Ozette Lake Watershed Administrative Unit

LANDSLIDE HAZARD ZONATION PROJECT

Clallam County, Washington

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February 25, 2008

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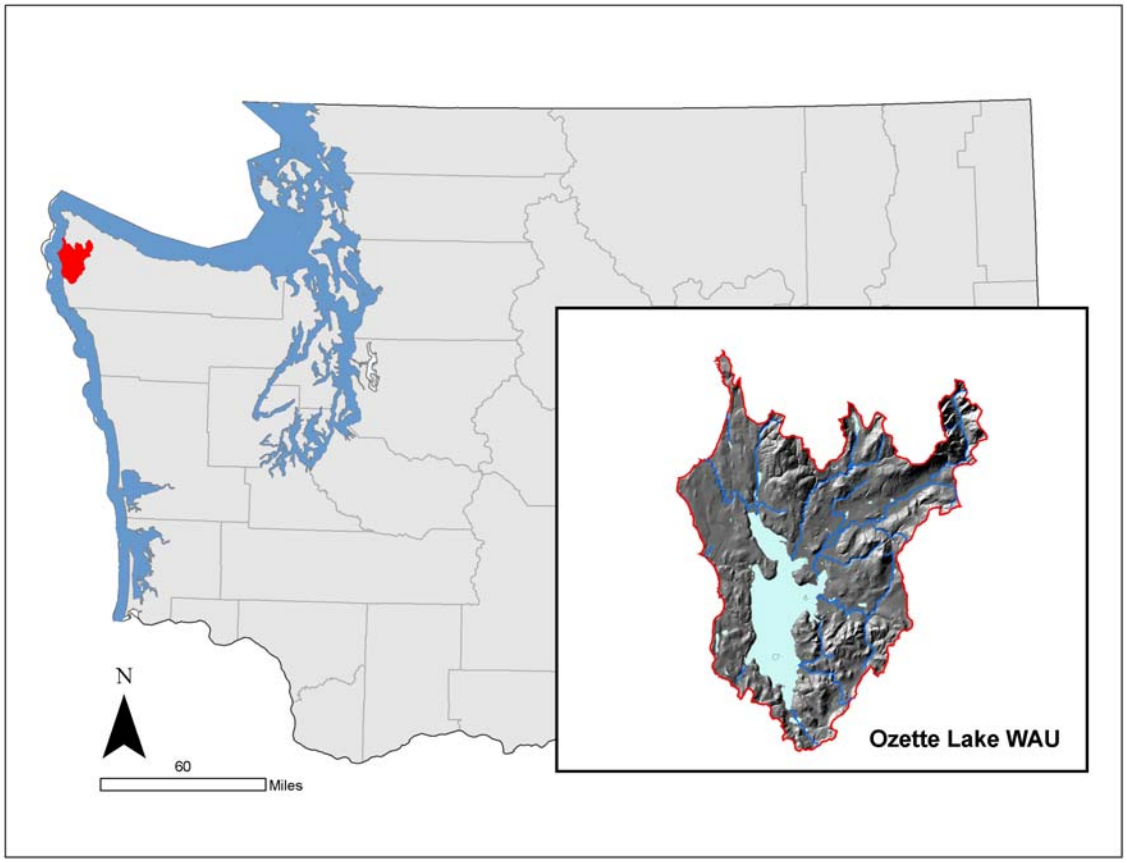

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1.0 Introduction

This mass wasting assessment includes forestlands in the Ozette Lake Watershed Administrative Unit (WAU) # 200120 in Clallam County**,** Washington. The purpose of the assessment was to identify and characterize landslide processes in the project area and use this information to divide the landscape into distinct hazard zones based on their mass wasting potential. The assessment consists of three parts: a map of observed landslides, a map of landslide hazard zones, and this report detailing the project findings. The assessment is intended for use by foresters, engineers, and other resource professionals as a landscape-scale screening tool to aid in planning and decision-making related to forest management activities in the Ozette Lake WAU. The work was completed using the protocol for the Landslide Hazard Zonation (LHZ) Project that is being conducted by the Washington Department of Natural Resources.

The Ozette Lake assessment includes all non-federal and non-tribal forestlands within the WAU. The basis of the Ozette Lake WAU assessment is a landslide inventory compiled from aerial photographs spanning the period 1985 to 2005. The assessment assumes that aerial photographs can be used to infer and record the history of land use and mass wasting in a project area. The assessment also assumes that the physical characteristics of sites where landslides have occurred in the past can be used to predict where landslides are likely to occur in the future. The majority of the landslide mapping reflects a reconnaissance level survey based on the aerial photograph analysis. The assessment should be applied to land management planning and decision-making with these limitations in mind.

2.0 Project Area Overview

2.1 Physical Setting

The Ozette Lake project area is located in Townships 30, 31, and 32, Ranges 14, 15, and 16 West, respectively and Township 29, Ranges 14 and 15 West in western Clallam County, Washington. The Ozette Lake WAU includes 119,162 acres, of which approximately 54,560 acres are the Pacific Ocean. Of the remaining 64,602 acres, approximately 20,500 acres are National Park lands (including Lake Ozette), 4,800 acres are DNR-managed lands, and less than 1,000 acres are tribal lands. The assessment does not include lands that are federally managed or tribally owned.

2.2 Physiography

Elevations in the Ozette Lake project area range from sea level along the coast to just under 2,000 feet in the northeast near Sekiu Mountain. A significant portion of the project area includes low elevation, gently sloping topography with slope gradients less than 40 percent; however, extremely rugged terrain exists in some areas underlain by non-glacial sediments including the northeast portion of the WAU where the headwaters of Big River originate. This part of the project area includes inner gorges, bedrock hollows, and over-steepened planar slopes. Many of the slope gradients in this area exceed 70 percent. Big River and Umbrella Creek both initially flow north to south

through this rugged terrain, while Crooked Creek flows east to west through relatively flat terrain. All three streams flow into Lake Ozette and are important sockeye spawning habitat.

2.3 Climate

The western coast of the Olympic Peninsula has a temperate marine-influenced climate. Average annual maximum temperature for 1966-2007 was 57.3°F at Quillayute; average annual minimum temperature for the same time period was 41.1°F (Western Regional Climate Center, 2007). Average annual precipitation was approximately 102 inches, with an average of 14.6 inches falling in December, the wettest month. Approximately 75 percent of this precipitation falls between October and March. The most notable extreme precipitation years were 1975 (131.6 inches), 1999 (131.4 inches), 1968 (129.4 inches), 1997 (128.9 inches), and 1974 (127.8 inches).

2.4 Geology

The geology of the Ozette Lake area has been mapped and described by Long (1976), Tabor and Cady (1978), Snavely et al. (1993), and Schasse (2003). The dynamic geologic history of the region has shaped the weathering and mass wasting processes of the project area. The marine sediments in the area have undergone extensive tectonic uplift, which has resulted in ongoing stream incision and steep, rugged slopes and deep valleys. The area was also altered during the Pleistocene glaciation, during which time glacial till (and more generally mapped glacial drift) was deposited by the Juan de Fuca lobe of the Cordilleran ice sheet. Lake Ozette, for instance, is dammed on its western side by a glacial moraine.

Due in part to this varied geologic history, the project area can be broken down into three fairly distinct geologic zones which are unique in terms of their frequency of mass wasting and landforms. These three geologically homogeneous areas are (i) the extensive, flat to low-gradient glacial deposits found in the central and coastal regions of the project area; (ii) the steep to gently sloping northwestern and southern portions of the project area, dominated by the Ozette-Lake Calawah Ridge Block, Oligocene-Eocene marine sedimentary rocks (OEm(o)); and (iii) the northeastern portion of the project area that consists of very steep, rugged terrain due in part to a series of thrust and other faults and a mix of basic intrusive rocks, marine sedimentary rocks, basalt flows, and volcanic rocks. Figures 1-3 at the end of the report illustrate the regional geology. A summary of each geologic zone follows.

2.4.1 Glacial Deposits

The majority of the Ozette Lake WAU is mapped as Qgt or Qgd. Schasse (2003) described the Qgt as an unsorted, unstratified, compact mixture of clay, silt, sand, gravel, and boulders. The deposits resulted from the Juan de Fuca lobe of the continental ice sheet that was present in the Strait of Juan de Fuca from approximately 15,000 years B.P. (Heusser, 1973) to approximately 13,000 years B.P. (Gerstel and Lingley, 2000). Qgd includes till and outwash deposits from continental and alpine glaciers, including lacustrine deposits and glacial deposits that have been stream-modified.

2.4.2 Marine Sedimentary Rocks
OEm(o), a member of the Ozette Lake-Calawah Ridge Block within the Ozette terrane, forms steeper slopes and dominates the northwestern part of the project area just east of the coastal National Park lands. These Oligocene to Eocene sandstones and siltstones include medium- to very thick-bedded, micaceous, quartzose, feldspathic and feldspatholithic sandstone. There are minor turbidite and conglomerate debris flow layers, as well as coal seams and local interbeds of phyllitic or basaltic sandstone. These areas of marine sedimentary rocks form steeper slopes and higher hazard landforms than the low-gradient glacial sediments. Fewer faults are present in the OEm(o) in the Ozette Lake WAU than in the volcanic mixture in the northeastern portion of the project area and the terrain is generally not as rugged.

2.4.3 Basic Intrusive Rocks, Marine Sedimentary Rocks, Basalt Flows, Volcanic Rocks
The northwest-southeast trending Ozette thrust fault separates the more gently sloping marine sedimentary rocks and glacial sediments from the steep rugged terrain in the northeastern portion of the Ozette Lake WAU. This area is made up of the Snag Peak Block, a geologic sequence of parallel bands of lower Eocene to Oligocene rock separated by prominent thrust faults. The mapping from southwest to northeast (Figure 3) indicates the first unit of the Snag Peak Block is Em(sc) (middle to lower Eocene sandstone and conglomerate) (Schasse, 2003). This unit was originally mapped by Snavely (1993) as Tspsc, a very thick-bedded to medium-bedded, gritty coarse-grained, locally graded sandstone and minor pebble conglomerate with local mudflow deposits. The quartzose sandstone contains grains of phyllite, basalt, and distinctive chert fragments, as well as locally present coal layers. The next unit to the northeast (OEm(ss)) was also originally mapped by Snavely et al (1993) as Tspss, a thin- to medium-bedded siltstone and graded fine-grained sandstone of Oligocene to Eocene age. In some places, the siltstone is severely sheared and drag-folded in proximity to major faults. The next member of the Snag Peak Block (mapped as Tspsp by Snavely et al, 1993) is OEm(sp), which is nearly identical to Em(sc). OEm(sp) in this area is severely faulted, which has created a series of parallel ridges alternating with high hazard convergent headwalls. Last in the Snag Peak Block is OEm(st), a unit that is similar to the other units listed above in age and composition and forms relatively steep slopes adjacent to Big River.

Big River cuts through a band of Qgd and is located in the same position/orientation as the Calawah fault in the northeastern portion of the WAU. The geologic units to the northeast of Big River between the Calawah Fault and the Crescent Fault are sedimentary and basaltic rocks of Hobuck Lake (middle to lower Eocene) and are locally mapped as Evc(h) and Ev(h). Evc(h) is a thin-bedded tuffaceous siltstone with basaltic fine-tuff to tuff-breccia and thin-bedded to massive siltstone, with areas of massive sandstone. Ev(h) consists of volcanic rocks, including tuff breccia with minor interbedded basaltic sandstone, siltstone, and massive basaltic breccia. Inner gorges and steep slopes are common in both Evc(h) and Ev(h).

The Crescent Formation, Ev(cp) (middle and lower Eocene), lies to the northeast of the Hobuck Lake rocks and the Crescent Fault. This formation, which consists mainly of

basalt pillow lava and breccia, forms steep rugged slopes such as Sekiu Mountain and has a relatively high incidence of debris flows. The upper part of the sequence contains thick interbeds of siltstone, basaltic sandstone, basalt breccia, and conglomerate. There are locally mapped patches of Em1c, basaltic siltstone and fine-grained sandstone, and Eibc, silicified intrusive volcanics, both of which are part of the Crescent Formation.

3.0 Summary of Methods

The Ozette Lake mass wasting assessment was conducted in accordance with the methods described in the Landslide Hazard Zonation Project Protocol (Department of Natural Resources, 2006; http://www.dnr.wa.gov/forestpractices/lhzproject). The LHZ protocol involves information collected through an aerial photograph-based landslide inventory. Information gained through the landslide inventory is used to develop landslide hazard zones that are defined according to their mass wasting process(es), morphology, sensitivity to forest practices, and risks to public resources and public safety. The result is a reconnaissance-level survey with limited field validation of landslide and landform mapping. Due to the limited field work involved, it is unlikely that all landslides have been identified and that all landforms are precisely and accurately mapped. Therefore, field verification should accompany the application of mapped hazard zone boundaries in the field.

The Ozette Lake assessment was completed using three years of 1:12,000 black-and-white stereo-paired aerial photographs (Table 1). (Note: selection of aerial photographs accounted for several blocks of aerial photographs that were missing from the collection, namely a large portion of the high-altitude flight lines and many of the State Lands blocks.) In addition to stereo-pair evaluation, 2005 color orthophotographs (at 0.5-meter resolution) and 1999-2000 black and white orthophotographs (at 1-meter resolution) were also utilized during GIS analysis and digitization. Light Detection And Ranging (LiDAR) images of the project area were not available at the time of inventory.

Table 1. Aerial photographs and orthophotographs used in developing the Ozette Lake landslide inventory.

Year	Scale	Image	Flight ID	Origin	Coverage
1975	1:24,000	Color	OL-C-75	WDNR	Partial
1985	1:12,000	B/W	OL-85	WDNR	Partial
1990	1:12,000	B/W	OL-90	WDNR	Partial
1997	1:12,000	B/W	OL-97	WDNR	Partial
2000	1-meter	B/W	OL2000	WDNR	Complete
2005	0.5-meter	Color	OLC-QT	WDNR	Complete

The aerial photographs were examined using a mirror stereoscope with 3x magnification. All visible mass wasting features were identified on the aerial photographs and traced onto mylar transparencies that were attached to alternating photographs in the flight line. The traced landslides were then digitized using ArcGIS software and attributed according to mass wasting process, photo year, certainty of occurrence, landslide size, landform, slope shape, slope gradient, sediment/debris delivery, associated land use, and elevation. The resulting landslide inventory map is included as Map A-1. Landslide inventory data (i.e., landslide attributes) are shown on Form A-1. These are available from the DNR-Forest Practices Division as PDF files or ArcInfo coverages.

Two field visits were also undertaken, on January 25 and April 4, 2007. The first field visit focused on the northeast portion of the WAU, which contained steep rugged ground and numerous mapped debris flows. Field visits complemented the aerial photograph and GIS analysis by verifying approximately 20 percent of the mapped landslides (many of them originally attributed as "questionable"), possible triggering mechanisms, and land use associations. (The verification of questionable landslides and landforms in this area was hampered by limited road access following the heavy winter storms.) The second field visit included portions of DNR-managed lands in the south-central part of the WAU that contained potentially unstable landforms and mass wasting despite the fact that they had been previously classified according to GIS evaluation as low hazard due to low relief.

Accurately transferring the size and location of landslides from aerial photographs to ArcGIS was difficult in some cases, particularly when landslides were small or nearby geographic references were absent. In many cases, it was most effective to digitally map the landslides using the orthophotograph as a backdrop reference layer.

Developing the landslide hazard zones involved several levels of analysis. The objective of creating a landform map is to divide the landscape into geomorphically unique areas that differ in terms of their landform characteristics, forest practices sensitivity, and landslide delivery potential. The initial delineation of low hazard areas was based solely on GIS-derived slope gradients. Areas that were <40 percent based on the DEM were considered low hazard**.** The areas within these low hazard zones were generally not evaluated via aerial photographs or field verification. In some cases, areas that exceeded 40 percent slope gradient but were less than one half acre were also identified as low hazard (according to LHZ protocol). Also based on the LHZ protocol, landforms classified as "high hazard" under the Forest Practices Rules including convergent headwalls, bedrock hollows, and inner gorges with slopes >70 percent (WAC 222 16-050) were identified using aerial photographs and DEM-based topographic evaluation. These landforms are by default assigned at least a "high" hazard, but can be upgraded to "very high" based on landslide frequency.

To develop the remaining landslide hazard zones, commonalities among landforms and landslide attributes were identified using aerial photographs, GIS information, and field investigation. Mapping of individual landforms was based primarily on slope gradient, slope form, forest practice sensitivity, lithology, and sediment/debris delivery potential.

Extrapolation of landform delineation was applied when regions had similar slope shape, elevation, and geology. Landform extrapolation was necessary in some cases due to the absence of past forest practices and resulting dense canopy cover which made landform delineation difficult. The portions of the project area with a high frequency of landslides were generally identified as high hazard areas. The landform map is included as Map A-2 and the landform descriptions are included as Form A-2.

4.0 Results

A total of 166 landslides were mapped from aerial photographs and field visits between 1985 and 2007 in the Ozette Lake project area (Map A-1 and Table 2). Eighty four of these landslides were debris flows, many of which initiated at higher elevations and traveled down steep slopes through deeply incised channels. Fifty of the debris flows were road-related out of a total of 82 road-related landslides. There were only eight mapped deep-seated landslides in the project area, one of which was identified because it had been previously identified by Schasse (2003) as part of the Cape Flattery 1:100,000 quadrangle**.** However, there are undoubtedly additional unmapped deep-seated landslides in the project area. The lack of LiDAR, the low resolution of the DEM, and the limited availability of high-altitude aerial photographs limited confidence in identifying some landforms as deep-seated landslides.

Table 2. Landslides mapped in the Ozette Lake WAU occurring between 1985 and 2007 listed by landslide process class.

Mass Wasting Process	Number of Landslides
Debris Flow	**84**
Shallow-undifferentiated	**74**
Deep-seated	**5**
Small, sporadic deep-seated	**3**
TOTAL	**166**

The landslide inventory results, geologic map, topography of the project area, and statistical analysis of the landslides were used to develop five Landslide Hazard Zones. The hazard ratings for the different zones range from “low” to “very high” and are included on Map A-2. Part of the landform assessment is a mass wasting summary table and landform descriptions, which summarize the physical descriptions of the landforms, mass wasting process(es) and likely triggering mechanisms (i.e., land use correlations). A summary of each hazard zone is provided below.

Landslide Hazard Zone #1 – Ridgetops, Low-gradient (<50%) Slopes, Divergent Noses, Planar Slopes – LOW Hazard

This low hazard zone includes three main slope types (i) the GIS-derived low-gradient (<40 percent) areas; (ii) ridges and other divergent slopes that separate sub-basins; and (iii) planar slopes with field-measured gradient of <60 percent with no history of mass wasting. According to the Level One Analysis protocol, the first type was delineated

based on the slope calculation from the DEM. Landslide Hazard Zone #1 can generally be identified based on field-derived slope gradients of less than 50 percent (with small local steeper areas that were beyond the resolution of this analysis). These landforms primarily occur in the low-elevation glacial sediments that don't display the same level of channel incision or high-gradient slope-building as the sedimentary or igneous rocks and at higher elevations in the form of ridges and benches. Some of the slopes in this zone did exceed the typical 50 percent gradient, including the divergent noses and low-lying planar valley walls both of which were insensitive to forest practices. The landform includes varying slope shapes (low-gradient convergent features, divergent ridges, and planar slopes). This zone includes 39,944 acres or 92.1 percent of the Ozette Lake WAU.

Landslide Hazard Zone #2 – Steeper (>50%) Valley Walls – VERY HIGH Hazard
This zone includes steep planar and divergent slopes that are typically greater than 50 percent, but can surpass 100 percent. These slopes, found predominantly in the northern and northeastern portions of the project area above 400-800 feet in elevation, form steeper walls upslope of the low hazard low-gradient broad stream valleys of Zone #1. These upper valley walls, though not convergent and not rule-identified, are sensitive to timber harvest and very sensitive to road construction. It is fairly typical for these slopes to contain numerous inner gorges and to be steep enough that they cannot sustain vegetation. There are many instances of road-initiated debris flows, but harvest-related slides are not as common. (This observation is potentially due in part to limited harvesting that has occurred on such steep high-elevation slopes.) The slopes are generally associated with the marine sedimentary rocks of the Snag Peak Block (OEm(sp) and the Hobuck Lake sedimentary and basaltic rocks). This zone can be differentiated from the other zones by its steepness, non-convergence, un-vegetated areas, and high frequency of road-related debris flows. This zone includes 1,474 acres or 3.4 percent of the Ozette Lake WAU.

Landslide Hazard Zone #3 – Moderate-Gradient Convergent Slopes – HIGH Hazard
The features in this hazard zone most closely resemble moderate-gradient bedrock hollows that contain steep areas but overall do not exceed the 70 percent threshold currently used in the Forest Practices Rules to define "high-hazard" bedrock hollows. Field reconnaissance of shallow landslides associated with these convergent areas revealed overall slope gradients that typically ranged from 40 to 70 percent with portions of the landforms exceeding 70 percent. One distinguishing feature of this hazard zone is that it is limited to the southeastern portion of the Ozette Lake WAU and is associated with the marine sedimentary rocks of the Ozette Lake-Calawah Ridge Block (OEm(o)) that are surrounded by low-gradient glacial deposits. The hazard level of these convergent features is not as high as the convergent features in the rugged faulted terrain in the northern part of the WAU, though several cases of road-related landslides were discovered. This area required a separate hazard zone from Landslide Hazard Zone #5, as the risk in this area is not as high due to more gentle ground and differing geology. This zone was delineated with a lower confidence due to the low resolution of the DEM and the relatively limited extent of bedrock with which the zone is associated. This zone includes 214 acres or 0.5 percent of the Ozette Lake WAU.

Landslide Hazard Zone #4 – Steep Inner Gorge Slopes Adjacent to High-Order Streams – VERY HIGH Hazard

This zone includes steep inner gorge slopes that are adjacent to high-order streams such as Umbrella Creek and Big River and their major tributaries. The walls of these inner gorges are low elevation (below 800 feet) and are typically below the slope break of higher elevation steep, planar slopes. Slope gradients typically exceed 70 percent and slope form includes locally planar, convergent, and divergent slopes. These inner gorges can be distinguished from inner gorges in Landslide Hazard Zone #5 based on their association with the larger rivers and streams as opposed to the smaller, incised tributary streams. This zone is found primarily at low elevations in glacial sediments. Short run-out debris flows and other shallow landslides are the most common mass wasting processes and delivery potential is very high. This zone includes 477 acres or 1.1 percent of the Ozette Lake WAU.

Landslide Hazard Zone #5 – Convergent Headwalls, Bedrock Hollows, and Inner Gorges – VERY HIGH Hazard

Half of the mapped landslides in the project area occurred in this very high hazard zone. Typical landforms in the rugged incised terrain in the northeast section of the WAU include large, convergent headwalls that contain numerous bedrock hollows. These hollows converge to form inner gorges that are separated by extremely steep planar (Hazard Zone #2) to divergent slopes (Hazard Zone #1). The inner gorge landforms are primarily associated with smaller headwater streams and many of them show evidence of past debris flows and long run-out debris torrents. Field investigations confirmed that channel incision within these headwater streams led to inner gorge development, even when the DEM did not indicate such features were present. Typical inner gorge slopes exceeded 70 percent and much of the time exceeded 85 percent. The bedrock hollows and convergent headwalls also had slopes greater than 70 percent, often closer to 85 to 90 percent. Slope forms range from broadly convergent (in some of the bedrock hollows) to highly convergent (in the case of the incised headwater streams and associated inner gorges). The majority of this zone is found in the highly faulted basic intrusive rocks, marine sedimentary rocks, basalt flows, and volcanic rocks within the northeastern portion of the WAU. This zone includes 1,266 acres or 2.9 percent of the Ozette Lake WAU. *Note: Landslide Hazard Zone #5 is split into #5 (inner gorges) and #52 (bedrock hollows and convergent headwalls) in the state-wide GIS landslide spatial data layer.*

The quantitative approach described in the Landslide Hazard Zonation Project Protocol was used in assigning the overall hazard levels for three of the five hazard zones (Table 3). Overall hazard ratings depend on the Landslide Frequency Rate (number of landslides per acre per year) and the Landslide Area Rate for Delivery (area of landslides per acre per year). Calculations only included landslides with probable or definite delivery potential. The only deviation from the Landslide Hazard Zonation Project Protocol was that landslides used in calculations were not limited to those identified as “definite” in the first photo year due to the limited availability of some photo years.

Table 3. Landslide frequency rate (landslides/acre/year x 10^6), landslide area rate for delivery (area of delivering landslides/acre/year x 10^6), and overall hazard rating for Landslide Hazard Zone #2 (steep valley walls), Zone #3 (lower-gradient convergent features), and Zone #4 (planar walls and inner gorge slopes adjacent to high order streams) in the Ozette Lake WAU.

	Zone 2	Zone 3	Zone 4
Hazard Zone Area (Acres)	1,474	214	477
Number of Delivering Landslides	25	3	10
Area of Delivering Landslides (acres)	13.1	5	10.4
Landslide Frequency Rate	1,727	637	1,239
Landslide Area Rate w/ Delivery	404	1,062	991
Overall Hazard Rating	Very High	High	Very High

Note: According to LHZ Protocol, the Overall Hazard Rating for Zone #3 should be "Very High" due to the "High" landslide frequency rate and the "Very High" potential for delivery. However, these calculations were affected by the limited area included in the zone due to the uncertainty in mapping from the DEM slope calculations and the hazard zone has been more appropriately downgraded to "High" hazard.

According to the protocol, two of the landslide hazard zones (when combined with the landslide inventory) have a pre-assigned hazard rating: Zone #1 (ridgetops, low-gradient (<40% from the DEM) slopes, planar slopes, divergent noses) and Zone #5 (and #52) (convergent headwalls, bedrock hollows, and inner gorges). Zone #1 was identified as part of the Level One Analysis and automatically receives a low hazard rating due to low gradients and absence of mass wasting. Zone #5 (and #52) include convergent landforms considered "high hazard" under the Forest Practices Rules and by default receive at least a high hazard rating. Although Zone #4 includes inner gorge landforms, it was analyzed quantitatively due its variation in slope shape and gradient.

5.0 Limitations and Confidence in Work Products

The Ozette Lake mass wasting assessment is intended to be used as a screening tool for foresters, engineers, and other natural resource professionals involved in forest practices activities on forestlands in the project area. The hazard zones have been assigned and delineated as accurately as possible based on landslide data specific to the project area and the authors' knowledge working in similar terrain in other parts of Washington.

There should be a reasonably good association between the mapped hazard zones, their written descriptions, and what is present on the ground; however this assessment is not meant to stand alone. The LHZ protocol was designed to provide representative samples in a timely manner with minimal field verification, which can result in small bedrock hollows and inner gorges differing from their mapped extent. In some cases, these features are mapped as too large, in some cases, part of the features are inadvertently excluded. The overall confidence in the landform description/response to forest practices was high, while the landform mapping was moderate to high. Slope angle measurements

from digital elevation models typically misrepresent true hillslope angles and scale issues may exist between maps and aerial photographs that could cause inaccuracies in calculations.

Although every attempt was made to define accurate landforms, there are some instances in which individual high hazard landforms fall within low hazard zones or small inner gorges may be mapped in a larger moderate hazard area. Aerial photographs provide useful tools for identifying landslides and landforms; however, due to differing availability and vegetation cover, not all landslides are found or landforms accurately delineated. Users should be aware of these limitations and utilize the map as a coarse tool to help identify general areas of forest practice sensitivity within the larger project area.

6.0 References

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Form A-1: Landslide Inventory

SLIDE_ID	LSI_PROCES	CERTAINTY	ID_DATE	LS_SIZE	INIT_ELEV	PHOTO_NUM	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	GEOL_UNIT	WAU_LANDFO	ACRES	Haz_zone
1050	2	P	1997	4	1419	OL-97 43-14-269	5	2	120	Y	5	OEm(sp)	16	0.3	5
1051	4	P	1997	5	1432	OL-97 43-13 269	2	1	102	I	4	Em (sc)	24	4.6	2
1052	1	P	1997	1	532	OL-97 43-13-269	1	3	46	Y	2	OEM (ss)	11	0.0	5
1053	1	P	1985	3	1466	OL85 35-014-056	1	3	87	Y	1	Evc(h)	24	0.1	2
1054	1	P	1985	1	1466	OL-85 35-014-056	7	3	55	N	1	Evc(h)	24	0.0	2
1055	2	D	1985	3	1250	OL85 35-014-054	1	1	96	Y	1	OEm(sp)	11	0.2	5
1056	1	P	1985	2	1319	OL-85 35-014-056	1	3	93	Y	1	Ev(cp)	11	0.0	5
1057	1	D	1985	1	1644	OL-85 35-014-056	1	2	89	P	6	Ev(cp)	11	0.0	5
1058	1	P	1985	1	1466	OL-85 35-014-056	7	3	55	N	1	Evc(h)	24	0.0	2
1059	1	P	1985	2	1569	OL85 35-014-054	7	3	69	N	3	Ev(cp)	24	0.0	2
1060	1	D	1985	3	1568	OL-85 35-014-056	7	5	75	N	5	Ev(cp)	24	0.2	2
1061	1	D	1985	2	1570	OL-90 6-14-207	7	4	57	N	5	Ev(cp)	24	0.0	2
1062	1	P	1997	3	513	OL97 43-10-119	7	3	18	Y	5	OEm(o)	11	0.2	5
1063	2	P	1985	5	1359	OL90 11-13-181	9	1	85	Y	5	OEm(sp)	11	3.2	5
1064	1	D	1997	2	1310	OL97 43-13-269	7	2	103	N	2	Em(sc)	12	0.1	5
1065	1	Q	1985	1	1574	OL-85 35-014-056	5	1	63	N	7	Ev(cp)	11	0.0	5
1066	1	Q	1985	1	1446	OL-85 35-014-056	8	4	75	N	1	Evc(h)	11	0.0	5
1067	1	D	1985	3	1321	OL-85 35-014-056	1	3	47	Y	1	Ev(cp)	11	0.1	5
1068	1	D	1985	3	1494	OL-85 35-014-056	7	3	91	I	5	Ev(cp)	16	0.3	5
1069	1	P	1985	2	1475	OL85 35-014-056	7	3	72	N	5	Ev(cp)	16	0.1	5
1070	1	D	1997	3	603	OL-97 31-9-193	7	3	26	N	3	OEm(o)	31	0.2	4
1071	2	P	1990	4	1242	OL90 6-14-207	1	1	58	Y	3	Ev(cp)	11	0.5	5
1072	2	D	1985	3	1412	OL-85 35-014-056	5	1	72	Y	1	Ev(cp)	16	0.1	5
1073	1	P	1985	1	1520	OL85 35-014-056	2	1	47	N	3	Ev(cp)	11	0.0	5
1074	2	Q	1997	4	365	OL-97 43-10-119	7	3	29	Y	5	OEm(o)	11	0.5	5
1076	2	P	1997	3	952	OL-97 43-13-273	1	2	54	Y	5	Ev(cp)	24	0.3	2
1077	2	D	1990	3	1013	OL90 6-14-207	7	3	63	Y	5	Ev(cp)	24	0.3	2
1078	2	D	1985	3	772	OL85 35-014-056	7	3	29	Y	5	Ev(cp)	24	0.1	2
1079	1	P	1985	2	783	OL-85 35-014-054	9	3	26	Y	5	Ev(cp)	24	0.1	2
1080	1	Q	1985	2	818	OL85 35-014-056	7	3	42	N	5	Ev(cp)	24	0.0	2
1081	1	D	1985	3	1322	OL85 35-014-056	2	3	59	Y	5	Ev(cp)	12	0.3	5
1082	2	D	1985	5	1302	OL85 35-014-056	2	1	76	Y	5	Ev(cp)	12	1.1	5
1083	2	P	1985	4	1271	OL85 35-014-056	2	1	82	Y	5	Ev(cp)	12	0.6	5
1084	1	D	1985	2	560	OL-85 29-007-204	7	3	27	N	1	OEm(o)	31	0.0	4
1085	1	D	1990	3	1430	OL-90 6-14-207	7	3	80	N	3	Ev(cp)	24	0.2	2
1086	4	D	1990	4	1511	OL90 6-14-207	8	3	81	N	4	Ev(cp)	23	0.6	2
1087	2	P	1990	4	1173	OL90 6-14-207	5	1	79	Y	3	Ev(cp)	12	1.0	5
1088	2	P	1985	3	1170	OL85 35-014-054	1	1	46	Y	3	Ev(cp)	11	0.4	5
1089	2	D	1985	4	1253	OL-90 6-14-207	7	2	45	Y	3	Ev(cp)	11	0.4	5
1090	2	P	1997	4	899	OL-97 43-13-273	2	2	62	Y	5	Ev(h)	11	1.0	5
1091	1	D	1985	2	973	OL85 35-014-054	7	3	87	N	3	Ev(cp)	23	0.1	2
1092	2	P	1985	4	735	OL-85 29-007-204	1	1	32	Y	5	OEm(o)	11	0.6	5
1093	4	Q	1985	3	866	OL-85 35-014-054	7	2	21	Y	4	Evc(h)	24	0.3	2
1094	2	P	1985	3	848	OL85 35-014-054	7	3	44	Y	5	Evc(h)	24	0.3	2
1095	4	P	1997	5	965	OL-97 43-10-133	8	2	58	Y	4	Ebx(e)	24	32.7	2
1096	1	D	1985	2	1126	OL-85 35-014-054	7	2	47	N	5	Ev(h)	24	0.0	2

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1097	2	D	1985	4	1190	OL-85 35-014-054	7	3	43	Y	5	Ev(cp)	11	0.6	5
1098	1	P	1985	1	1188	OL85 35-014-054	7	3	44	N	3	Ev(cp)	23	0.0	2
1099	1	D	1985	2	1149	OL85 35-014-054	7	3	63	N	3	Ev(cp)	24	0.1	2
1100	2	D	1990	4	1163	OL90 6-14-207	2	2	74	I	3	Eib(c)	16	0.8	5
1101	2	D	1997	5	596	OL-97 31-9-193	7	3	25	Y	3	OEm(o)	31	1.3	4
1102	1	P	1997	4	280	OL-97 43-10-124	7	2	48	Y	3	Qgt	31	0.5	4
1103	2	P	1990	4	1324	OL90 6-14-207	1	1	101	Y	3	Ev(h)	11	0.9	5
1104	2	P	2005	4	1393	ORTHOPHOTOS	1	1	79	Y	3	Ev(cp)	11	0.4	5
1105	2	D	1990	4	1363	OL-90 6-14-207	1	3	100	Y	5	Ev(cp)	24	0.5	2
1106	2	D	1990	4	1431	OL85 35-014-054	1	1	81	Y	5	Ev(cp)	16	0.5	5
1107	2	D	1990	4	1355	OL-90 6-14-207	1	1	100	Y	5	Ev(cp)	24	0.6	2
1108	2	P	1985	5	901	OL-85 35-014-050	1	1	30	P	1	OEm(sp)	11	1.7	5
1109	2	Q	1997	3	367	OL-97 43-10-119	7	3	35	Y	3	OEm(o)	11	0.4	5
1110	2	D	1985	4	1384	OL-90 6-14-207	2	1	43	Y	5	OEm(sp)	11	0.8	5
1111	1	D	1997	3	1328	OL-97 43-13-273	2	2	76	P	5	OEm(sp)	16	0.3	5
1112	2	D	1997	4	1462	OL-97 43-13-273	2	1	72	I	5	OEm(sp)	16	0.7	5
1113	2	P	1997	2	1325	OL-97 43-13-273	2	2	79	Y	3	OEm(sp)	16	0.1	5
1114	1	P	1997	2	1168	OL-97 43-13-273	7	2	79	N	5	OEm(sp)	16	0.1	5
1115	2	D	1997	5	579	OL-97 31-9-193	7	3	16	Y	5	Em(ec)	31	1.3	4
1116	1	P	1985	4	1204	OL85 35-014-054	1	1	52	Y	5	Ev(cp)	11	0.8	5
1117	2	P	1997	5	746	OL-97 43-10-133	1	2	49	Y	5	Ebx(e)	11	1.0	5
1118	1	D	1985	3	1482	OL85 35-014-054	7	3	71	N	3	Ev(cp)	24	0.3	2
1119	1	P	1985	3	1462	OL85 35-014-054	7	3	60	N	3	Ev(cp)	24	0.1	2
1120	2	D	1985	4	1085	OL-85 29-007-206	5	1	38	Y	1	OEm(o)	16	0.5	5
1121	1	P	1985	2	1287	OL85 35-014-054	2	2	60	N	3	Ev(cp)	24	0.1	2
1122	1	D	1985	3	1819	OL-85 35-014-054	7	4	85	Y	5	Eib(c)	24	0.2	2
1123	2	D	1990	3	1846	OL-85 35-014-054	7	3	85	Y	5	Eib(c)	24	0.2	2
1124	1	D	1985	2	1777	OL85 35-014-054	7	3	78	N	3	Eib(c)	24	0.0	2
1125	5	P	1997	5	325	OL-97 43-10-124	7	1	40	Y	3	Qgd	31	1.7	4
1126	1	D	1985	4	1841	OL-85 35-014-054	7	3	85	Y	5	Eib(c)	24	0.6	2
1127	2	P	1985	3	1550	OL-85 35-014-054	7	3	80	N	4	Ev(cp)	24	0.2	2
1128	2	P	1997	5	588	OL-97 43-10-119	2	1	63	Y	5	OEm(o)	27	2.2	3
1129	1	P	1985	1	1734	OL85 35-014-054	7	3	76	N	3	Eib(c)	24	0.0	2
1130	1	P	1985	1	1778	OL85 35-014-054	7	3	76	N	3	Eib(c)	24	0.0	2
1131	1	P	1985	2	1378	OL85 35-014-054	7	4	97	N	5	Ev(cp)	24	0.1	2
1132	1	P	1985	2	1376	OL85 35-014-054	7	4	99	N	5	Ev(cp)	24	0.1	2
1133	1	P	1985	2	1330	OL85 35-014-054	7	3	88	N	5	Ev(cp)	24	0.1	2
1134	1	P	1985	3	1465	OL85 35-014-054	2	2	81	Y	3	Ev(cp)	24	0.4	2
1135	2	P	1997	5	606	OL-97 43-10-119	2	1	59	Y	5	OEm(o)	27	1.8	3
1136	1	D	2005	3	876	ORTHOPHOTO	1	1	34	Y	2	Evc(h)	11	0.2	5
1137	2	P	1985	4	868	OL85 35-014-052	1	1	44	Y	2	Evc(h)	11	0.6	5
1138	1	P	1990	3	1343	OL90 6-14-205	9	3	69	Y	3	OEm(sp)	24	0.2	2
1139	1	P	1985	3	1157	OL85 35-014-054	1	1	44	Y	5	OEm(sp)	16	0.3	5
1140	1	Q	1997	3	1423	OL-97 43-13-269	7	4	86	N	5	OEm(ss)	16	0.3	5
1141	2	D	2007	5	1101	FIELD	8	3	80	Y	5	Ev(cp)	24	1.4	2
1142	1	P	2007	2	844	FIELD	9	2	18	Y	5	Ev(cp)	11	0.0	5
1144	1	P	2005	3	477	ORTHOPHOTOS	7	3	44	Y	5	OEm(o)	24	0.1	2
1145	5	D	2007	4	978	OL-97 43-13-269	2	2	60	Y	5	OEm(ss)	12	0.9	5
1146	2	P	2007	3	1365	FIELD	1	1	45	P	5	OEm(sp)	16	0.2	5
1147	2	D	2007	4	1465	OL-97 43-13-273	1	1	69	Y	5	OEm(sp)	11	0.7	5
1148	2	P	2007	5	1309	ORTHOPHOTOS	1	1	65	Y	5	Ev(cp)	11	6.4	5
1149	2	P	2007	3	1658	FIELD	2	2	75	Y	5	OEm(sp)	24	0.3	2

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1150	2	D	2007	4	1461	FIELD	2	1	76	Y	5	OEm(ss)	16	0.6	5
1151	1	P	2007	3	1446	FIELD	2	1	76	N	5	Ev(cp)	24	0.2	2
1152	2	P	1997	4	1515	OL-97 43-13-273	1	1	47	Y	3	Ev(cp)	11	0.4	5
1153	1	P	1997	2	1330	OL-97 43-13-273	1	3	85	Y	3	Ev(cp)	11	0.1	5
1154	2	P	1997	4	1513	OL-97 43-13-273	2	1	71	Y	5	OEm(sp)	16	0.5	5
1155	2	P	1997	3	1325	OL-97 43-13-273	2	2	61	Y	3	OEm(sp)	16	0.1	5
1156	2	P	1990	5	1637	OL-90 6-14-205	2	1	73	Y	5	OEm(sp)	11	1.5	5
1157	2	P	1997	3	1421	OL-97 43-13-269	1	3	97	Y	5	OEm(sp)	11	0.3	5
1158	2	P	1997	4	1327	OL-97 43-13-269	1	3	83	Y	3	OEm(sp)	16	0.1	5
1159	1	P	1997	3	936	OL-97 43-13-269	7	3	73	Y	3	OEm(ss)	16	0.1	5
1160	2	P	1990	3	1232	OL-90 6-14-205	7	2	58	Y	5	OEm(sp)	11	0.3	5
1161	2	P	1985	3	1234	OL-85 35-014-054	7	3	57	Y	2	OEm(sp)	16	0.3	5
1163	2	P	1985	4	1171	OL90 6-14-205	1	1	60	Y	2	OEm(sp)	11	0.2	5
1164	2	D	1985	5	1244	OL-85 35-014-054	1	1	69	Y	2	OEm(sp)	11	1.6	5
1165	1	P	1990	3	599	OL-90 6-14-203	7	3	76	Y	1	OEm(ss)	24	0.2	2
1166	2	D	1997	5	614	OL-97 31-9-193	7	3	28	Y	3	OEm(o)	31	1.1	4
1167	2	D	1985	4	1447	OL-85 35-014-052	1	1	106	Y	5	OEm(sp)	11	0.6	5
1168	2	D	1985	4	1240	OL-85 35-014-052	1	1	73	Y	3	OEm(sp)	11	0.8	5
1169	2	P	1985	3	1218	OL-85 35-014-052	1	1	57	Y	2	OEm(sp)	11	0.1	5
1170	2	P	1990	4	1576	OL-90 6-14-207	1	1	55	Y	3	Ev(cp)	11	0.8	5
1171	2	D	1990	3	1525	OL-90 6-14-207	1	1	42	Y	5	Ev(cp)	11	0.4	5
1172	1	P	1985	3	1558	OL-85 35-14-056	7	4	72	P	5	Ev(cp)	24	0.3	2
1173	2	P	1990	3	1649	OL-90 11-13-181	1	2	70	Y	5	OEm(sp)	24	0.3	2
1174	2	P	1990	4	859	OL90 11-13-181	9	1	54	Y	5	Em(sc)	16	0.4	5
1175	1	P	1997	2	1133	OL-97 43-13-269	7	3	71	N	5	OEm(ss)	12	0.1	5
1176	1	P	1997	4	757	OL97 43-13-269	7	3	104	Y	2	OEm(ss)	12	0.9	5
1177	1	Q	1997	2	546	OL97 43-13-269	7	3	52	Y	2	OEm(ss)	12	0.1	5
1178	1	P	1997	3	640	OL97 43-13-269	7	3	76	Y	2	OEm(ss)	24	0.2	2
1179	1	P	1997	3	948	OL97 43-13-269	7	3	64	Y	2	OEm(ss)	11	0.3	5
1180	2	P	1990	4	1711	OL90 6-15-176	7	4	54	P	3	Eib(c)	24	0.6	2
1181	1	D	1990	3	1613	OL90 6-15-176	7	3	81	N	5	Ev(cp)	16	0.2	5
1182	2	P	1990	4	1551	OL90 6-15-176	7	3	93	Y	5	Ev(cp)	16	1.0	5
1183	1	P	1990	3	1724	OL90 6-15-176	7	3	73	N	3	Eib(c)	23	0.2	2
1184	1	P	1990	3	1545	OL90 6-15-176	7	3	77	N	5	Ev(cp)	16	0.4	5
1185	1	P	1990	2	1680	OL90 6-15-176	7	3	80	N	3	Eib(c)	23	0.1	2
1186	1	P	1990	3	1687	OL90 6-15-176	7	3	83	N	3	Eib(c)	23	0.1	2
1187	1	P	1997	2	856	OL97 31-9-198	7	3	71	N	5	Em(2ec)	23	0.1	2
1188	1	P	1997	5	566	OL97 31-9-194	7	3	36	Y	5	OEm(o)	31	1.8	4
1189	1	P	1997	4	453	OL97 31-9-194	7	3	34	Y	3	Qgd	31	0.6	4
1190	1	P	1997	4	409	OL97 31-9-194	7	3	56	Y	5	Qgt	31	0.7	4
1191	5	D	2005	4	713	ORTHOPHOTO	7	2	83	Y	3	Em(2es)	23	0.6	2
1194	2	Q	1997	3	353	OL-97 43-10-119	7	3	32	Y	3	OEm(o)	11	0.3	5
1195	2	D	1985	3	717	OL-85 29-007-208	7	1	48	P	2	OEm(w)	11	0.6	5
1196	2	D	1985	2	847	OL-85 29-007-206	5	1	49	Y	1	OEm(o)	12	0.1	5
1197	1	D	2005	4	630	ORTHOPHOTO	7	3	40	N	5	Qgt	24	0.4	2
1199	2	D	1985	3	1069	OL-85 29-007-206	5	3	35	Y	1	OEm(o)	16	0.3	5
1200	2	P	1997	3	594	OL97 43-10-119	2	2	45	Y	5	OEm(o)	24	0.2	2
1202	2	P	1997	4	487	OL-97 43-11	7	1	30	Y	3	Qgd	27	1.0	3
1203	2	P	1997	5	853	OL-97 43-10-124	7	4	50	Y	5	OEm(o)	24	1.6	2
1204	2	D	1997	4	536	OL-97 31-9-193	7	2	43	Y	3	Qgd	31	0.6	4
1205	2	D	1997	5	890	OL-97 43-10-124	7	3	51	Y	5	OEm(o)	24	1.7	2
1206	2	D	1985	2	622	OL-85 29-007-204	1	3	36	Y	1	OEm(o)	11	0.1	5

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1207	1	Q	1997	4	480	OL97 43-10-119	7	3	55	N	3	OEm(o)	24	0.4	2
1208	2	P	1997	5	875	OL-97 43-10-124	7	3	47	Y	5	OEm(o)	24	1.7	2
1209	1	P	1985	3	1051	OL-85 29-007-208	7	2	55	N	5	OEm(w)	24	0.2	2
1210	2	Q	1997	3	309	OL-97 43-10-119	7	3	21	Y	5	OEm(o)	11	0.4	5
1211	2	D	1997	4	523	OL-97 31-9-193	7	1	31	Y	5	Em(ec)	31	0.8	4
1212	2	P	1997	5	863	OL97 43-10-133	1	3	45	Y	5	Ebx(e)	11	1.4	5
1213	2	P	1997	4	509	OL97 43-10-119	9	2	25	Y	5	OEm(o)	11	0.7	5
1215	2	Q	1997	4	355	OL97 43-10-119	7	3	28	Y	5	OEm(o)	11	0.6	5
1216	1	P	1997	3	600	OL97 31-9-193	7	3	28	N	3	OEm(o)	31	0.2	4
1217	2	D	1985	3	1180	OL-85 35-014-054	5	3	44	Y	5	OEm(sp)	16	0.4	5
1218	1	D	2005	4	908	ORTHOPHOTOS	7	3	48	N	3	Ebx(e)	11	0.8	5
1219	4	Q	2003	5	960	MAP	8	2	178	I	4	Em(2ec)	23	53.5	2
1220	2	P	2005	4	1207	ORTHOPHOTOS	1	1	62	Y	5	OEm(sp)	11	0.9	5
1221	2	D	2005	4	1078	ORTHO	1	1	44	Y	5	OEm(sp)	11	0.8	5
1222	2	D	2005	5	1460	ORTHOPHOTOS	1	1	99	Y	5	Eib(c)	11	5.2	5
1223	1	D	2005	3	1434	ORTHOPHOTOS	5	3	62	N	9	OEm(sp)	16	0.2	5

Form A-2: Landform Description

Landform (Hazard Zone) Number – 1

Landform (Hazard Zone) Description - Low-gradient planar, convergent, and divergent slopes, including ridgetops, divergent noses, and low-elevation planar walls

Slope – The low-gradient features have GIS-derived slopes of less than 40 percent (according to Level One protocol), but can be identified in the field as slopes of less than 50 percent, with higher gradients (exceeding 60 percent) on the ridges/noses and in small local areas beyond the resolution of this assessment.

Slope Shape – planar and convergent (low-gradient valley walls and floors); divergent (ridges)

Lithology - These landforms are formed primarily in glacial sediments.

Elevation – 0 – 1,900 feet

Total Area – 39,944 acres

Mass Wasting Processes – Very infrequent shallow rapid slides/debris flows related to road failures

Forest Practices Sensitivity – LOW

Mass Wasting Potential – LOW

Delivery Potential – LOW

Delivery Criteria Used – Slope gradient; location of water

Hazard Potential Rating – LOW

Trigger Mechanisms – Roads

Confidence – HIGH for landform description and forest practices sensitivity; MODERATE for landform mapping

Comments – The extent of these Low Hazard landforms was mapped to the best ability using heads-up digitizing and slope gradient calculations from GIS. Further accuracy was achieved through field reconnaissance, although small areas of greater slope gradient (greater than 60%)/higher hazard features (not picked up with the resolution of the DEM) could be locally present in the large areas mapped as Low Hazard.

Form A-2: Landform Description

Landform Number – 2

Landform Description – Moderate to steep planar and divergent slopes upslope of the low-gradient Zone 1 and extending to the highest elevations of the WAU.

Slope – Typically greater than 50 percent, but commonly exceeding 80 percent

Slope Shape – planar to divergent

Lithology – These steep slopes form predominantly in the non-glacial deposits, primarily in the marine sedimentary rocks of the Snag Peak Block (OEm(sp)) and the Hobuck Lake sedimentary and basaltic rocks.

Elevation – 400 – 1,900 feet

Total Area – 1,474 acres

Mass Wasting Processes – The majority of landslides that occur in this hazard zone are road-related shallow landslides and long run-out debris flows

Forest Practices Sensitivity – VERY HIGH for road construction and HIGH for timber harvest

Mass Wasting Potential – VERY HIGH

Delivery Potential – HIGH

Delivery Criteria Used – High slope gradient, high density of streams, particularly downslope of road construction; easy sediment transport through highly incised down-slope inner gorges

Hazard Potential Rating – VERY HIGH

Trigger Mechanisms – When no management has taken place, the extreme steepness of this hazard zone could result in shallow landslides most likely in response to heavy precipitation events (although most of the landslides mapped were in areas that had undergone management). Road construction triggered many additional shallow landslides that did not deliver and long run-out debris flows that did deliver.

Confidence – HIGH for landform description and forest practices sensitivity; MODERATE to HIGH for landform mapping

Comments – The mapping of this zone had to be extrapolated to areas that had not undergone management due to their steepness, which led to a slightly lower confidence in

mapping. It is possible that steep, broadly convergent features were included in this zone; however, these are easily missed due to their smaller size and are not inaccurately ranked due to the “High hazard” ranking of both zones. The delineation of this hazard zone on the ground can be difficult due to the variety of slope shapes; however, the most distinct features of this zone are slopes that are steep enough to be high hazard despite being planar to divergent and the typical long run-out debris flow response to road construction.

Form A-2: Landform Description

Landform Number – 3

Landform Description – Low-elevation convergent slopes that generally have moderate gradients (but contain high gradient areas) and are formed in marine sedimentary rocks.

Slope – Typically 40 to 70 percent with local areas within convergent features reaching higher gradients

Slope Shape – convergent

Lithology – This hazard zone occurs in the marine sedimentary rocks of the Ozette Lake-Calawah Ridge Block (OEm(o)) within the low-elevation glacial sediments.

Elevation – 150 – 800 feet

Total Area – 214 acres

Mass Wasting Processes – Debris Flows

Forest Practices Sensitivity – HIGH

Mass Wasting Potential –HIGH

Delivery Potential – VERY HIGH

Delivery Criteria Used – proximity to streams, delivery of mapped landslides

Hazard Potential Rating – HIGH

Trigger Mechanisms – Large-magnitude precipitation events would most likely trigger shallow landslides (debris flows) in this zone. Due to the lower slope gradients, road construction in the convergent areas would have a greater likelihood of triggering landslides than timber harvest, though delivery potential for both is high.

Confidence – LOW TO MODERATE

Comments – The low confidence of this hazard zone results from the more moderate slope gradients. Many of the convergent features within this zone were originally defined under Level One analysis as “Low Hazard” because the convergent areas contain both high and low-gradient slopes based on the DEM; however, a separate hazard zone was defined when field reconnaissance revealed convergent areas that included steep slopes and cases of road-related slides. The resulting mapping is a combination of varying-gradient convergent areas defined in the field and other GIS-defined areas with similar morphology. The description of this hazard zone is similar to Zone #5; however Zone #3

occurs only in the low-elevation marine sedimentary rocks in the southeastern portion of the WAU and due to different erosion levels, incision, slope percents, elevation, and proximity to streams, it was defined as a separate (lower hazard) landform.

Form A-2: Landform Description

Landform Number – 4

Landform Description – Steep inner gorge slopes that are associated with high-order streams, such as Umbrella Creek and Big River and their unnamed tributaries

Slope – Typically greater than 70 percent

Slope Shape – The slopes locally vary from convergent to planar to divergent.

Lithology – Glacial till and glacial drift as well as marine sedimentary rocks

Elevation – 100 – 800 feet

Total Area – 477 acres

Mass Wasting Processes – short run-out debris flows and shallow landslides

Forest Practices Sensitivity – VERY HIGH

Mass Wasting Potential – VERY HIGH

Delivery Potential – VERY HIGH

Delivery Criteria Used – steep slope gradients and close proximity to large streams

Hazard Potential Rating – VERY HIGH

Trigger Mechanisms – Road construction and timber harvest in areas so close to large streams is unlikely; however, steep slopes undercut by large streams could result in natural debris flows that deliver. The occurrence of shallow rapid landslides could be increased in this zone due to changes in root strength and addition of water on steep slopes.

Confidence – HIGH for landform description and sensitivity to forest practices; HIGH for landform mapping

Comments – This zone is differentiated from Hazard Zone #5 by its variety of slope shapes and its orientation relative to the streams. The steep potentially unstable slopes in this hazard zone can be identified as valley inner gorges versus the hillslope inner gorges of Zone #5.

Form A-2: Landform Description

Landform Number – 5 *Note: in the state-wide landslide database, Landform #5 is split into #5 (inner gorges) and #52 (bedrock hollows and convergent headwalls).*

Landform Description – Steep slopes associated with convergent headwalls, bedrock hollows, and inner gorges associated with low-order streams

Slope – Typically greater than 70 percent, with average gradients closer to 85 percent

Slope Shape – Convergent

Lithology – The majority of the landforms in this zone are formed in the highly faulted basic intrusive rocks, marine sedimentary rocks, basalt flows, and volcanic rocks, with some occurrence in the lower elevation marine sedimentary rocks

Elevation – 0 – 1,900 feet

Total Area – 1,266 acres

Mass Wasting Processes – Long run-out debris flows through inner gorges, shallow landslides in bedrock hollows, short run-out debris slides on inner gorge walls

Forest Practices Sensitivity – VERY HIGH

Mass Wasting Potential – VERY HIGH

Delivery Potential – VERY HIGH

Delivery Criteria Used – slope gradient; location of surface water

Hazard Potential Rating – VERY HIGH

Trigger Mechanisms – Forest practices could increase the likelihood of shallow-rapid landslides and debris flows by increasing water in highly convergent areas, loss of root strength, and soil disturbance on steep delivering slopes.

Confidence – HIGH for landform description and sensitivity to forest practices; MODERATE for landform mapping

Comments – The confidence in delineating this hazard zone was decreased due to the orientation of inner gorges, in that the landslides frequently initiated on the inner gorge walls, whose steepness (perpendicular to the contours) is rarely captured in the 10-meter DEM.

Form A-3: Mass Wasting Summary Table

Landform #2

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep seated Landslides	Snow Avalanche	TOTAL
Clearcut (0-5 years)	4	0	0	0	0	4
Young Forest (5-15 years)	1	0	0	0	0	1
Submature Forest (15-50 years)	17	1	0	1	0	19
Mature Forest (>50 years)	0	1	0	5	0	6
Road	16	14	0	0	0	30
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	0	0	0	0	0
Other	0	0	0	0	0	0
TOTAL	38	16	0	6	0	60

Landform #3

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep seated Landslides	Snow Avalanche	TOTAL
Clearcut (0-5 years)	1	0	0	0	0	1
Young Forest (5-15 years)	0	0	0	0	0	0
Submature Forest (15-50 years)	2	0	0	0	0	2
Mature Forest (>50 years)	0	0	0	0	0	0
Road	0	0	0	0	0	0
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	0	0	0	0	0
Other	0	0	0	0	0	0
TOTAL	3	0	0	0	0	3

Form A-3: Mass Wasting Summary Table

Landform #4

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep seated Landslides	Snow Avalanche	TOTAL
Clearcut (0-5 years)	0	0	0	0	0	0
Young Forest (5-15 years)	0	0	0	0	0	0
Submature Forest (15-50 years)	2	4	0	1	0	7
Mature Forest (>50 years)	0	0	0	0	0	0
Road	2	4	0	0	0	6
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	0	0	0	0	0
Other	0	0	0	0	0	0
TOTAL	4	8	0	1	0	13

Landform #5

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep seated Landslides	Snow Avalanche	TOTAL
Clearcut (0-5 years)	3	7	0	0	0	10
Young Forest (5-15 years)	6	6	0	0	0	12
Submature Forest (15-50 years)	4	14	0	0	0	18
Mature Forest (>50 years)	0	1	0	0	0	1
Road	13	32	0	1	0	46
Partial Cut	1	0	0	0	0	1
Yarding	1	0	0	0	0	1
Alpine	0	0	0	0	0	0
Other	1	0	0	0	0	2
TOTAL	29	60	0	1	0	90

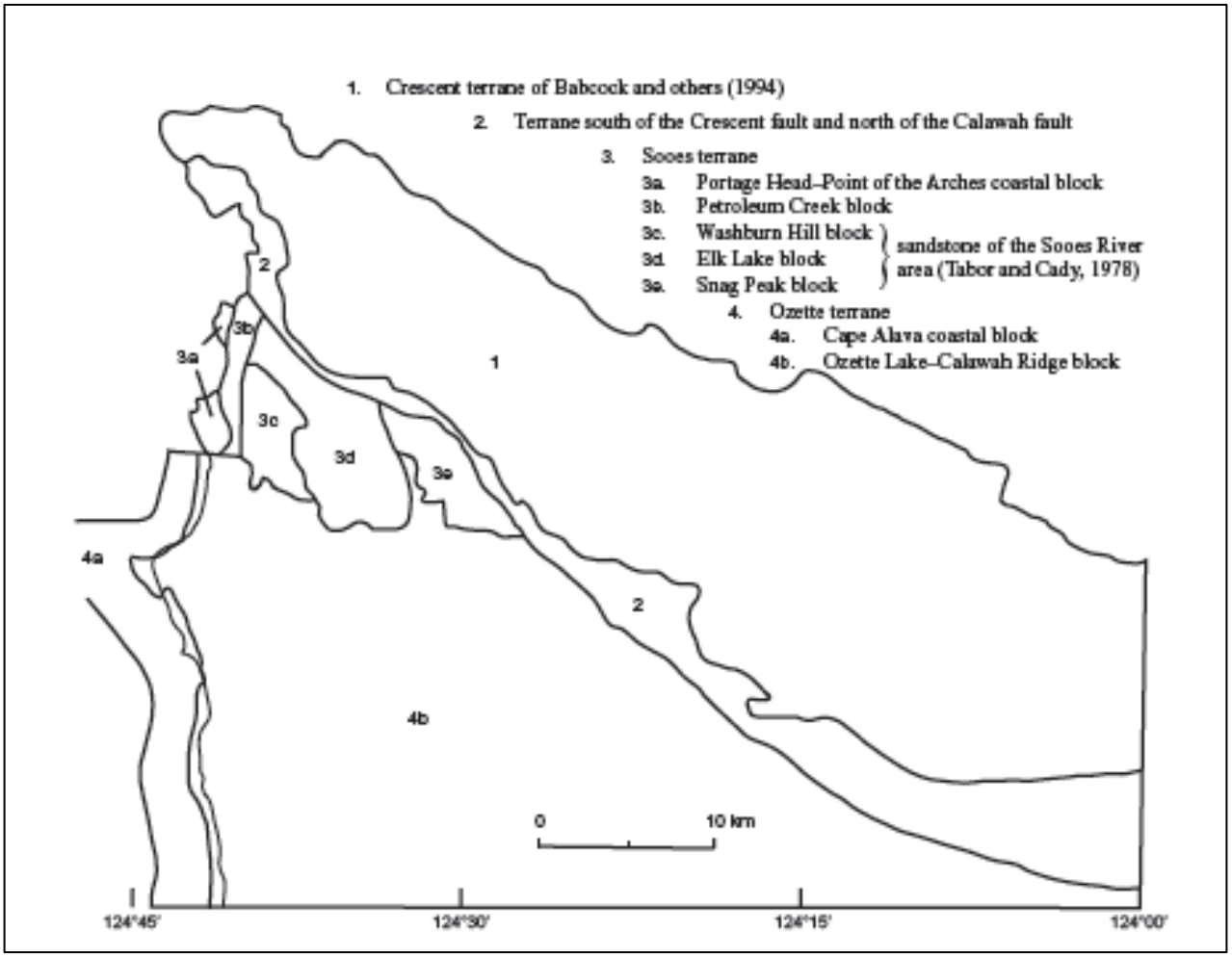

Figure 1. Terrane and block boundaries of the northwestern Olympic Peninsula (modified from Snavely and others, 1993). The term 'block' is used to denote tectonically bounded sequences within a specific tectonostratigraphic terrane. Some lithologic units within individual blocks correlate with units in adjacent blocks in other terranes. (Taken from Schasse, 2003.) Geology described in the northeastern portion of the Ozette WAU is the Snag Peak Block (3e) and the Ozette Lake-Calawah Ridge Block (4b).

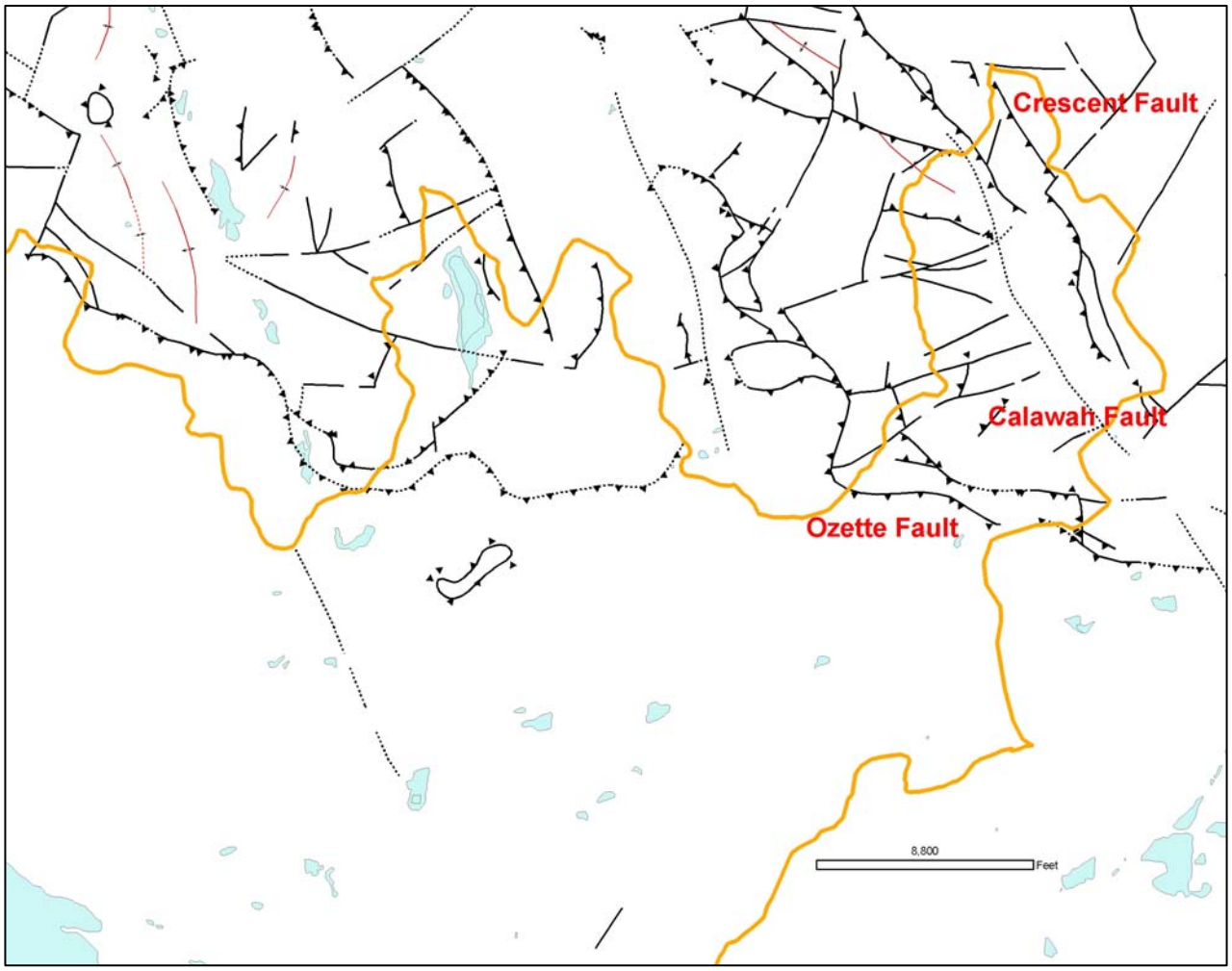

Figure 2. Region map showing thrust faults (curved lines with barbs) and faults with unknown offset (curved lines with no barbs) within and surrounding the northeastern part of the Ozette Lake WAU (gold outline). The Snag Peak Block (Block 3e from Figure 1) lies between the Ozette thrust fault and the Calawah fault. Block 2 (see Figure 1) lies between the Ozette thrust fault and the Calawah fault. The Crescent terrane (see Figure 1) lies north of the Crescent thrust fault.

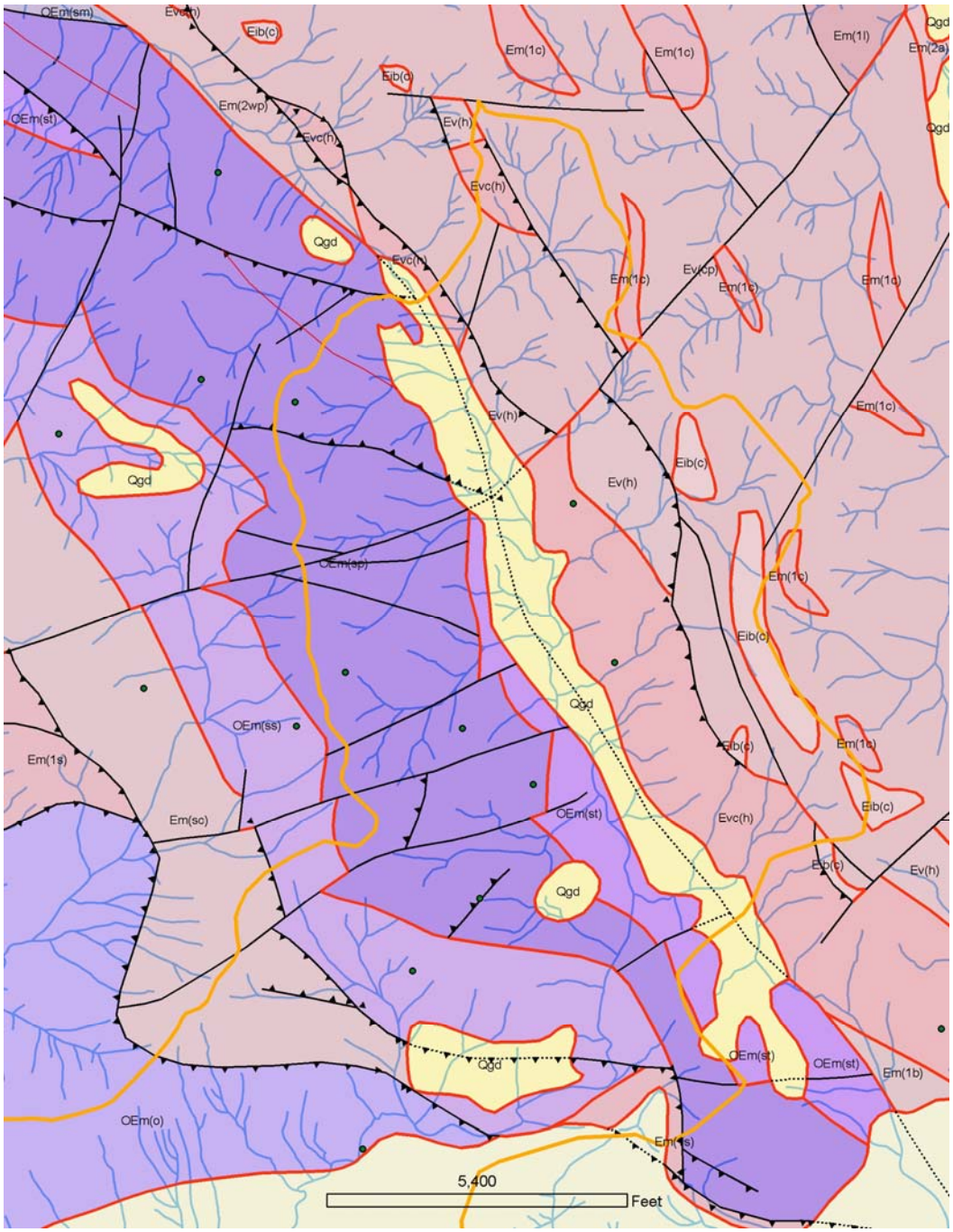

Figure 3. Geological map of the Snag Peak Block in the northeastern portion of the Ozette Lake WAU. WAU boundary is shown as gold line. Created at 1:24,000 scale.