LANDSLIDE HAZARD ZONATION PROJECT
Sultan River Watershed, Snohomish County, Washington

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Priority 3
Mass Wasting Assessment
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site location

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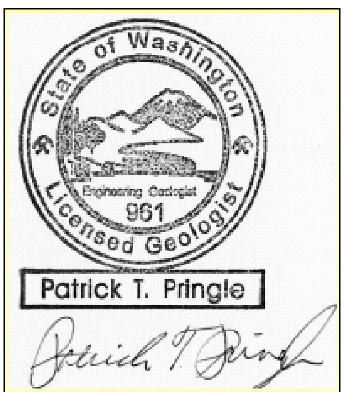

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1.1 Use of this report

The purpose of this mass wasting assessment is to identify non-federal, non-tribal areas within the Sultan River watershed (WAU) that have landforms[1] with moderate or high risk of landslides due to the effects of forest management (logging, roading, thinning, yarding, etc.). Maps of these watershed-specific landforms (Maps A1 and A2 herein) will be used by the Department of Natural Resources region staff to identify those forest practice applications (see Chapter 222-20 WAC) that will require a site investigation prior to assigning the class of forest practice relative to potential unstable slopes and landforms (Chapter 222-16-050). Additionally, these maps are designed to be used by land managers to assist in developing harvest strategies.

This is a reconnaissance study and its level of resolution must be kept in mind when using this document and Maps A1 and A2. For example, analysis of individual landslides or slopes is not an appropriate use of this report nor should it be used for zoning purposes. 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 likely that some landslides or landforms have been accidentally omitted, some benign features are improperly mapped as landslides, and some data have been miscoded herein.

This assessment was conducted using aerial photographs, various maps, and field observations. Information was collected and compiled from these sources in a manner designed to respond to the critical questions or to suggest areas where more detailed information 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

No comprehensive study of slope stability in the Sultan River watershed had been conducted prior to this investigation, but several project-related studies have been performed in the vicinity.

[1] Landforms as defined herein can be more inclusive than the small-scale unstable landforms commonly defined in rule (WAC 222-16-050). These rule-identified landforms include inner gorges, convergent headwalls, the outsides of meander bends, bedrock hollows, and the toes of deep-seated landslides. These will be referred to as “rule-identified landforms” herein.

Kleinfelder, Inc. on behalf of the city of Sultan, conducted an investigation in 1995 on an unstable region located on the bluffs north of the city of Sultan. Snohomish County, for submission to the Federal Energy Regulatory Commission for licensing, conducted an extensive study in 1965 around the construction of the George Culmback Dam and Lake Chaplain. Their report detailed specific information about impacts from the construction of the reservoir and dam systems. Slope stability was investigated around the construction area, but not within the entire watershed (Snohomish County Public Utility District No. 1, 1979). In 1995, Snohomish County and the city of Everett conducted a gravel quality and quantity study along the Sultan River, from the confluence with the Skykomish River to the Culmback Dam. Their report details mostly gravel and spawning habitat, but also included landslides along the Sultan River gorge system (Schuh and Meaker, 1995).

1.3 Introduction to Mass Wasting Processes and Terminology

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

4 types of mass wasting process were identified in the Sultan Watershed related to forest practices:

1. Shallow landslides from side-cast failures
2. Debris flows from failed culverts
3. Debris flows from loss of root strength in soil
4. Deep-Seated landslides from excess water concentration

1.4 Summary of Methods

This assessment follows the Landslide Hazard Inventory Protocol dated April 12, 2005 (http://www.dnr.wa.gov/forestpractices/lhzproject/lhz-protocol.doc), with minor modification.

Seven sets of aerial photographs acquired between 1958 through 2001 were viewed with a mirrored stereoscope with 3x magnification (Table 1). Unfortunately, many key images were missing from DNR’s collection in Olympia and could not be viewed. In addition, 1998 ortho-photographs coverage was used as a layer during GIS analysis and mapping. LIDAR was not available for this area.

Table 1. Photographic surveys used in this study.

Year	Scale	Image	Flight Number	Comment
1958	1:12,000	black and white	WSF-S-8 11 to 16B	10 missing photos
1965	1:12,000	black and white	KSN-65 32A to 38A	5 missing photos
1965	1:60:000	black and white	WFPA-65 38 to 39	2 missing photos
1978	1:12,000	black and white	NW78 78C to 87C	17 missing photos
1983	1:12,000	color	NWC83 16-65 to 20-74	9 missing photos
1991	1:12,000	black and white	NW91 15-64 to 30-67	58 missing photos
1998	1:12,000	ortho-photographs	NWH98	Complete coverage

Mapping was generally accomplished by heads-up digitizing the landslides on Department of Natural Resources (DNR) ortho-photographs, the USGS 10-meter Digital Elevation Model (DEM), DEM derived contours, slopes and hillshades. The maximum resolution of these techniques is about 10 meters. Small failures identified on the photos are not represented by the 10-meter DEM's as slope distances of less than 10 meters are not represented and are averaged into gentler slopes above and below. Failed slopes of less than 5 meters are common in inner gorges and along the toes of deep-seated landslides and are not accurately reflected by the 10m DEM contour map.

Slope gradients were determined by exploring a DEM-derived slope percent map within each feature polygon in its individual shape file. 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. Slopes derived from DEMs are generally lower than those measured in the field, but are less subjective. Conversely, the steepest slopes on rotational failures are on the failure plane and therefore steeper than the slope of the ground just before landslide initiation. As a result, the method of slope gradient estimation presented is an approximation.

The landslide coverage is provided as Map A-1 with an additional sheet with the attributes of the landslides. These are available from the DNR, Forest Practices Division as PDF files, or ArcInfo coverages. Most of the landslides were recorded during an aerial photo review from 1958 to 1998 and field visits. These landslides range from 'questionable' to 'definite', mainly owing to their size and the amount of canopy coverage seen on the aerial photos. The aerial photo review was also used determining the land-use features as well as the landform features. A slope-percent map derived from the USGS 10-meter digital elevation model (DEM) of the watershed and USGS 1:100,000 geologic map 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. All landslides were recorded into a GIS coverage to aid in identifying their delivery potential, slope shapes, gradient and elevation, primarily with DEM derived grids, and a modeled slope stability GRID (SLPSTAB; Vaugeois 2000). The information from these landslide features, once completed, were used to extrapolate the landform map (Form A-2).

The following landslide processes were used to identify and classify features observed on the stereo photos: shallow-rapid landslides (debris slides), debris flows, debris avalanches, deep-seated landslides, shallow sporadic deep-seated landslides, large persistent deep-seated landslides, earth flows, rock topple, and snow avalanches. Table 1.4.1 provides a summary of the number and type of process features catalogued during this investigation.

Process	Number of landslides
Shallow undifferentiated landslides	109
Debris Flows	217
Debris slide/avalanche	5
Deep-seated	90
Earth flow	4
Rock topples/falls	4
Snow avalanche	0

Table 1.4.1: A summary of the number and type of landslides in the Sultan watershed.

2.0 Physical Setting Pertinent to Mass-Wasting Interpretations

2.1 Introduction

The Sultan River watershed covers 24,000 acres in the brink of the Cascades, from the city of Sultan to Culmback Dam at Spada Lake in Snohomish County (Map A1). The study area includes the drainage area of the lower Sultan River, exclusive of U.S. Forest Service ownership. Three major deep-seated landslides intersected with the U.S. Forest Service boundary and were included in map A-1 to improve the hazard interpretation on LHZ project lands within the watershed.

The watershed ranges in elevation from 100 feet at the confluence of the Sultan and Skykomish River, to 3,080 feet on the summit of Blue Mountain.

Precipitation within the watershed is high, averaging 50 inches of rain a year near the confluence of the Sultan River and Skykomish River, to 90 inches near Spada Lake Reservoir. Rain-on-snow events most likely occur between 1,800 feet to 3,100 feet on the ridges west of the Culmback Dam. Rain-on-snow events have triggered widespread slope failures in many watersheds within the Cascade foothills.

2.2 Topography

The Sultan River drains the watershed, whose major tributaries are dammed for drinking and energy production and flows into the Skykomish River at the City of Sultan. Gradients of hill slopes range from steep (greater than 60%) near Sultan to flat plains (0%-10%) and bogs above the Sultan River. Blue Mountain and the Sultan Canyon contain the steepest (over 100%) and highest slopes in the watershed. The Sultan River is incised in glacial and intrusive rock and has created steep valley walls that can stand near vertical for 50 to 100 feet. Intrusive igneous rock can create very high gradients (up to 100%), but maintain good slope stability. A good example of this is located in T. 28N R. 8E, section 2 and 11, where the hill slope contains very high gradient hills, on which no landslides were recorded.

2.3 Land use and Historical Considerations

The Sultan River had established logging and mining activity early in Washington history. Exploration by European prospectors first started placer mining along the Sultan River in 1870's (Bethune, 1891; Herring and Murray, 1942; Broughton, 1942) and continued to attract prospectors in search for mineral wealth for many years (Hodges, 1897; Conway, 1915; Cameron, 2005). The city of Sultan was established in 1885 and the Stone and Ewing Company established the first sawmill in 1890. The Great Northern Railroad finished construction of its tracks through Sultan by 1892, starting a logging boom throughout the area (Whitfield, 1926). By 1900, one fourth of the timber in the watershed had been harvested, primarily from Sultan City to the northern extent of Lake Chaplain (along the Sultan River). Nearly half of the watershed had burned by 1900 (Gannett, 1899). Logs were hauled down to sawmills in Sultan City and beyond. Access into the area for logging companies was gained predominately by horse road and mine to market roads (Hodges, 1897; Stoess, 1934). Extensive rain-on-snow events and large storms ravaged this area in 1896 and 1897 (1897 being a recorded rain-on-snow event, 14 inches of snow melting near the divide between the Sultan River and the Pilchuck River) considered being "greater than any known in tradition of the Indians" (Gannett, 1900). Another severe storm system triggered a large flood event during the winter of 1902. These repeated seasons of flooding, combined with past logging of old growth timber along the Sultan River gorge system, spawned many of the deep seated landslides along the Sultan River.

The creek that drained Woods Lake was dammed at the present day outlet around this time as well. A cedar bolt mill, splash dam and logging flume were also constructed in this area. Logging was sporadic on non-Weyerhaeuser land south of Lake Chaplain from the early 1900s to the 1930s (Taubeneck, 2005).

Logging continued until the 1930s. Extensive logging railway tracks were constructed and old growth was more easily transported. During World War II (1937-1945), the Sultan River Watershed was heavily logged for Western Hemlock primarily, along with Douglas Fir, Noble Fir, White Pine, White Cedar, and Yellow Poplar, heavily sought after for airplane construction (Taubeneck, 2005; U.S. Works, 1937). A severe storm system swept through during the winter of 1943-1944 and caused severe flooding (Carithers and Guard, 1945). Many old debris flow landslide scars seen in the field appear to correspond with this time frame. Logging slowed until the 1970's, when extensive logging once again took place, this time hauled out by motor vehicle instead of railroad. This logging cleared much of the land in the middle to northern sections of the watershed. The north face of the Blue Mountain was actively logged in 1972 (Farwell, 2005). A severe storm system in late 1977 created large scale flooding and contributed to debris flows along the north flank of Blue Mountain. Timber thinning occurred on the northern flank of Blue Mountain in 1995 (Lockwood Report, 1995). Timber harvest continues in much of the watershed, from the southern flanks of Blue Mountain to the City of Sultan.

The City of Everett expanded its water resources into the Sultan Watershed in 1929, creating a 22-foot earthen dam on Lake Chaplain in 1929. They continued by building a concrete diversion dam on the Sultan River and a pipeline to Lake Chaplain, diverting up to 250 million gallons per day. In 1942, the Lake Chaplain Dam was raised in efforts to increase reservoir storage of water (Palmer et al., 1999). By 1960, plans were underway to modify the region with the Sultan River Project, in two phases. Phase I, which was completed in 1965, lead to the construction of the George Culmback dam with an active reservoir (Spada Lake) and a new pipeline, from the Sultan River diversion dam to the Lake Chaplain Reservoir. Phase II (later named the Henry M. Jackson Hydroelectric Project), completed in 1984, raised the George Culmback dam by 62 feet with the purpose of increasing the Spada Lake reservoir and generating power. A hydroelectric powerhouse was constructed 12 miles downstream from the George Culmback Dam as well as a 4-mile long pipeline from the George Culmback Dam to the powerhouse. Water from Spada Lake flowing to the powerhouse is diverted either to Lake Chaplain or the Sultan River, depending on current conditions. The diversion dam was reworked to act as a reserve tunnel, pumping water into Sultan River during low-peak seasons and pumping water into Lake Chaplain during high-peak seasons (Bliton, 1989; Schuh and Meaker, 1995; Palmer et al., 1999).

Flow monitoring records by the USGS Water Resources website on the Sultan River did not start until the 1990 (USGS, 2005). Large peak flow events since the start of hydrologic monitoring occurred on Nov. 24, 1990 and Nov. 29, 1995. Canopy coverage deterred good aerial photo coverage for analysis of storm related slope failures.

2.4 Geology

2.4.1 Bedrock Units

Regional bedrock that includes the Sultan River watershed belongs to the Western Mélange Belt, part of the Western and Eastern Mélange Belts (WEMB) terrain. The WEMB includes Mesozoic (late Jurassic to early Cretaceous) marine sedimentary rocks, along with lenses of Paleozoic limestones, Mesozoic intrusives, and other rich types in fault-bounded bodies that were tectonically juxtaposed (Tabor et al, 1993). The WEMB rocks underwent high pressure, low temperature metamorphism in the late Cretaceous orogeny at about the time they were juxtaposed against the Northwest Cascade System terrain to the North.

Bedrock in the Sultan River watershed is mainly composed of the Western Mélange Belt (Phipps et al., 2003; Dragovich et al., 2002). These rocks were deposited during the late Jurassic to early Cretaceous (170 to 100 million years ago) periods (Carithers and Guard, 1945). Sediment was thickly deposited in a marine setting, comprising mostly of silt and mud. Hydrothermal systems and submarine eruptions (similar to black smokers) formed from intruding magma, creating large pyritic deposits (such as the Lockwood Pyrite deposit) and overlaid the marine sediment with volcaniclastic and mafic flows (for example, basalt) material (Olson, 1995; Snohomish County, 1979). This magma chamber underwent differentiation, where the heavier mafic material (rich in iron and other metallic minerals) filtered to the bottom of the chamber and lighter felsic material (rich in silica, such as quartz and feldspar) rose to the top (Stewart, 2005). These rocks were then metamorphosed (exposed to heat and pressure), folded, uplifted and eroded. The metamorphism changed the marine sedimentary and volcaniclastic rocks into argillite (metamorphosed siltstone) and phyllite (metamorphosed mudstone). The granitic magma chamber also experienced metamorphism, altering the granitic rocks into meta-tonalites (light colored granitic rock), meta-gabbros and meta-peridotites (dark colored granitic rock).

As the rocks experienced pressure from the west (most likely from the oceanic plate colliding with the North American continental plate), they tilted the stratigraphic section to the northeast. This tilting, along with erosion of the overlying rock, exposed the relict magma chamber (gabbro and peridotite in the west, grading east to tonalite) in the western part of the Sultan River watershed. The metamorphic marine rock, which overlies the relict magma chamber, can be found primarily in the southern and eastern parts of the watershed. The metamorphic volcaniclastic rock, which overlies the marine rock, is located primarily on Blue Mountain, in the northeast part of the watershed.

The meta-tonalite rocks, where not overlain by glacial drift, is very stable, even with slopes steeper than 60% (A prime example of this is the large hill, located in T. 28N R. 8E, section 2 and 11). The meta-marine rocks can be unstable, especially when the beds are tilted to near vertical. The north flank of Blue Mountain is an excellent example, where the meta-sedimentary rocks are tilted to near vertical and failures are frequent within the section. The meta-volcanic rocks can be very unstable and appear to be very susceptible to slope failures when the rock is exposed to water. A prime example of this is the water run-off from the radio tower located at the highest peak on Blue Mountain; many debris flows initiated from this deposit, independent from harvest or road construction.

2.4.2 Poorly-Consolidated Surficial Units

Surficial units in the study area consist of continental glacial drift. Other surficial deposits are composed of alpine glacial drift, colluvium, and alluvium. About 14,000 years ago, the Puget Lobe of the Cordilleran ice sheet, which represents the most recent advance of continental ice sheet, flowed into surrounding valleys. This advanced was named the ‘Vashon Glaciation’ locally. Tongues of the Vashon glacier dammed valleys that were tributaries to the Puget Lowlands, creating large ice dammed lakes. Glaciers advanced up the Pilchuck River system and the Sultan valley, covering the northwestern portion of the watershed (Tabor et al., 1993). This blocked the paleo-Pilchuck River, creating a large ice-dammed lake and depositing deltas and lake deposits on the north flanks of Blue Mountain to Bald Mountain. This rising lake eventually overflowed, washed over Olney Pass, and deposited fluvial outwash across the plains in the west and south parts of the Sultan River watershed.

Ice margins near Lake Chaplain and Echo Lake also produced significant outwash towards the town of Startup (Booth, 1990). As the glaciers retreated, the terminal moraine (called the Pilchuck plug) blocked the upper drainage of the Pilchuck River, creating the new Sultan River watershed (Coombs, 1969; Bliton, 1989). The Sultan River established a channel, rapidly incised into the glacial material, cut into the bedrock, and became entrenched. This incision is probably due to easily eroding glacial material and isostatic rebound of the bedrock in the area. Old meander bends and channels can be seen near the main channel of the present Sultan River.

Near the confluence of the Sultan and Skykomish River, glacial lakes formed by the advancement of the Cordilleran ice sheet, creating thick lake deposits in the southern extent of the watershed (Booth, 1990). These lake deposits formed low-permeability clay and silt layers that perch water and spawn large landslides during high precipitation. The silt and clay layers are commonly overlain by permeable glacial outwash from the paleo-Spada Lake and ice-margin flows. This combination of silt, clay and sand makes much of the hillsides in the southern part of the watershed susceptible to shallow and deep-seated landslides.

3.0 Summary of Results

Most of the landslides were recorded during a review of 1958 to 1998 aerial photo and field visits. The landslides were rated as ‘questionable’ to ‘definite’, depending on their size and the amount of canopy coverage. The aerial photos were also used to determine the land-use and delivery, as well as the landform features. All landslides were recorded into a GIS coverage to aid in identifying their delivery potential, slope shapes, gradient and elevation. The information from these landslides, once inventoried and mapped, was used in the creation of the landform map (Form A-2).

In reviewing the Sultan River watershed, a representative sample of 385 landslides were recorded in DNR regulated lands, however, 510 were recorded on all lands within the watershed. Of these landslides recorded on LHZ Project lands, 336 were shallow landslides, 94 deep-seated landslides. 291 of these landslides were interpreted to have delivered and were used in construction of the overall hazard ratings (Form A-4). 121 of these landslides were not road related and were used to construct hazard ratings for harvest and other related forest practice uses. No deep-seated landslides were included in these calculations, but their locations and statistics are presented within this report. These deep-seated features should be evaluated during field visits. A quick review of Form A-1 should determine whether the deep-seated landslides were identified as ‘definite’, ‘probable’, or ‘questionable’ and their activity level. Deep-seated landslides can range in age from about 14,000 years (glacial related deep-seated landslides) to present.

Two specific areas must be evaluated carefully for harvest or road construction due to their natural failure rate (which is amplified by harvest and road construction). Landform 9, specifically along the northern flank of Blue Mountain, produced 98 landslides that are predominately debris flows. This figure is unusually high for this watershed. 38 of these landslides are not related to roads and have occurred due to the natural instability of the landscape. These landslides can flow to the Sultan River, expose the bedrock, carry off the thin soils and trees, and destroy everything in its path, including roads. Landform 10, which encompasses the Sultan River gorge system, produced 38-recorded shallow landslides and 44 deep-seated landslides. Of these shallow landslides, only 1 was road related. The deep-seated landslides likely will continue to be persistent, due to the geologic placement of glacial drift on low permeable metamorphic bedrock, high precipitation, and very steep valley walls. The Sultan River will continue to undercut the valley walls, creating large amounts of erosion and slope failures during flooding and high precipitation events.

4.0 Landforms

The Sultan River watershed has been delineated into 13 landforms that characterize areas having similar features. Of the 13 landforms, the Landslide Hazard Zonation Project Protocol predefines 9 landforms. Four additional landforms were added due to their unique features. These landforms have been delineated due to their similar landslide characteristics and potential to deliver to public resources. Landforms were based on a number of characteristics, such as geology, hydrology, geomorphology, topography, and landslide characteristics. The following section presents the results of this investigation, which has been split into low and high-hazard potential landforms. High-hazard landforms will require careful review and field investigation.

4.2 Landform Descriptions
Low Hazard Descriptions (Landforms 1 through 5)

LANDFORM NUMBER: 1, 2
LANDFORM NAME: Alluvial Plains, Valley Bottoms
OVERALL HAZARD: Low
Description:

Landform 1 (Alluvial Plains) and 2 (Valley Bottoms) are comprised of level (0-10%) slopes of recent outwash colluvium of the Sultan River (Geologic Unit: Qa), glacial outwash colluvium (Geologic Unit: Qgo), glacial till (Geologic Unit: Qgt), and swamps and peat bogs (Geologic Unit: Qp). Some small, non-delivering landslides were mapped in roadside casts, but present no danger to harvest or road construction. Landslide Rate Delivery is low. Confidence is high.

LANDFORM NUMBER: 3, 4
LANDFORM NAME: Ridge Tops, Ridge Noses and Low Gradient Hills
OVERALL HAZARD: Low
Description:

Landform 3 (Ridge Tops and Ridge Noses) and 4 (Low Gradient Hills) are comprised of low hill slopes (10-40%) as well as ridge tops and noses of glacially carved hills. Some minor landslides have occurred along these hills but do not constitute a danger to harvest practices or road construction. Many failures that occurred along the Blue Mountain were recorded in low gradient hills, but are predominately spawned by the relict road system. (see landform 6). Confidence is high.

LANDFORM NUMBER: 5
LANDFORM NAME: High Gradient Hills
OVERALL HAZARD: Low
Description:

Landform 5 is comprised of steep gradient hills (greater than 40%). A unique feature within this watershed is the Jurassic granitic unit (meta-tonalite) located in the eastern part of the watershed. Although this delineated hill has very steep slopes (as much as 100%), no evidence of landslides was seen within the landform. These steep slopes maintain stability through harvest and road construction. Confidence is high.

Moderate to High Hazard Descriptions (Landforms 6 through 13)

6 - Blue Mountain North Flank Roads

Description of Mass Wasting Unit: Landform 6 consists of orphaned roads built prior to modern forest practice rules. These roads contain culverts and side casts that have spawned over 80 debris flows along the north flank of Blue Mountain. These roads have great potential to continue to trigger debris flows regardless of future harvest activity. Reopening of these roads will most likely require geotechnical consultation.

Slopes: Greater than and equal to 30% (due to over steepened side cast)
Slope Shape: Convergent to Planar
Material: Predominantly Glacial Till and Outwash.
Elevation: 260 to 3,000 feet
Total Area: Unknown

Mass Wasting Process: Orphaned roads along Blue Mountain were built using side cast fills and small culverts. Instability along the side cast has spawned numerous shallow landslides, many of which develop into debris flows to that can continue to flow the Sultan River.

Forest Practice Sensitivity: New road construction, if done within Forest Practice rules, should maintain stability along this hillside. Reopening of orphaned roads has the potential to trigger shallow rapid landslides and debris flows.

Mass Wasting Potential: <u>**Very High for Orphaned Road Systems**</u>. This landform (see landform 3 in A-4) has a Landslide Frequency Rating of high for roads (orphaned).

Delivery Potential/Criteria: <u>**Very High.**</u> Shallow slide failures often develop into debris flows and tend to flow into stream systems and the Sultan River.

Hazard Potential Rating: <u>**Very High for Orphaned Road Systems**</u> based on LHZ Protocol and Standard Forest Practices Rules.

Confidence: <u>High</u>, based on the number of landslides located in this landform, excellent photo quality and coverage, communication with field foresters, and field observations.

7 – Body of Deep Seated Landslide (Active)

Description of Mass Wasting Unit: Landform 7 consists of the bodies of active deep-seated landslides, primarily in glacial material. The majority of these landslides are located along the gorge system of the Sultan River, commonly within 100 ft of the gorge edge. Where the slides flow into the gorge, the toes are eroded, and the body can become very steep, sometimes over 100%. These steep areas can produce numerous shallow rapids, debris avalanches, and rock falls.

Slopes: 30% to 90+%; Avg: 70%
Slope Shape: Convergent to Planar
Material: Predominantly Glacial Till and Outwash.
Elevation: 260 to 3,000 feet
Total Area: 197 acres

Mass Wasting Process: Deep-seated landslides are commonly composed of fractured and weakened bedrock. This fragmental material can absorb great amounts of water and has an increased susceptibility to shallow landslides. Due to high-density tree coverage, no shallow landslides where mapped on these features. Field checks in the Sultan Incised Gorge System have indicated many small shallow landslides present on bodies of deep-seated landslides.

Forest Practice Sensitivity: Increased water run-off on the deep-seated landslide has been found to be a factor in reactivation of deep-seated landslides. Timber harvest, road construction and/or landing construction should be done with caution. Water should be redirected off this feature if possible.

Mass Wasting Potential: Moderate for road construction and timber harvest. Because these features are associated with active deep-seated landslides, they are at a higher risk for failure and potential for reactivation of slide activity. This landform, by calculation, has a Landslide Frequency Rating of low, however is considered moderate due to the potential hazard.

Delivery Potential/Criteria: Moderate to Very High. Shallow slide failures on the body of deep-seated landslides within the Sultan Gorge system have a very high potential of delivery into the Sultan River. This is due to the lack of toes on most of the deep-seated landslides within these areas. On deep-seated landslides in other areas, delivery is possible and should be checked in the field.

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

Confidence: High, based on the number of landslides located in this landform, excellent photo quality and coverage, communication with field foresters, and field observations. Careful field review will be necessary to delineate all the areas containing increased risk of failures within these features, because field investigation has located a number of features masked by canopy.

8 – Relict Terraces

Description of Mass Wasting Unit: Landform 8 is consists of terraces carved by the Sultan River. Most of the terrace faces (or scarps) are along the valley walls surrounding the city of Sultan. These terraces can become undercut by the river or be steepened enough to create unstable slopes. The area with the highest risk of failure is located on the valley wall to the east and north of city of Sultan. The bluffs surrounding Lake Chaplain primarily have failed owing to road construction.

Slopes: Greater than or equal to 70%
Slope Shape: Convergent and Planar
Material: Predominantly clay and glacial outwash sand and gravel
Elevation: 300 to 1,800 feet
Total Area: 197 acres

Mass Wasting Process: Shallow and deep-seated landslides occur owing to saturated soils, specifically clay and silt rich layers (relict lake bed) overlain by glacial till. Shallow landslides can initiate debris flows that can flow into the valley floor, carrying rocks and woody debris. Deep-seated landslides, owing to the fluvial steepened slopes and geologic setting, likely will continue to fail throughout the area.

Forest Practice Sensitivity: This landform's instability is caused by layers of clay and silt that are overlain by glacial drift. Extreme storm events have triggered large landslides (deep seated as well as shallow rapid and debris flows) in these areas; therefore surface water should be redirected off of this landform to deter future mass wasting. Timber harvest and road construction has been observed to trigger an increase in landslide failures. Note, as the city of Sultan expands, more and more houses are being built near these unstable terraces, and thus cautionary steps should be taken to ensure harvesting does not activate a landslide that can cause destruction of property or injury to people.

Mass Wasting Potential: <u>Very High for road construction and timber harvest.</u> Based on 19 shallow landslides and numerous deep-seated landslides within a total area of 197 acres, this landform has a high rate of failure in shallow and deep-seated landslides. Disturbance could reactivate relict deep-seated landslides as well as initiate new slides. This landform has a <u>Landslide Frequency Rate</u> of 3,570 with roads and 1,879 without roads.

Delivery Potential/Criteria: <u>Very High.</u> Failures that occur within this landform deliver to tributary streams and into the main channel of the Sultan River. Delivery also could damage nearby residence roads and utilities (Beckham and Thompson, 1997). This landform has a <u>Landslide Area Rate of Delivery</u> of 960 with roads and 616 without roads.

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

Confidence: <u>High</u>, based on the number of landslides located in this landform, excellent photo quality and coverage, communication with field foresters, and field observations.

9 – Active Terraces

Description of Mass Wasting Unit: Landform 9 is consists of the scarps along the Sultan River (primarily around Blue Mountain) formed during the retreat of the glaciers about 12,000 years ago and the establishment of the Sultan River. As the ancestral Sultan River down cut into the glacial material, it eventually found bedrock and became entrenched within it. The ancestral Sultan River created steep scarps, many of which are unstable and can potentially produce landslides.

Slopes: Greater than or equal to 70%
Slope Shape: Convergent and Planar
Material: Metamorphic rock and glacial drift
Elevation: 1,200 to 2,800 feet
Total Area: 746 acres

Mass Wasting Process: This landform is prone to repeated shallow rapid landslides and debris avalanches, both of which can transform into debris flows. Thin soils combined with high amounts of precipitation make this landform extremely susceptible to repeated failures, particularly during and after extreme storm events. Some of these landslides do not appear to be related to harvest or road construction, but failed due to the natural instability. At times when harvest and road construction did occur, landslides increased dramatically in density.

Forest Practice Sensitivity: Road construction spawned high densities of debris flows within this landform. Harvest during the 1970's harvest also contributed to the high density of shallow rapid landslides and debris flows in the area. The thinning operations in 1995 did not appear to have spawned additional landslides. Water redirection and concentration has been observed to destabilize the slopes, creating large landslides

Mass Wasting Potential: Very High for road construction and timber harvest. Based on 96 shallow landslides having a total area of 49 acres, this landform is very active in slope instability and disturbance could activate massive debris flows that can travel to the Sultan River. Of the 85 shallow landslides recorded in the landform 6 were caused by road failures and occurred within this landform area (specifically Blue Mountain). The majority of the remaining 82 landslides appear to be sidecast and culvert failures. Field investigations on the northern flanks of the Blue Mountains have found unmapped road (possibly rail) grade, which may be the source of many of the landslides. This landform has a Landslide Frequency Rate of 4,767 with roads and 1,887 without roads.

Delivery Potential/Criteria: Very High. Failures that occur within this landform usually deliver to streams that directly flow into the Sultan River. Some of the debris flows along the northern flank of Blue Mountain stop along a flat ledge 2/3 of the way down, which is an old lakebed deposit. However, due to the high amount of rainfall and streams, any failure within this landform will probably deliver to a stream. This landform has a Landslide Area Rate of Delivery of 2,411 with roads and 828 without roads.

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

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

10 – Incised Gorge System (Sultan River)

Description of Mass Wasting Unit: Landform 10 is consists of steep valley walls of the Sultan River. These valley walls are very unstable and will continue to fail without harvest, road building, or human activity. A buffer should be placed at least 100 feet from the break in slope to the edge of the gorge wall. Small scarps near the gorge could be deep-seated landslide scarps. Deep-seated landslides can occur in any slope shape (convergent, planar and divergent). Shallow landslide failures occurred primarily on convergent and planar slopes.

Slopes: Greater than or equal to 70%
Slope Shape: Convergent (predominately), Planar and Divergent (minor)
Material: Predominantly glacial colluvium overlaying granitic rock
Elevation: 200 to 1,500 feet
Total Area: 456 acres

Mass Wasting Process: This landform is prone to repeated shallow landslides (shallow rapids, debris flows, debris avalanches, and rock topples) as well as rotational and combination deep-seated landslides. These landslides are triggered by saturated soils, especially at the contact between the lower permeability bedrock and the overlying glacial drift. Shallow landslides can initiate debris flows and will flow directly into the Sultan River. Debris avalanches, debris flows, and large shallow rapid landslides create temporary sediment dams and debris flows (or small dam burst floods) in the Sultan River. Due to the fluvial steepened slopes and geologic setting, deep-seated landslides will likely continue to fail throughout the area.

Forest Practice Sensitivity: This landform is potentially unstable because layers of lower permeability bedrock are commonly overlain by glacial outwash and drift. Surface water can greatly impact slides in this area and should be redirected off of this landform. Extreme storm events and prolonged rain have caused large landslides to occur and will continue to fail in these conditions. Timber harvest and road construction has been observed to cause an increase in landslide failures.

Mass Wasting Potential: Very High for road construction and timber harvest. Based on 47 shallow landslides and numerous deep-seated landslides with a total amount of area failed at 11 acres, this landform has a high density of shallow landslides and any disturbance could reactivate relict deep-seated landslides as well as initiate new slides. A greater danger to this area is the high occurrence of deep-seated landslides, both active and dormant. Failure of these landslides can cause massive amounts of material and damage to the Sultan River as well as create hazards to river navigation and dam burst flooding. The landform has a Landslide Frequency Rating of 3,822 with roads and 5,150 without roads.

Delivery Potential/Criteria: Very High. Landslides produced along the gorge system slide into the Sultan River. Delivery criteria are also based on historical occurrences observed on aerial photographs and confirmed during field investigations along from interviewing local foresters. The unit has a calculated Landslide Area Rate of Delivery of 894 with roads and 1,228 without roads.

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

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

11 and 12 - Inner Gorges and Bedrock Hollows

Description of Mass Wasting Unit: This unit consists of inner gorges and bedrock hollows. Bedrock hollows are steep (>70%) spoon shaped depressions or swales 75 to 200 feet across. The inner gorges are steep walled (>70%) gullies formed by a combination of stream action and mass wasting. Bedrock hollow evacuations can trigger debris flows that scour channels forming inner gorges.

Slopes: Greater than or equal to 70%
Slope Shape: Convergent
Material: Predominantly glacial material, metamorphic rocks
Elevation: 1,200 to 2,800 feet
Total Area: 122 acres

Mass Wasting Process: These landforms are prone to repeated shallow landslides (shallow rapids and debris flows). Shallow landslides within the bedrock hollow and inner gorges can initiate debris flows. These landforms can be located on deep-seated landslides, which can increase instability of these landforms.

Forest Practice Sensitivity: These landforms are naturally unstable, especially when there is a concentration of water on steep slopes. Water can greatly impact landslides in this landform and should be redirected off of this landform. Extreme storm events and prolonged rain have caused landslides to occur and will continue to fail in these conditions. Timber harvest and road construction have been observed to cause an increase in landslide failures.

Mass Wasting Potential: Very High for road construction and timber harvest based on 18 landslides totaling 12 acres of failed material. The inner gorges (landform 11) have a Landslide Frequency Rating of 6,688 with roads and 4,180 without roads. Bedrock hollows (landform 12) have a Landslide Frequency Rating of 20,106 with roads and 8,936 without roads .

Delivery Potential/Criteria: Very High. Inner gorges and often 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 investigation. Inner gorges have a Landslide Area Rate of Delivery of 3,837 with roads and 1,693 without roads. Bedrock hollows have a Landslide Area Rate of Delivery of 13,918 with roads and 7,797 without roads.

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

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

13 – Toes and Scarps of Deep Seated Landslides

Description of Mass Wasting Unit: Landform 13 consists of the toes and scarps of deep-seated landslides, predominately in glacial material. The majority of these landslides are located along the gorge system of the Sultan River, usually within 100 ft. As the slides flow into the gorge system, the toes are eroded and the body will continue to slide, creating a large, steep scarp, with gradients sometimes over 100%, which can produce numerous shallow rapids, debris avalanches and rock falls.

Slopes: Greater than or equal to 65%
Slope Shape: Convergent and Planar
Material: Predominantly Glacial Till and Outwash.
Elevation: 260 to 3,000 feet
Total Area: 27 acres

Mass Wasting Process: Deep-seated landslides are commonly composed of fractured and weakened bedrock. This fragmental material can absorb great amounts of water and has an increased susceptibility to shallow landslides. Four shallow landslides where mapped on these features. Field checks in the Sultan Incised Gorge System identified many small shallow landslides present on toes and scarps of deep-seated landslides.

Forest Practice Sensitivity: Increased water run-off on the deep-seated landslide has been found to be a factor for reactivation of deep-seated landslides. Timber harvest, road construction and/or landing construction should be done with some caution. Water should be redirected off this feature if possible.

Mass Wasting Potential: <u>High for road construction and timber harvest.</u> based on 4 landslides totaling 0.6 acres of failed material. Because these features are associated with active deep-seated landslides, they are at a higher risk for failure and/or potential for reactivation of slide activity. The landform has a <u>Landslide Frequency Rating</u> of 5,458 with or without roads.

Delivery Potential/Criteria: <u>High to Very High.</u> Shallow slide failures on the scarp of deep-seated landslides within the Sultan Gorge system have a very high potential of delivery into the Sultan River. This is due to the steepness and rapid erosion by the Sultan River on most of the deep-seated landslides within these areas. On deep-seated landslides in other areas, delivery is possible and should be checked in the field. The unit has a calculated <u>Landslide Area Rate of Delivery</u> of 846 with or without roads.

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

Confidence: <u>High</u>, based on the number of landslides located in this landform, excellent photo quality and coverage, communication with field foresters, and field observation.

5.0 Hazard Ratings

(Form A-4 contains all the data used to determine the calculations and hazard ratings) Overall Hazard Ratings was determined from the number of shallow landslides, rule-identified landforms (WAC 222-16-050) and the calculated Landslide Frequency Rate and Landslide Area Rate for Delivery (see Form A-4).

The Landslide Frequency Rate for Delivery is the area, in acres, of all the shallow landslides normalized for a period of full aerial photo coverage (usually the first photo set in the 1970's) and the area of each Landform. These values are then multiplied by one million for easier interpretation. The Landslide Area Rate for Delivery is calculated similarly, however the amount of area delivered (in acres) is used instead of the number of landslides. As of the writing of this report, the qualitative rating system below is used.

Qualitative Ratings	Landslide Frequency Rate	Landslide Area Rate for Delivery
Low	< 100	<76
Moderate	100 to 199	76 to 150
High	200 to 999	151 to 799
Very High	>999	>799

6.0 Note on Confidence in Work Products

The confidence in this mass wasting assessment is High. This rating is based on the Landslide Hazard Zonation Project design 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 are 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 these decisions are 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 reduce the confidence in the work products of 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 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.

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, steep north facing slopes always in shadow at any given time, and those areas covered with extensive glacial deposits. The scarcity of mass wasting features identified under mature canopy and steep north slope aspect shadow conditions is not necessarily an indication of the relative stability of slopes with mature vegetation regimes or steep north face aspects.

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 more likely. A recent detailed study in Cowlitz County, Washington, suggests that up to 25 percent of inferred deep-seated landslides identified from aerial photograph analysis are misinterpreted (Wegmann, 2003). 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 less than 50% of 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.

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7.0 References

Beckham, Gary; Thompson, James, 1997, Preliminary Investigation Report, Water Main Pipeline Washout, City of Sultan, Washington.

Bethune, George A., 1891, Mines and Minerals of Washington--Annual report of George A. Bethune, First State Geologist, 1890: Washington Geological Survey Annual Report, 122 p.

Bliton, William S., 1989, Sultan River project. IN Galster, R. W., chairman, Engineering geology in Washington: Washington Division of Geology and Earth Resources Bulletin 78, v. I, p. 209-216.

Booth, Derek B., 1990, Surficial geologic map of the Skykomish and Snoqualmie Rivers area, Snohomish and King Counties, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1745, 2 sheets, scale 1:50,000, with 22 p. text.

Broughton, W. A., 1942, Inventory of mineral properties in Snohomish County, Washington: Washington Division of Geology Report of Investigations 6, 64 p., 1 plate.

Cameron, David, March 30th, 2005, Personal Communication,

Carithers, Ward; Guard, A. K., 1945, Geology and ore deposits of the Sultan Basin, Snohomish County, Washington: Washington Division of Mines and Geology Bulletin 36, 90 p., 1 plate.

Conway, E. J., 1915, Georgia H. group, Snohomish Co., Wash.: Granby Consolidated Mining, Smelting and Power Co., Ltd., 3 p.

Coombs, H. A., 1969, Leakage through buried channels: Association of Engineering Geologists Bulletin, v. 6, no. 1, p. 45-52.

Dragovich, Joe D.; Logan, Robert L.; Schasse, Henry W.; Walsh, Timothy J.; Lingley, William S., Jr.; Norman, David K.; Gerstel, Wendy J.; Lapen, Thomas J.; Schuster, J. Eric; Meyers, Karen D., 2002, Geologic map of Washington--Northwest quadrant: Washington Division of Geology and Earth Resources Geologic Map GM-50, 3 sheets, scale 1:250,000, with 72 p. text.

Farwell, Don, March 21st, 2005, Personal Communication

Gannett, Henry, 1899, Forest reserves: U.S. Geological Survey Annual Report, 19th, Part 5, 400 p.

Gannett, Henry, 1900, Forest reserves: U.S. Geological Survey Annual Report, 19th, Part 5, 400 p.

Herring, Frances W.; Murray, A. H., 1942, Minerals and mining opportunities in Snohomish County: Washington State Planning Council, 42 p

Hodges, L. K., 1897, Mining in the Pacific Northwest: Seattle Post-Intelligencer.

Lockwood Report, 1995, Written Correspondence, unpublished Department of Natural Resource Data

Olson, Duane F., 1995, Geology and Geochemistry of the Lockwood Volcanogenic Massive Sulfide Deposit, Snohomish County, Washington: Western Washington University Master of Science thesis, 118 p., 8 plates.

Palmer, Richard; Marxen, Sara; Groome, Amy; Nelligan-Doran, Sherrill, 1999, Cascade Regional Yield SimulaTion and AnaLysis Model (CRYSTAL); PRISM, http://www.prism.washington.edu/crystal/CRYSTALhome.html (accessed on April 15th, 2005)

Phipps, Richard W.; McKay, Donald T., Jr.; Norman, David K.; Wolff, Fritz E., 2003, Inactive and abandoned mine lands--Spada Lake and Cecile Creek watershed analysis units, Snohomish and Okanogan Counties, Washington: Washington Division of Geology and Earth Resources Open File Report 2003-3, 36 p.

Schuh, Murray; Meaker, Bruce, 1995, Henry M. Jackson hydroelectric project (Federal Energy Regulatory Commission Project no. 2157); Licensees, Public Utility District no. 1 of Snohomish County and City of Everett, Washington; Gravel quality and quantity study; final report: Snohomish County Public Utility District no. 1, 1 v.

Snohomish County Public Utility District No. 1; Washington Department of Ecology, 1979, Sultan River project, Stage II; Application for amended license, FERC project no. 2157--State of Washington final SEPA EIS and FERC environmental report (exhibit W): Snohomish County Public Utility District No. 1, 2 v.

Stewart, Richard, May 27th, 2005, Personal Communication

Stoess, P. C., 1934, Preliminary Statement Regarding Mineral Deposits of the Sultan Basin, Snohomish County, Washington, unpublished DNR data.

Tabor, R. W.; Frizzell, V. A., Jr.; Booth, D. B.; Waitt, R. B.; Whetten, J. T.; Zartman, R. E., 1993, Geologic map of the Skykomish River 30- by 60-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1963, 1 sheet, scale 1:100,000, with 42 p. text.

Taubeneck, Walt, April 13th, 2005, Personal Communication

U.S. Geological Survey, 2005, Surface water peak stream flow for the Sultan River near Sultan, WA 1990 to 2005:http://waterdata.usgs.gov/wa/nwis/current?type=flow [accessed on 4/19/05].

U.S. Works Progress Administration Washington Mineral Survey, 1937, Report on a pyrite deposit in the Sultan Basin mining district, Snohomish County: U.S. Works Progress Administration, 16 p.

Vaugeois, Laura, 2000, Creation of a Slope Stability Screening Tool from Landslide Prediction Models, Forest Practice Board Presentation: Washington Department of Natural Resources, Olympia, Washington

Wegmann, Karl W., 2003, Digital landslide inventory for the Cowlitz County urban corridor--Kelso to Woodland (Coweeman River to Lewis River), Cowlitz County, Washington: Washington Division of Geology and Earth Resources Report of Investigations 34, 1 CD-ROM disk.

Whitfield, Wm., 1926, History of Snohomish County, Washington, Vol. I.

Appendix A - Form A-1: Landslide Inventory

Landform	SLIDE_ID	SOURCE_ID	LSI_PROCES	CERTAINTY	ID_DATE	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	INIT_ELEV	PHOTO_NU	DSLS_ACTI	DSLS_TYPE	DSLS_CER	Acres	COMMENTS
10	100	993	4	D	1983	8	1	125.7	Y	3	520	NW-C-83 18-67-060	AR	R	D	1.5	
10	101	993	4	P	1983	8	3	118.0	Y	3	480	NW-C-83 18-67-060	DD	R	D	0.3	
10	102	993	3	P	1983	1	2	74.6	Y	3	500	NW-C-83 18-67-060				0.7	
10	103	993	3	D	1983	1	3	68.4	Y	3	500	NW-C-83 18-67-060				0.6	
10	104	993	1	D	1983	5	3	143.2	Y	3	530	NW-C-83 18-67-060				0.2	
11	105i	993	2	D	1978	2	2	76.5	Y	5	2300	NW-78 83D-53 7-26-78				0.1	
11	105r	993	2	D	1978	2	2	76.5	Y	5	2300	NW-78 83D-53 7-26-78				1.4	
3	106i	993	2	D	1978	1	2	48.3	Y	5	2480	NW-78 83D-53 7-26-78				0.1	
3	106r	993	2	D	1978	1	2	48.3	Y	5	2480	NW-78 83D-53 7-26-78				1.9	
9	107i	993	2	D	1978	1	1	91.3	Y	5	2480	NW-78 83D-53 7-26-78				0.1	
9	107r	993	2	D	1978	1	1	91.3	Y	5	2480	NW-78 83D-53 7-26-78				1.1	
9	108i	993	2	D	1978	1	2	64.1	Y	5	2400	NW-78 83D-53 7-26-78				0.1	
9	108r	993	2	D	1978	1	2	64.1	Y	5	2400	NW-78 83D-53 7-26-78				0.4	
9	109i	993	2	D	1978	1	1	83.3	Y	5	2440	NW-78 83D-53 7-26-78				0.1	
9	109r	993	2	D	1978	1	1	83.3	Y	5	2440	NW-78 83D-53 7-26-78				0.6	
9	110i	993	2	D	1978	1	1	94.6	Y	5	2440	NW-78 83D-53 7-26-78				0.1	
9	110r	993	2	D	1978	1	1	94.6	Y	5	2440	NW-78 83D-53 7-26-78				0.5	
11	111i	993	2	D	1978	2	1	74.8	Y	5	2160	NW-78 83D-53 7-26-78				0.1	
11	111r	993	2	D	1978	2	1	74.8	Y	5	2160	NW-78 83D-53 7-26-78				2.3	
12	112i	993	2	D	1978	1	1	71.4	Y	5	1820	NW-78 83D-53 7-26-78				0.1	
12	112r	993	2	D	1978	1	1	71.4	Y	5	1820	NW-78 83D-53 7-26-78				0.6	
9	113i	993	2	D	1978	2	1	135.2	Y	5	2410	NW-78 83D-53 7-26-78				0.0	
9	113r	993	2	D	1978	2	1	135.2	Y	5	2410	NW-78 83D-53 7-26-78				2.4	
9	114i	993	2	D	1978	2	1	109.8	Y	5	2480	NW-78 83D-53 7-26-78				0.1	
9	114r	993	2	D	1978	2	1	109.8	Y	5	2480	NW-78 83D-53 7-26-78				0.8	
9	115i	993	2	D	1978	1	1	145.1	Y	5	2450	NW-78 83D-53 7-26-78				0.2	
9	115r	993	2	D	1978	1	1	145.1	Y	5	2450	NW-78 83D-53 7-26-78				0.2	
9	116i	993	2	D	1978	1	1	69.8	Y	5	2150	NW-78 83D-53 7-26-78				0.3	
9	116r	993	2	D	1978	1	1	69.8	Y	5	2150	NW-78 83D-53 7-26-78				3.4	
9	117	993	1	D	1978	4	1	48.3	I	5	2700	NW-78 83D-53 7-26-78				0.2	
3	118i	993	2	D	1978	1	2	39.9	Y	5	2680	NW-78 83D-53 7-26-78				0.2	
3	118r	993	2	D	1978	1	2	39.9	Y	5	2680	NW-78 83D-53 7-26-78				3.9	
9	119i	993	2	D	1978	2	2	51.0	P	5	1680	NW-78 83D-53 7-26-78				0.2	

9	119r	993	2	D	1978	2	2	51.0	P	5	1680	NW-78	83D-53	7-26-78				0.5
10	120	993	4	P	1983	8	1	151.0	Y	3	535	NW-C-83	18-67-060		DI	C	P	2.8
3	121i	993	2	D	1978	1	2	48.6	Y	2	1855	NW-78	83D-53	7-26-78				0.2
3	121r	993	2	D	1978	1	2	48.6	Y	2	1855	NW-78	83D-53	7-26-78				1.6
11	122i	993	2	D	1978	2	2	63.3	P	5	2020	NW-78	83D-53	7-26-78				0.3
11	122r	993	2	D	1978	2	2	63.3	P	5	2020	NW-78	83D-53	7-26-78				1.0
9	123i	993	2	D	1978	2	2	62.6	P	5	2120	NW-78	83D-53	7-26-78				0.2
9	123r	993	2	D	1978	2	2	62.6	P	5	2120	NW-78	83D-53	7-26-78				2.8
9	124i	993	2	D	1978	1	2	60.1	P	5	1940	NW-78	83D-53	7-26-78				0.1
9	124r	993	2	D	1978	1	2	60.1	P	5	1940	NW-78	83D-53	7-26-78				0.8
9	125i	993	2	D	1978	1	2	70.9	P	5	2480	NW-78	83D-53	7-26-78				0.1
9	125i2	993	2	D	1978	1	2	70.9	P	5	2480	NW-78	83D-53	7-26-78				0.1
9	125i3	993	2	D	1978	1	2	70.9	P	5	2480	NW-78	83D-53	7-26-78				0.0
9	125r	993	2	D	1978	1	2	70.9	P	5	2480	NW-78	83D-53	7-26-78				1.7
9	125r2	993	2	D	1978	1	2	70.9	P	5	2480	NW-78	83D-53	7-26-78				0.2
9	125r3	993	2	D	1978	1	2	70.9	P	5	2480	NW-78	83D-53	7-26-78				0.2
9	126i	993	2	D	1978	1	1	89.5	P	5	2240	NW-78	83D-53	7-26-78				0.1
9	126r	993	2	D	1978	1	1	89.5	P	5	2240	NW-78	83D-53	7-26-78				0.4
3	127i	993	2	D	1978	1	2	44.8	P	2	1940	NW-78	83D-53	7-26-78				0.1
3	127r	993	2	D	1978	1	2	44.8	P	2	1940	NW-78	83D-53	7-26-78				0.6
3	128	993	7	D	1978	4	4	25.7	Y	5	825	NW-78	79B-100	6-28-78				2.3
12	129i	993	2	D	1978	2	2	69.5	P	5	2805	NW-78	85A-110	7-26-78				0.2
12	129r	993	2	D	1978	2	2	69.5	P	5	2805	NW-78	85A-110	7-26-78				1.6
12	130i	993	2	D	1978	2	2	68.3	P	5	2640	NW-78	85A-110	7-26-78				0.1
12	130r	993	2	D	1978	2	2	68.3	P	5	2640	NW-78	85A-110	7-26-78				1.0
3	131	993	4	D	1978	8	1	68.2	Y	2	1360	NW-78	85A-110	7-26-78	AR		D	12.7
3	132i	993	2	D	1978	1	1	26.2	Y	5	1440	NW-78	85A-110	7-26-78				0.2
3	132r	993	2	D	1978	1	1	26.2	Y	5	1440	NW-78	85A-110	7-26-78				0.6
9	133i	993	2	D	1978	1	2	96.9	P	2	2800	NW-78	85A-110	7-26-78				0.1
9	133r	993	2	D	1978	1	2	96.9	P	2	2800	NW-78	85A-110	7-26-78				0.6
9	134i	993	2	D	1978	1	2	102.8	P	2	2800	NW-78	85A-110	7-26-78				0.1
9	134r	993	2	D	1978	1	2	102.8	P	2	2800	NW-78	85A-110	7-26-78				0.3
9	135i	993	2	D	1978	1	2	98.4	P	2	2760	NW-78	85A-110	7-26-78				0.1
9	135r	993	2	D	1978	1	2	98.4	P	2	2760	NW-78	85A-110	7-26-78				0.3
10	136	993	4	D	1983	8	4	141.6	Y	3	530	NW-C-83	18-67-060		DD	R	D	0.7
10	137	993	4	D	1983	8	4	141.1	Y	3	530	NW-C-83	18-67-060		DD	R	D	0.6
10	138	993	4	P	1983	8	1	132.7	Y	3	600	NW-C-83	18-67-060		DI		P	0.5
10	139	993	1	D	1983	1	1	85.4	Y	3	580	NW-C-83	18-67-060					0.1

3	140	993	1	D	1983	4	1	57.9	N	3	525	NW-C-83 18-67-060				0.1
10	141	993	1	D	1983	1	2	89.5	Y	3	500	NW-C-83 18-67-060				0.1
10	142	993	1	P	1983	1	3	62.5	Y	3	500	NW-C-83 18-67-060				0.1
10	143	993	4	D	2005	8	2	110.8	Y	3	600	Field	AR	R	D	2.1
3	144	993	1	D	2005	4	3	35.4	Y	3	600	Field				0.1
8	145	993	1	D	1983	4	3	86.4	Y	5	715	NW-C-83 18-66-019				0.2
8	146	993	1	D	1983	4	3	79.9	Y	5	725	NW-C-83 18-66-019				0.1
8	147	993	1	D	1983	4	3	74.7	Y	5	670	NW-C-83 18-66-019				0.2
8	148	993	1	D	1983	4	3	62.2	Y	5	650	NW-C-83 18-66-019				0.3
8	149	993	1	D	1983	4	1	132.7	Y	3	800	NW-C-83 18-66-019				0.1
8	150	993	1	D	1983	4	3	163.0	Y	3	800	NW-C-83 18-66-019				0.2
9	151i	993	2	D	1978	1	2	76.9	P	5	2920	NW-78 85A-110 7-26-78				0.1
9	151r	993	2	D	1978	1	2	76.9	P	5	2920	NW-78 85A-110 7-26-78				0.3
11	152	993	4	D	1978	8	1	60.2	Y	3	775	NW-78 80B-92 6-28-78	DD		D	0.9
8	153	993	1	D	1983	4	3	156.4	Y	3	800	NW-C-83 18-66-019				0.1
8	154	993	1	D	1983	4	3	101.7	Y	5	762	NW-C-83 18-66-019				0.1
3	155i	993	2	D	1978	1	2	55.1	P	5	2155	NW-78 85A-110 7-26-78				0.1
3	155r	993	2	D	1978	1	2	55.1	P	5	2155	NW-78 85A-110 7-26-78				0.6
9	156i	993	2	D	1978	1	2	57.1	P	2	2360	NW-78 85A-110 7-26-78				0.1
9	156r	993	2	D	1978	1	2	57.1	P	2	2360	NW-78 85A-110 7-26-78				0.5
3	157i	993	2	D	1978	2	2	53.5	P	2	2360	NW-78 85A-110 7-26-78				0.3
3	157r	993	2	D	1978	2	2	53.5	P	2	2360	NW-78 85A-110 7-26-78				1.3
9	158i	993	2	D	1978	2	2	69.5	P	5	2680	NW-78 85A-110 7-26-78				0.1
9	158r	993	2	D	1978	2	2	69.5	P	5	2680	NW-78 85A-110 7-26-78				1.6
3	159i	993	2	D	1978	1	2	57.6	P	5	2120	NW-78 85A-110 7-26-78				0.1
3	159r	993	2	D	1978	1	2	57.6	P	5	2120	NW-78 85A-110 7-26-78				0.6
3	160i	993	2	D	1978	1	2	55.9	P	5	2100	NW-78 85A-110 7-26-78				0.1
3	160r	993	2	D	1978	1	2	55.9	P	5	2100	NW-78 85A-110 7-26-78				0.3
8	161	993	1	D	1983	4	3	89.2	Y	5	789	NW-C-83 18-66-019				0.2
3	162	993	1	D	1978	4	2	53.2	P	5	2125	NW-78 85A-110 7-26-78				0.4
12	163	993	8	D	1978	6	2	91.1	I	2	2800	NW-78 85A-110 7-26-78				1.4
12	164	993	8	P	1978	6	2	101.3	I	2	2600	NW-78 85A-110 7-26-78				1.0
9	165	993	4	Q	1978	8	2	94.2	P	2	2800	NW-78 85A-110 7-26-78	DI		Q	18.5
9	166i	993	2	D	1978	1	1	51.0	Y	2	2480	NW-78 85A-110 7-26-78				0.1
9	166r	993	2	D	1978	1	1	51.0	Y	2	2480	NW-78 85A-110 7-26-78				0.8
3	167i	993	2	D	1978	2	1	76.4	Y	5	2500	NW-78 85A-110 7-26-78				0.1
3	167r	993	2	D	1978	2	1	76.4	Y	5	2500	NW-78 85A-110 7-26-78				0.6
9	168i	993	2	D	1978	2	1	85.8	Y	2	2600	NW-78 85A-110 7-26-78				0.1

9	168r	993	2	D	1978	2	1	85.8	Y	2	2600	NW-78	85A-110	7-26-78			2.3
9	169i	993	2	P	1978	1	1	108.2	P	2	2640	NW-78	85A-110	7-26-78			0.2
9	169r	993	2	P	1978	1	1	108.2	P	2	2640	NW-78	85A-110	7-26-78			0.7
12	170i	993	2	P	1978	2	1	71.7	P	2	2560	NW-78	85A-110	7-26-78			0.1
12	170r	993	2	P	1978	2	1	71.7	P	2	2560	NW-78	85A-110	7-26-78			0.5
9	171i	993	2	D	1978	2	1	81.9	P	2	2650	NW-78	85A-110	7-26-78			0.2
9	171r	993	2	D	1978	2	1	81.9	P	2	2650	NW-78	85A-110	7-26-78			2.7
8	172	993	1	D	1983	4	3	125.7	Y	5	780	NW-C-83	18-66-019				0.2
8	173	993	1	D	1983	4	3	128.0	Y	5	720	NW-C-83	18-66-019				0.2
12	174i	993	2	D	1978	2	2	66.7	Y	2	2300	NW-78	85A-110	7-26-78			0.2
12	174r	993	2	D	1978	2	2	66.7	Y	2	2300	NW-78	85A-110	7-26-78			4.1
12	175i	993	2	D	1978	2	2	85.9	Y	2	2360	NW-78	85A-110	7-26-78			0.2
12	175r	993	2	D	1978	2	2	85.9	Y	2	2360	NW-78	85A-110	7-26-78			1.6
12	176i	993	2	D	1978	2	2	69.7	P	5	2800	NW-78	85A-110	7-26-78			0.1
12	176r	993	2	D	1978	2	2	69.7	P	5	2800	NW-78	85A-110	7-26-78			1.2
9	177i	993	2	D	1978	2	1	60.3	P	2	2360	NW-78	84B-109	7-26-78			0.1
9	177r	993	2	D	1978	2	1	60.3	P	2	2360	NW-78	84B-109	7-26-78			0.2
3	178i	993	2	D	1978	1	1	43.4	Y	5	2820	NW-78	84B-109	7-26-78			0.1
3	178r	993	2	D	1978	1	1	43.4	Y	5	2820	NW-78	84B-109	7-26-78			1.2
9	179i	993	2	D	1978	1	1	65.2	Y	5	2020	NW-78	84B-109	7-26-78			0.1
9	179r	993	2	D	1978	1	1	65.2	Y	5	2020	NW-78	84B-109	7-26-78			1.3
9	180i	993	2	D	1978	1	2	68.1	P	5	2080	NW-78	84B-109	7-26-78			0.1
9	180r	993	2	D	1978	1	2	68.1	P	5	2080	NW-78	84B-109	7-26-78			0.3
9	181	993	1	D	1978	4	2	82.2	I	2	2180	NW-78	84B-109	7-26-78			0.5
3	182i	993	2	D	1978	1	2	56.1	P	2	2480	NW-78	84B-109	7-26-78			0.0
3	182r	993	2	D	1978	1	2	56.1	P	2	2480	NW-78	84B-109	7-26-78			0.2
9	183i	993	2	D	1978	2	1	76.1	P	2	2520	NW-78	84B-109	7-26-78			0.1
9	183r	993	2	D	1978	2	1	76.1	P	2	2520	NW-78	84B-109	7-26-78			0.5
9	184i	993	2	D	1978	2	1	80.4	P	2	2600	NW-78	84B-109	7-26-78			0.1
9	184r	993	2	D	1978	2	1	80.4	P	2	2600	NW-78	84B-109	7-26-78			0.3
9	185i	993	2	D	1978	2	1	86.2	P	5	2770	NW-78	84B-109	7-26-78			0.1
9	185r	993	2	D	1978	2	1	86.2	P	5	2770	NW-78	84B-109	7-26-78			0.5
9	186	993	4	Q	1978	8	1	45.9	P	5	2840	NW-78	84B-109	7-26-78	R	Q	10.1
4	187	993	1	P	1978	4	5	17.6	I	5	2800	NW-78	84B-109	7-26-78			0.6
4	188	993	4	P	1978	8	2	17.0	P	2	2840	NW-78	84B-109	7-26-78	DI	P	0.2
3	189	993	4	Q	1978	8	3	29.4	P	2	2880	NW-78	84B-109	7-26-78	R	Q	15.4
3	190	993	4	Q	1978	8	3	43.7	P	2	2920	NW-78	84B-109	7-26-78	R	Q	6.1
3	191	993	4	Q	1978	8	3	38.1	P	2	2920	NW-78	84B-109	7-26-78	R	Q	3.2

11	192	993	1	D	1978	9	2	42.2	Y	2	2500	NW-78	84B-109	7-26-78			0.2	
11	193	993	1	D	1978	9	2	38.6	Y	2	2520	NW-78	84B-109	7-26-78			0.2	
8	194	993	1	D	1983	4	4	97.0	Y	5	820	NW-C-83	18-66-019				0.3	
8	195	993	1	D	1983	4	2	100.2	Y	5	800	NW-C-83	18-66-019				0.2	
8	196	993	1	D	1983	4	3	115.3	Y	5	800	NW-C-83	18-66-019				0.2	
12	197	993	7	Q	1978	4	2	76.9	I	2	2320	NW-78	82C-75	7-26-78			10.6	
10	198	993	4	P	1978	8	3	119.0	Y	3	525	NW-78	80B-93	6-28-78	DI	P	0.8	
8	199	993	1	D	1983	4	3	113.4	Y	5	880	NW-C-83	18-66-019				0.8	
10	200	993	4	Q	1978	8	1	39.5	Y	3	605	NW-78	80B-93	6-28-78	R	Q	3.4	
10	201	993	4	P	1978	8	1	69.7	Y	3	520	NW-78	80B-93	6-28-78	DI	P	1.1	
10	202	993	4	D	1978	8	3	47.6	Y	3	605	NW-78	80B-93	6-28-78	DD	D	12.2	
10	203	993	4	Q	1978	8	3	91.4	Y	3	480	NW-78	80B-93	6-28-78	R	Q	1.6	
10	204	993	4	P	1978	8	3	102.8	Y	3	500	NW-78	80B-93	6-28-78	DI	P	1.3	
10	205	993	4	P	1978	8	3	51.8	Y	3	500	NW-78	80B-93	6-28-78	DI	P	1.5	
10	206	993	4	P	1978	8	1	39.3	Y	3	510	NW-78	80B-93	6-28-78	DI	P	8.2	
10	207	993	4	P	1978	8	1	77.0	Y	2	500	NW-78	80B-93	6-28-78	DI	P	19.8	
8	208	993	4	P	1978	8	2	59.6	Y	2	1600	NW-78	82C-75	7-26-78	DI	P	9.5	
8	209	993	2	D	1978	1	1	28.8	P	2	1310	NW-78	82C-75	7-26-78			0.4	
10	210	993	4	P	1978	8	3	58.4	Y	3	500	NW-78	80B-93	6-28-78	DI	P	9.4	
10	211	993	4	Q	1978	8	5	13.1	Y	2	500	NW-78	80B-93	6-28-78	R	Q	17.6	
3	212	993	1	D	1978	1	3	34.0	Y	3	300	NW-78	80B-93	6-28-78			0.3	
10	213	993	4	Q	1978	8	1	53.6	Y	3	460	NW-78	80B-93	6-28-78	DI	Q	9.1	
10	214	993	4	P	1978	8	3	18.9	Y	2	505	NW-78	80B-93	6-28-78	DI	P	9.8	
9	215	993	1	P	1978	4	3	55.2	I	2	1920	NW-78	82C-79	7-26-78			0.2	
9	216	993	2	D	1978	2	3	60.7	P	2	1840	NW-78	82C-79	7-26-78			0.7	Initiated by 215
9	217i	993	2	D	1978	1	4	41.3	Y	5	1480	NW-78	82C-79	7-26-78			0.1	
9	217r	993	2	D	1978	1	4	41.3	Y	5	1480	NW-78	82C-79	7-26-78			0.4	
3	218i	993	2	D	1978	1	4	40.1	Y	5	1480	NW-78	82C-79	7-26-78			0.2	
3	218r	993	2	D	1978	1	4	40.1	Y	5	1480	NW-78	82C-79	7-26-78			0.9	
3	219i	993	2	D	1978	1	4	25.2	Y	5	1500	NW-78	82C-79	7-26-78			0.2	
3	219r	993	2	D	1978	1	4	25.2	Y	5	1500	NW-78	82C-79	7-26-78			1.0	
10	220	993	4	D	1978	8	3	27.1	Y	2	400	NW-78	80B-93	6-28-78	DD	D	3.2	
10	221	993	4	D	1978	8	1	43.0	Y	3	380	NW-78	80B-93	6-28-78	DI	D	2.5	
10	222	993	4	P	1978	8	5	49.4	Y	2	460	NW-78	80B-93	6-28-78	DI	P	17.3	
10	223	993	4	P	1978	8	3	51.9	Y	3	445	NW-78	80B-93	6-28-78	DI	P	2.3	
10	224	993	1	D	1978	1	3	125.7	Y	3	500	NW-78	80B-93	6-28-78			0.2	
14	225	993	1	D	1978	5	3	111.2	Y	3	480	NW-78	80B-93	6-28-78			0.1	
10	226	993	1	D	1978	1	5	58.7	Y	3	460	NW-78	80B-93	6-28-78			0.1	

10	227	993	1	P	1978	1	3	89.9	Y	3	480	NW-78 80B-93	6-28-78				0.1	
9	228i	993	2	P	1978	4	3	65.0	P	5	2390	NW-78 82C-75	7-26-78				0.2	
9	228r	993	2	P	1978	4	3	65.0	P	5	2390	NW-78 82C-75	7-26-78				1.7	
3	229i	993	2	P	1978	4	3	51.3	P	5	2410	NW-78 82C-75	7-26-78				0.4	
3	229r	993	2	P	1978	4	3	51.3	P	5	2410	NW-78 82C-75	7-26-78				1.5	
3	230i	993	2	D	1978	1	2	42.3	P	5	2520	NW-78 82C-75	7-26-78				0.3	
3	230r	993	2	D	1978	1	2	42.3	P	5	2520	NW-78 82C-75	7-26-78				0.9	
3	231i	993	2	D	1978	1	2	39.3	P	5	2560	NW-78 82C-75	7-26-78				0.2	
3	231r	993	2	D	1978	1	2	39.3	P	5	2560	NW-78 82C-75	7-26-78				0.8	
3	232i	993	2	D	1978	1	2	31.0	P	5	2600	NW-78 82C-75	7-26-78				0.3	
3	232r	993	2	D	1978	1	2	31.0	P	5	2600	NW-78 82C-75	7-26-78				1.3	
10	236	993	1	D	1978	1	3	117.8	Y	3	440	NW-78 80B-93	6-28-78				0.1	
3	237i	993	2	D	1978	1	2	34.2	P	5	2220	NW-78 82C-77	7-26-78				0.2	
3	237r	993	2	D	1978	1	2	34.2	P	5	2220	NW-78 82C-77	7-26-78				1.1	
10	238	993	1	D	1978	1	3	129.7	Y	3	300	NW-78 80B-93	6-28-78				0.3	
10	239	993	1	D	1978	1	3	131.0	Y	3	300	NW-78 80B-93	6-28-78				0.2	
3	240i	993	2	D	1978	1	2	48.7	P	5	2100	NW-78 82C-77	7-26-78				0.3	
3	240r	993	2	D	1978	1	2	48.7	P	5	2100	NW-78 82C-77	7-26-78				2.2	
9	241i	993	2	D	1978	1	2	48.6	P	5	2160	NW-78 82C-77	7-26-78				0.2	
9	241r	993	2	D	1978	1	2	48.6	P	5	2160	NW-78 82C-77	7-26-78				1.3	
10	242	993	1	D	1978	1	3	30.4	Y	3	300	NW-78 80B-93	6-28-78				0.1	
10	243	993	1	D	1978	1	3	40.3	Y	3	300	NW-78 80B-93	6-28-78				0.1	
10	244	993	4	P	1978	8	3	79.8	Y	3	470	NW-78 80B-93	6-28-78	DI		P	0.6	
10	245	993	1	D	1978	1	3	107.3	Y	3	470	NW-78 80B-95	6-28-78				0.1	
10	247	993	4	P	1978	8	3	127.1	Y	3	515	NW-78 80B-95	6-28-78	DD	R	P	0.9	
10	249	993	4	D	1978	8	3	113.9	Y	3	525	NW-78 80B-95	6-28-78	DI		D	0.8	
10	250	993	4	D	1978	8	3	85.1	Y	3	490	NW-78 80B-93	6-28-78	DD	R	D	1.7	
14	251	993	1	P	1978	5	3	120.0	Y	3	530	NW-C-83 18-67-060					0.2	
14	252	993	1	D	1983	5	1	135.0	Y	3	540	NW-C-83 18-67-060					0.2	
8	253	993	1	D	1983	4	2	105.8	Y	9	800	NW-C-83 18-66-019					0.2	
10	254	993	4	D	1978	8	3	62.1	Y	3	695	NW-78 80B-95	6-28-78	DD		D	7.6	
11	256	993	1	P	1978	1	3	36.7	Y	3	605	NW-78 80B-95	6-28-78				0.5	
11	257	993	1	D	1995	1	1	100.0	Y	9	400	Geotech Report					0.7	From Kleinfelder Report
12	258l	993	3	D	2005	4	1	75.2	Y	3	2810	Field					0.6	Initiates a debris flow
12	258r	993	2	D	2005	4	1	82.3	Y	3	2810	Field					5.9	
14	259	993	3	D	2004	5	3	126.4	Y	3	520	Field					0.2	Available Footage of Collapse by Kayakers
9	261	993	4	P	1978	8	1	66.7	Y	2	1420	NW-78 82C-77	7-26-78	DD		P	4.7	
9	261a	993	4	P	1991	8	1	7.0	Y	2	945	NW91 30 68-58	9-5-91	DD		P	0.1	

9	261b	993	4	P	1991	8	1	68.0	Y	2	1440	NW91 30 68-58	9-5-91	DD		P	4.5
9	263	993	1	D	1978	1	2	43.5	I	2	1485	NW-78 81D-62	7-26-78				0.4
11	264	993	1	D	1978	1	1	42.0	Y	2	1460	NW-78 82C-77	7-26-78				1.3
10	266	993	4	Q	1978	8	1	22.2	Y	3	660	NW-78 80B-95	6-28-78	R		Q	1.8
10	267	993	4	P	1978	8	1	44.8	Y	3	760	NW-78 80B-95	6-28-78	DI		P	2.1
10	268	993	1	D	1978	1	3	83.5	Y	3	505	NW-78 80B-95	6-28-78				0.4
10	270	993	1	D	1978	1	3	41.7	Y	3	360	NW-78 80B-92	6-28-78				0.4
10	271	993	1	D	1978	1	3	46.2	Y	3	360	NW-78 80B-92	6-28-78				0.4
10	272	993	4	D	1978	8	3	100.5	Y	3	300	NW-78 80B-92	6-28-78	DD		D	0.5
10	273	993	4	P	1978	8	1	65.8	Y	3	340	NW-78 80B-92	6-28-78	DI		P	1.6
10	274	993	1	D	1978	1	3	101.6	Y	3	280	NW-78 80B-92	6-28-78				0.3
10	275	993	4	P	1978	8	1	71.6	Y	3	500	NW-78 80B-92	6-28-78	DI		P	3.2
10	276	993	4	Q	1978	8	5	54.9	I	3	495	NW-78 80B-92	6-28-78	R	E	Q	0.9
10	277	993	4	P	1978	8	3	69.2	Y	3	300	NW-78 80B-92	6-28-78	DI		P	2.1
8	278	993	4	P	1978	8	3	89.2	Y	2	400	NW-78 80B-92	6-28-78	DI		P	16.5
10	279	993	1	D	1978	1	3	87.1	Y	3	280	NW-78 80B-92	6-28-78				0.1
10	280	993	1	D	1978	1	3	80.8	Y	3	280	NW-78 80B-92	6-28-78				0.1
10	281	993	1	D	1978	1	3	76.8	Y	3	270	NW-78 80B-92	6-28-78				0.1
10	282	993	1	D	1978	1	3	82.5	Y	3	260	NW-78 80B-92	6-28-78				0.1
10	283	993	1	D	1978	1	3	101.0	Y	3	260	NW-78 80B-92	6-28-78				0.1
10	284	993	1	D	1978	1	3	44.9	Y	3	220	NW-78 80B-92	6-28-78				0.1
11	285i	993	2	D	1983	1	2	20.0	Y	2	1200	NW-C-83 18-67-065	6-7-83				0.2
11	285r	993	2	D	1983	1	2	20.0	Y	2	1200	NW-C-83 18-67-065	6-7-83				0.7
10	286	993	4	D	1983	8	2	99.3	Y	2	1100	NW-C-83 18-67-065	6-7-83	DD		D	12.5
10	287	993	4	P	1983	8	2	67.1	Y	3	1080	NW-C-83 18-67-065	6-7-83	DI		P	2.5
10	288	993	4	D	1983	8	2	54.2	Y	3	760	NW-C-83 18-67-063	6-7-83	DD		D	0.8
10	289	993	2	P	1983	1	2	60.1	Y	2	1065	NW-C-83 18-67-063	6-7-83				0.8
10	290	993	4	Q	1983	8	2	52.6	Y	2	1100	NW-C-83 18-67-063	6-7-83	R		Q	5.7
10	291	993	1	D	1983	1	2	60.3	Y	3	740	NW-C-83 18-67-063	6-7-83				0.1
10	292	993	1	P	1983	1	1	108.7	Y	3	880	NW-C-83 18-67-063	6-7-83				0.6
10	293	993	1	P	1983	1	4	102.9	Y	3	920	NW-C-83 18-67-063	6-7-83				0.6
10	294	993	4	P	1983	8	1	25.0	Y	2	920	NW-C-83 18-67-063	6-7-83	DI		P	4.3
10	295	993	1	D	1983	1	2	121.4	Y	3	800	NW-C-83 18-67-063	6-7-83				0.3
10	296	993	2	P	1983	5	1	71.3	Y	3	790	NW-C-83 18-67-063	6-7-83				1.0
10	297	993	2	P	1983	5	1	33.5	Y	3	800	NW-C-83 18-67-063	6-7-83				0.3
10	298	993	4	P	1983	8	1	46.2	Y	3	810	NW-C-83 18-67-063	6-7-83	DI		P	10.2
10	299	993	1	D	1983	1	1	127.5	Y	3	810	NW-C-83 18-67-063	6-7-83				0.3
10	300	993	4	P	1983	8	2	143.1	Y	3	700	NW-C-83 18-67-063	6-7-83	DI		P	1.2

10	301	993	4	P	1983	8	1	120.1	Y	3	800	NW-C-83	18-67-063	6-7-83	DI	P	0.8
10	302	993	4	Q	1983	8	2	67.0	Y	2	775	NW-C-83	18-67-063	6-7-83	R	Q	2.4
10	303	993	1	D	1983	1	1	20.9	I	3	700	NW-C-83	18-67-061	6-7-83			0.1
1	304	993	1	P	1983	7	2	3.0	I	5	475	NW-C-83	18-67-057	6-7-83			0.0
1	305	993	1	D	1983	7	2	2.9	I	5	475	NW-C-83	18-67-057	6-7-83			0.0
1	306	993	1	P	1983	7	2	2.9	I	5	475	NW-C-83	18-67-057	6-7-83			0.0
1	307	993	1	D	1983	7	2	3.0	I	5	475	NW-C-83	18-67-057	6-7-83			0.1
1	308	993	1	P	1983	7	2	1.5	I	5	475	NW-C-83	18-67-057	6-7-83			0.1
1	309	993	1	P	1983	7	2	1.5	I	5	485	NW-C-83	18-67-057	6-7-83			0.1
3	310	993	4	Q	1983	8	1	31.7	I	2	300	NW-C-83	18-66-013	6-7-83	R	Q	1.7
3	311	993	2	Q	1983	4	1	6.6	P	2	230	NW-C-83	18-66-013	6-7-83			1.1
3	312	993	4	P	1983	8	1	30.3	I	2	300	NW-C-83	18-66-013	6-7-83	DI	P	1.5
3	313	993	4	D	1983	8	1	24.9	I	2	340	NW-C-83	18-66-013	6-7-83	DD	D	5.9
3	314	993	4	P	1983	8	1	63.8	I	2	310	NW-C-83	18-66-013	6-7-83	DI	P	1.4
3	315	993	4	P	1983	8	1	39.5	I	2	260	NW-C-83	18-66-013	6-7-83	DI	P	1.2
9	317i	993	2	D	1983	1	2	60.0	Y	5	1400	NW-C-83	18-68-110	6-7-83			0.1
9	317r	993	2	D	1983	1	2	60.0	Y	5	1400	NW-C-83	18-68-110	6-7-83			1.2
3	318i	993	2	P	1983	1	2	23.2	Y	5	1500	NW-C-83	18-68-110	6-7-83			0.2
3	318r	993	2	P	1983	1	2	23.2	Y	5	1500	NW-C-83	18-68-110	6-7-83			1.3
9	319	993	1	D	1983	1	3	75.5	Y	2	1140	NW-C-83	18-68-110	6-7-83			0.4
9	327	993	4	P	1983	8	3	82.2	Y	3	975	NW-C-83	18-68-108	6-7-83	DI	P	1.9
10	331	993	4	D	2005	8	2	88.7	Y	3	810	Field			AR	D	0.6
10	332	993	1	D	1983	1	5	111.7	P	3	800	NW-C-83	18-68-108	6-7-83			0.1
10	333	993	1	D	1983	1	3	27.5	Y	3	785	NW-C-83	18-68-108	6-7-83			0.0
10	334	993	4	P	1983	8	1	32.0	P	2	860	NW-C-83	18-68-108	6-7-83	DI	P	1.1
10	335	993	1	P	1983	1	5	118.1	P	3	805	NW-C-83	18-68-108	6-7-83			0.1
10	336	993	7	D	1983	1	3	180.3	Y	3	805	NW-C-83	18-68-106	6-7-83			0.1
10	337	993	1	D	1983	1	3	196.1	Y	3	780	NW-C-83	18-68-106	6-7-83			0.1
10	338	993	8	P	1983	1	3	78.2	Y	3	775	NW-C-83	18-68-106	6-7-83			0.2
10	339	993	1	P	1983	1	3	152.8	Y	3	705	NW-C-83	18-68-106	6-7-83			0.1
10	340	993	8	D	1983	1	3	116.3	Y	3	725	NW-C-83	18-68-106	6-7-83			0.1
10	341	993	4	P	1983	8	2	195.1	Y	3	705	NW-C-83	18-68-106	6-7-83	DI	P	0.5
10	342	993	4	P	1983	8	4	209.7	Y	3	775	NW-C-83	18-68-106	6-7-83	DI	P	0.8
10	343	993	1	P	1983	5	2	108.0	Y	3	585	NW-C-83	18-68-104	6-7-83			0.2
3	344	993	1	D	1983	1	2	101.4	Y	3	550	NW-C-83	18-68-104	6-7-83			0.1
1	345	993	1	D	1983	7	1	9.4	I	5	765	NW-C-83	18-69-147	6-7-83			0.2
1	346	993	1	D	1983	7	3	0	I	5	745	NW-C-83	18-69-147	6-7-83			0.0
3	347	993	1	D	1983	7	3	0	I	5	745	NW-C-83	18-69-147	6-7-83			0.0

3	348	993	1	D	1983	7	1	12.8	P	5	805	NW-C-83	18-69-147	6-7-83			0.0
8	349	993	1	D	1983	7	3	12.5	I	5	905	NW-C-83	18-69-147	6-7-83			0.0
8	350	993	1	Q	1983	4	3	66.0	P	2	1395	NW-C-83	18-69-150	6-7-83			0.3
3	351	993	1	P	1983	4	4	149.9	Y	2	1325	NW-C-83	18-69-150	6-7-83			0.7
3	352	993	1	P	1983	4	2	33.6	I	2	1660	NW-C-83	18-69-150	6-7-83			0.6
3	353	993	1	D	1983	4	3	21.5	I	2	2440	NW-C-83	18-69-150	6-7-83			0.3
3	354i	993	2	D	1983	1	3	44.1	P	2	2340	NW-C-83	18-69-150	6-7-83			0.1
12	354r	993	2	D	1983	1	3	44.1	P	2	2340	NW-C-83	18-69-150	6-7-83			0.4
12	355i	993	2	P	1983	1	3	60.6	P	2	2140	NW-C-83	18-69-150	6-7-83			0.1
3	355r	993	2	P	1983	1	3	60.6	P	2	2140	NW-C-83	18-69-150	6-7-83			0.3
3	356	993	1	D	1983	4	3	55.0	I	5	2140	NW-C-83	18-69-152	6-7-83			0.2
3	357i	993	2	P	1983	1	2	42.9	P	5	2135	NW-C-83	18-69-152	6-7-83			0.2
3	357r	993	2	P	1983	1	2	42.9	P	5	2135	NW-C-83	18-69-152	6-7-83			1.1
3	358i	993	2	P	1983	1	3	34.6	Y	2	2060	NW-C-83	18-69-152	6-7-83			0.2
3	358r	993	2	P	1983	1	3	34.6	Y	2	2060	NW-C-83	18-69-152	6-7-83			0.3
3	362	993	1	D	1983	4	3	41.3	I	5	1525	NW-C-83	18-69-152	6-7-83			0.1
3	363	993	4	D	1958	8	4	35.3	Y	2	295	WSF-S-8	11-46		DI	D	2.5
3	364	993	4	P	1958	8	5	16.1	Y	2	260	WSF-S-8	11-46		DI	P	1.8
3	365	993	4	P	1958	8	1	44.5	Y	2	345	WSF-S-8	11-46		DI	P	11.8
3	366	993	4	D	1958	8	3	35.6	I	2	280	WSF-S-8	11-46		DI	D	0.4
8	367	993	1	D	1958	4	3	12.1	I	2	280	WSF-S-8	11-46				0.0
3	368	993	4	D	1958	8	3	63.6	I	2	300	WSF-S-8	11-46		DD	D	1.2
3	369	993	7	D	1958	4	3	71.2	P	2	415	WSF-S-8	11-46				0.3
8	370	993	1	D	1958	4	1	56.5	I	5	410	WSF-S-8	11-48				0.0
3	371	993	1	D	1958	4	1	64.5	I	5	415	WSF-S-8	11-48				0.0
3	372	993	1	D	1958	4	1	49.3	I	5	380	WSF-S-8	11-48				0.0
8	373	993	1	D	1958	4	1	54.3	I	5	395	WSF-S-8	11-48				0.0
8	374	993	1	D	1958	4	1	65.2	I	5	320	WSF-S-8	11-48				0.0
8	375	993	1	D	1958	4	1	65.0	I	5	320	WSF-S-8	11-48				0.0
8	376	993	1	D	1958	7	3	41.8	I	5	440	WSF-S-8	11-48				0.0
10	377	993	1	D	1958	7	3	43.4	I	5	440	WSF-S-8	11-48				0.0
10	378	993	1	D	1958	1	3	103.3	Y	3	445	WSF-S-8	12B-36				0.1
10	379	993	1	D	1958	1	5	84.1	Y	3	420	WSF-S-8	12B-36				0.1
3	380	993	1	D	1958	5	3	123.3	Y	3	520	WSF-S-8	12B-36				0.0
3	384i	993	2	D	1958	1	3	28.7	P	5	1445	WSF-S-8	13-58				0.5
3	384r	993	2	D	1958	1	3	28.7	P	5	1445	WSF-S-8	13-58				0.8
3	385i	993	2	D	1958	1	4	42.3	Y	5	1720	WSF-S-8	15B-7				0.1
9	385r	993	2	D	1958	1	4	42.3	Y	5	1720	WSF-S-8	15B-7				0.7

9	387i	993	2	D	1958	1	1	61.3	P	1	2200	WSF-S-8 15B-7				0.1
11	387r	993	2	D	1958	1	1	61.3	P	1	2200	WSF-S-8 15B-7				0.8
11	390i	993	2	D	1958	1	1	44.1	Y	2	2320	WSF-S-8 15B-5				0.1
9	390r	993	2	D	1958	1	1	44.1	Y	2	2320	WSF-S-8 15B-5				0.3
9	391i	993	2	P	1958	1	3	68.1	P	2	2410	WSF-S-8 15B-5				0.1
3	391r	993	2	P	1958	1	3	68.1	P	2	2410	WSF-S-8 15B-5				0.4
3	392i	993	2	P	1958	1	1	51.0	Y	2	2360	WSF-S-8 15B-5				0.1
10	392r	993	2	P	1958	1	1	51.0	Y	2	2360	WSF-S-8 15B-5				0.4
3	393	993	1	D	1958	5	5	98.6	Y	3	585	WSF-S-8 12B-36				0.3
10	394	993	4	Q	1991	8	1	39.7	I	2	300	NW91 15 65-65 7-7-91	DI		Q	5.2
10	395	993	4	Q	1991	8	2	14.2	Y	2	220	NW91 15 66-106 7-7-91	R		Q	1.9
3	396	993	1	D	1991	1	4	39.1	Y	3	220	NW91 15 66-106 7-7-91				0.1
3	397	993	4	Q	1991	8	4	57.0	I	2	520	NW91 15 66-106 7-7-91	R		Q	11.9
8	398	993	4	P	1991	8	1	41.2	I	2	320	NW91 30 67-2 9-5-91	DI		P	5.2
8	399	993	2	P	1991	4	3	92.2	Y	2	380	NW91 30 67-2 9-5-91				0.4
3	400	993	4	P	1991	8	2	68.5	Y	2	275	NW91 30 67-2 9-5-91	AR	E	P	0.5
8	401	993	2	P	1991	4	3	46.0	I	2	395	NW91 30 67-2 9-5-91				0.2
3	402	993	4	P	1991	8	2	48.7	I	2	460	NW91 30 67-2 9-5-91	DI		P	1.8
10	403	993	4	P	1991	8	3	56.1	I	3	510	NW91 30 67-2 9-5-91	DI		P	0.8
10	404	993	4	P	1991	8	3	72.7	Y	3	200	NW91 30 67-4 9-5-91	DI		P	0.4
10	405	993	4	P	1991	8	3	61.8	Y	3	290	NW91 30 67-4 9-5-91	DI	E	P	0.4
10	406	993	4	Q	1991	8	5	71.4	Y	3	400	NW91 30 67-4 9-5-91	R		Q	1.6
10	407	993	4	Q	1991	8	1	118.1	Y	3	430	NW91 30 67-4 9-5-91	R		Q	1.3
10	408	993	4	Q	1991	8	1	89.3	Y	3	510	NW91 30 67-6 9-5-91	R		Q	0.6
3	410	993	4	Q	1991	8	1	37.3	I	3	685	NW91 30 67-8 9-5-91	R		Q	6.3
3	411	993	1	D	1991	7	1	15.1	I	5	760	NW91 30 68-50 9-5-91				0.1
11	412	993	1	D	1991	7	3	32.8	I	5	735	NW91 30 68-50 9-5-91				0.1
9	413	993	4	P	1991	8	1	128.6	Y	2	1295	NW91 30 68-58 9-5-91	DI		P	0.4
3	414	993	4	Q	1991	8	1	91.8	Y	2	1245	NW91 30 68-58 9-5-91	R		Q	2.6
3	415i	993	2	P	1991	1	1	44.5	Y	5	1600	NW91 30 68-58 9-5-91				0.1
3	415r	993	2	P	1991	1	1	44.5	Y	5	1600	NW91 30 68-58 9-5-91				0.2
3	416i	993	2	P	1991	1	2	20.9	Y	5	1610	NW91 30 68-58 9-5-91				0.1
3	416r	993	2	P	1991	1	2	20.9	Y	5	1610	NW91 30 68-58 9-5-91				0.3
3	417i	993	2	Q	1991	1	2	20.4	P	5	1610	NW91 30 68-58 9-5-91				0.0
3	417r	993	2	Q	1991	1	2	20.4	P	5	1610	NW91 30 68-58 9-5-91				0.1
3	418i	993	2	Q	1991	1	2	38.5	Y	5	1610	NW91 30 68-58 9-5-91				0.0
3	418r	993	2	Q	1991	1	2	38.5	Y	5	1610	NW91 30 68-58 9-5-91				0.2
3	419i	993	2	Q	1991	1	2	20.0	Y	5	1610	NW91 30 68-58 9-5-91				0.0

3	419r	993	2	Q	1991	1	2	20.0	Y	5	1610	NW91 30 68-58 9-5-91				0.1	
3	420i	993	2	Q	1991	1	2	19.7	Y	5	1610	NW91 30 68-58 9-5-91				0.0	
3	420r	993	2	Q	1991	1	2	19.7	Y	5	1610	NW91 30 68-58 9-5-91				0.2	
3	421i	993	2	P	1991	1	2	25.3	Y	5	1610	NW91 30 68-58 9-5-91				0.0	
9	421r	993	2	P	1991	1	2	25.3	Y	5	1610	NW91 30 68-58 9-5-91				0.2	
4	422	993	1	D	1991	4	3	78.1	I	5	1615	NW91 30 68-58 9-5-91				0.1	
4	423	993	1	D	1991	7	3	7.8	I	5	885	NW91 31 69-268 9-5-91				0.2	
3	424	993	1	D	1991	7	3	26.1	I	5	885	NW91 31 69-268 9-5-91				0.1	
3	426i	993	2	P	1991	1	1	43.3	Y	5	1885	NW91 31 71-34 9-9-91				0.2	
3	426r	993	2	P	1991	1	1	43.3	Y	5	1885	NW91 31 71-34 9-9-91				0.7	
3	427i	993	2	P	1991	1	2	50.0	Y	5	1845	NW91 31 71-34 9-9-91				0.1	
3	427r	993	2	P	1991	1	2	50.0	Y	5	1845	NW91 31 71-34 9-9-91				1	
3	428i	993	2	P	1991	1	2	40.0	Y	5	2105	NW91 31 71-34 9-9-91				0.3	
3	428r	993	2	P	1991	1	2	40.0	Y	5	2105	NW91 31 71-34 9-9-91				1.9	
3	431i	993	2	P	1998	1	3	51.7	P	5	1710	Ortho				0.2	
9	431r	993	2	P	1998	1	3	51.7	P	5	1710	Ortho				0.5	
9	432i	993	2	P	1994	1	1	55.1	Y	5	1705	Ortho				0.2	
9	432r	993	2	P	1994	1	1	55.1	Y	5	1705	Ortho				0.9	
9	440	993	1	D	1983	4	3	82.4	P	2	2480	NWC 83 18-71-237				0.1	
9	441	993	1	D	1983	4	3	94.3	P	7	3000	NWC 83 18-71-237				0.1	
9	442	993	1	D	1983	4	3	87.4	P	7	3000	NWC 83 18-71-237				0.1	
3	443	993	4	D	1983	8	3	91.2	Y	7	3040	NWC 83 18-71-237	AR	E	D	2.6	
3	444i	993	2	D	1983	1	2	46.8	Y	2	1530	NWC 83 18-71-237				0.1	
9	444r	993	2	D	1983	1	2	46.8	Y	2	1530	NWC 83 18-71-237				0.7	
9	445r	993	2	D	1983	1	1	74.9	Y	2	2560	NWC 83 18-71-237				0.8	Initiated by 446
9	446	993	1	D	1983	2	3	79.3	P	2	2645	NWC 83 18-71-237				0.4	
9	447i	993	2	D	1998	1	3	75.7	P	5	2915	Ortho				0.1	
12	447r	993	2	D	1998	1	3	75.7	P	5	2915	Ortho				0.5	
12	448i	993	2	D	1998	1	3	77.7	P	5	2890	Ortho				0.1	
3	448r	993	2	D	1998	1	3	77.7	P	5	2890	Ortho				0.5	
3	449i	993	2	D	1998	1	2	74.8	Y	5	3000	Ortho				0.1	
3	449r	993	2	D	1998	1	2	74.8	Y	5	3000	Ortho				1.8	
3	450i	993	2	D	1998	1	3	55.8	Y	5	3045	Ortho				0.3	
11	450r	993	2	D	1998	1	3	55.8	Y	5	3045	Ortho				0.7	
11	451i	993	2	D	1998	1	2	71.1	Y	2	2690	Ortho				0.1	
9	451r	993	2	D	1998	1	2	71.1	Y	2	2690	Ortho				0.5	
9	452i	993	2	D	1983	1	2	66.6	Y	2	2810	NWC 83 18-71-237				0.1	
9	452r	993	2	D	1983	1	2	66.6	Y	2	2810	NWC 83 18-71-237				0.7	

9	453i	993	2	D	1983	1	2	75.4	Y	2	2745	NWC 83 18-71-237	0.2
9	453r	993	2	D	1983	1	2	75.4	Y	2	2745	NWC 83 18-71-237	0.6
9	454i	993	2	D	1983	1	2	71.3	Y	5	2090	NWC 83 18-71-237	0.1
3	454r	993	2	D	1983	1	2	71.3	Y	5	2090	NWC 83 18-71-237	1
3	455i	993	2	D	1983	1	4	39.0	Y	5	1840	NWC 83 18-71-237	0.1
3	455r	993	2	D	1983	1	4	39.0	Y	5	1840	NWC 83 18-71-237	1.4
3	456i	993	2	D	1983	1	3	39.9	Y	5	1790	NWC 83 18-71-237	0.2
3	456r	993	2	D	1983	1	3	39.9	Y	5	1790	NWC 83 18-71-237	1
3	457i	993	2	D	1983	1	4	26.4	Y	5	1680	NWC 83 18-71-237	0.1
9	457r	993	2	D	1983	1	4	26.4	Y	5	1680	NWC 83 18-71-237	1
9	459i	993	2	D	1991	1	1	75.0	P	5	2430	Field	0.1
9	459r	993	2	D	1991	1	1	75.0	P	5	2430	Field	0.4
9	460i	993	2	D	1991	1	2	56.7	P	5	1790	Ortho	0
11	460r	993	2	D	1991	1	2	56.7	P	5	1790	Ortho	0.7

Appendix B - Form A-3: Mass Wasting Summary Table

Mass Wasting Summary Table

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)		2				2
2 = young stands (timber 5-15 yrs)	14	65		38	2	119
3 = submature timber (15-50 years)	51	4	3	48	1	107
4 = mature timber (>50 years)						
5 = road	30	146	1		1	178
6 = partial cut						
7 = yarding	2			1		3
8 = alpine						
9 = other- e.g., housing, agriculture	2					2

Landform 6 (from Landform 3 data)

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)						
2 = young stands (timber 5-15 yrs)	3	16		18	1	38
3 = submature timber (15-50 years)	7			1		8
4 = mature timber (>50 years)						
5 = road	9	69		1	1	79
6 = partial cut						
7 = yarding				1		1
8 = alpine						
9 = other- e.g., housing, agriculture						

Landform 8

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)						
2 = young stands (timber 5-15 yrs)	2	3		3		8
3 = submature timber (15-50 years)	3					3
4 = mature timber (>50 years)						
5 = road	18					18
6 = partial cut						
7 = yarding						
8 = alpine						
9 = other- e.g., housing, agriculture	1					1

Landform 9

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)		1				1
2 = young stands (timber 5-15 yrs)	6	32		5		43
3 = submature timber (15-50 years)				1		1
4 = mature timber (>50 years)						
5 = road	1	59	1	1		62
6 = partial cut						
7 = yarding	2					2
8 = alpine						
9 = other- e.g., housing, agriculture						

Landform 10

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)						
2 = young stands (timber 5-15 yrs)		2		12		14
3 = submature timber (15-50 years)	37	2	2	45	1	87
4 = mature timber (>50 years)						
5 = road	1					1
6 = partial cut						
7 = yarding						
8 = alpine						
9 = other- e.g., housing, agriculture						

Landform 11

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)		1				1
2 = young stands (timber 5-15 yrs)	3	4				7
3 = submature timber (15-50 years)	1			1		2
4 = mature timber (>50 years)						
5 = road	1	8				9
6 = partial cut						
7 = yarding						
8 = alpine						
9 = other- e.g., housing, agriculture	1					1

Landform 12

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)						
2 = young stands (timber 5-15 yrs)		8			1	9
3 = submature timber (15-50 years)		1	1			2
4 = mature timber (>50 years)						
5 = road		10				10
6 = partial cut						
7 = yarding						
8 = alpine						
9 = other- e.g., housing, agriculture						

Landform 13

Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	Total
1 = clearcut (timber 0-5 yrs)						
2 = young stands (timber 5-15 yrs)						
3 = submature timber (15-50 years)	3	1				4
4 = mature timber (>50 years)						
5 = road						
6 = partial cut						
7 = yarding						
8 = alpine						
9 = other- e.g., housing, agriculture						

Appendix C - Form A-4: Landslide Area Hazard Rates

Landforms	**Landform 1**	**Landform 2**	**Landform 3**	**Landform 4**	**Landform 5**	**Landform 6 (see Landform 3)**	**Landform 7**	**Landform 8**	**Landform 9**	**Landform 10**	**Landform 11**	**Landform 12**	**Landform 13**	**Total WAU**
Years	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Landform Area	4853.700	1364.50	12023.73	1608.70	148.46	10.00	197.25	197.07	746.18	455.50	89.31	33.16	27.14	21754.70
Number of 'Delivering' Landslides	0.00	0.00	71.00	0.00	0.00	71.00	0.00	19.00	96.00	47.00	17.00	20.00	4.00	345.00
Area of 'Delivering' Landslides (acres)	0.00	0.00	39.04	0.00	0.00	39.04	0.00	5.11	48.55	10.99	9.91	18.97	0.62	172.23
Landslide Frequency Rate (Number of slides/Landform Area/Years) x 10^6	0.00	0.00	218.70	0.00	0.00	262963	0.00	3570.83	4765.01	3821.60	7049.93	22338.38	5458.66	587.36
Landslide Area Rate for Delivery (Delivering Landslide Area/Landform Area/Years) x 10^6	0.00	0.00	120.26	0.00	0.00	144592.59	0.00	960.37	2409.80	893.60	4109.70	21187.96	846.09	293.22
Overall Rating	Low	Low	Medium	Low	Low	Very High	Moderate*	Very High	Very High	Very High	Very High	Very High	Very High	High

Without Roads

Landforms	Landform 1	Landform 2	Landform 3	Landform 4	Landform 5	Landform 6 (see Landform 3)	Landform 7	Landform 8	Landform 9	Landform 1(	Landform 1:	Landform 1:	Landform 1:	Total WAU
Years	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Landform Area	4853.700	1364.50	12023.73	1608.70	148.46	10.00	197.25	197.07	746.18	455.50	89.31	33.16	27.14	21754.70
Number of 'Delivering' Landslides	0.00	0.00	25.00	0.00	0.00	25.00	0.00	10.00	38.00	46.00	11.00	10.00	4.00	144.00
Area of 'Delivering' Landslides (acres)	0.00	0.00	7.95	0.00	0.00	7.95	0.00	3.28	16.67	10.97	4.78	13.49	0.62	57.76
Landslide Frequency Rate (Number of slides/Landform Area/Years) x 10^6	0.00	0.00	77.01	0.00	0.00	92592.59	0.00	1879.38	1886.15	3740.29	4561.72	11169.19	5458.66	245.16
Landslide Area Rate for Delivery (Delivering Landslide Area/Landform Area/Years) x 10^6	0.00	0.00	24.49	0.00	0.00	29444.44	0.00	616.44	827.42	891.98	1982.28	15067.24	846.09	98.34
Overall Rating	Low	Low	Low	Low	Low	Very High	Moderate	Very High	Very High	Very High	Very High	Very High	Very High	Moderate