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Factors Contributing to Landslide Activity in the Winter of 1995-96, Clearwater County Near Orofino, Idaho

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FACTORS CONTRIBUTING TO LANDSLIDE ACTIVITY IN THE WINTER OF 1995-96, CLEARWATER COUNTY NEAR OROFINO, IDAHO

A Thesis

Presented to

The Graduate Faculty

Central Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Geology

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by

Aaron Paul Wisher

November, 1998

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

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Candidate for the degree of Master of Science

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ABSTRACT

FACTORS CONTRIBUTING TO LANDSLIDE ACTIVITY IN THE WINTER OF 1995-96, CLEARWATER COUNTY NEAR OROFINO, IDAHO

By

Aaron Paul Wisher

November, 1998

Significant landslide activity occurred in Clearwater County, Idaho in November 1995 and February-May 1996. Mass wasting in the study area consisted of debris slides and earthflows triggered by rain-on-snow weather events. It is important to determine what factors contribute to landsliding in this area so that reliable prediction can reduce the destruction of property. Through field observation and aerial photo analysis, the factors contributing to landslides were studied. The objectives included a study of the geology, soils, aspect, slope gradient, vegetation and slope position related to each slide. Also a goal was to assess the role of land use in triggering landslides, analyze climatic conditions during precipitation events, and to create a landslide hazard map of the Orofino, Idaho area.

Thirty-two landslides were identified in the study area. Forty-one percent of landslides were produced at sites impacted by roads, and involved either the road prism or artificial channel areas. Most of the landslides were associated with roads, and occurred at lower slope gradients than those found in forested areas. Most landslides originated on slope gradients of 30-50%. Forested slopes account for the steepest gradients, and frequently have a northerly aspect. Landslide activity occurred most frequently in soils with a basalt parent material component. The largest volume landslides occurred in forested areas in which a geologic contact between basalt and metamorphic rocks created springs. Within some areas of the study region the bedrock geology has a greater role in landsliding than land use. Historically, the Southern Oscillation has been positive in the winter months when large rain-on-snow weather events have caused flooding in the study area.

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In addition, I would like to thank Lisa Ely, Jim Hinthorne, and Karl Lillquist for giving me invaluable comments, and for reviewing my thesis.

Finally, I wish to express my deepest gratitude to my family and friends. I especially want to thank Ruth Otteman, for her field assistance, office, and spiritual help in getting my thesis rolling.

DEDICATION

This thesis is dedicated to my parents, who ultimately provided me with the foundation to build upon.

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INTRODUCTION

Mass wasting processes occur in a variety of geologic and climatological environments. A detailed on-site study must be conducted to understand what factors are involved in a specific study region. Types of mass wasting can range from the slow downhill movement of intact materials (creep), to the rapid avalanche of surface materials. Mass wasting is the dynamic responses of a hillslope to prevailing conditions such as slope gradient, climate, hydrology, weathering, soil, geology, and land use. Commonly associated with increased mass wasting activity are changes in stream morphology, increased sedimentation (Lyons and Beschta, 1983; Beschta and Platts, 1986), reduced productivity of forest soils, including road, bridge, and facilities damage (Swanston and Swanson, 1976), and destruction of riparian zones and wildlife habitat (Megahan and others, 1978).

The focus of this study is a series of landslides that occurred in November 1995 and in the spring of 1996 in Clearwater County, near Orofino, Idaho (Figure 1). Historically, flooding in the Orofino Creek drainage has been accompanied by mass wasting activity. Flooding is not the cause of the landslides, but the heavy precipitation associated with increased runoff often leads to both flooding and landsliding (Appendix A). The use of flooding in this study as a proxy for landslide activity was essential due to the lack of direct records of precipitation in the study area.

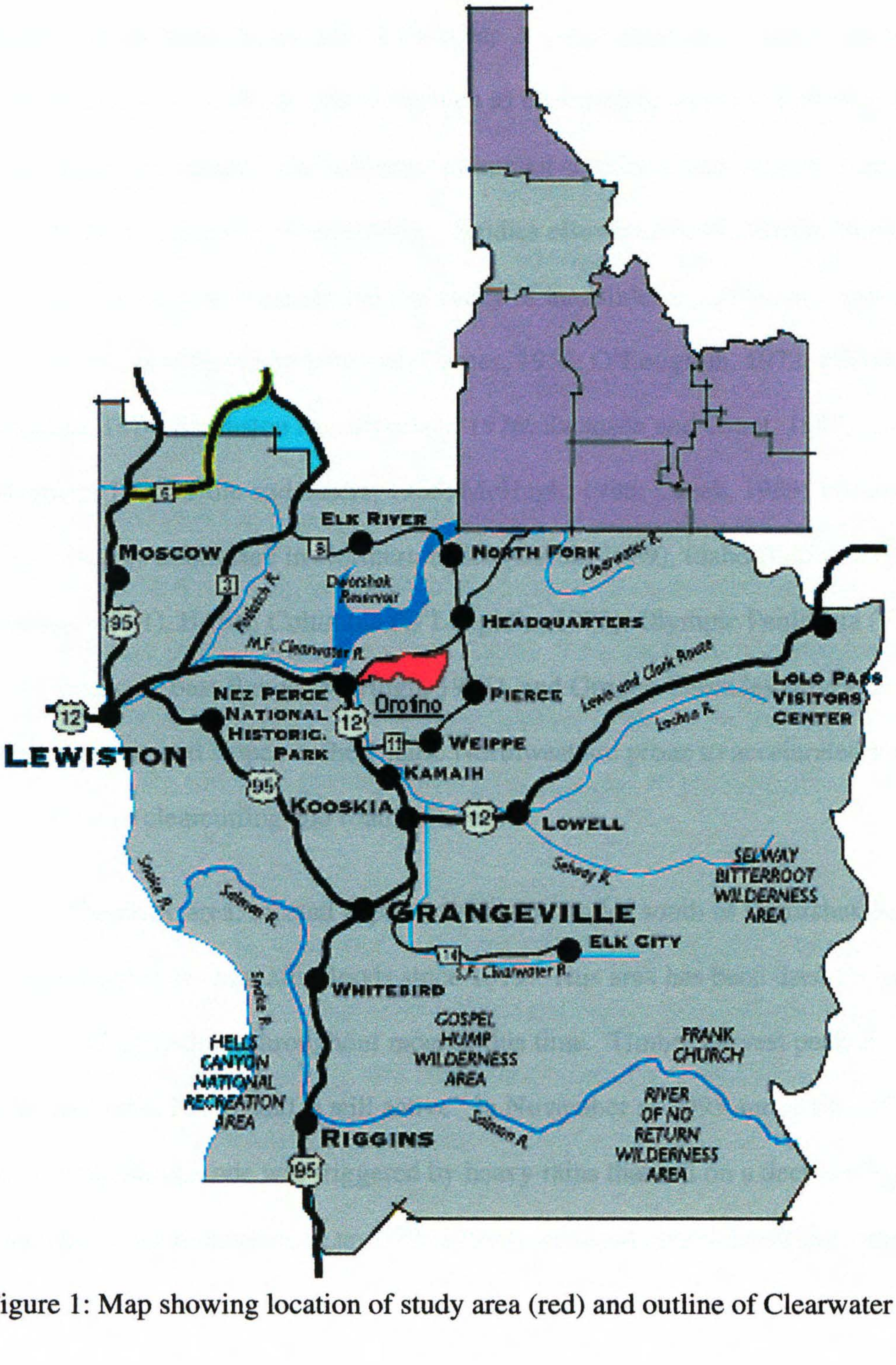


Figure 1: Map showing location of study area (red) and outline of Clearwater County.

The analysis of the factors contributing to these landslides was used to assess potential future landslide hazards in the area. A major objective of this study was to examine the role of land use practices, such as clearcutting and road building, on landslides in this region. The influence of human activity is well known to be a primary factor in the acceleration of landsliding. Studies elsewhere in the Pacific Northwest have shown several fold increases in the frequency of landslides in roaded or clearcut areas versus areas not affected by land use (Varnes, 1958; O'Loughlin, 1972; Fiksdal, 1974; Swanston, 1974; Swanston and Swanson, 1976; Swanson and Grant, 1982; Amaranthus and others, 1985; Sidle and others, 1985; McHugh, 1986; Cacek, 1989; Wieczorek, 1996). Studies conducted in Northern Idaho (Cacek, 1989), Idaho Batholith (Gray and Megahan, 1981), British Columbia (O'Loughlin, 1972), Olympic Peninsula (Fiksdal, 1974), Oregon Coast Range (McHugh, 1986), and Oregon Cascades (Marion, 1981) have shown that forested slopes in the Pacific Northwest are prone to accelerated mass wasting in response to clearcutting and road building.

The study area, located approximately two miles south of Dworshak Reservoir, has experienced seven major floods since 1919. This area has been used for both timber harvest and agriculture throughout most of this time. Timber harvest peaked in the late 1970s and early 1980s, and is still active. In November of 1995 and spring of 1996 a major landslide episode was triggered by heavy rains that fell on a deep widespread snowpack in the mountains. Landslide activity included debris landslides, and earthflows along the steep valley side slopes, resulting in significant damage to roads and bridges in the study area. Much of the damage was caused by deposition of landslide debris onto the road surface or erosion of the road prism.

Initially, causes of increased land failure were hypothesized by the author to be directly related to timber harvest and specifically the practice of clearcutting. Forest workers and contacts at the Potlatch Corporation suggested that the primary causes of the landsliding are the older outdated road-building techniques and increased frequency of rain-on-snow weather events. The influence of road design and forest practices has been an ongoing concern for forest, soil and timber researchers for many years. Researchers have found that new and improved road construction techniques and logging practices can dramatically reduce the frequency of landsliding along forest roads (Varnes, 1958, 1978; Sidle and others, 1985; Wieczorek, 1996). Rain-on-snow weather events are beginning to be recognized in the Pacific Northwest as one of the primary factors for regional flooding and mass wasting activity (Wieczorek, 1996; McClelland and others, 1997).

In the study area, numerous landslides occurred during one or two storm events in the same season, which provided an excellent opportunity to isolate the non-climatic controls on slope failure. Those data could then be used as a predictive tool for assessing the degree of landslide hazards in the area.

Objectives:

1. To determine what geologic, topographic, and land use conditions were present at each landslide that led to failure.

2. To determine what climatic conditions initiated flooding and mass wasting in the study area during the 1995-96 winter season.

3. To investigate whether there is a correlation between global weather phenomenon and local weather events.

4. To define what areas within the study might be prone to future landslide activity, and to develop a landslide hazard map for the area.

CHAPTER 1: PROJECT SETTING

INTRODUCTION

The project area is located in Clearwater County, Idaho near the town of Orofino (Figure 2). The area follows Orofino Creek from its confluence with the Clearwater River at Orofino to approximately section 7 of T 36 N R 4 E to the west. From Orofino Creek the study area extends south to the boundary of the Jim Ford Creek drainage basin. The study area comprises approximately 30 square miles.

This area is a combination of Indian reservation, state and private land, including land owned by the Potlatch Corporation. Potlatch Corporation land is concentrated in the eastern portion of the area while the Nez Perce Indian Reservation dominates the area to the west near Orofino.

Watersheds in this region of Idaho are part of the lower Snake River system and have a direct effect on water recreation, water transportation, irrigation, sport and commercial fisheries, and downstream hydroelectric projects.

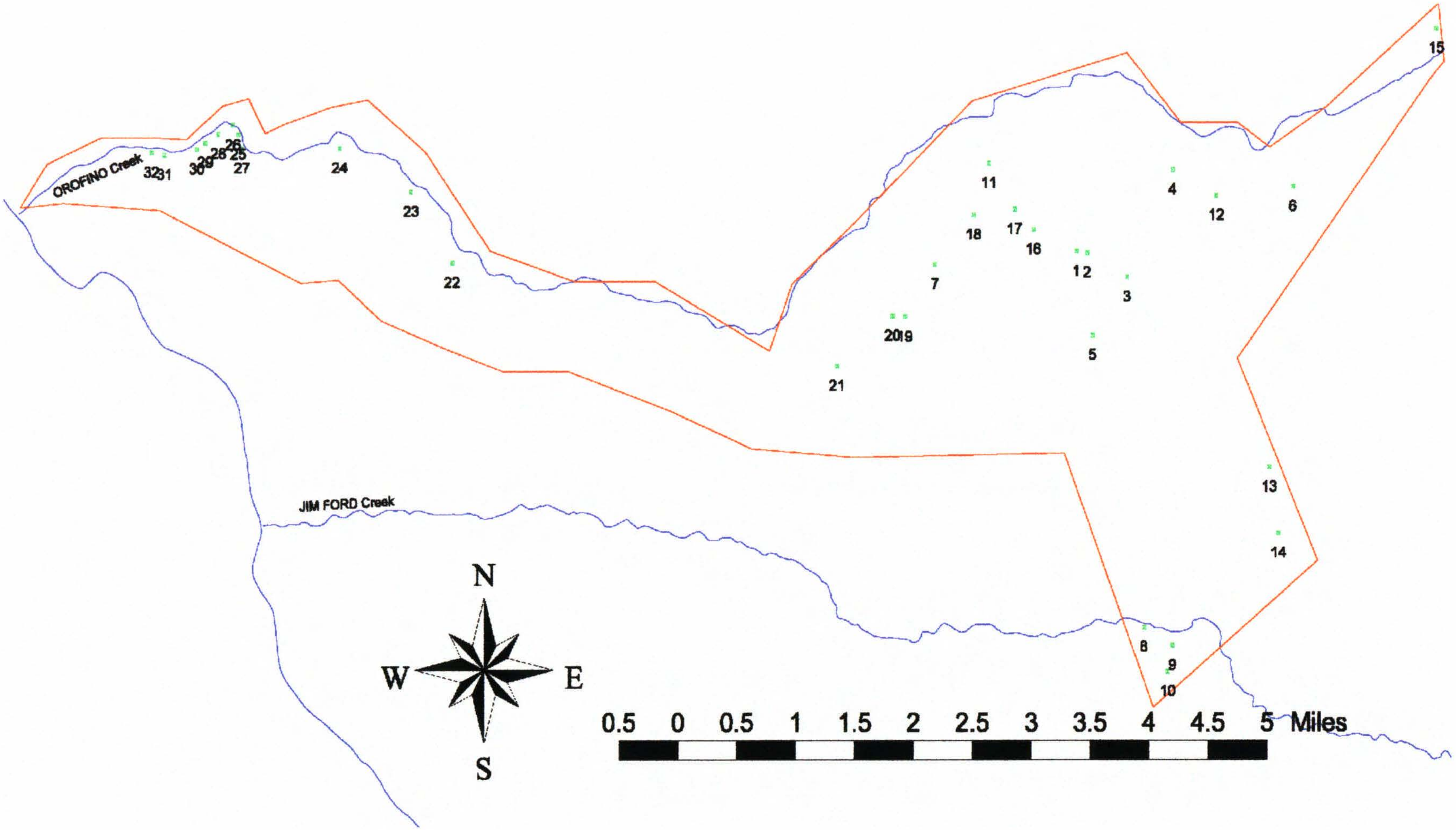


Figure 2: Map showing location of Landslide study sites.

This region is home to over 350 species of wildlife including moose, whitetail and moose deer, Rocky Mountain goats, mountain lions, black bears, and numerous small mammals and birds (Falter and Rabe, 1997). The northern bald eagle and gray wolf are listed as endangered species in the nearby Clearwater National Forest. Blue-ribbon cutthroat trout are an important fishery resource on many of the streams in this area. On larger streams such as Orofino creek, habitats for anadromous steelhead and chinook salmon are found.

Present primary range in the study consists of meadows interspersed with forestlands and private agricultural lands. In areas of timber harvest, temporary forage lands are produced.

GEOLOGY

The interpretation of the geology in the study area is based primarily on the work of Terry Maley in his book Exploring Idaho Geology (Maley, 1987), unless otherwise noted.

The geologic record covers about 2.5 billion years in this area. At that time, a sea was covering northern Idaho. The area in this study was near the mouth of a large bay extending east to Helena, Montana. Silt, clay, and fine sand were brought to the bay and deposited as siltstones, shales, and dirty sandstones. These became the lower Belt rocks, the Pritchard, Burke, Revett, St. Regis, and Wallace Formations. The only organisms living here at that time were the most primitive blue-green algae living in the oceans.

About 300 million years ago this area emerged from the sea that covered it, thought to be caused by a tectonic rise brought on by continental collision and volcanism near the Seven Devils area. Sediments continued to be deposited on the Belt rocks.

While volcanism continued in the area the intrusion of the Idaho Batholith was beginning. This body of granitic intrusive rock formed about 150 million years ago. The intrusion pushed the preexisting rocks upward, including the overlying Belt rocks. It was at this time that much faulting and mountain building was taking place along with intense deformation and metamorphism of the Belt rocks into schists and gniesses. The central part of the Idaho Batholith was implaced about 60 million years ago, during the early Tertiary period. Subsequent erosion stripped the upper rocks away exposing the lower Belt rocks, Border Zone, and newly formed batholith.

The project area is in the Columbia Plateau and Northern Rocky Mountains Geomorphic Provinces. The bedrock consists predominantly of Late Cretaceous rocks of the Idaho Batholith on the eastern side of the area, and Tertiary Columbia River basalt on the west. Rocks that are commonly deeply weathered have resulted in a grussic soil. Exposed surface soils derived from these materials are subject to severe surface and landslide erosion. Columbia River basalts are layered volcanic rocks, which in the field vary from hard slightly weathered rocks to extensively weathered rocks. The soils that result from these basalts are generally fine textured and cohesive. The southwest edge of the area consists of Cretaceous metamorphic rocks (orthogneiss) associated with the Idaho Batholith.

The portion of the watershed developed in granitics exhibits a large amount of topographic relief and the greatest channel density. This area is predominantly forestland with a small amount of hay and pastureland. All of the cropland and the majority of the hay and pastureland are in the west part of the study area, underlain by basalt bedrock. This area is typified by high, gently sloping uplands between deep, narrow canyon streams, indicating a relatively youthful watershed development in a rolling, dissected basalt plateau.

Materials resulting from stream erosion and deposition are called alluvium. Alluvium is found in all recent stream terraces adjacent to major streams and old terraces and bottomlands. Soils developed in alluvium commonly are well-developed silty soils and have associated with them high water tables and fragipans. These soils range from fine textured silts to coarse gravels.

GEOMORPHOLOGY

The geomorphology of the study area is influenced by the regional geology of the area. Streams drain steep precipitous landscapes with elevations ranging from 980 ft. at the Clearwater River to about 3,300 ft. in the eastern portion of the study area. The landforms in the area have been categorized as follows by Falter and Rabe of the United States Department of the Interior (1996).

- Breaklands are oversteepened slopes resulting from uplifting of the land surface and subsequent downcutting of rivers and streams. The slope gradient is commonly greater than 60%. The bedrock is weakly to moderately weathered with weakly developed colluvial soils. This type of landform is considered to be one of the most unstable in the area (Bruce Hanson, NRCS, Orofino, personal communication, 1997).

- Mountain slopes have formed by fluvial and colluvial processes. The ridges are generally convex and the sideslopes are straight. Slope gradient generally ranges from 35 to 60%. Bedrock weathering is variable with weakly to moderately developed soils (McClelland and others, 1997).

- Gentle hills consist of gently to moderately sloping hills with less than 400 feet of relief. These landforms are the result of shallow stream dissection of deeply weathered surfaces (Bruce Hanson, NRCS, Orofino, personal communication, 1997). Slope gradient ranges from 20 to 40%. Soils are deep and extensively weathered.

- Mass wasting landforms consist of historical large-scale mass movements including debris avalanches, slumps, and deep-seated failures. These landforms tend to have a step-like topography and slope gradient ranging from 20 to 60%.

- Valley landforms include terraces both recent and ancient, debris fans, and colluvial toeslopes. Slope gradient ranges from 30% on terraces to 60% on toeslopes and eroded terraces. The soils are weakly developed and often have drainage problems.

FLUVIAL HISTORY

The Clearwater River drainage has experienced several landslide and floods events. Major landsliding and flooding occurred in 1919, 1933 (December 23), 1948 (May 28 to June 1), 1964 (December 21-23), 1968, 1974 (January 13-17), and most recently 1995 (November) and 1996 (February and during spring thaw). For most of these floods, there are reliable streamflow records. Flooding in the study area is usually associated with landslides. There are no records of major landsliding episodes during non-flood periods. Flooding is not the cause of the landsliding, it is an indicator of increased precipitation.

There is no information readily available to assess the 1919 floods and landslides. The 1919 flood event was recorded by the Clearwater History museum in Orofino, Idaho. In 1933 the largest flow ever recorded on the St. Joe River, and the third largest on the North Fork Clearwater, Clearwater, and the Lochsa Rivers was recorded. These rivers were correlated to flood activity on the smaller Orofino Creek and other streams in the study area. There was extensive flooding in the town of Orofino as seen in the photograph in Figure 3. There were major landslides associated with this event, but they have never been studied in detail (McClelland and others, 1997).

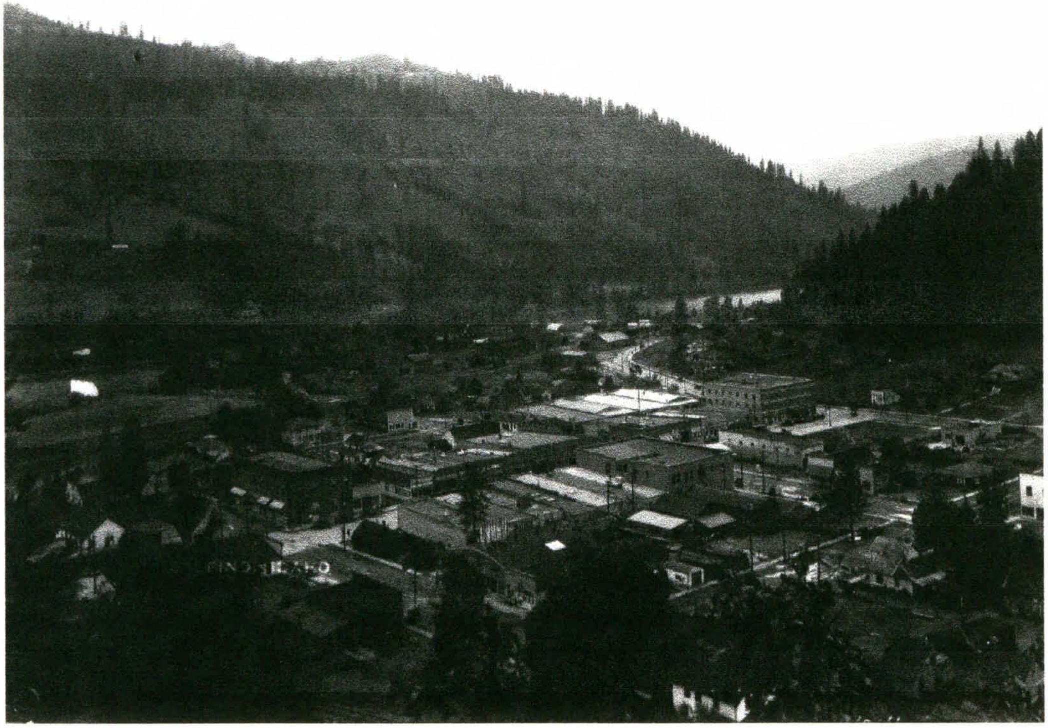


Figure 3: Photograph of flooding in 1933 near Orofino, Idaho.

In 1948 there was also extensive flooding in Orofino and along the Clearwater River (Figures 4 through 8). These were the largest floods ever recorded on the Lochsa and Selway Rivers. Anecdotal reports mentioned some landslide activity associated with the 1948 peak flows. Another large flood occurred in the area in 1964. Landslide activity from this event appears on aerial photographs. The 1964 flood was the second largest event on the Lochsa and third largest event on the Selway River. Figure 9 shows flooding in 1964 near the town of Orofino, Idaho.

Figure 4: Photograph of flooding in 1948 near Orofino, Idaho.

Figure 5: Photograph of flooding in 1948 near Orofino, Idaho.

Figure 6: Photograph of flooding in 1948 near Orofino, Idaho.

Figure 7: Photograph of flooding in 1948 near Orofino, Idaho.

Figure 8: Photograph of flooding in 1948 near Orofino, Idaho.

Minor flooding occurred in Orofino in 1968 (Figure 10), for which no studies were conducted. One of the largest floods on Orofino Creek occurred in 1974. This was the largest event ever on the Cour d' Alene River and the second largest on the St. Maries and Palouse Rivers. This was also the year that Dworshak Reservoir was completed, just outside of Orofino. Landslides associated with the 1974 events were studied and documented by Megahan and others, 1978.

Figure 9: Photograph of flooding in 1964 near Orofino, Idaho.

Figure 10: Photograph of flooding in 1968 near Orofino, Idaho.

The landslide events of 1995-96 can be divided into three distinguishable episodes. The first occurred in November and December of 1995. The second occurred in February of 1996. The final episode took place during the spring melt of 1996. Precipitation in the Clearwater River drainage was nearly 200 percent of normal during the period October through November (McClelland and others, 1997). November 23 marked the beginning of 13 consecutive days of precipitation. The streamflows that followed were considered to be between 2 and 25-year flooding events by the USGS (U.S. Department of the Interior, 1996). The landslide events that were associated with the February storms were similar to those in November. These storms were characterized by warm temperatures and several days of rainfall on a widespread, deep snowpack. The streamflows that resulted were between 2 and 100-year events. The majority of landslide activity occurred during the spring snowmelt season according to U.S. Forest Service researchers. This was due to wet conditions from October 1995 to February 1997. Peak streamflows were not unusual during the spring snowmelt season.

Table 1 shows the dates of historical flood events in the study area related to Oregon and Washington. Oregon shares only three historic flooding events with the study area while Washington shares six. This suggests that the weather patterns that are responsible for many of the floods in the study likely move across Washington from the Pacific Ocean.

Table 1: Correlation of local flooding to widespread regional flooding in Oregon and Washington (Data from US Geological Survey Water-Supply paper 2375.)

Date of Flooding	Study Area (Idaho)	Oregon	Washington
November 30, 1919	X		
December 11-22, 1933	X		X
May 28-June 1, 1948	X	X	X
December 21-23, 1964	X	X	X
1968	X		
January 13-17, 1974	X		X
November 23-December 3, 1995	X		X
February 4-8, 1996	X		X
April and May, 1996	X	X	X

SOILS

Soils in this study area are located on several different landforms with a mixture of parent materials, and have been divided into four groups. These groups are based on soil classifications from the NRCS in Orofino, Idaho, containing eighteen different soil mapping units. The four groups are based on landform, soil depth, drainage efficiency, and water erosion hazard.

Alluvial soils are located along stream and river terraces and in basins (Group 1). Soils on the upland and plateau areas formed in loess and residuum with some volcanic ash in areas (Group 2). Steep canyon sides and occasional sloping benches have soils that formed in colluvium, residuum, and slope alluvium with the addition of loess and volcanic ash in places (Group 3). Foothills and mountainsides have soils that formed in colluvium, residuum, and slope alluvium usually from granite or basalt parent material. Most of these have a volcanic ash mantle of varying thickness (Group 4).

Appendix B contains a breakdown of the four groups, listing the soil map units within each group and an explanation for each of the major soils within the map units.

CHAPTER 2: WEATHER AND CLIMATE

Climate in the watershed is characterized by cool, wet winters, and long, warm, dry, summers. Temperatures and precipitation vary according to elevation. In the valleys, summer high temperatures above 90 degrees Fahrenheit are common, and 80 degree temperatures are common in the upland. January low temperatures average 29 degrees in the valleys and about 23 degrees on the higher plateaus. During the winter months, subzero temperatures are not uncommon.

PRECIPITATION

Rainfall patterns in the region vary greatly according to elevation. The average annual precipitation ranges from 24 inches at Orofino (elev. 1,100 ft.) to 43 inches at Pierce (elev. 3,188 ft.) to more than 70 inches at Hemlock Butte (elev. 5,810 ft.) just to the east of the study area. All elevations receive the least precipitation in July, August, and September. At the lower elevations, the precipitation is distributed evenly throughout the rest of the year; the months of April - September (the growing season) receive 10 to 12 inches of precipitation. At the higher elevations, the bulk of the yearly precipitation comes during the winter months (November- March) in the form of snow. Pierce averages about 11 inches of snow water content at the season peak in mid-March (U.S. Department of Agriculture, 1987).

The average consecutive frost-free period (above 32 degrees) ranges from 158 days at the lowest elevations to 118 days on the upland prairies. A probability analysis of data collected by the Clearwater Soil and Conservation District shows 8 years in 10 will have a frost-free season of at least 140 days at the low elevations and 98 days in the higher areas.

STORM AND FLOOD CONDITIONS

The landslide events of 1995-96 can be divided into three distinguishable episodes. The first occurred in November and December of 1995. The second occurred in February of 1996. The final episode took place during the snowmelt in the spring of 1996. Precipitation in the Clearwater River drainage was nearly 200 percent of normal during the period October through November (McClelland and others, 1997). November 23 marked the beginning of 13 consecutive days of precipitation. The streamflows that followed were considered to be between 2 and 25-year flooding events by the USGS (U.S. Department of the Interior, 1996). The landslide events that were associated with the February storms were similar to those in November. These storms were characterized by warm temperatures and several days of rainfall on a widespread, deep snowpack. The streamflows that resulted were between 2 and 100-year events. The majority of landslide activity occurred during the spring snowmelt season according to U.S. Forest Service researchers. This was due to wet conditions from October 1995 to February 1996. Peak streamflows were not unusual during the spring snowmelt season.

November 1995 Weather Conditions

Although there are currently no direct streamflow measurements on Cooper, Cook and lower Orofino Creeks, the historical records on Orofino Creek (prior to 1970) correlate closely to elevated streamflows on the North Fork Clearwater River and Jim Ford Creek during large-scale storm events.

During the period of October through November 1995, precipitation in the Clearwater River drainage was nearly 200 percent of the historical average. The North Fork Clearwater drainage received 26.1 inches of precipitation compared to the normal two-month average of 13.4 inches. The precipitation levels for Jim Ford Creek are nearly identical at 26.7 compared to 13.4 inches (U.S. Department of Agriculture, 1987).

Snow depth at 3,400 feet elevation peaked at 12 inches on November 11. November 23 was the first day of 13 consecutive days of precipitation. Stream flow on the North Fork Clearwater was the highest in 41 years of record, and was estimated to be the 25-year flow level (McClelland and others, 1997). The Clearwater River at Orofino recorded the third highest flow in 38 years of record, another 25-year event.

February 1996 Weather Conditions

On February 4, 1996 snow depth was 19 inches at Orofino, Idaho and 36 inches in the upper reaches of Cooper and Cook Creeks. The events leading to landslides were very similar to those in November, 1995. A large storm generated in the Pacific Ocean moved into the inland Pacific Northwest bringing strong, warm winds and above average precipitation. The precipitation fell on the region, which already had an above average snowpack. On some rivers in the area, ice dams formed, which contributed to flooding problems. The floods that resulted were the largest since 1974, forcing the evacuation of many low-lying areas and causing extensive damage to public and private property (U.S.

Department of Interior, 1996). Fifteen northern Idaho counties, including Clearwater County, were declared Flood Disaster Areas.

The highest stream flows were recorded in the lower elevations. The Clearwater River at Orofino experienced the ninth highest flow in 38 years, and was considered a 50-year event. The North Fork Clearwater experienced the 18th largest flow in 41 years. Drainages in the higher elevations such as the Lochsa and Selway Rivers experienced the 58th and 50th highest flows in 67 years, respectively. This is evidence that the storm affected mainly the elevations below 4000 feet, the average snow level. All landslide study sites were below 3,290 feet elevation.

According to the NRCS in Orofino, Idaho and Potlatch Corp. personnel, significant landsliding occurred during the spring thaw due to saturated conditions from earlier flooding in 1996 and 1995.

SOUTHERN OSCILLATION INDEX

The Southern Oscillation Index is a useful tool to help predict future winter storms in the study area. Also, historical flood events in the study area can also be examined to see if there is a connection to past La Niña episodes. La Nina and the Southern Oscillation are discussed in more detail in the section titled "weather and climate" in chapter 5.

CHAPTER 3: METHODOLOGY

The data for this study was primarily gathered from available aerial photography and subsequent field investigation and office compilation. In the office, data was catalogued and analyzed using Microsoft Excel spreadsheet, Microsoft Access database, ArcView, ArcInfo, SPSS, and Microsoft Word software packages. Most data was digitized directly into ArcInfo and modified in ArcView.

The data collected for storm and flooding events was acquired from several sources, including the United States Geologic Survey, National Oceanographic and Atmospheric Administration, records from the Clearwater National Forest, and personal contacts. Snow pack and stream flow information was acquired from the NRCS in Orofino, Idaho.

Field-based landslide inventory was performed by the author and an assistant. The author and assistant worked side-by-side to limit any variation in measurement due to judgment differences.

LANDSLIDE TYPES AND PROCESSES

"Landslide" is a general term for a variety of processes and landforms. They all involve the movement of rock and soil masses downslope under the influence of gravity. Three principal types of movement are associated with landslides: falling, sliding, and flowing. Common "landslides" are debris slides, slumps, and channelized debris torrents.

Other processes such as debris avalanches, and debris, earth and mudflows have no true sliding but are usually referred to as landslides nonetheless.

Landslides can be classified in many ways, each emphasizing a particular process or characteristic useful to recognize, avoid, control, remediate, or plan for future events.

Mud and debris flows are mixtures of water and soil that move as “flowing” masses. Landslides and slumps in soil and rock move along discrete failure surfaces or a series of surfaces. On very steep slopes where there is no discrete failure surface, material falls in a jumbled pile at the base of the slope. These mass movements are classified as soil or debris avalanches. In some locations in the study area there was evidence of creep, or long term mass movement. In these cases, there also was evidence of movement during the 1995-96 events. These features were not included in this study due to the ambiguity of interpretation. Trees with bent trunks were evidence that these areas were tied to long term events, and may not be primarily influenced by recent events.

The majority of the landslides described in this study were landslides, slumps, flows, or combinations of these. Commonly a landslide began on steep slopes as a thin landslide or slump in surfacial soil and fragmented weak rock. When the landslide gained momentum downslope, it transformed into a mudflow or debris flow.

There are several long-term causes leading to landslides, including geologic, morphologic, hydrologic, and human-impact. Commonly there are only one or two immediate causes of failure, or triggering event. A landslide triggering event is an external stimulus such as intense rainfall, snowmelt, earthquake shaking, volcanic eruption, stream erosion, storm waves, or the activity of man that causes a near-immediate response in the form of a landslide by rapidly increasing the stresses in the slope or by reducing the strength of the slope materials (Wieczorek, 1996). Short-term cause and effect is critical in the identification of a landslide trigger (McClelland and others, 1997).

INVENTORY PROCEDURES

Landslide locations were first identified using aerial photography and then transferred to 1:24,000 topographic quadrangle maps for use in the field. The sites used in this study were not randomly located. Sites were selected based on concentration, and reasonable access. Most sites could be reached by hiking or logging roads. Additional sites were recorded in the field by observation. These sites were often in areas either not covered by aerial photography or in areas that aerial photography of the ground was obscured due to vegetation.

Data acquisition methods used in the field were as follows:

1. Tops of the landslides were surveyed using topographic maps and GPS.
2. Geology was recorded based on exposed rock at landslide or nearby outcrop.
3. Slope and aspect were recorded using topographic maps, clinometer, and compass.
4. Elevation was recorded from topographic maps.
5. Landslide measurements (height, width, and depth) were recorded from tape measure estimation in areas of limited access.

6. Soil thickness and type were recorded both in the field and from data supplied by the NRCS in Orofino, Idaho.
7. Vegetation type, amount, and age (where applicable) were recorded in the field.

Field data were collected from June through August 1996. Additionally, there were twelve months of data interpretation and database preparation, including weather and soil data collection and organization.

Aerial photography was used primarily to guide field investigation but it was also used to estimate timber harvest and road construction ages, as that information was not readily available elsewhere.

Landslides were categorized into five different land uses, including, roads, partial or clearcut timber harvest, stream, and natural. The road classification included landslides that were affected by a road above or below it. If a landslide occurred in an area subject to timber harvest, it was classified as either partial cut or clearcut. Landslides that occurred in areas directly adjacent to streams were classified as stream. Natural landslides occurred where the originating point of the landslide was not affected by any of the other factors. Table 2 shows the classification system used in this study to divide land use into groups and subgroups.

The steepness of the slope was categorized using 5% intervals. Steepness above 50% was categorized as 50%+.

Land use classifications for each landslide were obtained from an ongoing soil survey being conducted by the NRCS in Orofino, Idaho. Landforms and soil types were taken from unpublished, preliminary soil data and maps.

Table 2: Land use groups and subgroups (adapted from Espinosa, 1988)

Land use groups	Land use subgroups
Forest	1. Forest
Road	2. Above road 3. Below road
Clearcut/ Partial	4. Upper edge at clearcut/ partial 5. Lower edge at clearcut/ partial 6. Lateral margin of clearcut/ partial 7. Within clearcut/ partial
Stream	8. Stream size

The estimated volume for each landslide was included in the data analysis. The volume estimates included the source area plus any subsequent scour as the landslide moved down slope. No estimation of sediment delivery to stream channels was made in this study.

Each landslide site was studied and data was collected on the physical conditions at each site. These factors included landslide types and processes, estimation of landslide volume, slope position, elevation, aspect, geomorphic location, and land/soil type. A detailed explanation of each of these factors will be discussed next.

Initial identification of landslide study sites were made using aerial photography supplied by the Potlatch Corporation. Continuous aerial photography was available from 1990 to present. Sporadic coverage of the study area was also available for selected years. To identify landslide activity following the 1995-96 heavy precipitation events aerial photos taken in 1995 and 1996 were analyzed and marked. This excluded mass wasting events that occurred earlier then 1995-96. The dates and indexes of aerial photo coverage is included in Table 3.

Table 3: Table showing dates and indexes of aerial photography used in study area.

Date of Flight	Index Numbers	Color/B&W
June 25, 1995	PC-95 (45-00) to (51-25)	B&W
June 8, 1996	PC-96 (6A-00) to (9C-25)	B&W

Landslide Volume

The volume of material the landslide transported downslope was estimated both from aerial photography and direct field measurement. The volume estimates from aerial photography were compared to similar landslides that were measured in the field. All landslide estimates are only approximate and only used to compare site characteristics. Volume was calculated by multiplying height, width, and depth.

Slope Position

Slope position refers to the location on the slope with respect to elevation. The landslides initiated in three possible slope locations: Lower, Middle, and Upper. The division of the slope was completed using a topographic map. The slope was divided into thirds from the flood plain to the ridge.

Elevation

Elevation was determined using GPS and topographic maps, and was marked at the point of landslide initiation. The standard contour interval on maps used in this study area was 40 feet. Elevation was accurate to 2 feet.

Aspect

The aspect of the slope where the landslide initiated was recorded using a Brunton compass and topographic map. Aspects were grouped into 16 different classes; N, NNW, NW, WNW, W, WSW, SW, SSW, S, SSE, SE, ESE, E, ENE, NE, NNE.

Geomorphic Location

The geomorphic location of each site was characterized by the topographic and hydrologic location of the given hillslope. The classification was determined from topographic maps, field observation, and soil characteristics data acquired from the NRCS in Orofino, Idaho. Figure 2 shows a general layout of a slope and the corresponding settings used in the site characterization.

1. Smooth slope: Areas of relatively straight, parallel contour lines on continuous slopes. These are commonly located along valley sides, adjacent to streams or hollows.

2. Steep slope below bedrock outcrop: Areas of slopes greater than 60% located below resistant bedrock ridges or outcrops. These commonly occur as talus slopes or rockfalls.

3. Streamside: Areas adjacent to stream channels.

4. Lower slope break: Usually occurs 20 to 100 meters above flood plain near major streams. These areas are at or below the point of marked increase in slope gradient.

    a) Smooth slope: Areas of even contour lines.

    b) Slope nose: Areas of convex contour lines.

    c) Slope hollows: Areas of concave contour lines. These are often associated with perennial streams.

5. Hollow: Areas above the lower slope break with concave contour lines.

Land/Soil type

Land/soil types are based on field observation, NRCS soil data, and land use maps provided by the Potlach Corporation.

CONSTRUCTION OF HAZARD MAP

The hazard map was constructed using data collected from field observation and aerial photography. The map (pocket material) shows areas that are most likely to fail under weather conditions similar to those that occurred in 1995-96. The map is an ArcView coverage with colored areas which represent the hazard locations.

Construction of the hazard map was completed using ArcView mapping software for Unix and PC coverages were supplied by the Clearwater National Forest Ranger Station in Orofino, Idaho. The coverages were printed on a plotter then modified using colored pencils to show the hazard potential in the study region.

CHAPTER 4: DATA

The data contained within this chapter outlines the characteristics that occur at each of the 32 landslide sites. Data for each site are divided into three sections. "Site description" details basic characteristics of the site such as location and aspect. "Landslide type and description" describes the characteristics of the landslide, such as volume and geology. "Land and Soil description" details information about parent material, hazard probability, and causes of failure. Figure 2 shows the location of landslide sites. Tables 4 and 5 are a summary of the data collected for each landslide site.

Table 4: Data summary for landslide locations (soil, parent material, slope position, aspect, gradient, and elevation.

Site	Soil	Parent Material	Slope position	Aspect	Gradient	Elev.
1	Kr5	granitic/metamorphic	lower/mid./upper	ssw	45-50	3140
2	Ag5	loess/basalt	lower	ssw	45-50	3080
3	Bk1	colluvium/metamorphic	lower	s	35-40	3100
4	Ek1	loess/basalt	middle	nw	30-35	2650
5	Gk1	loess/silt	upper	ene	20-25	3250
6	Ek2	loess/basalt	upper	wnw	45-50	2980
7	Jn2	granitic/metamorphic	middle	sw	50+	2800
8	Bp2	loess/basalt	lower/middle	nne	45-50	1880
9	Kt1	loess/basalt	middle	ese	40-45	2280
10	Kt1	loess/basalt	middle	ese	40-45	2380
11	Ao1	granitic/metamorphic	upper	nne	50+	2880
12	Ek1	loess/basalt	middle	nnw	25-30	2600
13	Gk1	loess/silt	upper	sse	15-20	3120
14	Kn5	loess/basalt	upper	ssw	50+	2985
15	Kn1	loess/basalt	upper	sse	45-50	2590
16	Ao1	granitic/metamorphic	middle	ne	35-40	3290
17	Ao1	granitic/metamorphic	upper	sw	30-35	3250
18	Gk1	loess/silt	upper	nw	35-40	3040
19	Cn5	loess/basalt	upper	nnw	25-30	3000

Table 4 (continued)

20	Cn5	loess/basalt	middle	n	35-40	2890
21	Ty7	loess/silt	upper	wnw	05-10	2620
22	Cn4	loess/basalt	middle	ne	15-20	1750
23	Jn4	loess/granitic	lower	ne	40-45	1380
24	Tn2	colluvium/metamorphic	upper	nnw	50+	1620
25	Tn2	colluvium/metamorphic	lower/mid./upper	ene	50+	1250
26	Tn2	colluvium/metamorphic	lower/mid./upper	ene	50+	1250
27	Tn2	colluvium/metamorphic	lower	nne	50+	1250
28	Tn2	colluvium/metamorphic	lower/mid./upper	nw	50+	1240
29	Tn2	colluvium/metamorphic	lower/mid./upper	nw	50+	1255
30	Tn2	colluvium/metamorphic	lower/mid./upper	nw	50+	1240
31	Tn2	colluvium/metamorphic	lower/mid./upper	n	50+	1235
32	Tn2	colluvium/metamorphic	lower	n	50+	1240

Table 5: Data for each landslide (location, vegetation percent, vegetation type, and road type.

Site	Location	Vegetation %	Volume	Veg. Type	Road Type
1	Above road	80-90	3500	pine forest	unused dirt
2	Above road	80-90	550	pine forest	unused dirt
3	Below road	30-50	150	sparse shrub	dirt
4	Forest	90-100	1100	pine forest	dirt
5	Partial clearcut 2	60-70	150	pine forest	dirt
6	Above road	30-40	250	pine forest	dirt
7	Stream	30-40	75	pine forest	dirt
8	Stream	70-80	75	pine forest	none
9	Stream	70-80	150	pine forest	none
10	Stream	70-80	150	pine forest	none
11	Clearcut	80-90	25	pine forest	dirt
12	Clearcut	0-10	150	pine forest	dirt
13	Clearcut at edge	30-40	150	sparse shrub	improved dirt
14	Stream	30-40	250	sparse shrub	none
15	Forest	40-50	350	pine and shrub	none
16	Below road	80-90	150	pine forest	dirt
17	Below road	70-80	75	pine forest	dirt
18	Partial clearcut 1	80-90	150	pine forest	dirt
19	Below road	70-80	150	pine forest	dirt
20	Below road	70-80	75	pine forest	dirt
21	Below road	80-90	350	open field	dirt
22	Below road	80-90	350	pine forest	unused dirt
23	Forest	80-90	550	pine forest	none
24	Forest	80-90	1100	pine forest	none

Table 5 (continued)

25	Forest	80-90	550	pine forest	none
26	Forest	80-90	350	pine forest	none
27	Forest	80-90	550	pine forest	none
28	Forest	80-90	1100	pine forest	none
29	Forest	80-90	550	pine forest	none
30	Forest	80-90	750	pine forest	none
31	Forest	80-90	550	pine forest	none
32	Forest	80-90	750	pine forest	none

b.

SITE CHARACTERISTICS

Site 1

Site Description

This site operated as the base camp location for all fieldwork completed in this project. The landslide at this site is relatively large with an estimated volume of over 3500 cubic feet of displaced material. Cooper Creek flows northwest at this point approximately 15 feet from the base of the landslide. Across Cooper Creek is a clearcut forest older than 15 years, on a moderate slope that faces north. The landslide that initiated at this site is on a SSW facing slope. The landform here is a slope hollow. Steepness is approximately 45-50%. Twenty feet west of the landslide there is a very small perennial stream. An abandoned logging road crosses the slope approximately 1/3 of the distance from the bottom of the landslide to the top. This road was obliterated by the landslide.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. Forty feet beyond the initiation point of the landslide the slope flattens out and is cut by a gravel road. This road is still used by foresters and recreationists . Beyond the road is a clearcut forest about 2 to 4 years in age. The extent of influence that the clearcuts to the north and south of this landslide have on the initiation of the landslide is unclear. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is part of the Kruse-Aldermand complex (Kr5). These soils are characterized by very deep, well-drained, loams. Commonly found on the backslopes, this soil's dominant parent material is from both metamorphic/ granitic rock and loess. Locally in the field, there was some basalt outcroppings. Average annual precipitation for this soil is 25 to 35 inches. The available water holding capacity of the soil at this site is between 6.2 and 9.2 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate to high susceptibility to failure.

Site 2

Site Description

The landslide at this site is moderate in size with an estimated volume of over 500 cubic feet. Cooper Creek flows northwest at this point approximately 35 feet from the base of the landslide. Across Cooper Creek is a clearcut forest older than 15 years, on a moderate slope that faces north. The landslide that initiated at this site is on a SSW facing slope. The landform here is a smooth slope. Steepness is approximately 45-50%. A seldom-used logging road crosses the slope at the bottom of the landslide.

Landslide Type and Description

The landslide is approximately 50 feet in height. There is dense forest in the region adjacent to the landslide, and most trees and plants remain in place as part a slightly rotated slump at the base of the slope. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. Forty feet beyond the initiation point of the landslide the slope flattens out and is cut by a gravel road. This road is still used by foresters and recreationists . Beyond the road is a clearcut forest about 2 to 4 years in age. The extent of influence that the clearcuts to the north and south of this landslide have on the initiation of the landslide is unclear. The increased runoff that a clearcut might produce possibly would contribute to higher saturation than normal. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is called the Campra gravelly silt loam (Ag5). These soils are characterized by deep, well-drained, loams. Commonly found on the backslopes, this soil's dominant parent material is mixed volcanic ash and loess over material from basalt. The available water holding capacity of the soil at this site is about 7.2 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate to high susceptibility to failure.

Site 3

Site Description

The landslide at this site is moderate to small with an estimated volume of 100 cubic feet. Cooper Creek flows northwest at this point approximately 15 feet from the base of the landslide. Across Cooper Creek is a clearcut forest older than 15 years, on a moderate slope that faces north. The landslide that initiated at this site is on a south-facing slope. The landform here is a slope nose. Steepness is approximately 35-40%. A logging road crosses at the bottom. There is a basalt-gravel quarry located about 40 feet to the east of the landslide, where there is ongoing material removal for the construction of forest roads.

Landslide Type and Description

The landslide is approximately 20 feet in height. There is little or no vegetation in the region adjacent to the landslide. The top of the landslide is at the break in slope.

Sixty feet beyond the initiation point of the landslide the slope flattens out and is cut by a gravel road. This road is still used by foresters and recreationists . Beyond the road is a clearcut forest about 2 to 4 years in age. This landslide is rotational in nature the vegetation has continued to grow since the landslide initiated. The probable cause of this landslide is heavy infiltration of rainwater into the soil and lack of vegetation.

Land and Soil Description

The soil at this site is called the Boulder Creek silt loam (Bk1). These soils are characterized by deep, moderately well drained, loams. Commonly found on footslopes and backslopes, this soil's dominant parent material is mixed volcanic ash, colluvium, and residuals from metamorphic rocks. The Boulder Creek silt loam is commonly found at higher elevation between 3,600- 4,800 feet. The available water holding capacity of the soil at this site is unknown. This soil is commonly used as forestland or grazed forestland. These soils have a moderate to high susceptibility to failure.

Site 4

Site Description

The landslide at this site is moderate to large with an estimated volume of over 800 cubic feet. This landslide is located at the top of a very tall and steep canyon side overlooking Orofino Creek to the north. The landslide that initiated at this site is on a NW facing slope. The landform here is a slope nose. Steepness is approximately 30-40%.

Landslide Type and Description

The landslide is approximately 35 feet in height. There is a clearcut forest in the region adjacent to the landslide. The top of the landslide is at the break in slope. This landslide initiated along a minor logging road and moved downhill away from the road. The probable cause of land failure at this site is high infiltration into the soil, which has a low water holding capacity, which increased erosion, as well as disturbed material near road construction.

Land and Soil Description

The soil at this site is called the Elkridge-Riswold complex (Ek1). This soil is commonly found on slopes fewer than 40 percent. These soils are characterized by deep, well-drained, silt loams. Commonly found on the backslopes, this soil's dominant parent material is loess over material from basalt with a thin volcanic ash mantle. The available water holding capacity of the soil at this site is about 6.5 inches. This soil is commonly used as forestland or grazed forestland. These soils have a low to moderate susceptibility to failure.

Site 5

Site Description

The landslide at this site is relatively small with an estimated volume of less than 100 cubic feet. This landslide is entirely within an area of clearcut forest, approximately 15 years in age. Moderate second growth appears to have undergone a wildfire in the previous 5 to 10 years. The landslide is on an ENE facing slope. The landform here is a smooth slope. Steepness is approximately 20-25%.

Landslide Type and Description

The landslide is approximately 10 feet in height. There is clearcut forest in the region adjacent to the. The top of the landslide is at the break in slope. The increased runoff that a clearcut produces probably contributed to land failure. Increased runoff and the lack of stabilizing root systems are the probable causes of sliding.

Land and Soil Description

The soil at this site is called the Grangemont-Kauder complex (Gk1). These soils are characterized by very deep, well-drained, silt loams. Commonly found on the tops of hills and plateaus, this soil's dominant parent material is loess over silty sediments with a thin mantle of volcanic ash. The available water holding capacity of the soil at this site is about 8.2-10.5 inches. This soil is commonly used as cropland, hayland, pasture, forestland and grazed forestland. These soils have a low susceptibility to failure in areas on deep water table and moderate to high in areas with perched water tables.

Site 6

Site Description

The landslide at this site is moderate in size with an estimated volume of approximately 200 cubic feet. A logging road flanks the top of this landslide. The landslide is in an area of clearcut. Across the logging road at the top of the landslide is a dense forest. The landslide that initiated at this site is on a WNW facing slope. The landform here is a slope hollow. Steepness is 45-50%. Eighty feet beyond the base of the landslide there is a very small perennial stream.

Landslide Type and Description

The landslide is approximately 100 feet in height. There is sparse forest in the region adjacent to the landslide. The landslide is at the top of the slope, and is covered with scrubby underbrush. The initiation point of the landslide is above a dirt road. This road is still used by foresters and recreationists . The road at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is called the Elkridge-Riswold complex (Ek2). This soil is found on slopes between 40 and 70 percent. This soil is characterized by deep, well-drained, silt loams. Commonly found on the backslopes, this soil's dominant parent material is loess over material from basalt with a thin volcanic ash mantle. The available water holding capacity of the soil at this site is about 6.5 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate susceptibility to failure.

Site 7

Site Description

The landslide at this site is moderate in size with an estimated volume of approximately 50 cubic feet. This landslide initiated on a SW facing slope, which has Cooper Creek at its base. The landform here is a slope hollow. Steepness is 45-50%.

Landslide Type and Description

The landslide is approximately 30 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope that partially block Cooper Creek. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is called the Johnson-Texas Creek complex (Jn2). These soils are characterized by deep, well-drained, loams. Commonly found on all slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is about 4.1 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate susceptibility to failure.

Site 8

Site Description

The landslide at this site is the smallest with an estimated volume of approximately 30 cubic feet. This landslide empties into Jim Ford Creek. This entire area is covered with dense forest. The landslide that initiated at this site is on a NNE facing slope. The landform here is a slope hollow. Steepness is 45-50%.

Landslide Type and Description

The landslide is approximately 15 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope that partially block Jim Ford Creek. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is part of the Kettenbach-Gwin association (Bp2). These soils are characterized by moderately deep, well-drained, gravelly silt loams. Commonly found on south-facing canyon side slopes, this soil's dominant parent material is loess mixed with basalt colluvium. The available water holding capacity of the soil at this site is low. This soil is commonly used as rangeland. These soils have a very high susceptibility to failure.

Site 9

Site Description

The landslide at this site is small with an estimated volume of approximately 50 cubic feet. This landslide empties into a small tributary of Jim Ford Creek. This entire area is covered with dense forest. The landslide that initiated at this site is on an ESE facing slope. The landform here is a slope hollow. Steepness is 40-45%.

Landslide Type and Description

The landslide is approximately 25 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope that partially block the Creek. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is called the Keuterville-Rock outcrop complex (Kt1). These soils are characterized by very deep, well-drained, loams. Commonly found on the concave backslopes, this soil's dominant parent material is loess mixed with basalt colluvium. The available water holding capacity of the soil at this site is low. This soil is commonly used as rangeland. These soils have a moderate susceptibility to failure.

Site 10

Site Description

The landslide at this site is small with an estimated volume of approximately 50 cubic feet. This landslide empties into a small tributary of Jim Ford Creek. This entire area is covered with dense forest. The landslide that initiated at this site is on an ESE facing slope. The landform here is a slope hollow. Steepness is 40-45%.

Landslide Type and Description

The landslide is approximately 25 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope that partially block the Creek. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is called the Keuterville-Rock outcrop complex (Kt1). These soils are characterized by very deep, well-drained, loams. Commonly found on the concave backslopes, this soil's dominant parent material is loess mixed with basalt colluvium. The available water holding capacity of the soil at this site is low. This soil is commonly used as rangeland. These soils have a moderate susceptibility to failure.

Site 11

Site Description

The landslide at this site is relatively small with an estimated volume of 60 cubic feet. This site in entirely contained within a clearcut forest, on a moderate slope that faces north. The landslide that initiated at this site is on a NNE facing slope. The landform here is on a slope hollow. Steepness is more than 50%. Two hundred fifty feet north of the landslide there is a very small perennial stream.

Landslide Type and Description

The landslide is approximately 29 feet in height. The initiation point of this landslide is at the top of the slope. Forty feet beyond the initiation point of the landslide the slope flattens out. The clearcut at this site is the probable cause for land failure. There are no immediate concerns from road construction. The steep slope at this location is the probable reason that the land failed under intense runoff conditions.

Land and Soil Description

The soil at this site is called the Aldermand loam (Ao1). These soils are characterized by very deep, well-drained, loams. Commonly found on the backslopes in canyons, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is about 6.2 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate to high susceptibility to failure.

Site 12

Site Description

The landslide at this site is relatively small with an estimated volume of 90 cubic feet. This site in entirely contained within a clearcut forest, on a shallow slope. The landslide that initiated at this site is on a NNW facing slope. The landform here is on a slope hollow. Steepness is 25-30%. One hundred feet south of the landslide, there is a small logging road, which shows some signs of runoff channelization.

Landslide Type and Description

The landslide is approximately 35 feet in height. The initiation point of this landslide is at the middle of the slope. The clearcut at this site is the probable cause for land failure. There is some concern about road construction to the SE. Road construction may have helped channel runoff to the landslide location. The shallow slope at this location combined with focused runoff from road construction to the SE is a possible contributing factor for land failure.

Land and Soil Description

The soil at this site is called the Elkridge-Riswold complex (Ek1). This soil is commonly found on slopes gradients below 40 percent. These soils are characterized by deep, well-drained, silt loams. Commonly found on the backslopes, this soil's dominant parent material is loess over material from basalt with a thin volcanic ash mantle. The available water holding capacity of the soil at this site is about 6.5 inches. This soil is commonly used as forestland or grazed forestland. These soils have a low to moderate susceptibility to failure.

Site 13

Site Description

The landslide at this site is relatively small with an estimated volume of 50 cubic feet. This site in contained within a clearcut forest, on a shallow slope. The landslide that initiated at this site is on a SSE facing slope. The landform here is on a slope hollow. Steepness is 15-20%. 100 feet south of the landslide, a major gravel road connects Orofino and Weippe.

Landslide Type and Description

The landslide is approximately 10 feet in height. The initiation point of this landslide is at the top of the slope. The clearcut at this site is the probable cause for land failure. There is a homestead at this site, which may have contributed to the modification of the hillslope by grazing animals or trails. The shallow slope at this location combined with multiple types of human impact is the contributing factors for land failure.

Land and Soil Description

The soil at this site is called the Grangemont-Kauder complex (Gk1). These soils are characterized by very deep, well-drained, silt loams. Commonly found on the tops of hills and plateaus, this soil's dominant parent material is loess over silty sediments with a thin mantle of volcanic ash. The available water holding capacity of the soil at this site is about 8.2-10.5 inches. This soil is commonly used as cropland, hayland, pasture, forestland and grazed forestland. These soils have a low susceptibility to failure in areas on deep water table and moderate to high in areas with perched water tables.

Site 14

Site Description

The landslide at this site is moderate in size with an estimated volume of approximately 200 cubic feet. This landslide initiated on a SSW facing slope, which has Meadow Creek at its base. The landform here is a slope hollow. Steepness is 50+%.

Landslide Type and Description

The landslide is approximately 45 feet in height. There is thin forest in the region adjacent to the landslide, and few logs and debris mixed with the landslide at the base of the slope that partially block Cooper Creek. The top of the landslide is at the break in slope near the top, and is forested with scrubby underbrush. The stream at the bottom of the landslide is the probable cause, and the heavy rains the trigger.

Land and Soil Description

The soil at this site is called the Klickson-Rock complex (Kn5). These soils are characterized by very deep, well-drained, loams. Commonly found on the backslopes in deep canyons and basalt cliffs, this soil's dominant parent material is mixed volcanic ash and loess over material from basalt. The available water holding capacity of the soil at this site is about 6.0 inches. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 15

Site Description

The landslide at this site is relatively large with an estimated volume of over 300 cubic feet of displaced material. Orofino Creek flows southwest at this point approximately 65 feet from the base of the landslide. The landslide that initiated at this site is on a SSE facing slope. The landform here is on a slope hollow. Steepness is 45-50%.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Klickson-Rock complex (Kn1). These soils are characterized by very deep, well-drained, loams. Commonly found on the backslopes in deep canyons and basalt cliffs, this soil's dominant parent material is mixed volcanic ash and loess over material from basalt. The available water holding capacity of the soil at this site is about 6.0 inches. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 16

Site Description

The landslide at this site is relatively small with an estimated volume of over 100 cubic feet of displaced material. The landslide that initiated at this site is on a NE facing slope. The landform here is on a slope hollow. Steepness is 35-40%. There is a road at the top of this landslide from which a section of the road prism was removed.

Landslide Type and Description

The landslide is approximately 35 feet in height. There is a partial cut forest in the region around the landslide. This landslide initiated at the top of the slope. There is a road above this landslide. The likely cause of land failure at this site is the road construction that oversteepened the slope and subsequently re-stabilized during increased runoff.

Land and Soil Description

The soil at this site is called the Aldermand loam (Ao1). These soils are characterized by very deep, well-drained, loams. Commonly found on the backslopes in canyons, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is about

6.2 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate to high susceptibility to failure.

Site 17

Site Description

The landslide at this site is relatively small with an estimated volume of over 80 cubic feet of displaced material. The landslide that initiated at this site is on a SW facing slope. The landform here is on a slope hollow. Steepness is 30-35%. There is a road at the top of this landslide from which a section of the road prism was removed.

Landslide Type and Description

The landslide is approximately 35 feet in height. There is a partial cut forest in the region around the landslide. This landslide initiated at the top of the slope. There is a road above this landslide. The likely cause of land failure at this site is the road construction that oversteepened the slope and subsequently re-stabilized during increased runoff.

Land and Soil Description

The soil at this site is called the Aldermand loam (Ao1). These soils are characterized by very deep, well-drained, loams. Commonly found on the backslopes in canyons, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is about

6.2 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate to high susceptibility to failure.

Site 18

Site Description

The landslide at this site is moderate in size with an estimated volume of 150 cubic feet. The landslide that initiated at this site is on a NW facing slope. The landform here is on a slope hollow. Steepness is more than 35-40%. In the area surrounding the landslide there is a partial clearcut forest. There is also a road near the top of the landslide.

Landslide Type and Description

The landslide is approximately 45 feet in height. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. Forty feet beyond the initiation point of the landslide the slope flattens out and is cut by a gravel road. This road is still used by foresters and recreationists . Beyond the road is a clearcut forest about 2 to 4 years in age. The combination of road construction and partial clearcut forest is the probable causes of land failure at this site.

Land and Soil Description

The soil at this site is called the Grangemont-Kauder complex (Gk1). These soils are characterized by very deep, well-drained, silt loams. Commonly found on the tops of hills and plateaus, this soil's dominant parent material is loess over silty sediments with a thin mantle of volcanic ash. The available water holding capacity of the soil at this site is about 8.2-10.5 inches. This soil is commonly used as cropland, hayland, pasture, forestland and grazed forestland. These soils have a low susceptibility to failure in areas on deep water table and moderate to high in areas with perched water tables.

Site 19

Site Description

The landslide at this site is relatively small with an estimated volume of over 60 cubic feet of displaced material. The landslide that initiated at this site is on a NNW facing slope. The landform here is on a slope hollow. Steepness is 25-30%.

Landslide Type and Description

The landslide is approximately 20 feet in height. There is a forest in the region around the landslide. This landslide initiated at the top of the slope. There is a road above this landslide. The likely cause of land failure at this site is the road construction that oversteepened the slope and subsequently re-stabilized during increased runoff.

Land and Soil Description

The soil at this site is called the Sly-Campra complex (Cn5). These soils are characterized by very deep, well-drained, silt loams. Commonly found on gentle canyon side slopes, this soil's dominant parent material is loess mixed with basalt colluvium. The available water holding capacity of the soil at this site is very high. This soil is commonly used for timber production, livestock grazing, wildlife habitat, homesites, and watershed areas. These soils have a low susceptibility to failure, but a very high rate of erosion.

Site 20

Site Description

The landslide at this site is relatively small with an estimated volume of over 80 cubic feet of displaced material. The landslide that initiated at this site is on a north-facing slope. The landform here is on a slope hollow. Steepness is 35-40%.

Landslide Type and Description

The landslide is approximately 40 feet in height. There is a forest in the region around the landslide. This landslide initiated at the top of the slope. There is a road above this landslide. The likely cause of land failure at this site is the road construction that oversteepened the slope and subsequently re-stabilized during increased runoff.

Land and Soil Description

The soil at this site is called the Sly-Campra complex (Cn5). These soils are characterized by very deep, well-drained, silt loams. Commonly found on gentle canyon side slopes, this soil's dominant parent material is loess mixed with basalt colluvium. The available water holding capacity of the soil at this site is very high. This soil is commonly used for timber production, livestock grazing, wildlife habitat, homesites, and watershed areas. These soils have a low susceptibility to failure, but a very high rate of erosion.

Site 21

Site Description

The landslide at this site is relatively large with an estimated volume of over 400 cubic feet of displaced material. The landslide that initiated at this site is on a north-facing slope. The landform here is on a slope hollow. Steepness is more than 05-10%.

Landslide Type and Description

The landslide is approximately 40 feet in height. There is an open prairie in the region around the landslide. This landslide initiated at the top of the slope. There is a road above this landslide. The likely cause of land failure at this site is the road construction that oversteepened the slope and subsequently re-stabilized during increased runoff.

Land and Soil Description

The soil at this site is called the Taney-Setters complex (Ty7). These soils are characterized by moderately deep, moderately well drained, silt loams. Commonly found on concave and smooth positions on undulating basalt plateaus, this soil's dominant parent material is loess over silty sediments with a thin mantle of volcanic ash. The available water holding capacity of the soil at this site is high. This soil is commonly used as cropland, hayland, pasture, and homesites. These soils have a low susceptibility to failure in areas on deep water table and moderate to high in areas with perched water tables.

Site 22

Site Description

The landslide at this site is relatively large with an estimated volume of over 400 cubic feet of displaced material. There is a small dirt road at the top of this landslide. The landslide that initiated at this site is on a NE facing slope. The landform here is on a slope hollow. Steepness is 15-20%.

Landslide Type and Description

The landslide is approximately 50 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of land failure at this site is the road construction that oversteepened the slope and subsequently re-stabilized during increased runoff.

Land and Soil Description

The soil at this site is called the Sly silt loam (Cn4). These soils are characterized by very deep, well-drained, silt loams. Commonly found on gentle canyon side slopes, this soil's dominant parent material is loess mixed with basalt colluvium. The available water holding capacity of the soil at this site is very high. This soil is commonly used for timber production, livestock grazing, wildlife habitat, homesites, and watershed areas. These soils have a low susceptibility to failure, but a very high rate of erosion.

Site 23

Site Description

The landslide at this site is relatively large with an estimated volume of over 600 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure 11). The landslide that initiated at this site is on a NE facing slope. The landform here is on a slope hollow. Steepness is more than 40-45%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 11: Photograph showing landslide site 23. (Notice mitigation of stream channel.)

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the

base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Johnson loam (Jn4). These soils are characterized by deep, well-drained, loams. Commonly found on all slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is about 8.9 inches. This soil is commonly used as forestland or grazed forestland. These soils have a moderate susceptibility to failure.

Site 24

Site Description

The landslide at this site is relatively large with an estimated volume of over 1000 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure 12). The landslide that initiated at this site is on a NNW facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

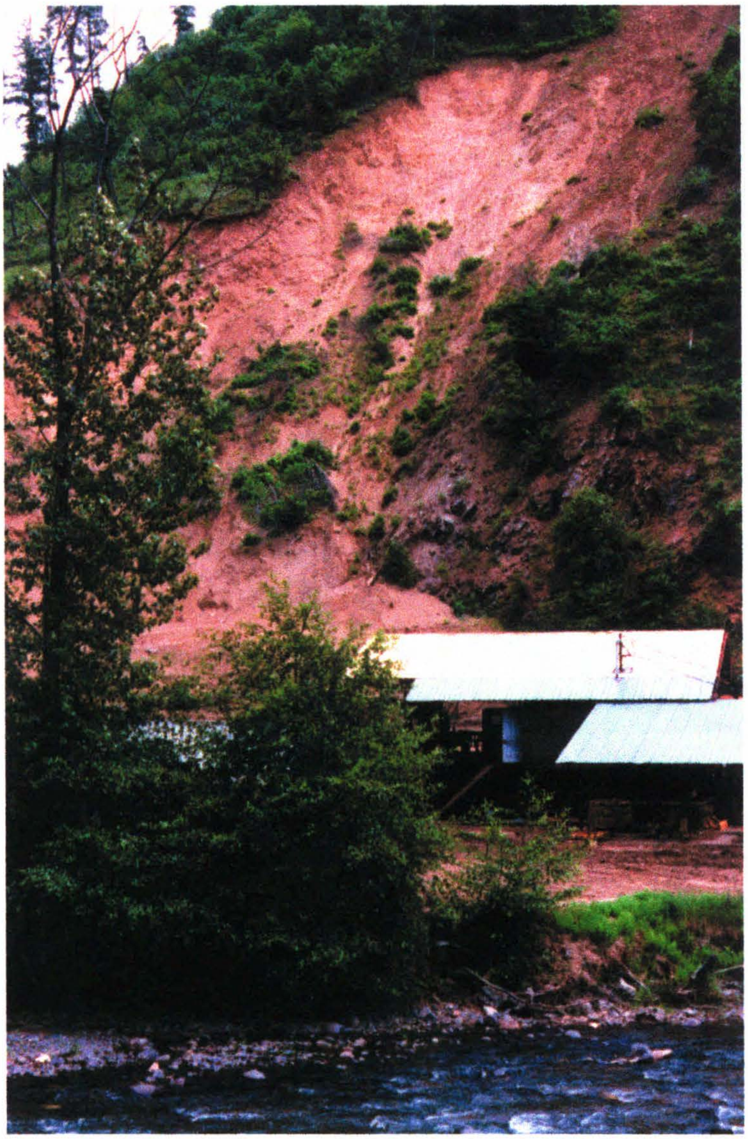


Figure 12: Photograph of landslide at site 24.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the

base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 25

Site Description

The landslide at this site is relatively large with an estimated volume of over 600 cubic feet of displaced material. Orofino Creek flows at the base of this landslide. The landslide that initiated at this site is on an ENE facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 26

Site Description

The landslide at this site is relatively large with an estimated volume of over 400 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure

13). The landslide that initiated at this site is on an ENE facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 13: Photograph of landslide at site 26.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 27

Site Description

The landslide at this site is relatively large with an estimated volume of over 600 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure 14). The landslide that initiated at this site is on a NNE facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 14: Photograph of landslide at site 27. Arrow indicates location of springs.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino

Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 28

Site Description

The landslide at this site is relatively large with an estimated volume of over 1100 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure 15). The landslide that initiated at this site is on a NW facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 15: Photograph of landslide at site 28.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 29

Site Description

The landslide at this site is relatively large with an estimated volume of over 800 cubic feet of displaced material. Orofino Creek flows at the base of this landslide. The landslide that initiated at this site is on a NW facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 30

Site Description

The landslide at this site is relatively large with an estimated volume of over 800 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure

16). The landslide that initiated at this site is on a NW facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 16: Photograph of debris levee formed from displaced material. Landslide site 30 in background (center).

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 31

Site Description

The landslide at this site is relatively large with an estimated volume of over 600 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure 17). The landslide that initiated at this site is on a north-facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 17: Photograph of Landslide at site 31.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the

base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

Site 32

Site Description

The landslide at this site is relatively large with an estimated volume of over 700 cubic feet of displaced material. Orofino Creek flows at the base of this landslide (Figure 18). The landslide that initiated at this site is on a north-facing slope. The landform here is on a slope hollow. Steepness is more than 50%. There are natural springs approximately 5 feet from the top of the landslide.

Figure 18: Photograph of Landslide at site 32. Notice pile of mixed debris at bottom of slope.

Landslide Type and Description

The landslide is approximately 80 feet in height. There is dense forest in the region adjacent to the landslide, and many logs and debris mixed with the landslide at the base of the slope. Much of the debris that slid downslope partially blocked Orofino Creek and later formed a debris levee. The top of the landslide is at the break in slope, and is forested with scrubby underbrush. The likely cause of failure at this site is a geologic contact between Columbia River Basalt and metamorphic rocks, which forms springs at the contact. These springs increase pore pressure and reduce shear strength of the landslide.

Land and Soil Description

The soil at this site is called the Township-Rettig-Stepoff Complex (Tn2). These soils are characterized by deep, well-drained, loams. Commonly found on steep canyon side slopes, this soil's dominant parent material is loess and material from granite and metamorphic rocks. The available water holding capacity of the soil at this site is low. This soil is commonly used as forestland or grazed forestland. These soils have a very high susceptibility to failure.

CHAPTER 5: RESULTS AND DISCUSSION

There are 32 landslide features identified in the study area. Each of these sites has previously been described in terms of site factors, and characteristics (Chapter 4). Landslide frequency and volume distributions were generated for the site characteristics. To achieve a consistent baseline, most characteristics are rated for all land use groups (stream, below road, above road, partial clearcut edge, partial clearcut middle, forest, clearcut, and edge of clearcut).

The immediate causes of the 1995-96 landslides in the study area were heavy rainfall from winter storms that moved across northern Idaho from the Pacific Ocean, and the melting of large amounts of snow pack due to the intense rain. The rapid snowmelt combined with heavy rain infiltrated the soils and quickly reduced the shear strength of the slope materials.

LANDSLIDE VOLUME

Landslide volume was determined by both field and aerial photo measurement. Once measured, the landslides were categorized into one of nine volume classes, ranging from 25 to 3500 cubic feet.

Landslide volumes are closely grouped in the study area (Figure 19), with 87.6% of the landslides ranging from 75 to 1,100 cubic feet and 65.7% ranging from 150 to 750 cubic feet. The modes for road and clearcut land use groups are 250 and 75 cubic feet, respectively. However, if roads within clearcuts are analyzed the mode is 150 cubic feet.

Landslides occurring in forested areas showed the highest mode at 750 cubic feet. The dominance of smaller volume classes associated with impacts may be a function of sampling bias and location. Smaller landslides are easier to identify and access is better in areas of road and/or clearcut impact. Landslides occurring on lower portions or slopes, along roads and near stream have a limited slope length and therefore smaller volumes. Alternatively, the mechanism of failure may vary due to the variation in land use areas and forested lands. Increased landslide frequency along roads can also be partially attributed to the formation of cut slopes and fill practices. Often the fill or cut slope is the material that fails and results in a small volume.

Schultz (1980) suggests that the large concentration of total landslide volume at the lower end of the range of landslide volumes can be attributed to the soil block being easily detached during periods of increased pore pressure. The landslides in the study area tend to follow this behavior. The average volume of landslides occurring in forested areas is comparatively higher. This is most likely caused by the increased energy needed to overcome the intrinsic strength of rooting from trees and plants. The total volume of forested landslides is still less than the total volume of landslides derived from non forested areas. This observation can be attributed to the higher frequency smaller scale sliding along roads and clearcut areas (Cacek, 1989).

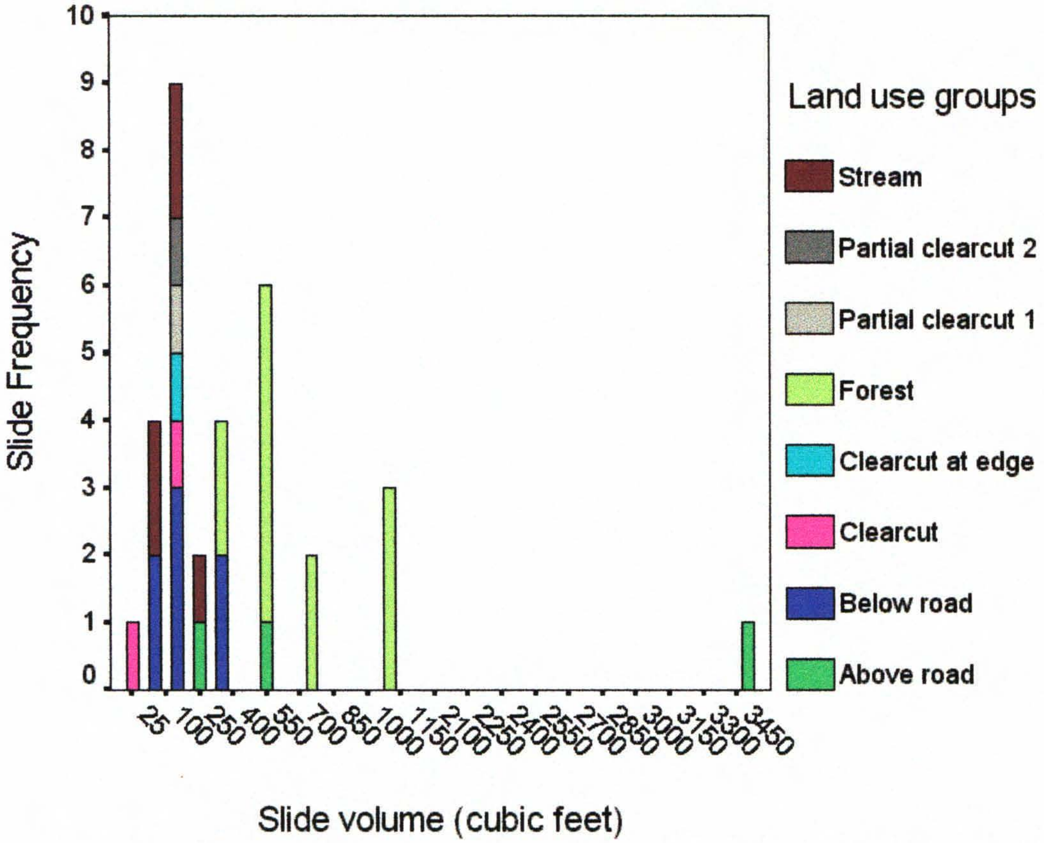


Figure 19: Landslide frequency distribution of landslide volume classes segregated into land use groups.

The total volume of the 32 landslides selected for this study is 15,175 cubic feet. Figure 20 shows the relationship between landslide volume and land use group. This diagram shows that 41% of the total landslide volume was derived from clearcut, partial clearcuts, and road construction. Forested areas produced 54% of the landslides in the study area. Areas where clearcut or partial clearcuts were the only impact have 2% of the total, and 5% of the total landslide volume was ascribed to streams.

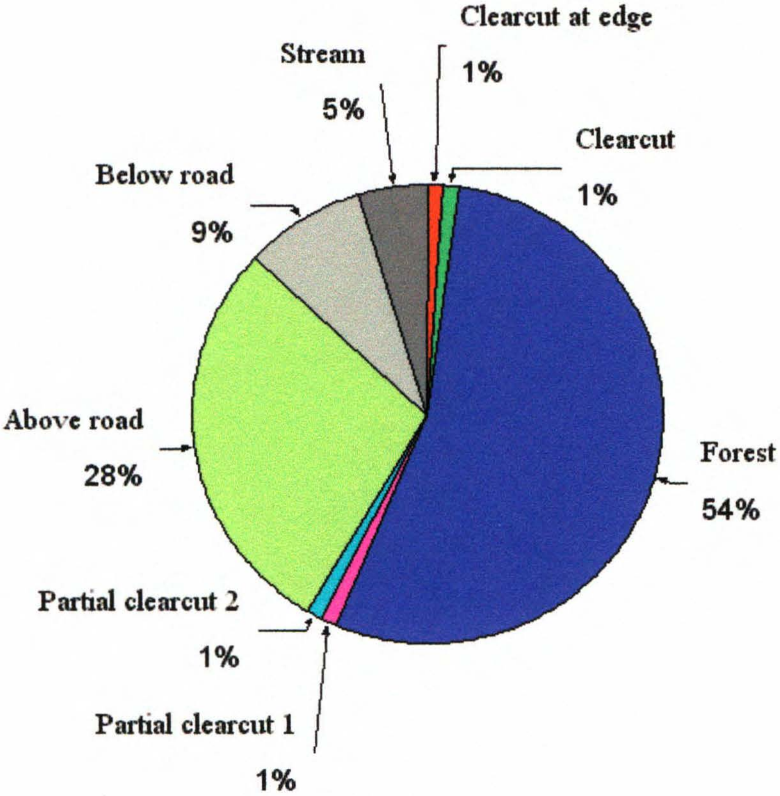


Figure 20: Pie diagram showing percent total landslide volume per land use group.

SLOPE GRADIENT

Slope gradient ranged from 5% to 50+% in the study area. Figure 21 shows the frequency of landslides at each slope gradient group. The majority of the landslides with high volumes occurred at sites with greater than 45% slope. There are two main reasons for this. First, many of the landslides on steep slopes (sites 25-32) have a runout that is from nearly the top of the slope all the way to the valley floor. Often (25%) near the initiation point of the landslide, there is a contact between Columbia River basalts and granitic or metamorphic rocks. This contact is usually associated with springs which are the probable cause of failure during increased groundwater movement. Second, the parent material on many of the severe slopes in the study is either basalt-colluvium-metamorphic or loess-basalt. Basalt colluvium and metamorphic parent material is the predominant material in landslides in the study area. This will be discussed further in a later section. Forest cover is evenly distributed over all slope percentages throughout the study area. The distribution of land use groups throughout the study area also is not biased toward any specific slope gradient. An unbiased sample of land use groups is essential to create continuity among the landslide study sites. If a specific land use were to only occur on low gradient slopes it could significantly skew the result leading to flawed results.

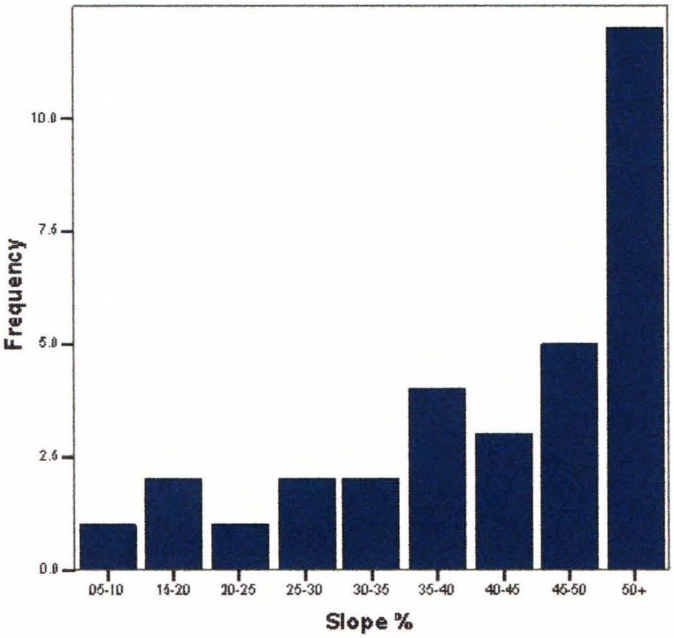


Figure 21: Landslide frequency at specific slope gradients (in percent).

The mode of the slope for slides in forested areas plus slides adjacent to streams is 51%, which is greater than all land use related landslides (35-50%). Of the landslides that form below 35% slope, 42% are related to roads, suggesting that slopes with lower gradients are more susceptible to sliding if they are impacted by roads (Figure 22). Landslides associated only with clearcut activity are generally found at sites with a moderate slope gradient (25-35%). This observation implies that clearcuts alone do not result in increased landslide activity on low gradient slopes as they do at sites associated with road impacts.

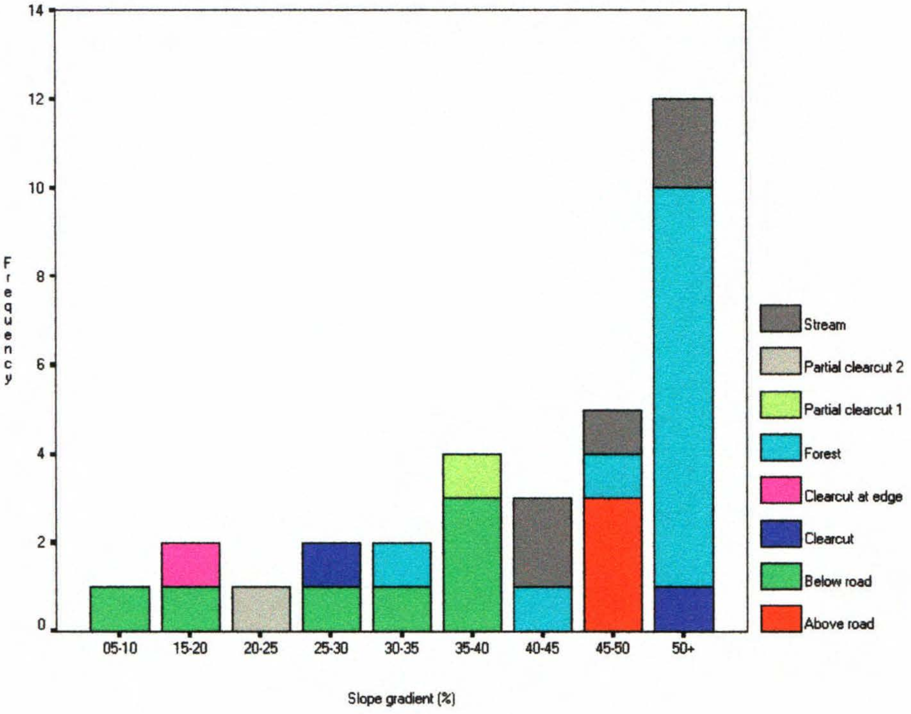


Figure 22: Landslide frequency distribution of slope gradient segregated into land use groups.

ASPECT

Landslides of all land use groups occur most often on slopes with an aspect NW (Figure 23a). Forest and clearcut events show a strong preference for northerly aspects, with 68.6% of landslides originating with a northern component of aspect. Sites that were impacted by roads have a high landslide frequency to the southwest. Parent material type is evenly distributed on all slope aspects. Parent material does however vary locally in some places from one side of the valley to the other. This helps explain why in some areas (sites 25-32) there is landsliding on one aspect and not the opposite. Sites with geologic contacts have parent material of varied composition (basalt-colluvium-metamorphic)while in most cases across the valley the parent material is metamorphic.

Volumetrically, forest landslides to the NW and road-impacted landslides to the SW have the highest total landslide volume (Figure 23b). The large volume in the SSW aspect is due to site 1, which has a much larger volume than any other road related site. The higher volume is due more to the fact that it is in a forested area than the presence of the road. Still, over 60% of the total landslide volume has occurred in the northern aspects. This is not unexpected since north facing slopes are generally subject to greater soil moisture retention and snowpack. During intense runoff events this greater moisture will lead to increased pore pressure and lower slope stability (Chorely and others, 1984). Aspect is most useful for landslide prediction over small areas with limited geographic diversity (Amaranthus and others, 1985).

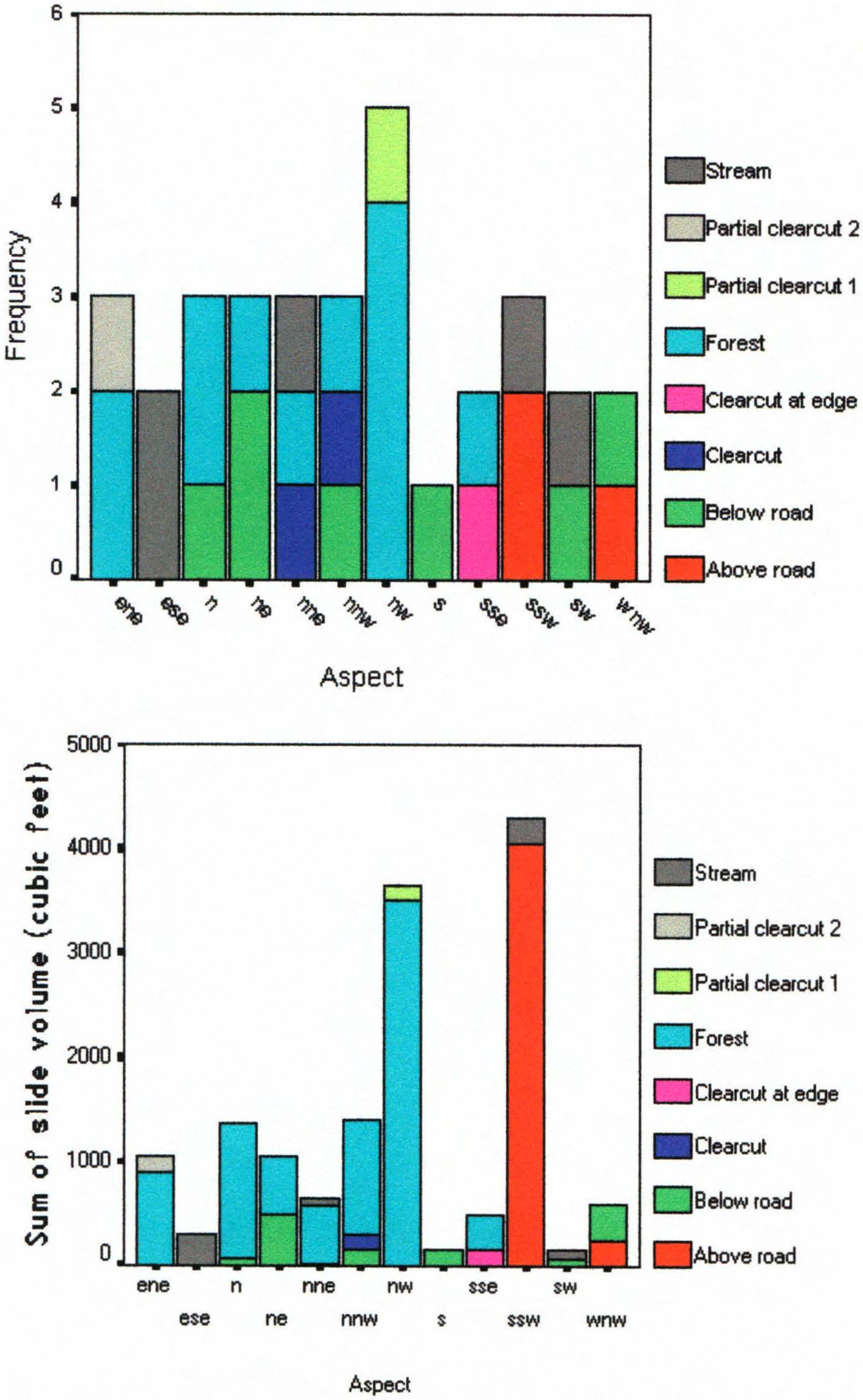


Figure 23: Landslide a) frequency and, b) volume distributions of slope aspect segregated into land use groups.

SLOPE POSITION

The majority of landslide features in the study area originate on the upper third of the slopes (Figure 24). Land use sites show a strong preference for the middle and upper slopes. Nearly 22% of the landslides in the study area involved the entire slope from ridge top to valley bottom. These generally occurred in forested areas that were not effected by land use.

Average volume for all land use related landslides is proportional to slope position, with the largest landslides originating in the highest slope positions.

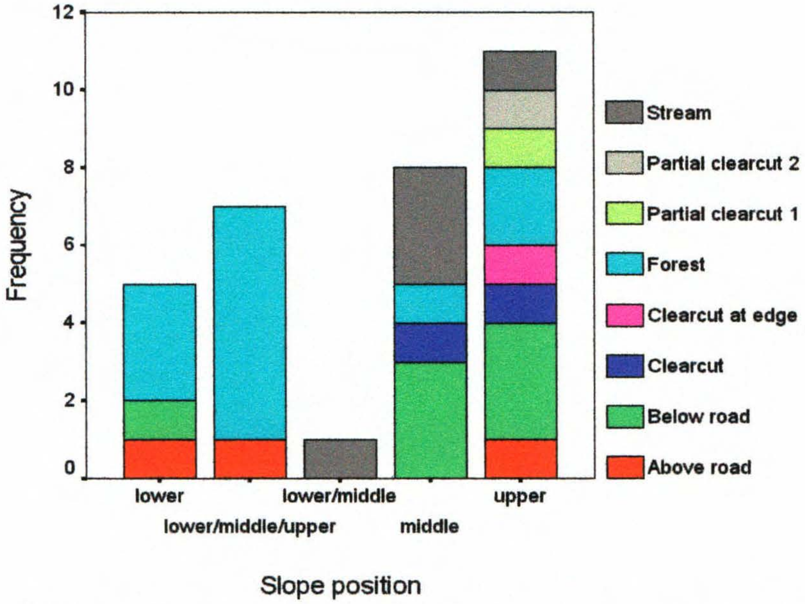


Figure 24: Landslide frequency distributions of slope positions, segregated into land use groups.

Sixty percent of all landslides occur on the upper third of the slope, or involve the entire slope. Landslides that envelope the entire slope (lower, middle and upper) account for the greatest volume. These landslides are commonly in forested areas, due to the greater energy needed to break the rooting systems of the trees. Landslides in the middle and lower slope area are more frequent, but yield a smaller volume. These findings are somewhat contradictory to some previous studies. Furbisch (1981) thought that such major slope breaks mark a pronounced discontinuity of usable energy for transport of slope material and serve as an intermediate storage site for upland-derived material. The sliding mechanism may represent episodic exceedence of intrinsic thresholds of soil strength in response to loading of lower slope (Pipp and others, 1997). In the case of this study it is felt that the forest areas involving the entire slope were more influenced by spring water and existing geology than by previous loading, accounting for the higher than expected numbers for landslide volumes at the upper and middle slope positions.

ELEVATION

Elevation of each landslide location ranged from 1,235 to 3,290 feet. Eighty-seven percent of the landslides originate at elevations between 1,240 and 3,100 feet, with bimodal distribution peaks of 1240 and 2900 feet (Figure 25). The distribution is bimodal due to the numerous landslide locations along Orofino Creek near the town of Orofino (elevation 1,235 feet), where there are six landslides within a half mile of each other. The majority of the remaining landslides are atop the plateau above an elevation of 2,500 feet.

Nearly all the landslides occurring in forested areas or influenced by streams are located lower than 2,400 feet. Areas impacted by roads and/or clearcuts are found at the higher elevations and account for less volume than those of the lower elevations (Figure 26).

Higher elevations in the region are used more frequently for timber production, and therefore have increased road building activity and clearcut influence. These areas are also more widespread than the low elevation areas, which are confined to the deep valleys. The lower elevations also have a much higher human population, so roads are constructed better, will be less prone to sliding, unlike most roads in forested areas.

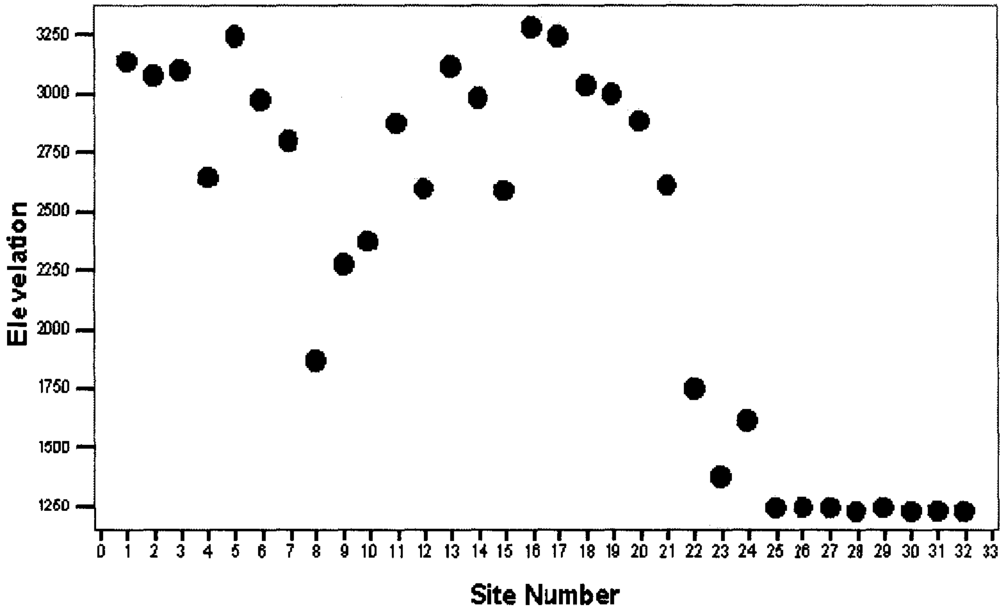


Figure 25: Elevation at each landslide location.

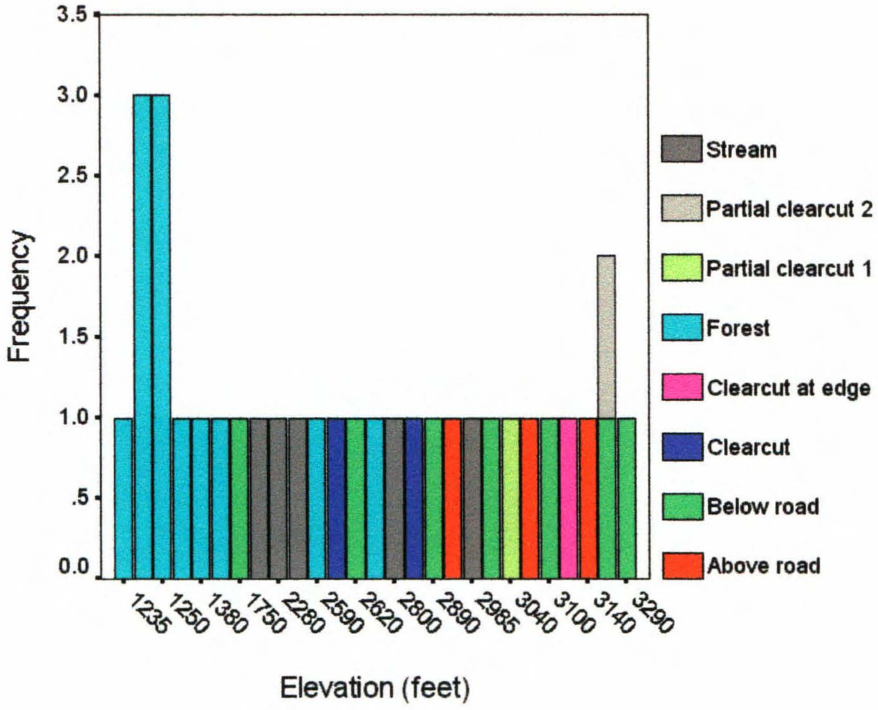


Figure 26: Landslide frequency distribution of elevation segregated into land use groups.

PARENT MATERIAL AND SOILS

Parent material in the study area is statistically the strongest determining factor for both landslide frequency and volume. In Figures 27 and 28 the classifications of "colluvium/metamorphic" and "loess/basalt" account for 68.8% of all landslide activity. Colluvium is defined as gravity driven deposits of basaltic nature. Sites with a parent material type of "colluvium/metamorphic" are sites associated with springs at a geologic contact between basalt colluvium and metamorphic rocks. At these sites, the parent material type is an indicator of a geologic cause for landsliding, rather than parent material type. Thirty-one percent of the total landslides in the area are associated with colluvium/metamorphic parent material, whereas 37.5% of total landslides are associated with a loess/basalt parent material. This indicates that basalt has a strong influence on slope stability during saturated ground conditions. The greatest volume of material is associated with colluvium/metamorphic parent material type.

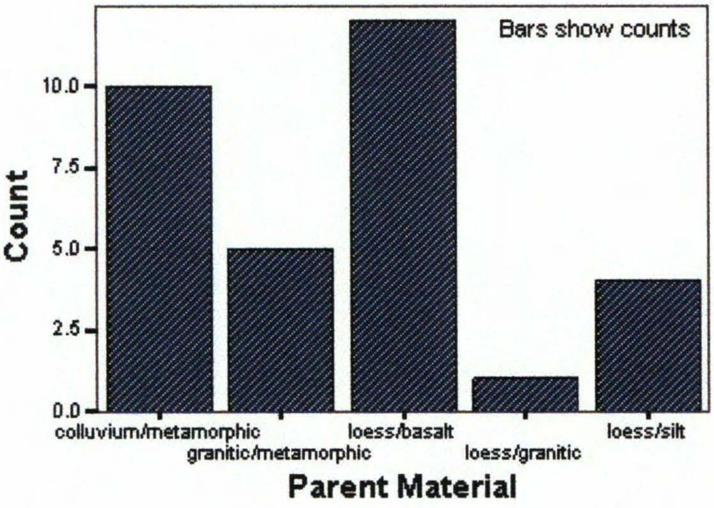


Figure 27: Frequency of landslide activity for each parent material type.

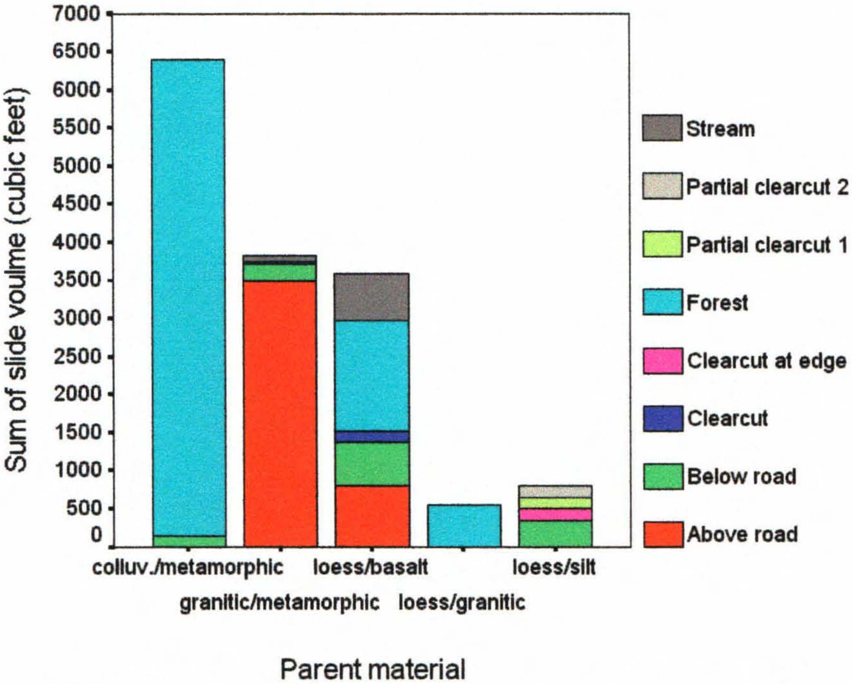


Figure 28: Landslide volume distributions of parent material segregated into land use groups.

Schultz (1980) suggests that the large concentration of total landslide volume at the lower end of the range of landslide volumes can be attributed to the soil block being easily detached during periods of increased pore pressure. The landslides in the study area tend to follow this behavior. The average volume of landslides occurring in forested areas is comparatively higher. This is most likely caused from the increased energy needed to overcome the intrinsic strength of rooting from trees and plants. The total volume of forested landslides is still less than the total volume of landslides derived from non forested areas. This observation can be attributed to the higher frequency smaller scale sliding along roads and clearcut areas (Cacek, 1989).

The bedrock geology and soil types control the nature, and in some cases trigger, slope instability in the study area. The soils found in the study area have very little induration, allowing groundwater to pass through them easily. The soils form directly into bedrock, and in some cases into the colluvium or sediments. The nature of much of the bedrock in the area acts as a barrier to water often leading to perched water tables and a build up of pore pressure in times of increased runoff.

HAZARD POTENTIAL

The potential effects of roads and clearcuts on slope stability are summarized in Table 6. The effects of roads may be blatant, such as failure of the road prism, or implicit, such as failure downslope from a water diversion structure. The effects of road destabilization may linger on for many years until infilling from sliding or creep stabilizes the slope. Alternatively, clearcut sites show the greatest vulnerability 5 to 10 years following harvest due to deterioration of rooting strength. After this, the bulk soil strength begins to increase again due to regrowth (Swanston and Swanson, 1976). In sensitive areas not influenced strongly by other characteristics, road location, construction, and maintenance are critical to slope stability.

Clearcut areas were found not to exhibit a significant increase in landslide activity unless they were associated with road construction. In clearcut areas, runoff often takes the form of surface runoff and gulling, not major landsliding. The addition of roads at the site of clearcuts often leads to landsliding in the areas adjacent to the roads, either in the fill or the cut bank. Road impacts have shown strong relationships to landsliding throughout the Pacific Northwest, including the Oregon Cascades (Gresswell and others, 1979; Harr, 1981; Marion, 1981; McHugh, 1986; Berris and Harr, 1987) the Olympic Peninsula (Fiksdal, 1974) British Columbia (O'Loughlin, 1972) and the Idaho Batholith (Gray and Megahan, 1981; Cacek, 1989; Falter and Rabe, 1997; Cundy,1997; Cundy and Murphy, 1997).

Table 6: Potential negative effects of engineering activities on slope stability (adapted from Swanston and Swanson, 1976).

Land use impact	*Potential effect*
1). Potential road effects	a) Eliminate evapotranspiration. b) Alter snowmelt hydrology. c) Alteration of slope drainage network via culverts and water bars. d) Interception of subsurface water at cutslope. e) Reduce infiltration by compacted road surface. f) Increase slope angle at cut and fill slopes. g) Reduced compaction and apparent cohesion of soil used as road fill. h) Removal of toe support of cut slope.
2). Potential clearcut effects	a) Reduce evapotranspiration. b) Eliminate lateral and vertical rooting support. c) Alter snowmelt hydrology. d) Alter storm runoff hydrology. i. Increase runoff intensity ii. Alter soil piezometry by forming a discontinuous macropore network.

The primary effects of clearcutting on slope stability include an increase in the depth of saturated soil and a deterioration of rooting strength (Megahan, 1992). Stabilizing effects of rooting systems are the greatest when roots penetrate deep into the underlying bedrock or compacted soil surface. Furbish (1981) stated that roots provide a reinforcing effect to soil through their tensile resistance to friction. Vertical tap and sinker roots contribute the most to sliding resistance of soils on steep, inclined slopes (Gray and Megahan, 1981). All of the landslides in the study area are shallow (less than 3 feet), yet rarely expose broken sinker roots on the landslide surface. This shows that there was a lack of vertical reinforcement due to the horizontal root growth pattern. This also helps to explain the lack of landslides in clearcut areas not affected by road construction. In areas of clearcutting, the removal of the trees and the subsequent disintegration of the rooting system will have a minor influence on decreasing shear strength of the surface material. There would be an increase in landslide activity in areas where deeply penetrating root systems were removed and a dramatic loss in shear strength resulted. The effect of clearcutting, particularly where ground disturbance is minimal, generally does not act to concentrate storm runoff or increase slope angle the way that road construction does (Cacek, 1989).

Table 7 shows the criteria used to produce the included hazard map. Soil and parent material type for areas not previously discussed are included in Appendix C.

Table 7: Criteria used for the creation of hazard map

Location	**Potential Causes of Landsliding**	**Hazard Severity**
1. Forested	(a) High Slope Gradients (over 50%) (b) Geologic Contact with Spring (c) Basalt Parent Material as Component (d) Along Roads (e) NW Aspect (f) Unaffected Areas	(a) Low-Moderate (b) High (c) Moderate-High (d) Low (e) Moderate (f) none
2. Partial Clearcut	(a) Along Roads (b) Moderate-High Slope Gradients (c) Basalt Parent Material as Component (d) Unaffected (Except by Partial Clearcut)	(a) Moderate-High (b) Moderate (c) Moderate (d) Low
3. Clearcut	(a) Along Roads (b) Moderate-High Slope Gradients (c) Basalt Parent Material as Component (d) Unaffected (Except by Clearcut)	(a) High (b) Moderate (c) Moderate (d) Low-Moderate
4. Road Construction	(a) Slope Gradient (30%-50%) (b) Condition of Road (Unused) (c) Condition of Road (Frequently Used) (d) Fill Material (Basalt) (e) Cut Slope (f) Fill Prism	(a) Moderate (b) Moderate-High (c) Moderate (d) Moderate (e) High (f) High
5. Streams	(a) Cut Slope (b) High Gradient (over 40%)	(a) High (b) Low-Moderate

The map included with this study (pocket material) shows which areas are likely to produce landslides in conditions similar to those in the spring of 1996. Areas near Orofino are characterized by steep forested slopes, that are cut near the slope break by springs. Areas in red show areas with a high likelihood of slope failure. Purple and green show areas which have a moderate or low failure potential, respectively. Higher elevation in the study area are to the east on the map. Areas with high hazard potential in those areas are mainly along roads in clearcuts, or in areas which have basalt parent material. Uncolored regions within the study area show areas that have little or no landslide hazard potential. Uncolored areas outside the study area were not included in the landslide hazard map.

WEATHER AND CLIMATE

There is a strong correlation between years of flooding in the study area and La Niña weather events. Figure 29 shows the trend of Southern Oscillation values since 1919 to present. The Southern Oscillation Index is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin. Negative values of the Southern Oscillation Index are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean known as El Niño.

Figure 30 shows the values of the southern Oscillation for the flood years in the study area. In 1919 and 1974, there was a strong El Niño, while in every other year the Southern Oscillation was positive (La Niña). In the winter of 1995-96 the Southern Oscillation was at its second highest value.

There are a few different definitions of how to calculate the Southern Oscillation Index. The definition used by the Australian Bureau of Meteorology is the Troup

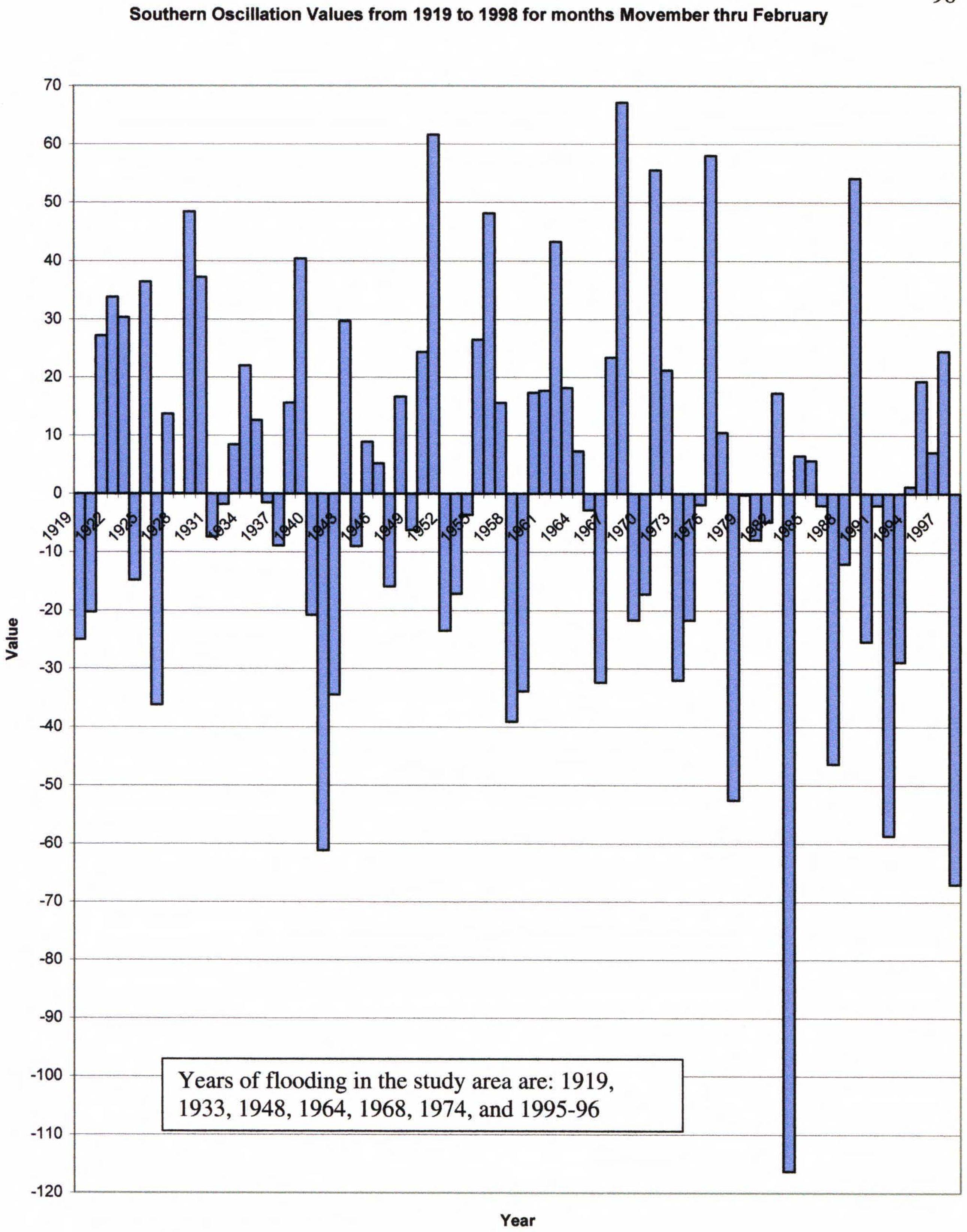
Southern Oscillation Index which is the standardized anomaly of the Mean Sea Level Pressure difference between Tahiti & Darwin. It is calculated as follows:

Table 8: Equation used for calculation of Southern Oscillation Index in this study

$$\mathrm{SOI} = 10 * [\mathrm{Pdiff} - \mathrm{Pdiffave}] / \mathrm{SD}(\mathrm{Pdiff})$$

Pdiff = Tahiti MSLP - Darwin MSLP
Pdiffave = long term average of Pdiff for the month in question
SD(Pdiff) = standard deviation of Pdiff for the month in question

Other effects can include a decrease in the strength of the Pacific trade winds, and an increase in rainfall over the southwestern United States. The most recent El Niño was in 1997-98. Positive values of the Southern Oscillation Index are often associated with stronger Pacific trade winds and warmer sea temperatures to the north of Australia, popularly known as a La Niña episode. Together this gives a high probability that the southwestern United States will be dryer than normal (Figure 31 and 32). Waters in the central and eastern tropical Pacific Ocean become cooler during this time. The most recent strong La Niña was in 1988-89; a fairly weak event occurred in late 1995 and early 1996.



Years of flooding in the study area are: 1919, 1933, 1948, 1964, 1968, 1974, and 1995-96

Figure 29: Graph showing values of Southern Oscillation from 1919 to 1998

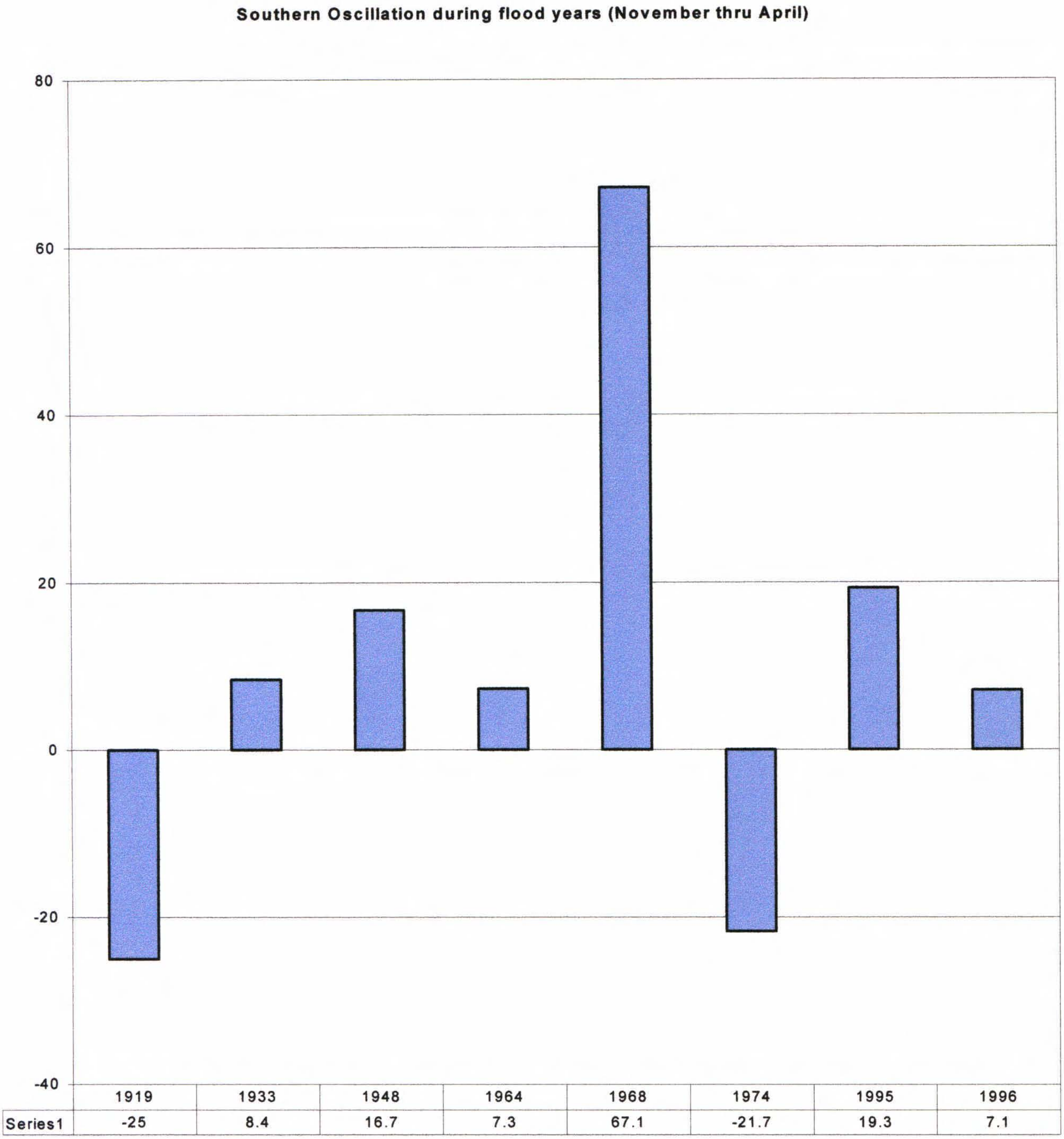


Figure 30: Southern Oscillation values for flood years in the study area.

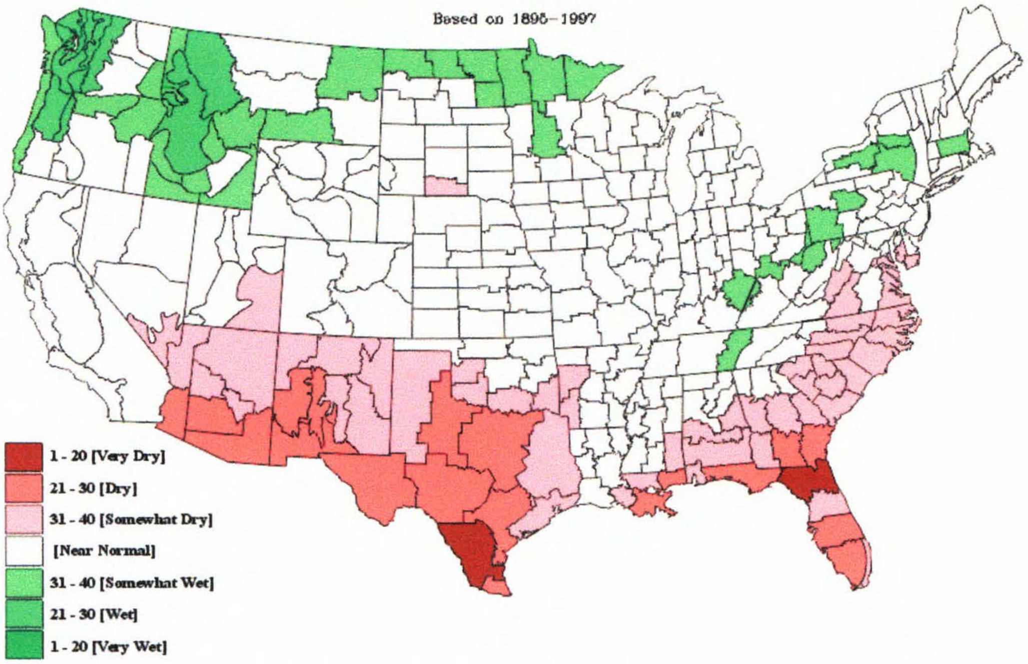


Figure 31: Average precipitation ranks during La Niña events by climate division December - February.

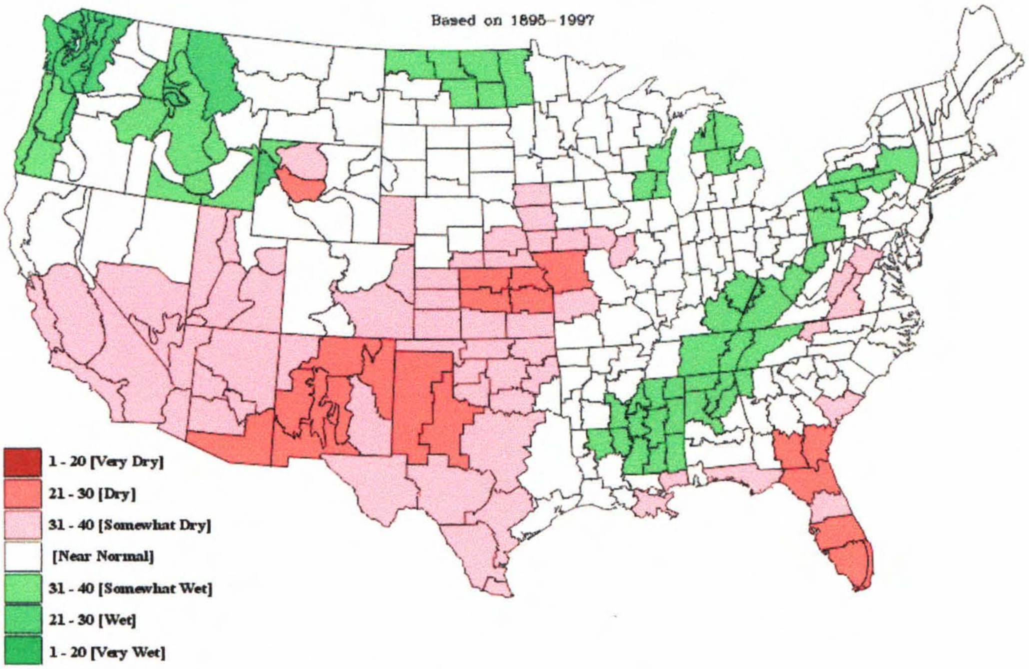


Figure 32: Average precipitation ranks during La Niña events by climate division January - March.

Figure 33 summarizes the results graphically. River basins with correlations greater than 0.35 are shown in red, basins with correlations less than -0.35 in blue, basins with little or no SOI-spring runoff correlation are shown in yellow, and the white indicates areas not analyzed and/or streams that are not water supply forecast points.

Basins with correlations less than -0.35 (blue) tend to have higher than average streamflow during El Niño years (when the SOI is negative, as it is now), and lower than average streamflow during La Niña (when the SOI is positive). Basins with correlations greater than 0.35 (red) tend to exhibit lower than average streamflow during El Niño years and higher than average streamflow during La Niña. Basins with significant SOI correlations (blue and red areas) will require further monitoring as the water year progresses.

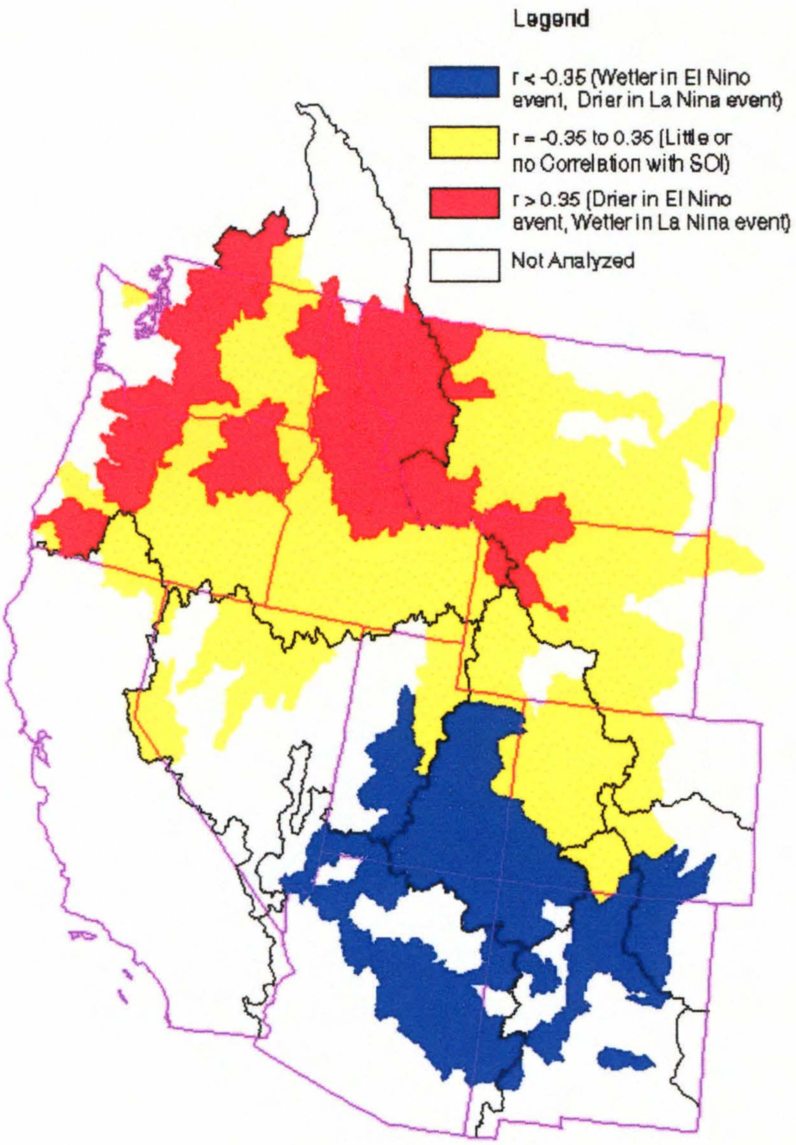


Figure 33: Correlation Map of the Southern Oscillation Index with spring and summer volume runoff

SUMMARY

The previous sections have considered long and short-term climatic and weather conditions associated with flood/mass wasting events. The findings for the study area related to specific site conditions which were segregated into land use groups and other important site specific characteristics.

Landslide activity is strongly related to a few factors in the study area. These factors are not all-inclusive and vary widely depending on specific conditions. Landslides toward the west of the study area and at lower elevations are most strongly related to the underlying geology. The formation of springs at the contacts between basalt and metamorphic bedrock is the primary cause of land failure. This conclusion is supported by the observation that on the opposite side of the canyon, similar land types that do not have the same geologic influence exhibit no landsliding or mass movement. Over the entire study area, sites with a component of basalt in the parent material have a much greater frequency of land failure than those associated with granitic or metamorphic parent material alone.

Long term climate fluctuations such as La Niña and El Niño have shown strong relationships to flooding in the study area. Six of the eight flood events in the study are occurred in years of La Niña, or positive Southern Oscillation. The remaining two flood events occurred in El Niño years, or negative Southern Oscillation. In years of positive Southern Oscillation the climate in the study area, become warmer and wetter (Cayan and Webb, 1992). Increased moisture falls as snow in the high elevations, and as rain at lower elevations (Nicholls, 1988). The warmer climate increases the probability that rain can fall at higher elevations on snow pack that may already be partially melting, leading to extremely high stream flows and runoff rates (Cayan and Webb, 1992; Redmond and Koch, 1991).

CHAPTER 6: CONCLUSIONS

The following conclusions are drawn from consideration of precipitation and climatic data, frequency and volume distributions, landslide characteristics, and timing of landslide initiation.

1) In November and December of 1995 precipitation in the study area was nearly 200 percent of the historical average. In February of 1996, flooding was triggered by intense rainfall on deep, widespread snowpack. These two events had the effect of over-saturating the ground in the area. During the spring 1996, the excess snowmelt coupled with saturated conditions, triggered many landslides in the study area. Presumably, this has also happened during previous similar climatic events.

2) The majority of the landslides initiated on slopes over 35%. The steepest landslides occurred in forested areas where shear strengths were much higher. The lowest gradient landslides initiated in areas near streams or roads. Moderate slopes were required for sliding to initiate in clearcut areas not affected by road construction. Areas with a combination of clearcut and road construction activity had frequent landslides along the road prisms and cut-slopes.

3) The landslides involving the greatest volume of material were located in forested areas because of the higher energy needed to overcome the shear strength, the high slope gradient, and mixed basalt and metamorphic parent material type. The greatest total frequency of landslides was in land use areas such as clearcuts and roads.

Landslides with the smallest volume were located in clearcut and roaded areas, due to the relatively low energy needed to initiate a landslide..

4) Landslides most frequently occur on slopes with northerly aspects. Aspects of landslides in land use areas are fairly random, suggesting a destabilizing effect on slope stability with respect to land use impacts.

5) The largest landslides involve the entire slope, while smaller landslides in the study area are concentrated in the upper and middle slope positions. Preexisting geology and ground water conditions have a greater influence on where the landslide initiates than slope position.

6) Land use impacts that involve roads have the effect of increasing the frequency of landslides in the study area, but not increasing the volume of individual landslides. Smaller landslides in land use areas occur more often than larger landslides occurring in forested areas.

7) Very large landslides along Orofino Creek between Orofino and Konkoville are the result of intense saturation of the contact between basalt and metamorphic rocks. Springs were formed at the top of the slope, which increased pore pressure and initiated sliding. Large landslides near the headwaters of Cooper Creek were caused by several factors including intense runoff, which was locally channelized; oversteepening from road construction and stream activity; and clearcutting beyond the top of the landslide which increased runoff that concentrated at the landslide channel.

8) Southern Oscillation Index data collected show a strong relationship between large-scale flooding in the study area and La Niña weather phases. This relationship correlates well with La Niña data from Washington State.

9) The potential hazards for other sites in the study are summarized in the table below and as a map located in the pocket at the end of this report.

This study area offers opportunities for further work. The following are suggestions for further study.

1. In this study, landslides were studied based on specific conditions for the 1995-1996 flood and landslide events. Further study of landslides that occurred before 1995 may give a clearer picture of landslide history in the area.

2. A useful study might include an investigation of channel modification, sediment discharge, flood dynamics, hydrology, and vegetation.

3. Extensive aerial photo analysis could help establish additional historical landslide activity in the area.

4. Other global weather phenomena could also help to understand and predict the weather conditions that set up large flood and landslide events in the area. Looking for a historical pattern in some weather phenomenon might help planners predict and prepare for future problems.

5. The installation of a stream gauge on Orofino Creek would greatly assist any scientific research in the future. Such a stream gauge on Orofino Creek would allow for better monitoring of streamflow conditions that directly affect the town of Orofino, especially if used in conjunction with SNOWTEL data collected in the high areas. The combination of data from these two sources would help predict the severity of potential flooding should a major storm occur.

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APPENDIX A: PRECIPITATION, PEAK STREAM FLOW, AND SNOW DEPTH DATA

Year	Precip. At Orofino, ID				Precip. At Dworshak Dam, ID				Precip. At Pierce, ID				Snow Depth	Clearwater River At Orofino, ID. Dates and Values of Peak Flows. Base Discharge = 30000		Lochsa River At Lowell, ID. Dates and Values of Peak Flows. Base Discharge = 12000		Selway River At Lowell, ID. Dates and Values of Peak Flows. Base Discharge = 18000		Potlatch River At Kendrick, ID. Dates and Values of Peak Flows. Base Discharge = 3600	
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	(cm)			discharge (c.f.s)		discharge (c.f.s)		discharge (c.f.s)	discharge (c.f.s)
1930																04/24/1930	11800	04/24/1930	14600		
1931														05/17/1931	38600	05/16/1931	12900	05/16/1931	17500		
1932											612	567		05/14/1932	73400	05/14/1932	22800	05/14/1932	30300		
1933	**382**	**241**	**210**	**1201**					**476**	**396**	**276**	**1488**		**06/10/1933**	**81500**	**06/10/1933**	**34800**	**06/14/1933**	**33800**		
1934	669	293	115	192					675	132	704	711				12/23/1933	22500	04/24/1934	20500		
1935	160	391	467	159					477	142	156	419		05/24/1935	42900	05/23/1935	15200	05/23/1935	21900		
1936	90	5	218	240					600	855	53	373		05/15/1936	66800	05/15/1936	21000	05/15/1936	31600		
1937	262	214	374	227					190	571	699	696		05/20/1937	33800	05/19/1937	12100	05/19/1937	17400		
1938	140	192	162	305					434	426	546	380		04/19/1938	72300	04/18/1938	24500	05/28/1938	32800		
1939	629	169	427	265					367	686	80	668				05/04/1939	16900	05/04/1939	23600		
1940	128	99	494	123					447	914	400	432				05/12/1940	12700	05/12/1940	20400		
1941	364	223	229	339					356	191	388	503				05/13/1941	9850	05/13/1941	16100		
1942	200	521	636	316					106	272	775	884				05/26/1942	11800	05/26/1942	19500		
1943	284	380	966	431					559	369	275	395				05/28/1943	19400	05/29/1943	26400		
1944	271	16	170	22					91	397	369	360				05/16/1944	11500	05/16/1944	18600		
1945	304	55	18	475					520	450	770	611				05/06/1945	16000	05/06/1945	20400	12/28/1945	7600
1946	145	340	149	231					647	573	533	866				05/05/1946	13800	05/27/1946	18100	12/15/1946	3660
1947	195	150	322	213					512	309	925	533				05/09/1947	24500	05/08/1947	37000		
1948	**407**	**335**	**456**	**252**					**494**	**560**	**827**	**755**				**05/29/1948**	**34600**	**05/29/1948**	**48900**	**02/26/1948**	**13000**
1949	278	285	189	730					185	877	404	554				05/16/1949	29600	05/16/1949	38600	03/19/1949	5480
1950	318	74	397	295					892	670	512	539				06/17/1950	26200	06/17/1950	32500	03/17/1950	8900
1951	207	63	109	250					705	572	550	853				05/24/1951	16100	05/24/1951	23100	02/12/1951	8550
1952	600	421	48	203					405	329	172	391				04/28/1952	17700	04/28/1952	24200	04/07/1952	4630
1953	172	335	434	447					1211	601	492	647				06/13/1953	18900	06/13/1953	27500	01/23/1953	4540
1954	196	310	288	220					897	320		411				05/21/1954	24500	05/21/1954	29900	03/10/1954	3090
1955	173	346	44	397					374	404	825	663				06/12/1955	24100	06/13/1955	32400	04/10/1955	5380
1956	372	604	368	184					548	484	193					05/24/1956	28500	05/24/1956	41200	12/22/1955	7000
1957	184	99	286	274							357	691				05/20/1957	21100	06/03/1957	26500	05/20/1957	8500
1958	98	185	625	556												05/22/1958	23400	05/22/1958	31600	05/02/1958	4720
1959	251	169	146	200					429	536	722	652				06/06/1959	20900	06/06/1959	29000	01/24/1959	8740
1960	58	265	228	150					809	339	404	220				06/04/1960	18600	06/04/1960	27300	05/30/1960	5750
1961	299	213	399	379					343	376	597	346				05/27/1961	22900	05/27/1961	31300	02/22/1961	7300
1962	330	224	365	396					409	708	589	631	185.1			05/28/1962	16100	04/20/1962	19500	05/20/1962	7800
1963	217	147	504	640					462	245	551	344	255.1			05/24/1963	13900	05/24/1963	21100	02/03/1963	2200
1964	**440**	**545**	**445**	**451**									**120.1**			**06/08/1964**	**35100**	**06/08/1964**	**43400**	**04/16/1964**	**3800**
1965	82	388	324										181.1			12/23/1964	19500	06/12/1965	25600	01/29/1965	16000
1966	201	369	367	364									253	04/21/1965	52000	05/07/1966	16700	05/07/1966	18400	04/01/1966	4500
1967	333	180	254	278		112	124	344					127.3	05/07/1966	42900	05/23/1967	22800	05/23/1967	35200	01/29/1967	5700
1968	**140**	**182**	**77**	**174**	**135**	**422**	**349**	**447**					**165.9**	**05/23/1967**	**66600**	**06/03/1968**	**14600**	**06/03/1968**	**22500**	**02/19/1968**	**11000**
1969	816	348	301	411	423	120	53						203.8	06/03/1968	42600	05/20/1969	17800	05/30/1969	25500	03/27/1969	6820
1970	398	84	163	129	553	153	347	176					265.3	05/20/1969	48500	06/06/1970	23400	06/06/1970	35800	01/24/1970	7920
1971	170	202	464	404	407	192	377	415					115.3	06/06/1970	68400	05/30/1971	27000	05/29/1971	35800	01/20/1971	5310
1972	389	267	129	332	295	569	171						233.1	05/29/1971	69500	06/02/1972	31800	06/02/1972	43400		

Appendix A (continued)

1973	271	136	274	553	145	96	663	583					311.9	06/02/1972	87300	05/18/1973	13100	05/18/1973	19000		
1974	**348**	**473**	**506**	**449**	**386**	**282**	**166**	**305**					**179.3**	**05/18/1973**	**36100**	**06/16/1974**	**32000**	**06/16/1974**	**43100**		
1975	264	200	271	149	636	276	351	501					287.9	06/16/1974	85800	06/07/1975	22100	06/07/1975	32400		
1976	156	226	379	342	326	243	93	69					167.7	06/03/1975	67000	05/11/1976	24500	05/11/1976	33300		
1977	238	397	422	389	129	105	354	610					255.3	05/11/1976	72200	05/02/1977	10400	05/02/1977	15400		
1978	175	114	378	241	247	181	248	282					73	05/02/1977	31100	06/07/1978	17500	06/07/1978	27900		
1979	145	230	250	333	145	200	196	251					272.9	06/07/1978	51400	05/24/1979	20600	05/27/1979	25500		
1980	281	71	317	736	310	231	281						191.7	05/24/1979	56200	04/29/1980	15300	05/06/1980	18400		
1981	561	176	225	69	218	288	284	420					140.9	05/26/1980	40200	05/22/1981	18100	05/22/1981	22000		
1982	331	227	335	330	445	362	187	299					116.3	06/19/1981	46900	06/14/1982	22300	06/17/1982	32000		
1983	476	93	129	379	295	346	319	319					203.1	06/17/1982	60900	05/30/1983	18700	05/29/1983	27000		
1984	194	394	385	460	226	177	324	335					183.4	05/30/1983	50800	05/31/1984	24000	05/31/1984	38000		
1985	455	98	59	259	50	159	218	54					182.9	05/31/1984	71200	05/25/1985	20800	05/25/1985	22900		
1986	564	161	342	208	338	467	406	88					320.4	05/25/1985	49100	05/30/1986	20400	05/30/1986	32000		
1987	413	199	309	420	133	192	149	243					126.1	05/30/1986	59700	05/01/1987	16800	05/01/1987	20100		
1988	354	501	174	416	248	163	347	164					142.6	05/01/1987	42200	05/17/1988	12400	05/17/1988	17700		
1989	193	96	585	569	445	128	163	136					101.8	04/18/1988	38700	05/10/1989	17800	05/11/1989	24600		
1990	381	342	174	347	327	186	547	242					185.6	05/11/1989	53600	04/23/1990	13500	05/30/1990	16600		
1991	509	283	346	568	193	164	538	222					109.3	05/29/1990	53600	05/19/1991	16800	05/19/1991	19800		
1992	359	260	101	112	119	143	321	102					252.8	05/19/1991	51300	04/30/1992	12200	05/09/1992	15200		
1993	98	98	374	650	124	85	133	194					214.6	05/01/1992	30900	05/15/1993	19000	05/15/1993	28600		
1994	310	210	242	306	223		426	357					201.4	05/15/1993	62800	04/22/1994	13000	04/22/1994	18200		
1995	**188**	**291**	**149**	**255**	**284**	**232**	**607**	**421**					**111**	**04/23/1994**	**39500**	**06/04/1995**	**12100**	**06/03/1995**	**17200**		
1996	**291**	**263**	**248**	**353**	**558**	**423**	**428**	**488**					**226.6**	**05/12/1995**	**35700**	**11/30/1995**	**27900**	**06/09/1996**	**31100**		
1997	168	341			484	280	223	169					151.6	11/30/1995	80000						

APPENDIX B: SOIL DATA USED IN HAZARD MAPPING

GROUP 1

	SOIL NAME	POSITION	SLOPE	TEXTURE	DEPTH	DRAINAGE	PARENT MATERIAL	WATER CAPACITY
Cr1	Crumarine silt loam	Upper terraces	0-3%	Silt loam	Very deep	Somewhat poorly drained	Alluvium	About 7.7 inches
Cr2	Crumarine Variant sandy loam	Upper terraces	0-4%	Sandy loam	Very deep	Somewhat excessively well drained	Alluvium	About 4.1 inches
Jo4	Joel-Setters complex	Backslopes	5-20%	Silt loam	Very deep	Well drained	Loess over basalt residuum	About 12.0 inches
Jt1	Jacket silt loam	Backslopes and footslopes	3-12%	Silt loam	Very deep	Well drained	Loess over weathered basalt residuum	About 10.3 inches
Kn4	Klickson silt loam	Footslopes and benches	15-35%	Silt loam	Very deep	Well drained	Loess over basalt colluvium	About 6.0 inches
Kt2	Keuterville gravelly silt loam	Footslopes	10-25%	Gravelly silt loam	Very deep	Well drained	Loess over material from basalt	About 5.5 inches
Ty7	Taney-Setters complex	Footslopes	3-8%	Silt loam	Very deep	Moderately well drained	Loess over silty sediments	About 9.4 inches
Wk1	Wilkins-Setters complex	Footslopes	0-5%	Silt loam	Very deep	Moderately well drained	Loess over silty sediments	About 11.6 inches

GROUP 2

	SOIL NAME	POSITION	SLOPE	TEXTURE	DEPTH	DRAINAGE	PARENT MATERIAL	WATER CAPACITY
Ag3	Agatha gravelly silt loam	Backslopes	40-75%	Gravelly silt loam	Deep	Well drained	Loess and material from basalt	About 7.2 inches
Ca1	Seddow silt loam	Summits and shoulders	5-15%	Silt loam	Deep	Well drained	Mixed volcanic ash and loess over material from basalt	About 6.6 inches
Ca2	Seddow silt loam	Summits and backslopes	15-25%	Silt loam	Deep	Well drained	Mixed volcanic ash and loess over material from basalt	About 6.6 inches
Ca4	Cavendish silt loam	Summits and shoulders	2-8%	Silt loam	Deep	Well drained	Loess over material from basalt	About 8.1 inches
Cn1	Carlinton silt loam	Summits and Backslopes	3-20%	Silt loam	Very deep	Moderately well drained	Loess over silty sediments	About 7.2 inches
Cn3	Carlinton-Kruse complex	Summits, footslopes, and backslopes	5-20%	Silt loam	Moderately deep	Moderately well drained	Loess over silty sediments	About 8.2 inches
Cn4	Sly silt loam	Benches	3-20%	Silt loam	Very deep	Well drained	Mixture of loess and volcanic ash over weathered basalt	About 8.2 inches

Group 2 (continued)

Cn6	Carlinton-Seddow complex	Plateaus	3-15%	Silt loam	Moderately deep	Moderately well drained	Mixture of loess and volcanic ash over weathered basalt	About 8.2 inches
Jn1	Johnson-Swayne complex	Backslopes and summits	20-40%	Loam	Deep	Well drained	Loess over material from granitic rocks	About 9.8 inches
Jn2	Johnson-Texascreek complex	Backslopes, footslopes, and summits	35-75%	Loam	Deep	Well drained	Loess and material from granitic or metamorphic rocks	About 8.0 inches
Ko1	Kooskia silt loam	Summits and backslopes	3-10%	Silt loam	Very deep	Moderately well drained	Loess and material from basalt	About 10.4 inches
Ko2	Kooskia silt loam	Summits and backslopes	10-20%	Silt loam	Very deep	Moderately well drained	Loess and material from basalt	About 10.4 inches
Rg1	Gwin-Kettenbach complex	Summits and shoulders	10-25%	Gravelly silt loam	Moderately deep	Well drained	Loess and basalt residuum	About 2.4 inches
Sy1	Swayne silt loam	Benches and toe slope	10-20%	Silt loam	Very deep	Moderately well drained	Loess, alluvium and material weathered from granite	About 8.0 inches

GROUP 3

	SOIL NAME	POSITION	SLOPE	TEXTURE	DEPTH	DRAINAGE	PARENT MATERIAL	WATER CAPACITY
Ag1	Agatha gravelly silt loam-Rock outcrop complex	Backslopes and shoulders	35-75%	Gravelly silt loam	Deep	Well drained	Loess and material from basalt	About 7.2 inches
Ag2	Agatha gravelly silt loam	Backslopes and shoulders	15-40%	Gravelly silt loam	Deep	Well drained	Loess and material from basalt	About 7.2 inches
Ag4	Campra gravelly silt loam	Backslopes	20-40%	Gravelly silt loam	Deep	Well drained	Mixed volcanic ash and loess over material from basalt	About 7.2 inches
Ag5	Campra gravelly silt loam	Backslopes	40-75%	Gravelly silt loam	Deep	Well drained	Mixed volcanic ash and loess over material from basalt	About 7.2 inches
Bp2	Kettenbach-Keuterville association	Backslopes	35-75%	Gravelly silt loam	Deep	Well drained	Loess and material from basalt	About 3.5 inches
Cn2	Carlinton silt loam	Backslopes and shoulders	20-30%	Silt loam	Moderately deep	Moderately well drained	Loess over silty sediments	About 7.2 inches
Cn5	Sly-Campra complex	Benches and sideslopes	10-35%	Silt loam	Very deep	Well drained	Mixture of loess and volcanic ash over weathered basalt	About 8.2 inches
Dk4	Dworshak silt loam	Backslopes	15-35%	Silt loam	Very deep	Moderately well drained	Volcanic ash over silty alluvium	About 12.0 inches

Group3 (continued)

Ea1	Grangemont Variant-Riswold complex	Benches, canyon side slopes	5-20%	Silt loam	Very deep	Moderately well drained	Volcanic ash over silty alluvium	About 12.0 inches
Fo1	Fordcreek loam	Backslopes	5-15%	Loam	Deep	Well drained	Loess and alluvium over material from granitic rocks	About 6.9 inches
Jn4	Johnson loam	Backslopes	45-65%	Loam	Deep	Well drained	Loess over material from granitic rocks	About 8.9 inches
Jt4	Jacket-Wellsbench complex	Backslopes and footslopes	20-35%	Silt loam	Very deep	Well drained	Loess over basalt residuum	About 10.7 inches
Kn1	Klickson silt loam	Backslopes	35-90%	Silt loam	Very deep	Well drained	Loess and material from basalt	About 6.0 inches
Kn2	Klickson-Agatha association	Backslopes	35-75%	Silt loam	Very deep	Well drained	Loess and material from basalt	About 6.0 inches
Kn3	Klickson-Kettenbach association	Backslopes	35-90%	Silt loam	Deep	Well drained	Loess and material from basalt	About 5.0 inches
Kn5	Klickson-Rock outcrop complex	Backslopes	45-90%	Silt loam	Very deep	Well drained	Loess and material from basalt	About 6.0 inches
Kt1	Keuterville-Rock outcrop complex	Backslopes	35-90%	Gravelly silt loam	Very deep	Well drained	Loess and material from basalt	About 5.5 inches

Group 3 (continued)

Kt3	Keuterville gravelly silt loam	Backslopes	25-50%	Gravelly silt loam	Very deep	Well drained	Loess over material from basalt	About 5.5 inches
Pt1	Porrett silt loam	Backslopes	0-3%	Silt loam	Very deep	Very poorly drained	Mixed volcanic ash and alluvium	About 12.0 inches
Re1	Reggear silt loam	Backslopes	5-15%	Silt loam	Very deep	Moderately well drained	Mixed volcanic ash and loess over silty sediments	About 7.6 inches
Se1	Setters silt loam	Backslopes	3-8%	Silt loam	Very deep	Moderately well drained	Loess over silty sediments	About 11.6 inches
Sk2	Southwick-Larkin complex	Backslopes and footslopes	12-25%	Silt loam	Very deep	Well drained	Loess over silty sediments	About 9.0 inches
Sp1	Texascreek-Rock outcrop complex	Backslopes	45-75%	Loam	Moderately deep	Well drained	Loess and material from granitic or metamorphic rocks	About 4.1 inches
Ty4	Cavendish-Taney complex	Backslopes	8-20%	Silt loam	Deep	Well drained	Loess over basalt residuum and silty sediments	About 8.2 inches
Ty5	Taney-Setters complex	Backslopes	8-20%	Silt loam	Very deep	Moderately well drained	Loess over silty sediments	About 9.4 inches

GROUP 4

	SOIL NAME	POSITION	SLOPE	TEXTURE	DEPTH	DRAINAGE	PARENT MATERIAL	WATER CAPACITY
Ao1	Aldermand loam	Backslopes	35-75%	Loam	Very deep	Well drained	Mixed volcanic ash and material from granitic or metamorphic rocks	About 6.2 inches
Br2	Broquito-Mushell complex	Backslopes	15-35%	Silt loam	Very deep	Well drained	Loess and material from granitic rocks with a thin volcanic ash mantle	About 10.0 inches
Ek1	Elkridge-Riswold complex	Backslopes and footslopes	20-40%	Silt loam	Deep	Well drained	Loess over material from basalt with a thin volcanic ash mantle	About 6.5 inches
Ek2	Elkridge-Riswold complex	Backslopes and footslopes	40-70%	Silt loam	Deep	Well drained	Loess over material from basalt with a thin volcanic ash mantle	About 6.5 inches
Gk1	Grangemont-Kauder complex	Backslopes, footslopes, and summits	5-20%	Silt loam	Very deep	Well drained	Loess over silty sediments with a thin mantle of volcanic ash	About 10.5 inches
Pd2	Placer-Dowper-Grangemont complex	Backslopes, shoulders, and summits	15-40%	Silt loam	Very deep	Well drained	Loess over silty sediments with a thin mantle of volcanic ash	About 10.5 inches
Rk1	Reggear-Kauder complex	Backslopes	5-20%	Silt loam	Deep	Moderately well drained	Loess over silty sediments with a thin mantle of volcanic ash	About 7.8 inches
Rw1	Riswold-Grangemont complex	Backslopes, footslopes, and shoulders	15-35%	Silt loam	Very deep	Well drained	Loess over material from basalt with a thin volcanic ash mantle	About 10.0 inches

APPENDIX C: SOUTHERN OSCILLATION DATA

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1876	11.3	11	0.2	9.4	6.8	17.2	-5.6	12.3	10.5	-8	-2.7	-3
1877	-9.7	-6.5	-4.7	-9.6	3.6	-16.8	-10.2	-8.2	-17.2	-16	-12.6	-12.6
1878	-8.7	-21.1	-15.5	-8.8	2.1	-3.1	15.9	13	17.7	10.9	15.1	17.9
1879	12.7	14.3	13.2	12.7	2.1	16.4	21.8	22.6	18.9	15.2	9.8	-5.5
1880	10.8	7.7	14.3	5.3	12.3	9.1	1.6	14.3	8.1	4.8	7.2	-1.9
1881	-7.3	-5.5	1.8	0.3	-4.3	-4.7	-5.6	-11.4	-13.6	-23.9	7.2	9.8
1882	-6.8	-1.3	5.1	1.2	6.8	-12	-21.3	-25.6	-14.8	-2.5	2.6	10.3
1883	6	9.1	-25.3	14.4	13.9	3.4	-10.2	1.4	-8.2	4.8	5.2	-15.2
1884	-12.5	-5	9.4	-15.4	1.3	9.1	-3	-5	-7	4.2	-1.4	-12.6
1885	-16.3	1.6	5.1	-0.5	-4.3	-14.4	-5	-9.5	-4	-17.8	-15.9	5.2
1886	-0.6	1.6	2.9	4.5	6	5	7.4	13.6	13.5	13.4	10.5	14.4
1887	12.2	11	10	9.4	-4.3	5	4.8	4.6	5.1	4.8	-5.3	5.2
1888	-3	-2.2	-11.7	-23.6	-9.8	-16	-16.7	-8.9	-9.4	-14.7	-12.6	-2.4
1889	-25.9	-1.7	-27.5	-0.5	-1.9	22	1.6	2.1	11.1	4.2	23	22
1890	20.8	11	14.3	6.9	3.6	5.8	-2.3	-3.1	9.3	3.6	2.6	0.6
1891	15.6	-3.6	-9.5	4.5	-0.3	-1.5	-6.3	-8.9	-10.6	0.6	-4.7	-4.5
1892	2.7	-10.2	11.1	6.9	10	19.6	7.4	5.9	6.3	8.5	-0.7	3.7
1893	11.3	7.7	-1.4	1.2	-3.5	10.7	14	7.8	5.7	7.9	2.6	1.6
1894	17.5	10	5.6	-3	-5.1	-1.5	-2.3	-5.7	-1.6	1.8	7.2	0.1
1895	5.6	3	-0.3	-7.1	-8.2	-4.7	-0.4	-6.3	-4	-5.6	-8.6	-3.5
1896	1.3	4.9	-6.3	-8.8	-42.2	-30.6	-20.6	-22.4	-19	-19	-11.9	-14.2
1897	-12.5	-7.4	-16.6	-17.8	-16.9	0.2	-2.3	0.8	0.2	1.8	-8	10.3
1898	7	6.3	19.2	11.1	-1.9	-2.3	6.1	2.1	3.2	-0.7	-2.7	-0.4
1899	13.2	9.1	13.8	4.5	-7.4	-10.4	-5.6	-10.1	-1.6	6.1	15.8	-3
1900	-7.3	-6.5	-25.3	-18.7	-7.4	26.1	10	7.8	-16.6	-17.2	-6	-5.5
1901	-0.1	3	9.4	4.5	-0.3	19.6	14.6	9.8	-16	-22.1	-8.6	-1.9
1902	17	-2.2	11.6	7.8	7.6	2.6	1.6	-8.9	-17.8	-7.4	-3.4	-3
1903	-9.2	-10.2	17.6	17.7	7.6	-0.6	6.1	0.1	8.7	4.2	1.3	15.9
1904	14.1	16.2	9.4	31.7	9.2	-7.1	-8.9	0.8	0.2	1.2	-17.2	2.6
1905	-9.2	-16.8	-30.2	-42.6	-37.4	-31.4	-21.3	-7.6	-7	-5.6	-17.9	-13.1
1906	-3.5	-7.4	-5.2	-8.8	1.3	-3.9	6.8	15.5	18.3	9.1	21.7	4.7
1907	5.1	1.6	-0.3	4.5	10	8.3	-4.3	-8.2	0.2	0.6	-2	8.8
1908	-10.6	7.7	0.2	16.8	-1.1	-2.3	2.2	5.3	17.7	7.9	2.6	-5.5
1909	-2.5	-3.2	-0.3	-14.5	2.1	22.8	10.7	9.8	0.8	4.2	9.2	4.7
1910	5.6	15.2	12.7	5.3	0.5	22	20.5	9.8	15.3	10.3	19.7	15.9
1911	3.2	1.6	3.5	2	-8.2	-12	-12.8	-12.1	-8.8	-11.7	-7.3	-1.4
1912	-9.7	-17.3	-9	-21.1	-13	-6.3	-0.4	-7.6	-4	-8	2.6	-8
1913	-3.5	-5	1.3	-6.3	-8.2	-3.9	-1.7	-7.6	-9.4	-9.2	-11.9	-7
1914	-5.4	2	9.4	-14.5	-0.3	-16.8	-18	-17.2	-12.4	-8.6	-11.9	-1.4
1915	-21.6	-2.2	-20.4	-17.8	-12.2	6.6	14	7.2	7.5	2.4	-14.6	9.8
1916	5.6	-3.6	-6.3	-0.5	6.8	9.1	25.7	16.2	4.5	6.1	9.8	15.4
1917	5.1	10	18.1	21.8	21.8	21.2	28.3	34.8	29.7	15.2	21	22.5

1918	14.6	16.6	-2	16.8	10	-4.7	-14.1	-4.4	-8.2	-5	1.3	-8
1919	-14.9	-11.2	-12.8	-3	-7.4	-10.4	-8.9	-6.9	-5.8	-10.5	-11.3	-9.1
1920	1.8	-1.7	-4.1	0.3	-2.7	6.6	9.4	5.3	5.1	-4.3	-0.1	9.8
1921	10.8	6.7	8.9	-7.1	2.1	22	2.9	-6.9	5.1	9.7	8.5	8.2
1922	8	9.1	5.6	-5.5	-5.1	5.8	2.2	-1.2	5.1	6.1	8.5	11.8
1923	5.6	4.4	8.9	8.6	2.1	1	-11.5	-18.5	-14.8	-6.2	-12.6	2.1
1924	-5.4	1.1	2.4	-15.4	11.5	8.3	7.4	10.4	8.1	7.9	11.8	5.2
1925	5.6	13.8	14.9	14.4	-1.1	-4.7	-13.4	-10.8	-6.4	-12.9	-9.3	-7
1926	-5.4	-14.5	-13.3	-7.1	-2.7	-7.1	-1	-7.6	1.4	4.2	1.3	6.2
1927	5.1	1.1	18.1	6.9	6	8.3	6.1	-5	-0.4	-4.3	-8	7.7
1928	-10.1	10.5	13.8	11.9	-2.7	-7.9	-0.4	9.8	8.1	9.1	2.6	11.8
1929	16	18	5.1	4.5	-12.2	1	1.6	0.1	-0.4	7.9	11.1	5.7
1930	12.7	7.7	1.8	-3.8	2.1	-5.5	-4.3	-1.8	-7	3.6	1.9	-1.4
1931	7	-14.9	5.6	8.6	13.1	18.8	9.4	0.1	5.1	-12.9	-4.7	4.7
1932	1.8	-3.6	-2.5	-2.1	2.8	-4.7	-5	-6.9	-8.8	-4.3	-4.7	3.2
1933	-11.1	4.9	-2	3.6	6	-3.9	3.5	-0.5	2	3.6	7.2	8.2
1934	6.5	0.1	0.2	6.1	-7.4	10.7	2.9	-22.4	-6.4	4.2	13.1	-2.4
1935	6.5	-4.6	12.2	2.8	-6.6	-2.3	-0.4	2.1	6.3	7.3	3.9	-4
1936	-2	0.6	1.8	22.6	4.4	-1.5	4.2	-8.9	2.6	-0.1	-13.9	0.6
1937	9.4	-5	6.2	2	-0.3	3.4	-5.6	3.3	0.8	-2.5	-2	6.7
1938	7.5	3.4	-3.6	3.6	13.1	18	18.5	13	7.5	12.8	1.9	13.8
1939	17	7.7	11.6	9.4	-1.1	-1.5	8.1	-0.5	-9.4	-14.7	-8	-8.6
1940	-0.1	-4.1	-10.6	-9.6	-14.5	-19.3	-15.4	-18.5	-19.6	-18.4	-6.7	-29.4
1941	-9.7	-15.4	-10.6	-11.2	-6.6	-14.4	-20.6	-19.1	-8.2	-20.2	-9.3	-8.6
1942	-13	-3.6	-5.8	-5.5	5.2	8.3	-1	4	8.7	8.5	-4	13.8
1943	9.4	10.5	4	13.5	2.8	-7.9	2.9	7.8	5.7	9.1	3.9	-8.6
1944	-8.2	3.9	5.6	-5.5	-1.1	-3.9	-8.9	3.3	2.6	-8.6	-6.7	4.2
1945	5.1	6.3	13.2	-7.1	-0.3	8.3	3.5	11.7	8.7	2.4	-3.4	6.7
1946	-2.5	4.4	-2	-9.6	-11.4	-9.6	-10.2	-4.4	-16	-12.3	-1.4	-5.5
1947	-4.9	-4.1	11.6	-4.6	-13.7	2.6	9.4	7.2	11.7	-1.9	9.2	5.2
1948	-3	-2.7	-4.1	2.8	3.6	-4.7	0.9	-4.4	-7.6	6.1	4.6	-5.5
1949	-7.3	2	5.6	1.2	-5.8	-12	-1.7	-4.4	2	5.4	-6	7.7
1950	5.1	17.6	17.6	16.8	7.6	26.9	21.1	12.3	6.9	17.1	12.5	23
1951	16.5	9.6	-1.4	-1.3	-6.6	5	-8.2	-0.5	-7	-8	-3.4	-3
1952	-9.2	-7.9	0.2	-8.8	6	7.4	3.5	-3.7	-3.4	1.8	-0.7	-12.6
1953	2.2	-6	-5.8	-0.5	-31.9	-2.3	-1	-17.2	-13	-0.1	-2	-4
1954	6	-3.6	-0.9	6.9	4.4	-1.5	4.2	10.4	4.5	1.8	3.9	12.8
1955	-5.4	15.2	2.9	-3	13.1	16.4	19.2	14.9	14.1	15.2	15.1	9.3
1956	11.3	12.4	9.4	11.1	17.9	12.3	12.6	11	0.2	18.3	1.9	10.3
1957	5.6	-2.2	-0.9	1.2	-12.2	-2.3	0.9	-9.5	-10.6	-1.3	-11.9	-3.5
1958	-16.8	-6.9	-1.4	1.2	-8.2	0.2	2.2	7.8	-3.4	-1.9	-4.7	-6.5
1959	-8.7	-14	8.4	3.6	2.8	-6.3	-5	-5	0.2	4.2	11.1	8.2
1960	0.3	-2.2	5.6	7.8	5.2	-2.3	4.8	6.6	6.9	-0.7	7.2	6.7
1961	-2.5	6.3	-20.9	9.4	1.3	-3.1	2.2	0.1	0.8	-5	7.2	13.8
1962	17	5.3	-1.4	1.2	12.3	5	-0.4	4.6	5.1	10.3	5.2	0.6
1963	9.4	3	7.3	6.1	2.8	-9.6	-1	-2.4	-5.2	-12.9	-9.3	-11.6
1964	-4	-0.3	8.4	13.5	2.8	7.4	6.8	14.3	14.1	12.8	2.6	-3
1965	-4	1.6	2.9	-12.9	-0.3	-12.8	-22.6	-11.4	-14.2	-11.1	-17.9	1.6
1966	-12	-4.1	-13.9	-7.1	-9	1	-1	4	-2.2	-2.5	-0.1	-4

1967	14.6	12.9	7.8	-3	-3.5	6.6	1.6	5.9	5.1	-0.1	-4	-5.5
1968	4.1	9.6	-3	-3	14.7	12.3	7.4	0.1	-2.8	-1.9	-3.4	2.1
1969	-13.5	-6.9	1.8	-8.8	-6.6	-0.6	-6.9	-4.4	-10.6	-11.7	-0.1	3.7
1970	-10.1	-10.7	1.8	-4.6	2.1	9.9	-5.6	4	12.9	10.3	19.7	17.4
1971	2.7	15.7	19.2	22.6	9.2	2.6	1.6	14.9	15.9	17.7	7.2	2.1
1972	3.7	8.2	2.4	-5.5	-16.1	-12	-18.6	-8.9	-14.8	-11.1	-3.4	-12.1
1973	-3	-13.5	0.8	-2.1	2.8	12.3	6.1	12.3	13.5	9.7	31.6	16.9
1974	20.8	16.2	20.3	11.1	10.7	2.6	12	6.6	12.3	8.5	-1.4	-0.9
1975	-4.9	5.3	11.6	14.4	6	15.5	21.1	20.7	22.5	17.7	13.8	19.5
1976	11.8	12.9	13.2	1.2	2.1	0.2	-12.8	-12.1	-13	3	9.8	-3
1977	-4	7.7	-9.5	-9.6	-11.4	-17.7	-14.7	-12.1	-9.4	-12.9	-14.6	-10.6
1978	-3	-24.4	-5.8	-7.9	16.3	5.8	6.1	1.4	0.8	-6.2	-2	-0.9
1979	-4	6.7	-3	-5.5	3.6	5.8	-8.2	-5	1.4	-2.5	-4.7	-7.5
1980	3.2	1.1	-8.5	-12.9	-3.5	-4.7	-1.7	1.4	-5.2	-1.9	-3.4	-0.9
1981	2.7	-3.2	-16.6	-5.5	7.6	11.5	9.4	5.9	7.5	-5	2.6	4.7
1982	9.4	0.6	2.4	-3.8	-8.2	-20.1	-19.3	-23.6	-21.4	-20.2	-31.1	-21.3
1983	-30.6	-33.3	-28	-17	6	-3.1	-7.6	0.1	9.9	4.2	-0.7	0.1
1984	1.3	5.8	-5.8	2	-0.3	-8.7	2.2	2.7	2	-5	3.9	-1.4
1985	-3.5	6.7	-2	14.4	2.8	-9.6	-2.3	8.5	0.2	-5.6	-1.4	2.1
1986	8	-10.7	0.8	1.2	-6.6	10.7	2.2	-7.6	-5.2	6.1	-13.9	-13.6
1987	-6.3	-12.6	-16.6	-24.4	-21.6	-20.1	-18.6	-14	-11.2	-5.6	-1.4	-4.5
1988	-1.1	-5	2.4	-1.3	10	-3.9	11.3	14.9	20.1	14.6	21	10.8
1989	13.2	9.1	6.7	21	14.7	7.4	9.4	-6.3	5.7	7.3	-2	-5
1990	-1.1	-17.3	-8.5	-0.5	13.1	1	5.5	-5	-7.6	1.8	-5.3	-2.4
1991	5.1	0.6	-10.6	-12.9	-19.3	-5.5	-1.7	-7.6	-16.6	-12.9	-7.3	-16.7
1992	-25.4	-9.3	-24.2	-18.7	0.5	-12.8	-6.9	1.4	0.8	-17.2	-7.3	-5.5
1993	-8.2	-7.9	-8.5	-21.1	-8.2	-16	-10.8	-14	-7.6	-13.5	0.6	1.6
1994	-1.6	0.6	-10.6	-22.8	-13	-10.4	-18	-17.2	-17.2	-14.1	-7.3	-11.6
1995	-4	-2.7	3.5	-16.2	-9	-1.5	4.2	0.8	3.2	-1.3	1.3	-5.5
1996	8.4	1.1	6.2	7.8	1.3	13.9	6.8	4.6	6.9	4.2	-0.1	7.2
1997	4.1	13.3	-8.5	-16.2	-22.4	-24.1	-9.5	-19.8	-14.8	-17.8	-15.2	-9.1
1998	-23.5	-19.2	-28.5	-24.4	0.5							

POCKET MATERIAL: LANDSLIDE HAZARD MAP OF STUDY AREA, NEAR OROFINO, IDAHO.