areas can only be truly determined through site-specific analysis of near surface and subsurface conditions prior to commencement of construction. As a result, the code should include more specific criteria for when a hazard area delineation or assessment is required. The code should stipulate that in addition to defining the presence and/or extent of a hazard area on a development site, developers should consider activities on adjacent areas that may result in an increased hazard. Failure to consider the entire physical and social environment, including secondary impacts and downstream or down slope conditions, can lead to dangerous conditions. The code should specify that analyses of geologic hazards should be prepared by qualified professionals with the appropriate expertise, credentials/certifications and experience. Douglas County’s critical areas code outlines a three-step process for identifying and addressing geologically hazardous areas during the development review process, which may be an appropriate model for Kittitas County.

For some types of hazards, it may be appropriate to include language on the building permit, plat and/or property title concerning the location and extent of the hazard. Requiring notice on title to disclose presence of a hazard area as part of the County’s permit process would ensure that future property owners are alerted to the presence of potential hazards.

6.2 Code Considerations for Erosion Hazard Areas

Erosion hazards are closely related to drainage control, ground disturbing activities, and slope failure. Typically, the soil erosion potential is reduced once the soil is graded and covered with concrete, structures, asphalt, or given slope protection. Incorporation of appropriate drainage control features into project design can help reduce erosion hazards. Projects proposed to be located on soils shown to possess a high risk for erosion should be required to comply with the appropriate BMP as outlined by the *Model Municipal Stormwater Program for Eastern Washington* (Ecology, 2003). Prevention of soil erosion should consider construction phase activities as well as post construction conditions to ensure that soils are stabilized while exposed during construction, and then protected from the effects of stormwater runoff during operational phases. The Washington Department of Ecology (Ecology) oversees drainage activities, BMP utilization, and water quality standards related to the federal Clean Water Act. Adherence to the requirements of the Clean Water Act and Ecology drainage control standards would include measures to minimize the potential for erosion. The County should consider developing a comprehensive set of building, drainage, and erosion guidelines and regulations that focus on minimizing potential erosion during construction as well as post-construction. In general, BMP requirements that are enforced for the purpose of protection of water quality through minimization of sedimentation in offsite runoff, especially during construction phases, are adequate to prevent or minimize the erosion potential.

6.3 Code Considerations for Landslide Hazard Areas

There are a number of ways in which the hazards of slope failures or landslides can be prevented:

- Prevent building above or on the hazard area, to prevent overweighting or altering drainage patterns that might trigger the hazard area;
- Include provisions for requiring setbacks from the top and toe of landslide-prone areas where necessary;
- Avoid grading into old slide materials or into areas with sliding tendencies;
- Implement building setbacks at the base of cliffs or steep slopes prone to rock falls;
- Include provisions to require retention of native vegetation on steep slopes to improve stability;
- Use of effective vegetation control with timely application implemented immediately following construction or grading;
- Add code language that identifies seismically generated landslide and run-out areas, and develop an approach to classify high, moderate, and low risk areas; and
- Implement drainage guidelines.

Building setbacks, vegetated buffers, terraced slope construction, and drainage guidelines are commonly used to reduce hazards from landslides or in landslide prone areas. Because small landslide areas and many erosion areas can be modified with structures provided that adequate drainage improvements and other construction methods are implemented, the code should remain adaptable to address site specific conditions under the oversight of a licensed geotechnical engineer or engineering geologist. This places considerable responsibility on site specific geotechnical studies, design approaches, review processes, construction methods, and effective monitoring.

6.3.1 Avalanche Hazards

Protection against potential avalanche hazards can be accomplished through avoidance or employment of engineering techniques. In general, the code should prohibit structures directly within the risk zones or immediately downslope from these areas. Engineering techniques such as snow sheds and wedges can be applied to modify terrain so as to divert moving snow from facilities, and various fence structures have been designed to stabilize snow on mountainsides. Artificial release techniques focus on the frequent release of small avalanches to inhibit the formation of large avalanches, and employ explosive charges. However, these artificial release techniques are generally not as effective as simple avoidance and any hazard areas located within state controlled land would not be subject to County requirements.

The County's Hazard Mitigation Plan notes that measures that have been used in other jurisdictions to reduce avalanche threat include monitoring timber harvest practices in slide-prone areas to ensure that snow cover is stabilized as well as possible, and encouraging reforestation in areas near highways, buildings, power lines and other improvements. The Hazard Mitigation Plan also recommends development of a standard avalanche report form, and the maintenance of a database of potential avalanche hazards as additional measures to mitigate avalanche risks (Kittitas County, 2012).

6.3.2 Channel Migration Hazards

Flood damage, degradation of stream channel or streambank stability, and development in the flood or channel migration zone are all closely related. Development in the floodway and channel migration zone creates potential risks of damage from either intense storm events or through long term changes in channel geomorphology. Structures intended to protect developments that encroach into the channel migration zone and floodway can cause further damage downstream as well as degrade aquatic habitat conditions.

The most basic but least used approach to reducing problems related to stream channel migration is simply to allow adequate room for stream processes. Although this approach often conflicts with historic development and property ownership, long-term reduction of encroachment (over 30 to 100 years) will greatly reduce flood and channel migration damage costs, protect habitat values and will allow for restoration of aquatic habitat, which is expensive and difficult to accomplish while the encroachment still exists. Long-term planning needs to account for and work with ongoing stream processes to reduce the danger from sudden channel changes, reduce flood and river management costs, and allow for aquatic habitat improvements. Specific restrictions or limits on development within the floodplain, the channel migration zone, and the avulsion hazard areas should be incorporated into the code. The code should also prohibit structures within or near an active alluvial fan. The code should also include standards to retain vegetated riparian buffers to mitigate bank erosion and channel migration.

6.4 Code Considerations for Seismic Hazard Areas

Basic risk reduction strategies in seismically hazardous areas are intended either to limit the intensity of land use or to apply more stringent building standards for development. Building code requirements incorporate the latest scientific findings based on actual seismic events that occur throughout the world. If the seismic risk is high and cannot be reduced, then development may be prohibited or limited through zoning or other land use regulations. However, in general, most structures and improvements are feasible from a geotechnical perspective provided appropriate site preparations and foundation design measures are incorporated into construction specifications. International Building Code standards are routinely updated to incorporate the most current science regarding seismic performance of buildings, building foundations, and foundation soil preparations.

To respond to the evolving understanding of the seismic risk in this region, the County should continue to link regulations to the most current version of the IBC and relevant local USGS or other agency documents and studies; as codes and studies change, the County code should also change. The County could establish seismic retrofitting requirements for redevelopment projects in addition to new construction and development standards for this tectonically active area.

Critical and specialized structures such as hospitals and utilities should receive special analysis and design conditions that exceed standard code guidelines.

6.5 Code Considerations for Other Geologic Hazards

While Kittitas County is in close proximity to Mount Rainer and Mount St. Helens, the threat of volcanic hazards is minimal and limited to ash deposition. The more devastating effects of volcanic activity, such as lava flows and lahars, are not possible due to intervening ridges. Therefore, development regulations to protect citizens and property from volcanic hazards are unnecessary in Kittitas County.

The County's standard to avoid siting structures in/near mine hazard areas is appropriate, but without better mapping or a mechanism for identifying these areas, the standard would be difficult to administer. Requiring developments in areas of suspected mining activity to investigate these risks would help to prevent hazardous situations.

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