WASHINGTON STATE DEPARTMENT OF
Natural Resources

Mass Wasting Assessment
Landslide Hazard Inventory Project

Kachess Watershed, Kittitas County, Washington

Prepared by:

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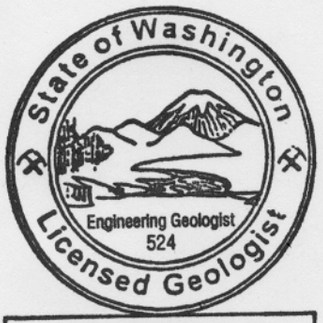
August 15, 2005



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Project Summary

This study evaluated 5722 acres within the Kachess Watershed located in the upper Yakima River basin of Kittitas County. Slopes in this mountainous area rise from a flat glacial plain at the south end of Lake Kachess, elevation 2178 ft, to the top of Kachess Ridge, elevation 5552 ft. Bedrock units within the study area consist of steeply dipping (inclined) sedimentary and volcanic rocks. A major structural feature, the Straight Creek Fault, bisects Lake Kachess north to south separating two geologically distinct terrains, the Cabin Creek Block located west of the Lake and the Teanaway Block located to the east. Bedrock lithology, structural integrity and tectonic history have resulted in significantly greater numbers of landslides occurring west of Lake Kachess than to the area east of the Lake. Ice age glaciers scoured out the valley currently occupied by Lake Kachess along the trend of the Straight Creek Fault leaving a steep walled "U" shaped valley.

This study identified 158 landslides (30% shallow undifferentiated, 27% debris flows & 43% deep-seated landslides). The majority (69%) of the landslides in the watershed occurred in recently harvested clear cuts (<5 years old). This apparent correlation between mass wasting and clear cuts may indicate nothing more than the inability to identify mass wasting features under forest canopy. Few road related failures were observed on photographs or in the field. Based on the failure history, the watershed was divided into twelve landform units listed in Appendix B. Five high or very high hazard landforms were rule identified, three low hazard landforms, one moderate hazard landform and three high or very high hazard landforms unique to this watershed were delineated for the study area. Table 1 summarizes the twelve landforms mapped in the Kachess Watershed.

Table 1. Landform summary for the Kachess study area, Kittitas County WA.

Landform #	Feature	Hazard Rating	Slope	Origin
1	Inner Gorge	High	>70%	FP Rule identified
2	Bedrock Hollow	High	>70%	FP Rule identified
4	Terrace Face/Meander	Very High	>50%	FP Rule identified
5	Headwall	High	>70%	FP Rule identified
8	Deep-Seated Toes	Very High	>65%	FP Rule identified
10	Valley & Stream Bottom	Low	<11%	LHZ Protocol
11	Low Gradient Hill Slopes	Low	11% to 40%	LHZ Protocol
12	Lodge Ck Mid Slope	High	40% to >70%	Unique to watershed
13	Ridge & Hill Tops	Low	<11%	LHZ Protocol
14	Moderate to Steep Hill Slopes	Moderate	40 to >70%	LHZ Protocol
15	Lodge Ck Toes Deep-Seated Ls	High	<41%	Unique to watershed
16	Lodge Ck Head Scarp Deep-Seated Ls	Very High	<60%	Unique to watershed

1.0 Introduction and Summary of Methods

1.1 Use of This Report

The purpose of this mass wasting assessment is to identify non-federal, non-tribal areas within the Kachess WAU that have landforms[1] with moderate or high landslide risk, that could be exacerbated due to the effects of forest management (logging, roading, thinning, yarding, etc.). Maps of these watershed-specific landforms (Map A2 herein) are designed to be used by the Department of Natural Resources region staff for the purpose of identifying those Forest Practice Applications (see Chapter 222-20 WAC) that may require a site investigation to assign a forest practice class relative to potential unstable slopes and landforms (Chapter 222-16-050). Additionally, these maps are intended to be used by land managers in the development of harvest unit polygons. Further, these data will be used for further unstable slopes research.

This is a reconnaissance study and its level of resolution must be kept in mind when using this document and Maps A1 and A2. Moreover, the report was prepared according to the schedule necessary to produce a statewide screening tool as quickly as reasonably possible. For this reason, it is possible that some landslides or landforms have been accidentally omitted, some benign features are improperly mapped as landslides, and some data have been miscoded.

Laura Vaugeois, Jack Powell, and Eric Bilderback reviewed and edited this text, and provided technical and field support. Laura kindly completed the final review of the document. Susan Ragland helped develop the individual coverage layers and final map layouts.

This assessment was largely conducted remotely, using aerial photographs, and various maps, with support from field visits to verify mapping results. Information was collected and compiled from these products in a manner that was designed to respond to the Critical Questions that are outlined in Section II of the Landslide Hazard Zonation (LHZ) Project Protocol, and to direct attention to areas where more detailed analysis is necessary. The objective of the data collection is to generate information sufficient to establish:

- A generalized characterization of mass wasting processes active in the basin.
- Portions of the landscape sharing similar physical characteristics relating to mass-movement behavior.
- The relative potential for mass wasting within each landscape unit.

1.2 Previous Investigations

Lofgren (1974) mapped the geology of the upper portion of the north end of Kachess Ridge, east of Lake Kachess. Ashleman (1979) mapped bedrock geology for a majority of the upper half of the watershed.

[1] These can be more inclusive than the small-scale landforms commonly defined in rule (WAC 222-16-050). Rule-identified landforms include inner gorges, convergent headwalls, the outside of meander bends, bedrock (and other) hollows, and toes of deep-seated landslides.

Frizzell and others (1984) completed the preliminary geologic map of the Snoqualmie Pass 1:100,000 Quadrangle. The Bureau of Reclamation studied the area adjacent to Kachess dam and maintains an electronic database of information related to the construction and bed material below and within the Bureau of Reclamation dams on Lake Kachess, Lake Keechelus, and Lake Cle Elum (Bureau of Reclamation, Upper Columbia Area Office).

1.3 Summary of Methods

This assessment follows the Landslide Hazard Inventory Protocol dated April 6, 2005 (Department of Natural Resources, 2004), with minor modification. Four sets of 1:12,000 stereo air photos from 1979 to 1998, and one set of 1:60,000 stereo aerial photos from 1969 were viewed through a mirrored stereoscope with 3x magnification (Table 1). High-resolution LIDAR topography was not available for this area.

Year	**Scale**	**Image**	**Flight Line Number**	**Reference Ownership**	**Comment**
1979	1:12,000	Black & White	KYK-79	DNR	Complete coverage
1984	1:12,000	Color	SCC-84	DNR	Complete coverage
1991	1:12,000	Black & White	SC91	DNR	Complete coverage
1998	1:12,000	Black & White	SC-98	DNR	Complete coverage
1967	1:60,000	Black & White	EC-67	DNR	Complete coverage

Table 1. Photographic surveys used in this study.

The following landslide processes were used to identify and classify features observed on the stereo photos: shallow-undifferentiated landslides, debris flows, debris slides, debris avalanches, deep-seated landslides, rock topple, and snow avalanches. Table 2 provides a summary of the number and type of process features catalogued during this investigation. *Note: the two snow avalanches were located on USFS ownership but not included in the inventory.

Process	Number of features
Shallow undifferentiated landslides	41
Debris Flows	48
Deep-seated	68
Snow avalanche*	2

Table 2. Inventoried mass wasting features in the Kachess Watershed.

Mass wasting features were mapped on transparent overlays from 1:12,000 stereo photo pairs. The transparent overlays were placed over a computer screen and data was digitized directly to USGS 7.5 minute quadrangle base maps electronically enlarged using Arc Map 9.0 to closely match road and stream locations identified on the stereo photos. A slope-percent map derived from the USGS 10-meter digital elevation model (DEM) and the USGS 1:100,000 geologic map of the watershed aided in evaluation of slope conditions prior to slope failures, assisted in predicting areas of potential future failures and aided in delineation of the landforms. This mapping technique results in a maximum resolution of 10 meters. Slope failures of less than 5 meters are common in inner gorges, bedrock hollows and along the toes of deep-seated landslides and are not accurately reflected by the 10m DEM contour or slope map.

Slope gradients were determined by exploring a DEM-derived slope percent map within each feature polygon. Slope values derived from DEMs are generally lower than those measured in the field, but are less subjective. The slope angle cannot be reliably determined for small or narrow landslides where accuracy is limited by the 10-meter resolution of the DEM. Slope angle is understated where steep slopes or inner gorge faces are less than 60 feet high as the 10-meter resolution averages gentler slopes above and below the steep face into the calculation. Conversely, landslide scarps are typically steeper than the pre-landslide failure slope, DEM derived slopes measured on features with scarps could overstate the pre-failure slope.

Once the locations of mass wasting features were mapped and evaluated, areas of similar mass-wasting potential were grouped into individual landforms. These are shown on Map A-2 and described in Appendix B. Four days were spent field verifying features mapped in the Kachess WAU. Features not visible on the photos were also mapped and added to the inventory.

1.4 Introduction to Mass Wasting Processes and Terminology

For the purposes of this study, most landslides that fail below rooting depth are categorized as deep-seated, consistent with the Forest Practices Board Manual. Those deep-seated landslides that move rapidly and clearly deliver sediment to public resources are included in the analyses of sediment delivery.

Five types of mass wasting process were identified in the Kachess WAU related to forest practices:

1. Shallow landslides from cut slopes and in clear cut inner gorges
2. Deep-seated toes failing in harvested inner gorges cutting the toes and from road cut slopes
3. Head scarp failures in clear cuts
4. Debris flows originating from bedrock hollow failures in clear-cut moderate (60%) to steep (70+%) slopes
5. Avalanche chutes (all present on USFS ownership)

2.0 Physical Setting Pertinent to Mass-Wasting Interpretations

2.1 Introduction

The Kachess watershed covers 41,096 acres and lies completely within Kittitas County. Approximately 35,374 acres of checkerboard ownership of this watershed are managed by the US Forest Service and Federal Bureau of Reclamation and are not included within this study (Map A-1). The remainder includes

approximately 5722 acres of private ownership and Department of Natural Resources (DNR) managed lands that were evaluated during this study. This study evaluated only areas of private ownership or State managed lands within the Kachess Watershed. Some of the marginal areas of Federal ownership adjacent to the privately owned lands were inventoried if features and/or failures generated on Federal ownership impacted or continued onto private ownership.

The headwaters of the Kachess watershed lie approximately eight miles east of the Cascade Crest and drain south to its confluence with the Yakima River. Elevations within the study area range from a high of 5552 feet along Kachess Ridge, the eastern boundary above Lake Kachess, to 2178 feet at its confluence with the Yakima River through Lake Easton.

2.2 Topography

The Kachess watershed is located in central Washington State, approximately eight miles east of the Cascade Crest and three miles south of the Alpine Lakes Wilderness boundary. This watershed drains to the south, joining the Yakima River in Lake Easton. Slopes range from vertical in the Chikamin Ridge area to flat on the south end of Lake Kachess near the Easton Airport. The steepest and highest slopes in the watershed are located along Chikamin Ridge. The watershed is bisected north to south by Lake Kachess. Pleistocene glaciation has modified the main valley topography as well as the major side drainages and headwater basins (Figure 1).

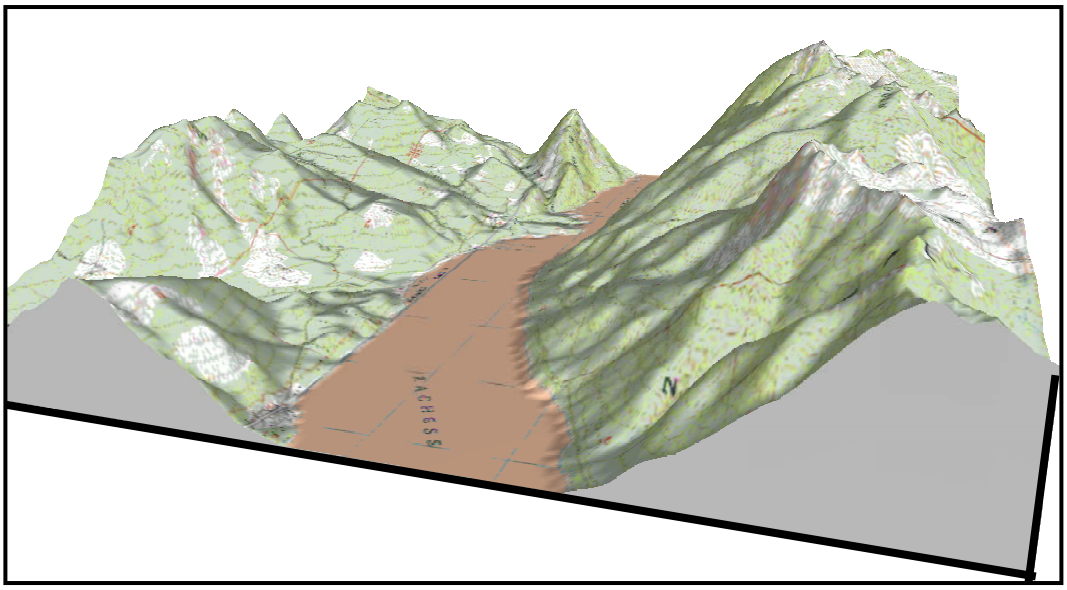


Figure 1. 3-D view of the main stem Kachess glaciated valley looking north. Note the rounded shoulders and broad, U shaped valley bottoms. Vertical exaggeration is 1.5:1.

2.3 Geology

Bedrock Units and Structure

The Kachess WAU straddles two "geologic" blocks described by Tabor and Frizzell (1984), the Teanaway Block present to the east of Lake Kachess and the Cabin Creek Block present west of the lake. Separating the two is the Straight Creek Fault, a major N-S oriented fault whose trace lies under Lake Kachess (Figure 2). The major bedrocks units in the Teanaway Block are sandstone, shale and coal of the Roslyn Formation, basalt and andesite flows of the Teanaway Formation, and sandstone units of the Swauk Formation. Bedrock units in the Cabin Creek block are rhyolite, basalt, and andesite, with minor sandstone, siltstone and rare coal units. The north south trending Straight Creek Fault system which bisects Kachess Lake north to south, trends into the northwest-southeast Olympic Willow Lineament (OWL) to the south of the study area. These major structural systems have caused bedrock units within the WAU to be broken by numerous faults and contorted by folding. This broken, tilted nature of the bedrock, combined with a thin veneer of glacially deposited material over stripped, dipping bedrock facilitates mass wasting.

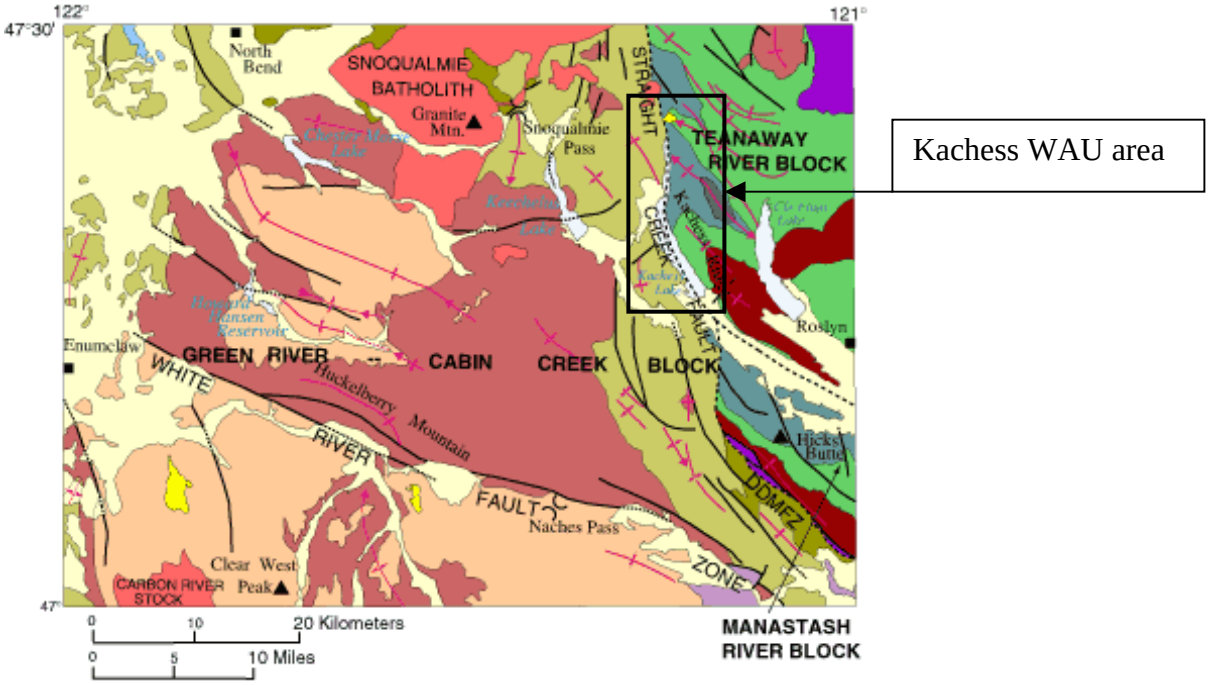


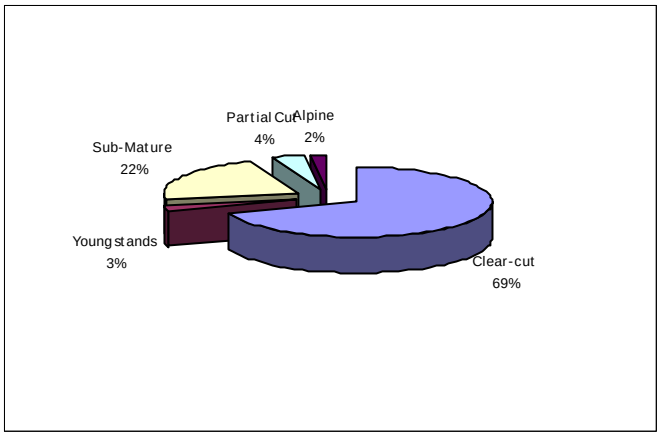
Figure 2. Geologic map from USGS Snoqualmie Pass 1:100,000 web site, http://geology.wr.usgs.gov/wgmt/pacnw/nc/snp2.html

In more recent geologic time (~2.6 million to ~11,000 years ago), alpine glaciers were repeatedly active in the watershed. Glacial erosion over steepened valley walls and deposited a blanket of unconsolidated sediments in valley floors and on stripped, steeply dipping bedrock units along both sides of the valley. Alpine glacial deposits, rock glaciers, glacial drift, small fans, bogs, and modern stream alluvium are present in the upper and lower portion of the Kachess drainage. A broad alluvial plain below the dam on Lake Kachess is composed of mixed alluvium and glacial drift, till, and outwash.

3.0 Summary of Results

During this review, a representative sample of 158 mass wasting features was inventoried using data obtained from both black & white and color aerial photos (Form A-1) and fieldwork. Of the landslides identified during this mass wasting assessment, 30% were mapped as shallow- undifferentiated failures, 27% were debris flows, and 43% were deep-seated landslides. The resulting mass wasting coverage is displayed as Map A-1. Pertinent attributes of individual features were recorded on data sheets (Form A-1).

The watershed was sporadically harvested in the early part of the 20th century. More intense harvest activity occurred after 1970. This assessment found that over 69% of the masses wasting features identified were located in clear cuts less than 5 years old (Figure 3). However, this apparent correlation between mass wasting and clear cuts may indicate nothing more than the inability to identify mass wasting features under forest canopy. Brardinoni et al. (2003) found that landslides not visible under forest canopy can represent up to 85% of the total number of failures in rugged forested watersheds. Land use was determined for each feature inventoried and is recorded in the inventory spreadsheet (Form A-1).



clear-cut (timber 0-5 years)

young stands (timber 5 – 15 years)

sub mature timber (15 – 50 years)

mature timber (>50 years)

Figure 3. Mass wasting feature location by stand age.

Clear-cuts and toes of deep-seated landslides were found to have had significant influence on the location of failures within the Kachess watershed. Loss of root strength appears to have resulted in failures as shallow landslides, large deep-seated landslides and debris flows originating within harvest areas less than 5 years old. If failures in clear-cuts and young stands are combined, 72% of all failures were located within harvest areas less than 15 years old. Road failures were not found to be significant triggers within this watershed.

Shallow landslide failures in clear-cut areas on toes of deep-seated landslides located along stream drainages and in inner gorges dominate mass wasting in the Kachess watershed.

Significantly higher numbers of large deep-seated landslides are located on the west side of Lake Kachess, probably due to lithology changes across the Straight Creek Fault. Slopes are steeper on the east side but more stable. Profile demonstrates slope differences.

4.0 Landform Descriptions

The distribution of the twelve landforms identified during the Kachess watershed study are shown on Map A-2 and described in Forms A-2, Appendix B. These units have been delineated to depict areas having similar mass wasting potential, potential to deliver to public resources, and potential to impact public safety. Mass wasting potential is based mainly on landslide process, failure density, lithology, geomorphology, and topography. Hydrogeology is considered as an important variable for delineating landforms in this watershed. The following sections briefly describe the characteristics of each landform with additional information given in Appendix B. Terrace faces and outside meander bends were combined into a single landform in this watershed. Landform numbers are identical to Landforms identified in the A-1 Inventory Data Sheet (column 10). Not all landforms identified in the protocol may be present within a specific Watershed. Form A-4 Appendix D summarizes all landform hazard ratings.

4.1 LANDFORM #1: Inner Gorges – Rule-identified high hazard and delivery features present in both asymmetrical and symmetrical forms. Slopes generally exceed 70% although failing gorge walls have been observed on slopes of 65%. This landform is often intermittent in lateral extent along smaller stream drainages (type 4, 5 & 9 streams, soon to be identified as type Np, Ns, and U). Inner Gorges are susceptible to both shallow undifferentiated failures and large deep-seated failures when they cut the toes of deep-seated landslides. Slope failures in inner gorges can transition to debris flows upon entering a stream channel. Inner Gorges are sensitive to both roads and harvest. Bedrock hollows located on the sides of inner gorges tend to be shallow and small (<10 feet wide and <2 feet deep).

LANDFORM #2: Bedrock Hollows – Rule-identified high hazard and delivery features. Hollows exhibit different physical characteristics between the east and west side of the Straight Creek Fault resulting from differences in types of bedrock, degree of weathering and degree of dip. Hollows in the steep headwall areas on the east side of Lake Kachess tend to be elongated and thin. Those on the west side of the lake and fault zone tend to be more teardrop shaped. Hollows within inner gorges in colluvium or glacial deposits appear to be similar in size and form regardless of location within the watershed.

4.2 LANDFORM #4: Terrace Face/Meander Bend – Rule identified, high hazard and delivery feature. Glacial terrace faces are located on both sides of the Kachess River directly adjacent to the outside of meander bends from the Kachess Dam spillway at the south end of Kachess Lake to its confluence with the Yakima River through Lake Easton (Figure 3).

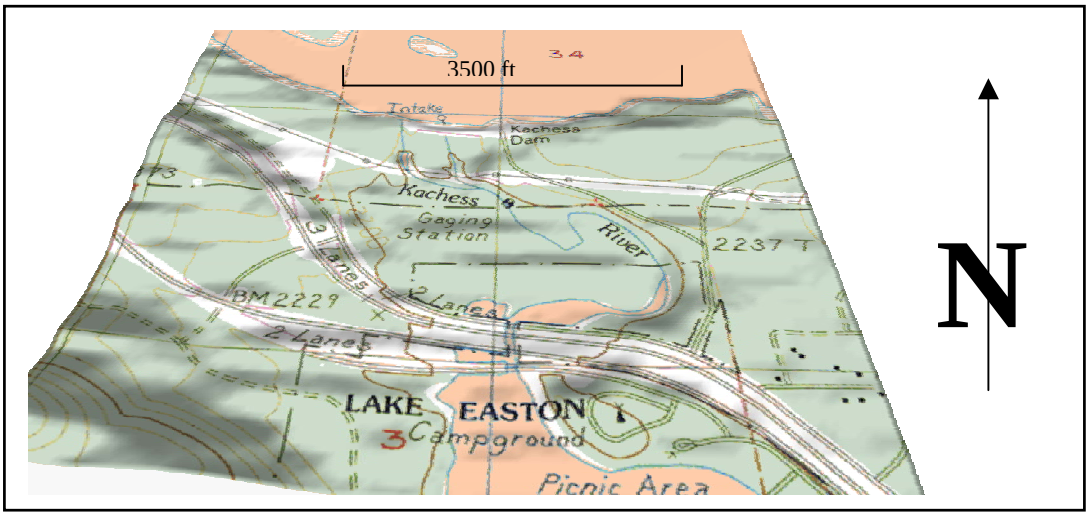


Figure 3. 3-D view of the area along the Kachess River between Kachess Dam and it's confluence with the Yakima River through Lake Easton. Vertical exaggeration is 1.5:1.

4.3 LANDFORM #5: Steep Headwalls – Rule identified, high hazard and delivery features. Steep (>70%) planar and convergent headwalls located at the upper end of drainage systems. Often headwalls are steep bedrock surfaces. Along the east side of Lake Kachess, the headwalls tend to be planar due in part to glacial erosion and the tectonic impact of the Straight Creek Fault Zone.

4.4 LANDFORM #8: Deep-Seated Landslide Toes Stream Adjacent – High hazard and delivery. Hummocky, steep (>65%) toes of deep-seated landslides that are stream adjacent. Often an inner gorge feature cuts the toes of these landslides. Shallow landslides, bedrock hollows and shallow deep-seated landslides are common within the toe. Larger failures have either dammed stream valleys creating flat, sediment filled areas upstream of the toe or the landslide toe mass has displaced the stream channel to one side of the valley. Roads located on or cut through the toes often fail. Debris flows originating from failed roads or plugged culverts under roads crossing on the toes may deliver directly to streams located at the bottom of or cutting through toes.

4.5 LANDFORM #10: Valley and Stream Bottoms – Low hazard and delivery features. Low gradient (0 – 10%) glacially carved valley and stream bottoms are generally composed of alluvium, colluvium, soil, landslide and glacial deposits. Streams are generally not deeply incised due to lower stream volumes compared to Pleistocene hydraulic activity. No mass wasting processes or features were observed on aerial photos in this landform.

4.6 LANDFORM #11: Low Gradient Hill Slopes and Valley Side Slopes (11 to 40%). Gentle hill and valley slopes are generally composed of alluvium, colluvium, soil, landslide & glacial deposits and minor bedrock outcrops of andesite, basalt, sandstone, rhyolite and schist. Deposits from deep-seated landslides on this landform often do not have toe adjacent streams. No mass wasting processes or features were observed on aerial photos in this landform.

4.7 LANDFORM #12: Lodge Creek Mid Slope (40 to 70%) Deep-Seated Landslide Complex. The North side of Lodge Creek is formed by a series of large deep-seated landslides that have all been active post glaciation. The Mid Slope area is a transitional zone between bulk transport and deposition of the landslide body mass (Figure 4). Aerial photos taken in 1991 clearly show a wall formed from landslide downed and transported trees piling into an older, dense standing forest in the mid slope area. This bulwark slowed and stopped the bulk of the landslide mass as it interfingered into the trees. This zone is critical in containing the body mass of the multiple landslides that have occurred here. Large old growth and second growth trees acted as debris dams forming massive wood containment structures helping contain and hold the landslide on the upper slopes away from older toe deposits lower on the slope.

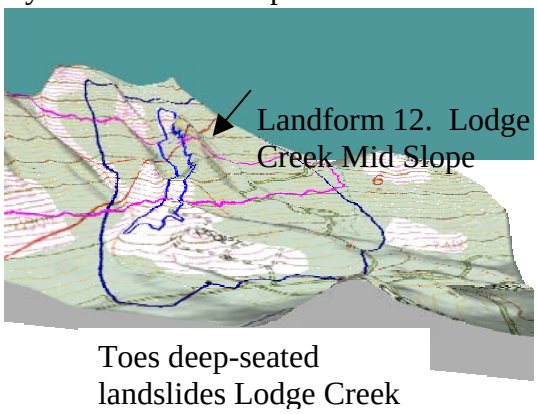


Figure 4. 3-D view of the Lodge Creek landslide complex showing the relationship of the mid slope Landform #12 area (outlined in pink) to the entire hill slope and landslide complex

4.8 LANDFORM #13: Ridge and Hill Tops (0 to 10% slopes) – Low hazard and delivery. This landform is located at the tops of ridges and hills. Most ridge tops were located on USFS ownership and were not inventoried for this report. No mass wasting processes or features were observed on aerial photos in this landform

4.9 LANDFORM #14: Moderate (40 to 69%) to Steep (70+%) Hill Slopes – Moderate hazard and delivery within this landform. These slopes are convergent but not as steep as convergent headwalls. They contain isolated areas of cliffs, and steeper (>70%) slopes, however the majority of the area within this landform falls below the threshold for rule-identified convergent headwalls. This landform often includes head scarps of deep-seated landslides that are not likely to deliver. Other unmapped rule-identified landforms may be located within landform# 14.

4.10 LANDFORM #15: Lodge Creek Toes of Active Deep-Seated Landslides – High hazard and delivery (Figure 5).

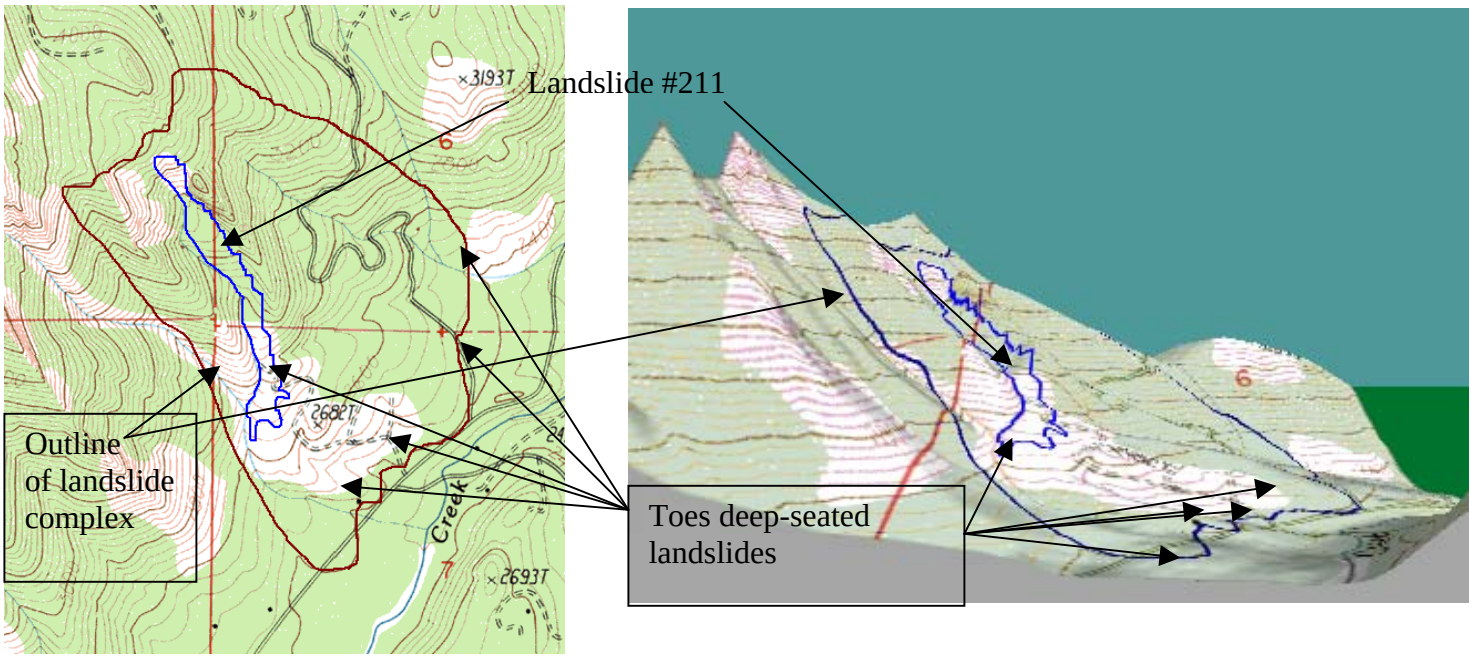


Figure 5. Landform #15 map and 3-D view.

A series of landslide toes are present at the bottom of the slope on the north side of Lodge Creek. More than 20 structures (houses, garages, shops, etc), power transmission lines and a paved county road are located on these toes. Second and old growth now covers all slopes with the exception of a recent landslide (1991 landslide #211) scarp, body and toe (Figure 5). The landslide complex head scarp area was harvested in 1990 or 1991, prior to the failure of landslide #211. Landslide debris from landslide #211traveling down slope removed a swath of timber and interfingered with standing timber before coming to rest down slope. Debris did not reach the homes or public resources located on the older toe deposits because large trees on the toe and mid slope area acted as a bulwark holding the debris back. These large trees acted as an important barrier restricting mass wasting damage to the mid slope and upper toe slope area and preventing damage to home sites located on the lower toe slopes.

4.11 LANDFORM #16: Lodge Creek Head Scarps of Active Deep-Seated Landslides – Very high hazard and high delivery potential. The hydraulic recharge area for head scarps of multiple deep-seated landslides was clear-cut in 1991. This is the source area from which the massive landslide deposits in Landforms 12, 15 and 16 originated. The most recent landslide occurred in 1991 after clear-cut harvest of the entire hydraulic recharge area. Multiple (>20) private residences, a paved highway, and public power lines are located on the toes of recent deep-seated landslides. Since the harvest of the head scarp area, only the mid and toe slope forests act as a protective buffer for multiple public resources from the impacts of massive landslides.

5.0 Confidence in Work Products

The confidence in this mass wasting assessment is High. This rating is based on the Landslide Hazard Zonation Project Protocol designed to provide a watershed overview of slope stability in a timely manner with minimal field verification. As a consequence, fieldwork and the number of aerial photograph sets examined were held to reasonable minimums. Omissions will be present due to the limited field verification of individual features, particularly in heavy canopy forested areas.

It is critical for the reader to understand that while this watershed study is sufficient to characterize aspects of the slope failure as functions of forest management, <u>this assessment would be entirely insufficient and misleading if it is used as a stand alone document for protecting private and public resources or for land use planning.</u> Keep in mind that this is only a reconnaissance study, and <u>undoubtedly, some landslides have been accidentally omitted and some benign features may be improperly mapped as landslides herein</u>.

In addition, there are several sources of systematic error that should be kept in mind when using the work products from this analysis, those being omission, misinterpretation, accuracy, and precision. Omission occurs when mass wasting features are not identified on aerial photographs or in the field due to canopy cover, gaps in the aerial photo record, quality of aerial photos, or interpreter errors. Misinterpretation occurs when a mass-wasting feature is identified but incorrectly classified or data are transposed, and where uncontrollable and potentially unrecognized software/file instability occurs. Accuracy involves the degree to which the physical parameters of a mass-wasting feature are correctly measured, and precision describes how variability within an assessment can be controlled when making multiple measurements over varying time and spatial scales (Parks, 2000).

This mass wasting assessment was primarily conducted with aerial photographs, and as a result, there is a high likelihood that errors of omission occurred primarily in areas covered by mature forest canopies (Brardinoni et al. 2003) and steep north facing slopes always in shadow at any given time. The scarcity of mass wasting features identified under mature canopy and steep north slope conditions is not necessarily an indication of the relative stability of those slopes.

Because many deep-seated landslide features are quite large, remain heavily vegetated during movement, and may not have obvious scars visible through the vegetation canopy, misinterpretation is likely. Confidence in work products related to classification of deep-seated landslide processes in this watershed is high due to visibility and completeness of photo coverage.

Another important source of potential error in this assessment is in the accuracy and precision of measurements of mass wasting features. Because very few landslides were actually visited in the field, it is not possible to report the degree to which location and measurement error in the GIS environment

compares to on-the-ground field measurements. Similarly, measurements of slope angle from digital elevation models typically misrepresent the true hill slope angle. Given these sources of error, the confidence in the precise location and accuracy of measurements of individual landslides is considered moderate.

6.0 Hazard Ratings

Hazard rating under this protocol may be determined in any one or combinations of the following: 1) Rule-identified status (WAC 222-16-050), 2) the Landslide Frequency Rate and the Landslide Area Rate For Delivery, or 3) professional judgment of the interpreter. For the Kachess watershed, rule-identified status, Landslide Frequency Rate and Area Rate For Delivery criteria and professional judgment of the interpreter were used.

Landslide Area Rate For Delivery is used to help quantify the potential hazard of delivery of sediment to public resources where rule identified status may mis-characterize slope stability in the landform as outlined in Table A-2 of Washington Forest Practices Board (1997). The Landslide Area Rate For Delivery is simply the area of delivering landslides normalized for the period of study and the area of each Landform. These values are multiplied by one million to provide whole numbers. Limited application suggests that Landslide Area Rates For Delivery less than 76 might be considered low; rates of 76 to 150 are probably moderate, rates of 151 to 799 are probably high, and rates greater than 799 appear to be very high (Lingley, 2004). Note that higher Landslide Area Rates For Delivery can be achieved by reducing the size of the Landform. While this may appear to be ‘data gerrymandering’, it has a favorable effect, which is to help limit the area of high-hazard mass wasting map units to those areas that are actually demonstrated to have high hazard.

Three unique landforms specific to a single area within the study area were identified, evaluated and found to represent a high hazard to public safety and homes. Specific criteria to name the identified hazard features have not yet been established. These three landforms were identified by their proximity to a major stream, Lodge Creek, and mapped to provide the forester with tools to evaluate future forest practices applications for harvest.

Landslide Area Rates For Delivery for the twelve Kachess landforms described herein are present in Appendix D, page 40.

7.0 References

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Appendices A through D

Kachess WAU

Appendix A A-1 Landslide Inventory

Kachess LHZ

slide_id	lsi_process	certainty	id_date	ls_size	id2_date	id2_size	init_elev	photo_num	landform	slp_shp	gradient	delivery	land_use	geologic unit	acreage	comments	ls_activity level	ls_type
100	2	D	1979				3626	KYK_79_15E15	1	3	43	Y	1	Evb(nap)	36	deep road fill failure debris flow		
101	1	D	1979	5	**1998**	5	3343	KYK_79_15E15	1	1	63	Y	1	Evb(nap)	0.5	toe deep-seated landslide reactivated	AR	T
102	1	D	1979	5	1998	5	3409	KYK_79_15E15	1	2	71	Y	1	Evb(nap)	2.8	toe deep-seated landslide reactivated, size increased to 4.3 acres	AR	T
103	1	D	1979				3205	KYK_79_15E15	1	5	72	Y	1	Evb(nap)	0.7		AR	R
104	1	D	1979				3221	KYK_79_15E15	1	5	73	Y	1	Evb(nap)	0.9		AR	R
105	4	D	1979	5			3438	KYK_79_15E15	8	1	51	Y	1	Evb(nap)	9	toe deep-seated landslide inside older ls	DD	R
106	4	D	1979	3			3172	KYK_79_15E15	1	3	36	Y	1	Evb(nap)	0.8	toe deep-seated landslide inside older ls	AR	R
107	4	D	1979	5			3333	KYK_79_15E15	8	3	39	Y	1	Evb(nap)	13.6	older dsl in toe of very old dls with younger failures in it	DD	R
108	4	P	1979	5	1998	5	3993	KYK_79_15E15	8	1	40	P	1	Evb(nap)	142	old indistinct dsl with bedrock hollows, shallow undifferentiated and small deep-seated in body	DD	C
109	2	P	1979				4121	KYK_79_15E15	1	3	45	Y	1	Evb(nap)	2.1			
110	2	P	1979				4011	KYK_79_15E15	1	3	64	Y	1	Evb(nap)	4.6			
111	4	P	1979	5			3410	KYK_79_15E15	8	4	28	Y	3	Evb(nap)	27.3		DI	C
112	4	D	1979	5			3028	KYK_79_15E15	8	2	47	Y	3	Evb(nap)	1.6		DD	R
113	4	D	1979	5			3211	KYK_79_15E15	1	4	44	Y	1	Evb(nap)	1.9		DD	C
114	4	D	1979	5			3956	KYK_79_15E15	8	3	48	Y	1	Evb(nap)	86.8		DI	C
115	1	D	1979	5			3349	KYK_79_15E15	8	1	51	Y	1	Evb(nap)	0.4	debris flow delivered to stream	AR	C
116	1	D	1979	5			3380	KYK_79_15E15	2	1	64	P	1	Evb(nap)	0.6	debris flor from hollow	AR	T
117	4	P	1979	5			3122	KYK_79_15E15	8	5	37	Y	1	Evb(nap)	9.9	displaced stream	DD	C
118	4	D	1979	5			3723	KYK_79_15E15	8	1	59	Y	1	Evb(nap)	33.3	DSL blocked stream forming sinificant dam and upstream filling of valley	DD	C
119	2	D	1979				3417	KYK_79_15E15	8	3	22	Y	1	Evb(nap)	0.6	initiated in headwall dsl		
120	4	D	1979	5			3333	KYK_79_15E15	8	5	52	Y	1	Evb(nap)	4.5	secondary failure on side of older dsl	AR	T
121	4	P	1979	5			3506	KYK_79_15E15	8	5	49	I	1	Evb(nap)	4.4		DD	R
122	2	D	1979				3718	KYK_79_15E12	1	3	26	Y	1	Evb(nap)	5.7	east side stream clearcut, westside partial cut		
123	2	D	1979				3830	KYK_79_15E12	1	3	32	Y	1	Evb(nap)	0.95	road initiated debris flow		
124	1	D	1979	5			4395	KYK_79_15E12	5	3	94	Y	3	Evb(nap)	1.1	steep bedrock outcrop vertical dipping beds	AR	T
125	1	D	1979	5			3651	KYK_79_15E12	5	1	94	Y	3	Evb(nap)	4.6	deep-seated landslide headwall secondary failure	AR	T
126	4	P	1979	5			4708	KYK_79_15E12	5	5	46	Y	3	Evb(nap)	11	steep bedrock outcrop vertical dipping beds	AR	R
127	4	D	1979	5			4127	KYK_79_15E12	8	5	61	Y	4	Evb(nap)	132		DD	C
128	4	P	1979	5			3789	KYK_79_15E12	8	5	49	I	6	Evb(nap)	115.8	indistinct hummocky body	DI	I
129	2	D	1979				3108	KYK_79_15E12	1	2	57	Y	1	Ec(2ras)	0.7	road failure debris flow	AR	T
130	2	D	1979				3249	KYK_79_15E12	1	3	19	N	1	Ec(2ras)	0.5	road failure debris flow	AR	T
131	4	P	1979	5			3815	KYK_79_15E12	8	2	33	Y	1	Evb(nap)	23	combination USFS/Pvt land feature located on - Thetis Ck thrashed	DI	C
132	1	D	1979	2			2961	KYK_79_15E12	1	3	61	Y	1	Ec(2ras)	0.2		AR	T

Kachess LHZ

slide_id	lsi_process	certainty	id_date	ls_size	id2_date	id2_size	init_elev	photo_num	landform	slp_shp	gradient	delivery	land_use	geologic unit	acreage	comments	ls_activity level	ls_type
133	1	D	1979	1			3308	KYK_79_15E12	8	2	41	Y	1	Evb(nap)	0.04	fresh failure on the side and toe of deep-seated landslidewithin inner gorge on outside meander	AR	T
134	4	P	1979	5			3578	KYK_79_15E12	8	3	40	P	1	Evb(nap)	6.8	USFS ownership adjacent to Thetis Ck.	DI	R
135	4	D	1979	5			3566	KYK_79_19D5	8	5	43	N	3	Evr(na)	6.8		DI	I
136	4	D	1979	5			3856	KYK_79_19D5	8	1	39	P	1	Evr(na)	23.4		DI	I
137	4	D	1979	5			4173	KYK_79_19D5	8	5	31	N	1	Evr(na)	5.8		DI	I
138	4	D	1979	5			4082	KYK_79_19D5	8	1	44	P	1	Evr(na)	10.8		DI	I
139	1	D	1979	3			3590	KYK_79_19D5	1	2	69	Y	1	Evr(na)	0.6		AR	T
140	1	D	1979	2			3418	KYK_79_19D5	1	2	79	Y	1	Evr(na)	0.2		AR	T
141	1	D	1979	2			3263	KYK_79_19D5	1	3	83	Y	1	Evr(na)	0.2		AR	T
142	2	D	1979				3469	KYK_79_19D5	1	2	81	Y	1	Ec(2na)	2.8			
143	2	D	1979				4019	KYK_79_19D5	1	1	18	Y	1	Ec(2na)	1.9			
144	2	D	1979				3949	KYK_79_19D5	1	1	33	Y	1	Ec(2na)	2.3			
145	2	D	1979				3857	KYK_79_19D5	2	1	32	Y	1	Ec(2na)	1			
146	2	D	1979				3577	KYK_79_19D5	1	3	41	Y	1	Evr(na)	6.1	17' deep incised inner gorge with numberous shallow undifferentiated landslides both walls 90% slopes		
147	2	D	1979				2612	KYK_79_19D11	2	2	41	Y	1	Ec(2nas)	0.35			
148	1	D	1979	3			2619	KYK_79_19D11	1	2	80	Y	1	Ec(2nas)	0.6	edge of clear cut and partial cut	AR	T
149	1	D	1979	2			2577	KYK_79_19D11	1	2	53	Y	1	Ec(2nas)	0.22		AR	T
150	1	D	1979	3			2537	KYK_79_19D11	1	2	69	Y	1	Ec(2nas)	0.4		AR	T
151	1	D	1979	3			2611	KYK_79_19D11	1	4	61	Y	1	Ec(2nas)	0.7		AR	T
152	4	D	1979	3			2508	KYK_79_19D11	1	2	52	Y	3	Ec(2nas)	0.8		AR	C
153	4	P	1979	5			2782	KYK_79_19D11	8	1	55	Y	1	Ec(2nas)	4.7		DD	T
154	4	D	1979	.			2710	KYK_79_19D11	1	1	60	Y	1	Ec(2nas)	0.9		DD	T
155	4	D	1979	5			2557	KYK_79_19D11	1	2	62	Y	1	Ec(2nas)	1.7		DD	T
156	4	D	1979	5			2651	KYK_79_19D11	1	2	65	Y	1	Ec(2nas)	2.7		AR	T
157	4	D	1979	5			2788	KYK_79_19D11	8	1	31	Y	1	Ec(2nas)	9.1		DI	T
158	4	D	1979	5			2879	KYK_79_19D11	8	2	50	Y	1	Ec(2nas)	2.6		AR	T
159	4	D	1979	5			2671	KYK_79_19D11	1	2	63	Y	1	Ec(2nas)	4.2		AR	T
160	2	D	1979				2886	KYK_79_19D11	1	3	44	Y	1	Ec(2nas)	0.1			
161	1	D	1979	2			2768	KYK_79_19D11	1	2	68	Y	1	Ec(2nas)	0.09		AR	T
162	1	D	1979	3			2725	KYK_79_19D11	1	2	66	Y	1	Ec(2nas)	0.2		DI	T
163	1	D	1979	3			2569	KYK_79_19D11	1	2	103	Y	1	Ec(2nas)	0.16		AR	T
164	1	D	1979	4			2986	KYK_79_19D11	1	2	61	Y	1	Ec(2nas)	0.19		DD	T
165	2	D	1979				2517	KYK_79_19D11	8	2	49	Y	1	Ec(2nas)	0.1	1979 debris flow in AR deep seated landslide		
166	4	Q	1979	5			3050	KYK_79_21E1	8	5	40	Y	1	Eva(ss)	74		DI	C

Kachess LHZ

slide_id	lsi_process	certainty	id_date	ls_size	id2_date	id2_size	init_elev	photo_num	landform	slp_shp	gradient	delivery	land_use	geologic unit	acreage	comments	ls_activity_level	ls_type
167	2	D	1979				3676	KYK_79_21E1	1	3	28	Y	1	Jsh(s)	8.3			
168	4	Q	1979	5			3851	KYK_79_21E3	8	1	45	I	1	Eva(ss)	8.4		DI	C
169	4	P	1979	5			4025	KYK_79_21E3	8	1	93	Y	1	Eva(ss)	1.3		DI	T
170	4	Q	1979	5			4451	KYK_79_21E3	8	1	56	Y	1	Eva(ss)	14.3		DI	C
171	4	P	1979	5			3866	KYK_79_21E3	8	2	34	Y	1	Jsh(s)	10.2		DI	R
172	4	Q	1979	5			4175	KYK_79_21E3	8	2	43	Y	1	Eva(ss)	7		DI	C
173	2	D	1979				5299	KYK_79_21E3	1	2	32	Y	3	Jsh(s)	5.4			
174	4	P	1979	5			4406	KYK_79_20D4	8	2	39	N	1	Evr(na)	139.4		DI	I
175	4	P	1979	5			4535	KYK_79_20D6	8	1	38	N	3	Ec(2na)	46.9		DI	I
176	2	D	1979				3501	KYK_79_20D4	1	2	47	Y	3	Evr(na)	3			
177	2	D	1979				4220	KYK_79_20D12	1	2	79	Y	3	Jsh(s)	5			
178	1	D	1979				3774	KYK_79_22F4	2	1	107	Y	3	Eva(ss)	2		AR	T
179	2	P	1979				3704	KYK_79_20D6	2	2	36	Y	1	Evr(na)	0.4			
180	1	P	1979	3			3128	KYK_79_20D6	1	2	75	Y	1	Evr(na)	0.2	small failure in inner gorge		
181	4	Q	1979	5			3992	KYK_79_20D12	8	2	63	Y	3	Jsh(s)	41.2		AR	T
182	4	P	1979	4			2849	KYK_79_22F4	8	1	72	Y	3	Eva(ss)	0.85		AR	T
183	2	D	1979	5			3402	KYK_79_22F4	5	1	88	Y	3	Eva(ss)	1.6			
184	1	D	1979	2			2197	KYK_79_22F2	4	3	18	Y	3	Qa	0.04		AR	T
185	1	D	1979	2			2188	KYK_79_22F2	4	2	6	Y	3	Qa	0.06		AR	T
186	1	D	1979	3			2200	KYK_79_22F2	4	3	51	Y	3	Qad(e)	0.11	should be Qa	AR	T
187	1	D	1979	3			2188	KYK_79_22F2	4	3	30	Y	3	Qa	0.13		AR	T
188	1	D	1979	3			3353	KYK_79_22F4	1	2	82	Y	3	Qad(e)	0.23		AR	T
189	2	D	1984				3408	SCC84_7_18_15	1	1	26	Y	1	Evb(nap)	0.3	interconnected bedrock hollows forming inner gorges		
190	2	P	1984				3934	SCC84_7_18_15	1	2	46	Y	1	Evb(nap)	0.5			
191	1	D	1984				3886	SCC84_7_18_15	1	2	60	Y	1	Evb(nap)	0.8		AR	T
192	2	D	1984				4192	SCC84_7_18_12	8	2	51	P	1	Evb(nap)	0.7	drainage in body of DSL		
193	4	D	1984	5			3744	SCC84_7_18_12	8	1	61	Y	1	Evb(nap)	1.2	recent failure on margin of older, larger DSL	AR	C
194	1	D	1984	3			3552	SCC84_7_18_12	1	2	52	Y	1	Evb(nap)	0.3	recent failure in inner gorge in DSL	AR	T
195	4	P	1984	5			4605	SCC84_7_18_12	8	1	44	Y	1	Evb(nap)	100		R	C
196	2	D	1984				4254	SCC84_7_19_24	2	1	41	Y	1	Ec(2na)	0.8			
197	2	D	1984				3510	SCC84_7_19_26	2	1	70	N	1	Ec(2na)	0.3	stream empties into broad plain. Little chance of delivery		
198	4	D	1984	5			3178	SCC84_7_19_24	8	1	75	Y	2	Evr(na)	4.8		AR	T
199	1	D	1984				3051	SCC84_7_19_24	1	2	86	Y	2	Evr(na)	0.4		AR	T

Kachess LHZ

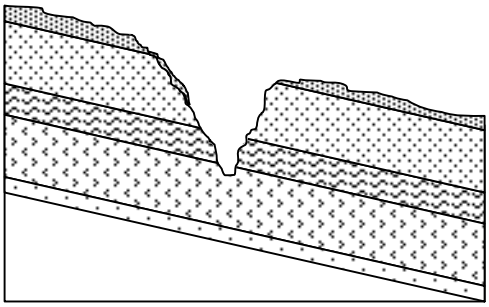
slide_id	lsi_process	certainty	id_date	ls_size	id2_date	id2_size	init_elev	photo_num	landform	slp_shp	gradient	delivery	land_use	geologic unit	acreage	comments	ls_activity_level	ls_type
200	4	D	1984				2946	SCC84_7_19_30	1	1	32	Y	1	Ec(2nas)	1		AR	C
201	4	D	1984	5			2781	SCC84_7_19_30	1	1	28	Y	6	Ec(2nas	3.9	evenly split between Ec(2nas) and Evb(nap)	DD	I
202	2	D	1991				3412	SC91_42_20_126	2	2	72	P	1	Ec(2na)	0.6			
203	2	D	1991				4829	SC91_40_22_8	5	2	57	Y	3	Eva(ss)	0.5			
204	2	D	1991				4269	SC91_40_22_8	1	2	33	Y	6	Eva(ss)	1.2			
205	4	P	1991				4118	SC91_40_22_8	8	2	59	P	1	Ec(2nas)	1.2	smaller younger DSL inside older larger DSL	DD	T
206	1	P	1984	5			3322	SCC84_7_22_180	5	2	99	P	3	Eva(ss)	1.8	USFS ownership	AR	T
207	1	P	1984	5			2717	SCC84_7_22_180	8	2	72	Y	3	Eva(ss)	0.5		AR	T
208	4	P	1984	4			3800	SCC84_7_18_11	8	2	51	P	3	Evb(nap)	27		DD	I
209	4	D	1991	5			3872	SC91_42_18_95	8	1	65	P	3	Evb(nap)	35	landslide dammed creek, moved to opposite side of drainage	AR	C
210	4	D	1991	5			4167	SC91_42_18_92	8	2	59	Y	1	Evb(nap)	54		DD	T
211	4	D	1991	5			3801	SC91_42_18_92	8	1	66	Y	1	Evb(nap)	23.7	large DSL occured 1991	AR	T
212	4	P	1984	5			4014	SCC84_7_18_15	8	1	49	P	1	Evb(nap)	78	dipping bedding plain failure, toe delivers	R	T
213	2	D	1984				4264	SCC84_7_18_11	2	1	42	P	1	Evb(nap)	0.2			
214	4	D	1984	5			4801	SCC84_7_18_11	8	2	54	P	1	Evb(nap)	11	dipping beds failing creating linear, deep-seated landslide		
215	4	Q	1984	5			2749	SCC84_7_19_30	8	3	28	P	1	Ec(2nas)	61	DSL in dipping beds	R	T
216	2	D	1984				2766	SCC84_7_19_30	1	3	21	Y	1	Ec(2nas)	2.6			
217	2	D	1991				4915	SC91_40_22_7	5	1	101	N	8	Ec(2nas)	0.2			
218	1	D	1991	2			5165	SC91_40_22_7	5	1	87	N	8	Ec(2nas)	0.1	convergent headwall alpine, no trees only bedrock exposed	AR	T
219	2	D	1991				4697	SC91_40_22_7	5	1	105	N	8	Ec(2nas)	0.3			
220	4	D	1991	5			3390	SCC84_7_19_30	8	4	27	N	1	Evb(nap)	5.9		DD	T
221	4	D	1991	5			3218	SCC84_7_19_30	8	4	45	Y	1	Ec(2nas)	1.8		DD	T
222	4	D	1991	5			2739	SCC84_7_19_30	8	3	33	Y	6	Ec(2nas)	1.2		DI	C
223	4	D	1991	5			2690	SCC84_7_19_30	8	3	30	Y	1	Ec(2nas)	1.4		DI	C
224	4	D	1991	4			2680	SCC84_7_19_30	8	2	53	Y	1	Ec(2nas)	1	smaller younger DSL inside older DSL	AR	C
225	4	P	1991	5			4922	SC91_40_22_8	8	1	59	N	6	Ec(2nas)	9.3	USFS	DI	I
226	4	P	1991	5			3076	SC91_40_23_24	8	1	87	Y	3	Ec(2nas)	40		DD	C
227	2	D	1991				2912	SC91_40_23_24	1	2	73	Y	3	Ec(2nas)	0.4			
228	2	P	1979				3989	KYK79_190_9	1	2	64	Y	3	Evb(nap)	0.2		AR	T
229	1	P	1979	3			4070	KYK79_190_9	2	1	79	P	3	Evb(nap)	0.2			
230	2	D	1991				3023	SC91_42_18_92	1	2	33	Y	1	Evb(nap)	1.4			
231	4	P	1991	5			3521	SC91_42_20_126	8	2	65	N	1	Evb(nap)	7.9	clearcut upper half dense forest lower half	DI	I
232	4	Q	1991	5			4056	SC91_42_20_126	8	5	39	N	6	Evb(nap)	9.1		DI	I
233	4	P	1991	5			4606	SC91_42_18_95	8	2	54	P	3	Evb(nap)	3.8		DI	T

Kachess LHZ

slide_id	lsi_process	certainty	id_date	ls_size	id2_date	id2_size	init_elev	photo_num	landform	slp_shp	gradient	delivery	land_use	geologic unit	acreage	comments	ls_activity_level	ls_type
234	4	D	1991				2974	SC91_42_18_95	8	2	42	Y	1	Evb(nap)	0.9	toe of DSL in inner gorge	RA	C
235	2	D	1991				3294	SC91_42_18_95	1	2	60	Y	1	Evb(nap)	0.9	body of DSL		
236	2	D	1991				3392	SC91_42_18_95	1	2	56	Y	1	Evb(nap)	0.1	body of DSL		
237	2	D	1991				3387	SC91_42_18_95	1	2	66	Y	1	Evb(nap)	0.3	body of DSL		
238	2	D	1991				3288	SC91_42_18_95	1	2	61	Y	1	Evb(nap)	0.2	body of DSL	AR	T
239	1	D	1991	3			3136	SC91_42_18_95	1	2	26	Y	1	Evb(nap)	0.2	failing toe in inner gorge	AT	T
240	2	D	1991				4079	SC91_42_18_95	8	2	67	Y	1	Evb(nap)	0.8		AR	C
241	4	D	1991	5			4381	SC91_42_18_95	8	2	45	Y	1	Evb(nap)	24.8			
242	2	D	1991				3374	SC91_42_18_95	1	3	62	Y	1	Evb(nap)	0.3	road failure triggered debris flow, USFS ownership		
243	1	D	1991	4			3698	SC91_42_19_104	1	2	65	Y	1	Ec(2na)	0.8		AR	T
244	2	D	1998				4551	SC98_23_18_174	5	3	32	P	1	Evb(nap)	0.3	road drainage discharge triggered debris flow		
245	2	D	1998				4142	SC98_23_18_174	2	3	41	P	1	Evb(nap)	0.1	failure on edge of DSL		
246	1	D	1998	5			3640	SC98_23_18_176	8	1	63	Y	3	Evb(nap)	3.5	shallow failure on scarp of older DSL	AR	T
247	4	D	1998	4			3349	SC98_23_18_117	8	1	75	Y	1	Evb(nap)	0.9	young failure in steep body of older DSL	AR	C
248	1	D	1998	5			3389	SC98_23_18_117	8	2	62	Y	1	Evb(nap)	1.3	recent failure partially including two older shallow undifferentiated failures	AR	T
249	4	P	1998	5			3886	SC98_23_18_117	8	1	45	Y	2	Evb(nap)	33		DD	R
250	1	D	1998	5			3703	SC98_23_18_172	8	2	91	Y	2	Evb(nap)	2.4	fresh failure on the headscarp of recent (1991) DSL	AR	T
251	1	D	1998	3			4807	SC98_23_21_129	1	2	52	Y	1	Jsh(s)	0.3		AR	T
252	4	P	1998	5			4692	SC98_23_21_129	8	2	57	Y	1	Jsh(s)	271	very old DSL	R	I
253	4	Q	1998	5			4874	SC98_23_21_129	8	1	48	P	1	Jsh(s)	83	possible DSL may also be glacial in origin as it is located in convergent headwall in glaciated zone	R	I
254	2	D	1979	5			4395	KYK_79_15E12	1	3	58	Y	3	Evb(nap)	3.1	steep bedrock outcrop vertical dipping beds		
255	2	D	1979				3273	KYK_79_15E15	8	1	49	Y	1	Evb(nap)	0.6	debris flow delivered to stream		
256	2	D	1979				3342	KYK_79_22F4	2	1	107	Y	3	Eva(ss)	0.4	debris flow below shallow undifferentiated		
257	1	D	1984	2			2272	SCC84_7_19_30	1	3	42	Y	1	Ec(2nas)	0.1	small failure in inner gorge	AR	T

Appendix B A-2 Landform Descriptions

11.0 Landform Number: #1 - Inner Gorges



Description of Mass Wasting Unit: Steeply (generally>70%) walled canyons or gullies with evidence of mass wasting along its sidewalls. Unit consists of symmetrical and asymmetrical inner gorges, often intermittent in lateral extent. Debris slides, debris flow, ravel and small rotational failures were observed within inner gorges. Gorge scarp slopes revegetate rapidly and are often covered with vegetation that masked slope failures on all aerial photos. Debris flows occur commonly in the inner gorge features during major hydrologic events.

Slopes: >65%
Material: Colluvium, alluvium, landslide & glacial deposits, basalt, andesite, rhyolite, sandstone, and shale.
Elevation: Variable, nearly all elevations possible
Total Area: 335 acres

Mass Wasting Process: Inner gorges form from down cutting of streams sometimes assisted by the scouring effect of debris flows. The over steepened wall(s) of the gorge (or gully) fails as debris slides, slope ravel, shallow landslides, or small rotational failures sometimes initiating debris flows.

Forest Practice Sensitivity: Root strength within inner gorges has been found to be a factor in limiting the rates of mass wasting. Trees adjacent to the inner gorge can have roots extending into the slopes of the gully providing slope stability. Timber harvest, road construction, landing construction and/or other activities that impact root strength on steep slopes in poorly consolidated colluvium draping bedrock can cause slope instability. Roads and landings can destabilize slopes in inner gorges by undercutting and over steepening slopes. Side cast and road (or landing) fill can over steepen and add weight to slopes; roads and landings can also capture runoff water or shallow groundwater and channel it to point locations that saturate road or landing fill and/or thin soils draping bedrock, triggering landslides.

Mass Wasting Potential: <u>High for road construction and timber harvest.</u> 21 failures occurred in inner gorges in an area of 335 acres over a 19-year time period (see LHZ protocol).

Delivery Potential/Criteria: <u>Very High</u>. Inner gorges are part of the drainage network and are adjacent to or contain streams (21 mapped landslides delivered to a public resource). Delivery criteria are also based on historical occurrence observed on aerial photographs and confirmed during field investigations. This unit has a calculated landslide rate for delivery of 2487 (see LHZ protocol).

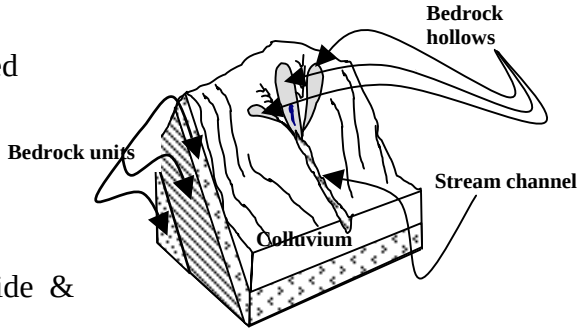
Hazard Potential Rating: <u>High for roads and harvest</u> based on LHZ Protocol and Standard Forest Practices Rules.

Trigger Mechanisms: Soil saturation, loss of root strength, changes in hydrology, over steepening and loading slopes in colluvium or toes of deep-seated landslides and glacial deposits can trigger debris slides or other landslides. These factors can be due to harvest, road building, landing construction and major rain-on-snow storms or intense precipitation events. A majority (63%) of landslides identified within this unit were located within clear-cut harvest areas.

Confidence: High based on the number of landslides located in this landform, excellent photo quality and coverage, and field observations.

Comments: Careful field review will be necessary for those areas of steep inner gorge walls in or adjacent to the toes of deep-seated landslides to delineate all unstable slopes. Inner gorges are described in more detail in the Forest Board Manual, Section 16.

Landform Number: # 2- Bedrock Hollows



Description of Mass Wasting Unit: Shallow, spoon or elongated teardrop depressions. Hollows in steep headwalls tend to be shallow and elongated (long, pointed ellipse shape) and are difficult to delineate from shallow landslides on photographs.

Slope: >70%
Material: Basalt, andesite, rhyolite, colluvium, alluvium, landslide & glacial deposits, sandstone, shale and soil.
Elevation: Variable, nearly all elevations possible
Total Area: 93 acres

Mass Wasting Process: Soil saturation, loss of root strength, and/or over steepening of slopes in hollows can trigger evacuations as debris slides or other shallow landslides. When located on steep inner gorge slopes, hollows often feed directly into streams, evolving into debris flows that scour channels.

Forest Practice Sensitivity: Root strength within bedrock hollows has been found to be a factor in limiting the rates of mass wasting. Timber harvest, road construction and/or landing construction on steep slopes in weathered bedrock or poorly consolidated colluvium draping bedrock can increase slope instability due to loss of root strength. Roads and landing can destabilize slopes in bedrock hollows by undercutting and over steepening slopes. Side cast and road (or landing) fill can over steepen and add weight to slopes; roads and landings can also capture runoff water or shallow groundwater and channel it to point locations that saturate road or landing fill and/or thin soils draping bedrock, triggering landslides.

Mass Wasting Potential: **High for road construction and timber harvest** in bedrock hollows based on 17 features identified in a landform covering 93 acres over a 19 year photo record.

Delivery Potential/Criteria: **Very High**. Bedrock hollows are part of the drainage network and are adjacent to or contain streams. Delivery criteria are also based on historical occurrence observed on aerial photographs and confirmed during field investigations. This unit has a calculated landslide rate for delivery of 3763 (see LHZ protocol).

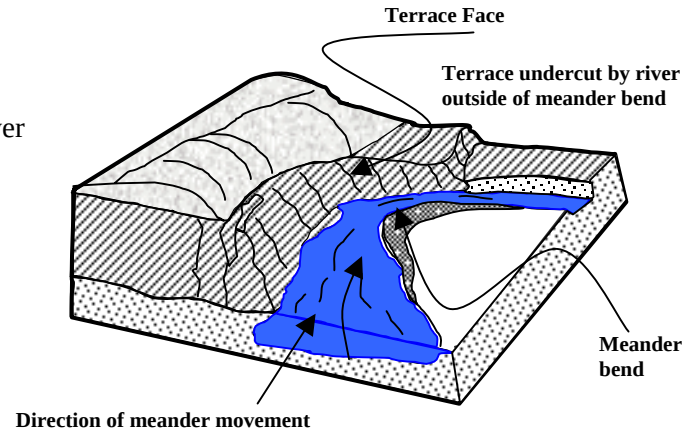
Hazard Potential Rating: **High for roads and harvest** based on LHZ Protocol and Standard Forest Practices Rules.

Trigger Mechanisms: Mass wasting is triggered by loss of root strength, changes in hydrology, oversteepening of slopes and loading slopes due to harvest, road building, and landing construction.

Confidence: High based on the excellent photo quality and coverage, and field observations.

Comments: Hollows located in steep headwall areas are extremely elongated in the Kachess watershed. Ground verification in this watershed is necessary on steep (>65%) slopes. Bedrock hollows are fully described in the Forest Board Manual, Section 16.

Landform Number: # 4- Terrace Faces Intersecting Outside of Meander Bends



Description of Mass Wasting Unit: Glacial terrace faces located on the east side of the Kachess River directly adjacent to the outside of meander bends along the Kachess River from the spillway at the south end of Kachess Lake to its confluence with Lake Easton.

Slopes: 50 to 90+%
Material: Flood plain, glacial outwash, soil, colluvium, alluvium
Elevation: 2175 ft to 2200 ft
Total Area: 7 acres

Mass Wasting Process: The river undercuts adjacent upland slopes causing ravel, shallow landslides and deep-seated landslides on the terrace face along the Kachess River. This process is most frequently observed on the outside of meander bends.

Forest Practice Sensitivity: This landform contains slopes that are currently failing in an undisturbed, fully forested condition. Any disturbance resulting from timber harvest or road construction will further destabilize these slopes. Timber harvest, road construction and/or landing construction on these steep terrace faces will result in the loss of critical root strength. Roads and landings can cause instability by undercutting and over steepening slopes. Side cast and road (or landing) fill can over steepen and add weight to terrace faces; roads and landings can also capture runoff water or shallow groundwater and channel it to point locations that saturate road or landing fill.

Mass Wasting Potential: **Very High for road construction and timber harvest** based on 4 features identified in a landform covering 7 acres over a 19 year photo record.

Delivery Potential/Criteria: **Very High.** Any disturbance delivers directly to the river. 4 of 4 shallow landslides delivered to water resource. This unit has a calculated landslide rate for delivery of 2556 (see LHZ protocol).

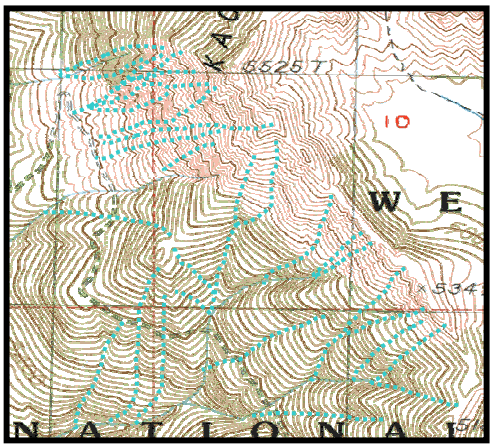
Hazard Potential Rating: **Very High for roads and harvest** based on LHZ Protocol and Standard Forest Practices Rules. This landform has a Landslide Frequency Rating of 30,075 (see LHZ Protocol).

Trigger Mechanisms: Erosion of stream bank and terrace face due to undercutting of this landform on the outside of meander bends sets this landform up for increased landslides resulting from forest management activities. Loss of root strength, changes in slope gradient, and changes in hydrology due to ground disturbance, timber harvest and road or landing construction near terrace lips or on terrace faces can destabiliz slopes causing failure during major rain-on-snow storms or intense precipitation events.

Confidence: High for the entire unit based on observed direct delivery to typed waters, excellent photo coverage, and field verification.

Comments: Surface disturbances (bike trails, hiking trails, off road vehicle travel, or gravel mining) create gullies, ravel and slope instability visible on aerial photos. Direct delivery of sediment to the main stem Kachess River has the potential impact to bridges and roads located down stream. The outsides of meander bends are more fully described in the Forest Board Manual, Section 16.

Landform Number: #5 - Steep Bedrock Headwalls >65%



Description of Mass Wasting Unit: This landform consists of steep (>65%) rocky slopes along Kachess and Keechelus Ridges. Cliff bands are common on and streams and gullies have incised through these sparsely vegetated slopes. This landform can consist of nearly plainer headwalls or convergent areas eroded by stream action to form headwall basins. These headwall basins can resemble rule identified convergent headwalls however, the slopes are somewhat gentler (65% vs 70%)
Slopes: >65°
Material: bedrock units of basalt, andesite, rhyolite, sandstone, shale & schist
Elevation: 2790 to 5850 ft
Total Area: 227 acres

Mass Wasting Process: Thin soil saturation, loss of root strength, and lack of vegetation results in ravel, debris slides, and shallow deep-seated landslides. If these failures become channelized they can form debris flows that erode stream channels and inner gorges. Channels draining linear and convergent headwall areas have experienced repeated debris flows forming incised streams within inner gorges. Natural levees are often present in the lower portion of the headwall drainages. These headwalls are prone to surface erosion from fire, & forest practices. Thin soils that drape bedrock units of weathered andesite, basalt, rhyolite, sandstone, shale, and schist fail frequently, in response to storm, events as debris flows, debris slides, ravel, and small, shallow landslides.

Forest Practice Sensitivity: This area of thin colluvium and thin soils over bedrock fail under natural conditions and can be further destabilized by any forest practices activities that result in loss of root strength, saturation of soils, increased slope gradient or slope loading.

Mass Wasting Potential: **High for road construction and timber harvest** based on 3 features identified in a landform covering 227 acres over a 19 year photo record.
.

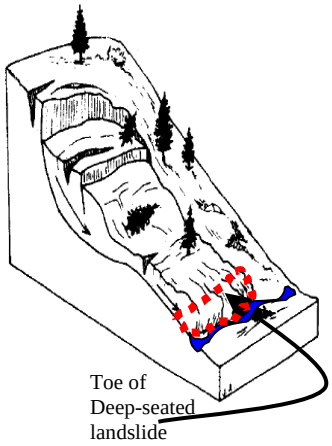
Delivery Potential/Criteria: **Very High.** The delivery rate for this unit is 3872. The very high delivery criterion is based on linear and convergent headwalls forming the headwater drainage network and water collection system for typed waters, on historical occurrence observed on aerial photographs, and confirmed during field investigations.

Hazard Potential Rating: **High for roads and harvest** based on LHZ Protocol and Standard Forest Practices Rules. This landform has a Landslide Frequency Rating of 1159 (see LHZ Protocol).

Trigger Mechanisms: Loss of root strength, changes in hydrology, over steepening of slopes and loading slopes due to harvest, road building, and landing construction can destabilize slopes that fail during major rain-on-snow storms or intense precipitation events.

Confidence: High confidence due to excellent exposures as a result of the extensive clear-cutting since the mid 1900's and two days of field checking photo interpretation.

Landform Number: #8 - **Deep-Seated Landslide Toes, Stream Adjacent**



Description of Mass Wasting Unit: The toes of deep-seated landslides are hummocky deposits, commonly over steepened by stream erosion. This landform, undercut by stream action, is usually steep (>65%), planar or irregular and commonly contain areas of ravel, deep-seated landslides form within the footprint of an older deep-seated landslide. This may superimpose a younger toe within the body.

Slopes: > 65%
Material: colluvium, alluvium, basalt, andesite rhyolite, sandstone, shale, and schist bedrock, glacial deposits and soils
Elevation: Variable, nearly all elevations possible
Total Area: 218

Mass Wasting Process: Streams undercutting and downcutting have oversteepened the toes of deep-seated landslides triggering slope ravel, debris slides, and small deep-seated landslides. Downcutting by side streams across the toe or marginal streams around the toe and debris flows associated with these streams can form inner gorges and bedrock hollows within the landslide toe. Occasionally, slopes of 60% or less fail within these stream channels. Debris flows, debris slides, and shallow bedrock hollows are often located within inner gorges cutting the toes.

Forest Practice Sensitivity: This landform is sensitive to any forest practice activity that reduces root strength, undercuts or over steepens or loads these slopes, and/or redirects water onto these slopes.

Mass Wasting Potential: **High for roads and harvest** based on 9 features identified in a landform covering 218 acres over a 19 year photo record.

Delivery Potential/Criteria: **Very High.** The delivery rate for this unit is 1091. Delivery is related to the proximity of the toes of these deep-seated landslides to streams within and adjacent to the landslide toe deposit.

Hazard Potential Rating: **Very High for road construction and timber harvest** based on finding 9 landslides with a total area of 4.52 acres in this landform that totals 218 acres. This landform has a Landslide Frequency Rating of 2173 (see LHZ Protocol).

Trigger Mechanisms: Loss of root strength changes in hydrology, oversteepening of slopes and loading slopes due to harvest, road building, and landing construction have destabilized toes.

Confidence: High confidence due to excellent exposures as a result of the extensive clear-cutting since the mid 1900's and two days of field checking photo interpretation.

Comments: All toes of deep-seated landslides in or near a stream or inner gorge will require a field review.

Landform Number: # 10- Valley & Stream Bottoms - Low Hazard Slopes

Description of Mass Wasting Unit: This map unit includes all slope forms and gradients less than 11% located in the valley bottoms, flat terraces, prairies and major stream flood plains that exhibit a low landslide potential, and/or are not likely to deliver sediment to a stream, impact public safety or impact a public resource. (Caution: Other map units could have been erroneously included in landform #10 through mapping errors.)

Slopes: Variable 0 to 10%
Material: Volcanics, colluvium, alluvium, glacial deposits, and landslide deposits
Elevation: 2170 ft to 3560 ft
Total Area: 913 acres

Mass Wasting Process: Shallow landslides and debris flows may occur but are not common and generally do not have the potential to deliver to waters of the state or impact public safety or resources. The most common mass wasting process observed on aerial photographs was stream erosion through the toes of deep-seated landslides and was located away from other public resources.

Forest Practice Sensitivity: Roads appear to be the most significant triggering mechanism for erosion within this landform. Undersized culverts may lead to road fill failures and debris flows.

Mass Wasting Potential: Low for road construction and timber harvest based on no features identified in a landform covering 913 acres over a 19-year photo record.

Delivery Potential/Criteria: Low. The delivery rate for this unit is 0. No mass wasting features were noted within this landform. Delivery is unlikely as lack of channel access precludes transport. Road and landing failures do not travel great distances. Distance from stream channels and topography inhibits transport of landslide debris deposited onto this landform from upper elevation sources and does not impact public safety. The delivery rate for this unit is 0.

Hazard Potential Rating: Low for entire unit. This landform has a Landslide Frequency Rating of 0 (see LHZ Protocol).

Trigger Mechanisms: Mass wasting triggering mechanism varies; however, landslides occurring in this map unit are unlikely to deliver to a public resource unless engineered (plugged culvert, side cast fill failure, landing fill failure). This type of mass wasting event can be engineered on any type of landform with any type of slope gradient even if the landform is not commonly unstable.

Confidence: High for the entire unit based on field review and excellent photo quality and coverage. There are areas of instability not identifiable on aerial photos due to size and view aspect that may have a higher potential for delivery. These areas will need to be delineated by the forester on the ground.

Comments: Very little failure activity noted.

Landform Number: # 11- Low Gradient Hill Slopes and Valley Side Slopes – Low Hazard

Description of Mass Wasting Unit: This map unit includes all hillside slope forms and gradients between 11% and 40% that exhibit a low landslide potential, and/or are not likely to deliver sediment to a stream, impact public safety or impact a public resource. (Caution: Other map units could have been erroneously included in landform #10 through mapping errors.)

Slopes: Variable between 11% and 40%
Material: Basalt, andesite, colluvium, alluvium, soils, rhyolite, glacial deposits, and landslide deposits.
Elevation: 2250 ft to 5550 ft
Total Area: 2345 acres

Mass Wasting Process: Shallow landslides, Deep-seated landslides, bedrock hollows and debris flows may occur but are not common and generally do not have the potential to deliver to waters of the state or impact public safety or resources. Most common mass wasting process observed on aerial photographs were portions of deep-seated landslides away from public resources.

Forest Practice Sensitivity: Roads, landings, and skidding trails changing hydrology appear to be the most significant triggering mechanisms for landsliding within this landform. Undersized culverts may lead to road fill failures and debris flows.

Mass Wasting Potential: Low for roads construction and timber harvest based on no features identified in a landform covering 2345 acres over a 19-year photo record.

Delivery Potential/Criteria: Low. The delivery rate for this unit is 0. Lack of channel access is the limiting criteria. Road and landing failures do not travel great distances. Steeper areas, terrace faces, and toes of deep-seated landslides lack sediment delivery mechanisms. Distance from stream channels and topography inhibits transport of landslide debris to public resources and does not appear to impact public safety.

Hazard Potential Rating: Low for entire unit. This landform has a Landslide Frequency Rating of 0 (see LHZ Protocol).

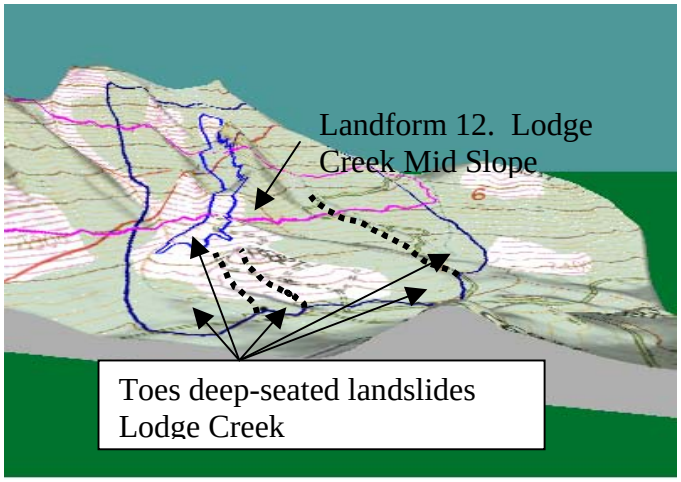
Trigger Mechanisms: Mass wasting triggering mechanisms varies; however, landslides occurring in this map unit are unlikely to deliver to a public resource unless engineered (plugged culvert, side cast fill failure, landing fill failure). This type of mass wasting event can be engineered on any type of landform with any type of slope gradient even if the landform is not commonly unstable.

Confidence: High for the entire unit based on field review and excellent photo quality and coverage. There are areas of instability not identifiable on aerial photos due to size and view aspect that may have a higher potential for delivery. These areas will need to be delineated by the forester on the ground.

Comments: Very little failure activity noted.

Landform Number: 12 - Lodge Creek Mid Slope (40 to 70+%) Deep-Seated Landslide Complex

Description of Mass Wasting Unit: The timber located in this landform forms a critical safety barrier to public resources located down slope. This landform is a unique feature in that it is not a landslide source area but is a buffer zone protecting homes located at the base of the slope on the toes of older landslides. Trees within this zone act as barriers to restrict the downslope movement of landslide debris.



Slopes: Variable between 40% to >70%
Material: Landslide deposits containing fractured basalt, andesite, minor sandstone, siltstone and colluvial material
Elevation: 2700 ft to 3900 ft
Total Area: 216 acres

Mass Wasting Process: This is an accumulation area for debris from deep-seated landslides where large trees act as energy dissipaters trapping debris on the mid slope and preventing material from being transported down slope to the base of the mountain where multiple homes are present. Multiple deep-seated landslide bodies formed from a sequence of major landslides. This area is transitional between head scarp failures and landslide toe depositional zones. This landform contains inner gorges, debris flows and deep-seated landslides.

Forest Practice Sensitivity: This landform is unique to this hillside in that existing timber has acted as a bulwark in catching and containing massive landslides (1991) deposits originating in the steep head scarp area located upslope. Trees formed logjams on dry slopes containing landslide debris on the slope limiting the lateral down slope run out on the toe. Multiple private residences are located below and on the toes of an older (dormant distinct) landslide complex underlying the 1991 landslide. Harvest will remove timber that in the recent past protected public resources (private homes, roads, power lines) located in the toe run out zone.

Mass Wasting Potential: High for timber harvest **Low** for road construction based on 1 feature identified in a landform covering 216 acres over a 19 year photo record and the potential threat to public resources.

Delivery Potential/Criteria: This landform has been assigned a **HIGH** delivery potential as it forms a protective tree barrier to public resources located down slope at the toe of the landslide complex. The delivery rate for this unit is 341 (see LHZ Protocol).

Hazard Potential Rating: High for harvest, **Low** for roads. Roads do not disturb significant timber density necessary to protect public resources. This landform has a Landslide Frequency Rating of 244 (see LHZ Protocol).

Trigger Mechanisms: Loss of large trees removes barriers between the landslide prone area and the homes located at the base of the slope.

Confidence: The 1991 landslide provides an excellent visual record of hazard issues. Large trees located in the mid slope area limited the down slope movement of landslide debris. Complete aerial photo coverage and two days field checking the photo interpretation have provided a high level of confidence in this watershed.

Landform Number: # 13- Ridge and Hill Tops – Low Hazard

Description of Mass Wasting Unit: This map unit includes all ridge tops and noses of ridges slope forms that have gradients between 0 % and 11 % , exhibit a low landslide potential, and/or are not likely to deliver sediment to a stream, impact public safety or impact a public resource. (Caution: Other map units could have been erroneously included in landform #13 through mapping errors.)

Slopes: Variable 0 to 11%
Material: Basalt, andesite, dacite, schist, colluvium, soils, minor rhyolite, sandstone, siltstone
Elevation: 2770 ft to 4822 ft
Total Area: 166 acres

Mass Wasting Process: Shallow landslides, deep-seated landslides, bedrock hollows and debris flows may occur but are not common and generally do not have the potential to deliver to waters of the state or impact public safety or resources. Most common mass wasting process observed on aerial photographs were portions of deep-seated landslides away from public resources.

Forest Practice Sensitivity: Roads, landings, and skidding trails appear to be the most significant triggering mechanism for landsliding within this landform. Undersized culverts may lead to road fill failures and debris flows.

Mass Wasting Potential: Low for road construction and timber harvest based on no features identified in a landform covering 166 acres over a 19 year photo record.

Delivery Potential/Criteria: Low. Lack of channel access. Road and landing failures do not travel great distances. Steeper areas and the toes of deep-seated landslides lack sediment delivery mechanisms. Distance from stream channels and topography inhibits transport of landslide debris to public resources and does not impact public safety.

Hazard Potential Rating: Low for entire unit. This landform has a Landslide Frequency Rating of 0 (see LHZ Protocol).

Trigger Mechanisms: Mass wasting triggering mechanism varies; however, landslides occurring in this map unit are unlikely to deliver to a public resource unless engineered (plugged culvert, side cast fill failure, landing fill failure). This type of mass wasting event can be engineered on any type of landform with any type of slope gradient even if the landform is not commonly unstable.

Confidence: High for the entire unit based on field review and excellent photo quality and coverage. There are areas of instability not identifiable on aerial photos due to size and view aspect that may have a higher potential for delivery. These areas will need to be delineated by the forester on the ground.

Comments: Very little failure activity noted.

Landform Number: # 14– Moderate to Steep Hillside Slopes - Moderate Hazard

Description of Mass Wasting Unit: These slopes are convergent but not as steep as convergent headwalls. They contain isolated areas of cliffs, and steeper (>70%) slopes, however a majority of the convergent areas fall below the threshold for headwalls, excluding their classification as true convergent headwalls. This landform often includes head scarps of deep-seated landslides that are not likely to deliver. Other unmapped rule-identified landforms may be located within landform# 14. .

Slopes: variable between 60 to >90%
Material: Basalt, andesite, schist, rhyolite, sandstone, siltstone, colluvium, soil
Elevation: Variable
Total Area: 1152 acres

Mass Wasting Process: Debris flows, rock fall/topple, large deep-seated landslides, and shallow undifferentiated landslides may occur within this map unit.

Forest Practice Sensitivity: Timber harvest, road construction and/or landing construction on steep slopes results in the loss of root strength. Roads and landing can cause instability by undercutting and oversteepening slopes. Side cast and road (or landing) fill can over steepen and add weight to slopes; roads and landings can also capture runoff water or shallow groundwater and channel it to point locations that saturate road or landing fill and/or thin soils draping bedrock, triggering slope failures and debris flows.

Mass Wasting Potential: Moderate for timber harvest and road construction based on 5 features identified in a landform covering 1152 acres over a 19 year photo record.

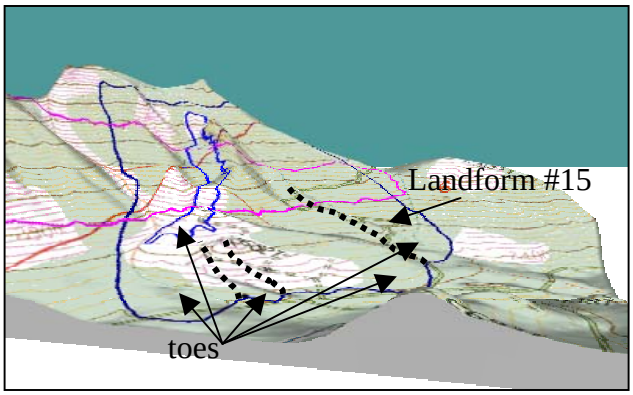
Delivery Potential/Criteria: **Moderate**. This landform has been assigned a moderate delivery potential because it is often spatially separated from streams by the high hazard landforms. The delivery rate for this unit is 116.

Hazard Potential Rating: Moderate for timber harvest and road construction because landslides are rare in this map unit. This landform has a Landslide Frequency Rating of 183 (see LHZ Protocol).

Trigger Mechanisms: Loss of root strength, changes in slope gradient, and changes in hydrology caused by timber harvest and road or landing construction has destabilized similar slopes that have failed during major rain-on-snow storms or intense precipitation events.

Confidence: High confidence due to excellent exposures as a result of the extensive clear-cutting since the mid 1900's and two days of field checking photo interpretation.

Landform Number: #15 - Lodge Creek Toes Deep-Seated Landslides



Description of Mass Wasting Unit: The timber located in this landform forms a critical safety barrier to public resources located within it. This landform is a unique feature in that it is not a landslide source area but is a buffer zone protecting homes located at the base of the slope on the toes of older landslides. Trees within this zone act as barriers to restrict the down slope movement of landslide debris.

Slopes: average 24%, range 0% to >70%
Material: Landslide deposits containing fractured basalt, andesite, minor sandstone, siltstone and colluvial material
Elevation: Variable 2330 ft and 2900 ft
Total Area: 355 acres

Mass Wasting Process: Massive bedrock failures in head scarp areas above this landform produced landslide deposits overlying older dormant distinct landslide toes. Streams undercutting slope walls and downcutting through the toe have oversteepened inner gorges located within this landform triggering slope ravel, shallow undifferentiated landslides, debris slides, and small deep-seated landslides. Inner gorges and bedrock hollows can occur within the landslide toe deposit. Occasionally, slopes of 55% or less fail within stream channels.

Forest Practice Sensitivity: This landform is sensitive to any forest Practice activity that reduces root strength, undercuts or over steepens or loads these slopes, and/or redirects water onto these slopes.

Mass Wasting Potential: **High for harvest, Low for roads** based on the potential to deliver to public resources.

Delivery Potential/Criteria: **High.** Delivery criteria are related to the proximity of the toes of these deep-seated landslides to streams within and adjacent to the landslide toe deposit, and the location of private residences, public roads and public power lines on the toes of landslides. Removal of standing timber will remove a barrier allowing run out of landslide deposits to the bottom of the valley and to the multiple public resources sited on the older toes of dormant distinct deep-seated landslide deposits.

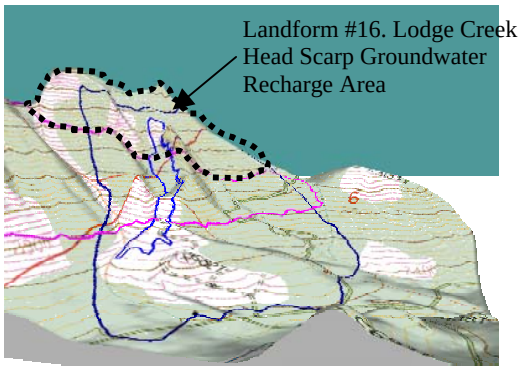
Hazard Potential Rating: **High for harvest, Low for roads**

Trigger Mechanisms: Loss of root strength, changes in hydrology, oversteepening of slopes and loading slopes due to harvest, road building, and landing construction have destabilized slopes that failed in the recent past (1991).

Confidence: High confidence due to excellent exposures as a result of the extensive clear-cutting since the mid 1900's and two days of field checking photo interpretation.

Comments: All harvest and road building within this landform should be evaluated for hazard and impact to public resources and public safety. Many private residences, public roads and public power lines are located within this landform.

Landform Number: # 16- Lodge Creek Head Scarp Groundwater Recharge Area, Active Deep-Seated Landslide Complex



Description of Mass Wasting Unit: The head scarp groundwater recharge source area of active deep-seated and dormant distinct landslides that have either the potential to deliver or have delivered to areas of public roads, private homes, public power lines in and along the northwest side of Lodge Creek, Kachess WAU. This unit consists of multiple active recent and dormant distinct deep-seated landslide head scarp groundwater recharge areas, the youngest landslide, #211 (24.7 acres), failed in 1991.

Slopes: average 63%, range 50% to >100%
Material: Landslide deposits containing fractured basalt, andesite, minor sandstone, siltstone and colluvial material
Elevation: Variable between 3000 ft and 4832 ft
Total Area: 239 acres

Mass Wasting Process: This landform is the head scarp source area for numerous, large deep-seated landslides. Groundwater recharge areas concentrate surface and subsurface water into springs and streams that trigger deep-seated landslides, shallow undifferentiated landslides, debris slides, debris flows, and small deep-seated landslides.

Forest Practice Sensitivity: This landform is sensitive to any forest Practice activity that reduces root strength, undercuts, oversteepens or loads these slopes, and/or redirects water onto these slopes.

Mass Wasting Potential: High for roads and harvest based on 7 features identified in a landform covering 239 acres over a 19 year photo record.

Delivery Potential/Criteria: <u>High</u>. Delivery criteria is directly related to the proximity of the toes of these deep-seated landslides to private residences, roads, power transmission lines, and streams within and adjacent to the landslide toe deposits.

Hazard Potential Rating: <u>High for roads and harvest</u>.

Trigger Mechanisms: Loss of root strength and changes in hydrology have destabilized slopes and contributed to post harvest failure.

Confidence: High confidence due to excellent exposures as a result of the extensive clear-cutting since the mid 1900's and two days of field checking photo interpretation.

Comments: A recent (1991) deep-seated landslide (#211) failed after clear-cut harvest in a normal water year. Only the presence of mature timber in the mid slope and toe areas of older landslide deposits prevented the recent landslide from impacting multiple homes, public resources and public safety.

Appendix C A-3 Mass Wasting Summary Tables

Landform #1 – Inner Gorges

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)	21	21		7		3		**52**
Young Stands (timber 5-15 yrs)	1							**1**
Submature (timber 15-50 yrs)	1	6		1				**8**
Mature (timber > 50 yrs)								
Road		4						**4**
Partial Cut		1				1		**2**
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #2 – Bedrock Hollows

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)	1	9						**10**
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)	2	1						**3**
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #4 – Terrace Face Intersecting Meander Bend

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)	5							5
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #5 – Steep Headwalls

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)	3	2		1				**6**
Mature (timber > 50 yrs)								
Road		1						**1**
Partial Cut								
Yarding	1	1						**2**
Alpine						1		**1**
Other (e.g. housing, agriculture)								

Landform #8 – Deep-Seated Landslide Toes Stream Adjacent

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)	4	5		40				**49**
Young Stands (timber 5-15 yrs)	1			2				**3**
Submature (timber 15-50 yrs)	2			11				**13**
Mature (timber > 50 yrs)								
Road								
Partial Cut				3				**3**
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #10 – Valley & Stream Bottoms

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)								
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #11 – Low Gradient Hill Slopes and Valley Side Slopes

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)								
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #12 – Lodge Creek Mid Slope

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)		1						1
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #13 – Ridge & Hill Tops

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)								
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #14 – Moderate to Steep Hill Slopes

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)								
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)								
Mature (timber > 50 yrs)								
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #15 – Lodge Creek Toes Deep-Seated Landslides

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)				1				**1**
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)				1				1
Mature (timber > 50 yrs)								
Road								
Partial Cut				1				**1**
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Landform #16 - Lodge Creek Head Scarp Groundwater Recharge Area, Active Deep- Seated Landslide Complex

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-Seated Landslides	Large Persistent Deep-Seated Landslides	Snow Avalanche	Totals
Clear Cut (timber 0-5 yrs)	4	1		1				**6**
Young Stands (timber 5-15 yrs)								
Submature (timber 15-50 yrs)								
Mature (timber > 50 yrs)				1				**1**
Road								
Partial Cut								
Yarding								
Alpine								
Other (e.g. housing, agriculture)								

Appendix D A-4. Landform Hazard Rating Table Kachess Watershed

19 year photo record (1979 – 1998)

LANDFORMS	LANDFORM 1	LANDFORM 2	LANDFORM 4	LANDFORM 5	LANDFORM 8	LANDFORM 10	LANDFORM 11	LANDFORM 12	LANDFORM 13	LANDFORM 14	LANDFORM 15	LANDFORM 16	Private & State Land Area	Federal * Land Area	WAU **
Landform Area (acres)	335	93	7	227	218	913	2345	216	166	1152	355	239	6266	34,830	41,096
Number of Landslides	21	3	4	5	9	0	0	1	0	5	1	7	56	na	na
Area of "Delivering" Landslides (acres)	15.83	6.65	.34	16.7	4.52	0	0	1.4	0	55	1	29	130.44	na	na
Landslide Frequency Rate (Number of slides/Landform Area/Years) x 10^6	3299	1698	30075	1159	2173	0	0	244	0	183	148	12704	470.4	na	na
Landslide Area Rate for Delivery (Delivering Landslide Area/Landform Area/Years) x 10^6	2487	3763	2556	3872	1091	0	0	341	0	116	148	6386	1095.6	na	na

* Federal Lands were not evaluated during this investigation; therefore cumulative hazard ratings for this watershed are not valid.
** Cumulative hazard ratings for this watershed are not valid; Federal ownership lands were not inventoried during the investigation.
na = Not applicable in this watershed