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LANDSLIDE HAZARD ASSESSMENT, HOWARD HANSON AND SMAY CREEK WATERSHED ADMINISTRATIVE UNITS, GREEN RIVER BASIN, KING COUNTY, WASHINGTON

by

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ABSTRACT

The Howard Hanson and Smay Creek watershed administrative units comprise a study area of about 95 square miles located in the upper Green River basin on the west slope of the central Cascade Range in Washington. We mapped 276 shallow landslides in the study area primarily by analysis of 1:12,000-scale aerial survey projects flown between 1962 and 1996. We also identified about 48 ancient deep-seated landslides or landslide complexes, which together comprise about 15 percent of the study area. The total length of mapped shallow landslides is about 68 miles, of which almost 61 miles coincides with ephemeral or perennial stream courses. Fifty miles of mapped landslide runout coincided with non-fish-bearing streams, and almost eleven miles coincided with fish-bearing streams. About 83 percent of all mapped shallow landslides originated at logging roads and slopes logged less than 20 years prior to landslide initiation. Altogether those landslides account for about 89 percent of the total length of mapped landslide runout through streams. Landslide hazards in the study area vary among eleven different map units we distinguished primarily on the basis of variations in their slope inclination, topographic convergence, geologic substrate, and potential for delivery of landslide debris to streams or other public resources. Twenty-five percent of all mapped shallow landslides initiated on slopes formed by ancient deep-seated landslides. More than 90 percent of all mapped shallow landslides originated in seven map units comprising less than 30 percent of the study area. The landslides that originated in those areas account for more than 95 percent of the total length of all mapped shallow landslides.

INTRODUCTION

This report summarizes the methods and results of a landslide hazard assessment for the Howard Hanson and Smay Creek watershed administrative units (WAUs), which comprise an area of about 95 square miles in the upper Green River basin, King County, Washington. The assessment is part of a Level-2 watershed analysis initiated by the Washington Department of Natural Resources, Tacoma Public Utilities, Plum Creek Timber Company, Weyerhaeuser Company, Guistina Resources, and Citifor, Inc., in October 1996 under the provisions of WAC 222-22-050. The content and format of this report (including product labels) conforms with version 4.0 of the Standard Methodology for Conducting Watershed Analysis under Chapter 222-22 WAC (Washington Forest Practices Board, 1997).

The principal objectives of this report are to (1) analyze landslide history, (2) classify landslide hazards, and (3) assemble information that will enable forest-land managers to make sound management decisions with respect to landslide hazards. In general terms, the analysis describes where landslides are likely to occur, and what management practices are likely to contribute to their initiation. The analysis also attempts to focus attention on the indicated hazards by identifying areas where landslides are unlikely to occur.

METHODS

We surveyed landslide history and classified landslide hazards following procedures outlined by the Washington Forest Practices Board (1997). An inventory describes our survey of landslide history in two formats. Map A-1 depicts the location of mapped landslides, and Form A-1 lists information about their age, type, size, and origin in a database. We evaluated the landslide inventory, aerial photographs, published topographic and geologic maps, and selected field sites to delineate and describe selected mass wasting map units (see Map A-2 and Form A-2, respectively), and classify their landslide hazards with respect to forest management and risk to certain public resources (see attached Causal Mechanism Reports).

Landslide Mapping

We mapped shallow landslides by examining successive sets of aerial photographs for the presence of new landslides (i.e., those not observed in photos from previous years), and for evidence of recurrent activity within old landslides (i.e., changes in the dimension of landslide disturbance between successive photo years). We mapped ancient, deep-seated landslides by analyzing slope morphology on topographic maps and aerial photos to identify landslide head scarps and interpret the downslope and lateral extent of associated mass movement. Previous mapping by Fiksdal and Brunengo (1981) and Frizzell and others (1984) aided our identification of ancient deep-seated landslides. Previous mapping by Fiksdal and Brunengo (1981), Koler and Ballerini (1996), and US Army Corps of Engineers (1998) focused our investigation of shallow landslides.

We analyzed photos from aerial survey projects flown over a period of 34 years between 1962 to 1996 (table 1). Landslides mapped from the oldest aerial survey project (1962) represent an additional but unquantified period of landslide history. The period between surveys that provided broad coverage of the study area from available photos ranged from three to eleven years. We did not map small shallow landslides or relict landslide scars hmmm. observed in the field (chiefly to avoid bias that would suggest landslides occur more frequently in areas chosen for field work), and we did not find evidence of large, recent (ca. post-1970s) debris torrents ~~we had~~ not already identified on aerial photos. Although we found evidence of older debris torrents indicated by the materials, vegetation, or morphology of some confined valley floors, we suspect most occurred before 1962 and did not record them in the inventory because of uncertainty about their age, origin, or contributing physical conditions.

Our field work included (1) verification of selected landslide mapping to reduce uncertainty about photo interpretation, and (2) evaluation of physical conditions at selected sites of landslide initiation and runout to refine interpretations about the nature, extent, and distribution of landslide hazards. The work included visits to sites in the Green River valley, the Green River canyon downstream of Howard Hanson reservoir, and the East Smay, West Smay, Gold, Sweeney, Charley, Gale, Sylvester, Cougar, May, and East Maywood creek basins, primarily during the summer and fall of 1997. It involved (1) evaluation of landslides mapped with low confidence, (2) observations of bedrock, surficial materials, vegetation, slope gradient, slope morphology, slope position, and methods of logging and road construction at landslide initiation sites, roads, and intact hillslopes, and (3) observations of vegetation, landslide deposits, and valley morphology at sites disturbed by landslide runout. We selected field sites chiefly to investigate uncertainty about mapping and hazard classification, but attempted no systematic evaluation of any particular subset of mapped landslides. Field work conducted in the Lester, Upper Green, and Sunday creek watershed administrative units (WAUs) between 1994 and 1996, and field review of forest practices applications in the study area between 1992 and 1998, provided additional information about circumstances of landslide initiation and runout that also constrained our interpretation of aerial photos and landslide hazards.

The landslides depicted on Map A-1 were originally plotted at 1:24,000-scale on USGS topographic maps with 40-foot contour intervals. The indicated landslide boundaries include both initiation points and areas disturbed by runout. Landslide widths are not necessarily drawn to scale, and no cross-cutting relationships are implied by the map symbology, which merely attempts to facilitate discrimination between individual landslides. Although portions of the indicated boundaries for ancient deep-seated landslides are well defined topographically, in most cases their boundaries are approximate or uncertain. We chose to omit some deep-seated landslides mapped by Fiksdal and Brunengo (1981), Frizzell and others (1984), and Koler and Ballerini (1996), as well as shallow-rapid landslides mapped by Koler and Ballerini (1996), in cases where we could not independently confirm their existence, *and* (in the case of deep-seated landslides) where they were not mutually recognized by the earlier workers.

Map A-1 depicts landslides identified with at least fifty percent confidence. Our distinction between landslide types is not technically rigorous, and we made only a cursory effort to map occurrences of rock fall. In general, we interpreted unchannelized landslides with relatively short slope lengths as shallow-rapid landslides (e.g., debris avalanches), and curvilinear features with slope lengths in excess of about 500 feet as debris torrents (e.g., debris flows). The smallest dimensions of the landslides mapped from aerial photographs are approximately 30 feet for length and 10 feet for width, suggesting the limit of photo resolution for landslides is about 300 square feet in area. We did not map all landslides with slope lengths of about 100 feet or less (e.g., landslide evident on photo SPP-C 3-17-19, located north of road on south side of Green River, in NE ¼, SE ¼, NE1/4, section 14, T20N, R09E) evident on slopes with immature forest (i.e., forest less than 20 years old), partly for purposes of expediency, but also because of concern for the possibility we could not discern small landslides on slopes with mature forest as readily as small landslides on slopes with immature forest. However, it is possible to identify many small landslides that originate on slopes with mature forest. The shortest mapped landslides (30 feet) originated on a slope with mature forest, and the number of small mapped landslides (i.e., landslides with slope lengths of 100 feet or less) that originated on slopes with mature forest (n=16) is only slightly less than the number of small mapped landslides that originated on slopes with immature forest (n=18), or at roads (n=18). The reflectivity of roads on aerial photos obscures some small landslides associated with cuts and fills, and Map A-1 omits many such plausible candidates (cf. mass-wasting maps of Fiksdal and Brunengo, 1981). Although we did not map them as landslides, portions of fills on some roads constructed with bulldozers prior to 1978 may have introduced as much sediment into streams as would a moderate-size debris avalanche.

The inventory provides a conservative estimate of channel disturbance by shallow landslides, recording only one event in cases where two or more landslides may have traveled along the same channel segment in a given photo interval (e.g., unnamed tributary to Smay Creek downstream of junction of landslides 78-48 and 78-49; Gold Creek downstream of the junction of landslides 78-32 and 78-33; Bear Creek downstream of the junction of landslides 65-3 and 65-4).

Landslide Database

The landslide database (Form A-1) lists selected information about the shallow landslides shown on Map A-1, describing (1) their type, size, and location, (2) aspects of the physical landscape at their initiation sites (including vegetation, slope character, and land management), and (3) the extent of their runout through the drainage network. Notes appended to Form A-1 outline methods of data collection and describe the abbreviations used in the database. The ancient deep-seated landslides shown on Map A-1 are not described further in the database because they result from geologic conditions beyond the scope of this analysis and have origins unrelated to forest management.

Landslide Hazard Classification

The landslide hazard assessment (Map A-2, Form A-2, and attached Causal Mechanism Reports) provides a forward-looking classification of the relative potential for landslide initiation within different types of terrain, as determined by the distribution and circumstances of shallow landslides described in the database.

We distinguished eleven mass wasting map units in the study area primarily on the basis of variations in slope inclination, topographic convergence, geologic substrate, and potential for delivery of landslide debris to streams or other public resources. We evaluated relationships among landslides, land use, and landscape features in a series of tables (see tables 1-14) and figures (see figures 1-9), and used this information to gage the relative level of hazard associated with given terrain. Map A-1 illustrates the distribution of delineated map unit polygons in the study area, and Form A-2 describes the physical characteristics and landslide history of each mass wasting map unit. The attached Causal Mechanism Reports describe "triggering mechanisms" commonly associated with landslides originating in mass wasting map unit classified as having either a moderate or high delivered hazard rating.

PHYSIOGRAPHY

Geography

The Howard Hanson and Smay Creek WAUs comprise about 95 square miles on the west slope of the Cascades Mountains in King County, Washington. They are located in the Green River basin, which today drains an area somewhat greater than 461 square miles west to Puget Sound (Wiggins et al., 1998). The mountainous, upper portion of Green River basin includes four other WAUs. The Upper Green, Sunday Creek, and Lester WAUs lie upstream of the Howard Hanson WAU. The Smay Creek and North Fork Green River WAUs drain to the Howard Hanson WAU from the north. The Green River drops in elevation from about 1,380 feet at the upstream end of the Howard Hanson WAU near the mouth of Smay Creek, to about 780 feet at the downstream end near Palmer, where it leaves the Cascade Range and flows into the Puget Lowland. The Green River basin has a drainage area of 231 square miles at the water purification plant located 2 miles southeast of Palmer (Wiggins et al., 1998). Maximum relief across the Howard Hanson and Smay Creek WAUs is approximately 4,330 feet. Elevation rises to about 5,112 feet along the divide between the Smay Creek WAU and the Cedar River basin to the north. Elevation in Howard Hanson WAU rises to about 4,764 feet along its divide with White River basin to the south.

Precipitation

Annual precipitation in the study area varies with elevation, increasing from about 60 inches in portions of the Green River valley, to between 80-90 inches along ridges to the south, and 80-110 inches along ridges to the north (Washington Department of Natural Resources, 1992). The intensity of the 2-year, 24-hour storm in the region ranges from about 3-5 inches per hour (7.5-13 cm/hr) (Fiksdal and Brunengo, 1981). The intensity of the 10-year, 24-hour storm in the Howard Hanson and Smay Creek WAUs ranges from about 4.0 to 5.5 inches (Washington Department of Natural Resources, 1992), where most prescription falls between November and May. From winter through early spring, snow pack is usually persistent at higher elevations, and transient at lower elevations where it is more frequently subject to rainfall.

Bedrock

The oldest rocks exposed in the study area are Eocene sedimentary rocks of the Puget Group. They consists of fluvialtile and nearshore marine sandstone, siltstone, claystone, and coal (Frizzell et al., 1984), and crop out at the western (downstream) end of the Howard Hanson WAU. Rocks of the Puget Group are unconformably overlain by Oligocene volcanic rocks of the Huckleberry Mountain unit, which includes most of the Enumclaw and Huckleberry Mountain Formations of Hammond (1963), and consists of well-bedded andesite and basalt breccia, tuffs, and flows, with minor dacite and rhyolite tuff and breccia, and volcaniclastic sedimentary rocks (Frizzell et al., 1984). The Huckleberry Mountain unit, which crops out in the western and southern portions of the Howard Hanson WAU, and in the southern and eastern portions of the Smay Creek WAU, is the most widely exposed rock unit in the study area. It is unconformably overlain by Miocene volcanic rocks of the Eagle Gorge unit, which includes most of the Eagle Gorge Andesite, as well as small parts of the Huckleberry Mountain and Cougar Mountain Formations of Hammond (1963), and consists of andesite and basalt flows, breccia, and minor well-bedded tuff and volcaniclastic sedimentary rocks, and locally a mappable sub-unit of rhyodacite tuff (Frizzell et al., 1984). Fiksdal and Brunengo (1981) note that rocks formed by lava flows predominate the Eagle Gorge Andesite. The Eagle Gorge unit crops out extensively in the Howard Hanson WAU on both sides of the Green River upstream of its North Fork, and locally north of Smay Creek in the Smay Creek WAU. The Eagle Gorge unit is unconformably overlain by Miocene volcanic rocks of the Cougar Mountain unit, which includes most of the Cougar Mountain Formation and minor parts of the Huckleberry Mountain Formation of Hammond (1963), and consists of andesite and basalt flows and flow breccia, mudflow breccia, and minor volcaniclastic sedimentary rocks, differing from the upper part of the Eagle Gorge unit by presence of mudflow breccia (Frizzell et al., 1984). The Cougar Mountain unit crops out in northern portions of the Howard Hanson and Smay Creek WAUs. In the Smay Creek WAU, plugs of Eocene to Miocene porphyritic andesite, and Miocene porphyritic dacite locally intrude the stratified volcanic rocks described above, forming prominent peaks at Rooster Comb Mountain, and along the northern divide of the basin immediately east of Goat Mountain. Rocks in the study area were uplifted in the middle Tertiary, and again in the late Tertiary and Quaternary, producing broad, open folds, and faults with relatively small offsets (Fiksdal and Brunengo, 1981). As mapped by Frizzell and others (1984), the larger folds and faults in the study area trend WNW to NW. Bedding orientation has influenced the development of some landforms in the study area, including prominent dip slopes located between the canyons of most major tributaries on the south side of the Green River upstream of Charley Creek.

Glaciation

Alpine glaciers have advanced and retreated across portions of the Cascade Range multiple times during the Pleistocene Epoch. Although the extent of alpine glaciations in the upper Green River basin has not been determined (Fiksdal and Brunengo, 1981), descriptions of their chronology and extent in adjacent basins suggest their potential role in the development of landforms in the study area.

In the upper Cedar River basin to the north, Hirsch (1975) recognized an older, more extensive alpine glaciation (probably equivalent to the Salmon Springs Glaciation in the Puget Sound lowland), and at least two younger, sequentially less extensive advances of valley glaciers during the Fraser Glaciation (when the Cordilleran ice sheet again invaded the Puget Sound lowland). According to Hirsch (1975), a pre-Fraser alpine glacier extended west to the mouth of the upper valley (beyond the present location of Chester Morse Lake), probably during the Salmon Springs Glaciation. Later during the Evans Creek stade of the Fraser Glaciation, another large alpine glacier advanced west to about the present location of Chester Morse Lake, again covering most of the upper Cedar River valley with ice (Hirsch, 1975). More recently during the Vashon and/or Sumas stades of the Fraser Glaciation, alpine glaciation was less extensive (only occupying cirques and portions of the valley network), such that at the time of Vashon maximum, ice in the Cedar River valley probably terminated east of Chester Morse Lake. The chronology and extent of Late Pleistocene alpine glaciation is similar for basins south of the study area, where valley glaciers were also less extensive during the Fraser Glaciation than the earlier Salmon Springs Glaciation, failing to advance as far west as the Puget Sound lowland as some had done previously (Crandell and Miller, 1974).

Galster (1989) reports that the Green River valley was extensively modified by alpine glaciers upstream of the North Fork Green River, but not downstream of there. We presume that advance(s) of valley glaciers to such a westerly extent in the upper Green River basin occurred prior to the Fraser Glaciation, or possibly during the Evans Creek stade of the Fraser Glaciation, based on the analysis by Hirsch (1975) of alpine glaciation in the upper Cedar River basin. Although glaciation in the upper Green River valley may have been more extensive prior to the Fraser Glaciation, alpine glaciers likely occupied significant portions of some valleys in the study area during the Evans Creek Stade of the Fraser Glaciation, when ice spanned the divide between the Cedar and Green River basins at the head Smay Creek and West Smay Creek basins (Hirsch, 1975), producing broad ridges and open upper valleys like those at the heads of other major drainages in the study area (e.g., Charley, Elder, Boundary, and May creeks). Smaller bowl-shaped hollows located on upper slopes near the heads of some tributaries to the Green River (e.g., at Albert Lake in the Smay Creek basin; E1/2, W1/2 section 26, T20N, R09E, Gold Creek basin; SW1/4, NW1/4, section 27, T20N, R09E, unnamed basin; N1/2, SW1/4 section 21, T20N, R08E, Charley Creek basin) are probably cirques that may have hosted lesser accumulations of ice during the Vashon and/or Sumas stades of the Fraser Glaciation, when valley glaciers were less extensive in adjacent basins to the north and south than during previous glaciations.

LANDSLIDE PROCESSES

The terminology used to describe landslides in this report is defined below. Most of the descriptions are modified after Benda and others, 1991.

LANDSLIDE: Any mass-movement process involving sliding over a discrete failure surface, and characterized by the downslope transport of soil and rock under gravitational stress; this term also refers to landforms resulting from such processes.

ROCK FALL: Rapid downslope movement of disaggregated rock and soil fragments by falling, rolling, and bounding.

DAM-BREAK FLOOD: Erosion from flooding caused by the failure of a temporary instream impoundment in a confined channel. The rapid failure of the dam (formed by a landslide, the deposit of a debris flow, or a debris jam) can produce a flood up to two orders of magnitude larger than conventional floods, causing widespread destruction of vegetation in riparian zones.

DEBRIS AVALANCHE: A landslide initiating on steep slopes and produced by the failure of the soil mantle (typically to a depth of less than six feet, and sometimes including weathered bedrock). Soil thickness is shallow compared to slope length or length of the landslide. Landslide debris moves rapidly downslope and often breaks up to form debris flows upon entering confined steep-gradient channels.

DEBRIS FLOW: A highly mobile slurry of soil, rock, vegetation, and water that can travel many miles down steep (greater than 5 degrees) confined mountain channels. Debris flows are initiated by liquefaction of landslide material concurrently with failure or immediately thereafter as the soil mass and reinforcing roots break apart. Debris flows contain 70 to 80 percent solids and only 20 to 30 percent water. Entrainment of additional sediment and organic debris can increase the volume of the original landslide by 1,000 percent or more, enabling debris flows to become more destructive as their volume increases with distance traveled.

DEBRIS TORRENT: A debris flow or dam-break flood.

DEEP-SEATED LANDSLIDE: Any mass movement along a surface of rupture located at depth several times greater than the thickness of the overlying soil (e.g., earth slumps and earthflows).

EARTH SLUMP: A deep-seated rotational landslide generally producing coherent movement (back-rotation) of a blocky mass over a concave failure surface. Slumps are typically triggered by the build-up of pore-water pressure in mechanically-weak materials such as deep soils or clay-rich rocks.

EARTHFLOW: Earthflows are deep-seated landslides that move through a combination of slumping and plastic flow. They commonly include a steep, arcuate headscarp, a lobate, hummocky body (which may be bounded on either side by a stream), and an oversteepened toe, however, in many cases one or more of these features may be absent or poorly expressed. Most earthflows are ancient features of the landscape, but they can remain active for thousands of years with intermittent periods of movement and dormancy. Steep slopes at the toe of an earthflow commonly produce earth slumps and debris avalanches.

SHALLOW LANDSLIDE: Any type of shallow-rapid landslide or debris torrent.

LANDSLIDE HISTORY

Shallow Landslides

We mapped 276 shallow landslides in the 95.5-square-mile study area (table 2), of which 251 occurred between 1962 and 1996 (the dates of the earliest and latest aerial surveys we examined), yielding a frequency of 7.4 landslides per year during that 34-year period of record, and a landslide rate of about 0.08 landslides per square mile per year. The observed rate of landslides in the study area is similar to that indicated by Reynolds (1996) for the adjacent Lester WAU during the 34-year period spanning 1958 and 1992 (0.07 landslides per square mile per year).

The frequency of mapped landslides in the study area ranged from a low of 3.1 per year between 1978 and 1989, to a high of 16.1 per year between 1989 and 1996. Although the landslide frequency between 1989 and 1996 (16.1 per year) was 3.2 times that of the preceding 27 years (5.1 per year between 1962 and 1989), the landslide frequency during the 18-year period between 1978 and 1996 (8.2 per year) was only 1.3 times that of the preceding 16-year period (6.5 per year between 1962 and 1978), and only 1.1 times greater than the landslide frequency during the 34-year period of record (7.4 per year).

We suspect most of the mapped shallow landslides in the Howard Hanson and Smay Creek WAUs that occurred prior to 1989 initiated in response to precipitation (and probably snowmelt in some cases) generated by large storms during November 1959, January 1965, December 1975, December 1977, January 1984, and November 1986, all of which produced discharges greater than 9,000 cubic feet per second at the USGS gage on the Green River about 3 miles upstream from the mouth of Smay Creek, near Lester, Washington. Fiksdal and Brunengo (1981) commented on the significance of the storm during December 1997, noting "[h]eavy rain and rapid snowmelt caused a large number of debris torrents, flooding on most major streams, and many road and bridge wash-outs." A forester who observed road drainage conditions during that storm noted ditches filled exceptionally fast in response to rapid snowmelt (Jim Creamer, personal communication, 1998). The number of landslides mapped from 1989 photos (n=34) is substantially less than the number mapped from 1978 photos (n=82), suggesting the storms during January 1984 and November 1986 had less influence on slope stability than the storm during December 1977 (and perhaps the storm during December 1975). The reason for such a variation in the influence of these storms is unclear. Large storms during January and November 1990 also produced discharges greater than 9,000 cubic feet per second at the Green River gage near Lester. However, we suspect the majority of mapped landslides that initiated between 1989 and 1996 probably occurred during large storms in November 1995 or February 1996, because vegetation is absent within most landslide tracks evident on 1996 photos. Again, the reason for the apparent variation in the influence of the 1990 storms and the storms during November 1995 and February 1996 is unclear.

Almost half (49.6 percent) of all mapped shallow landslides originated at roads. Among the remainder, which initiated on natural slopes, about twice as many occurred in association with immature forest as mature forest (33 percent versus 16 percent, respectively, of all mapped shallow landslides) (table 2). These data on the relative proportion of shallow landslides that originated on natural slopes covered by mature and immature forest contrast sharply with those collected by Koler and Ballerini (1996), who report that of the 272 landslides they mapped in the same area from aerial photos spanning 1960 to 1996 (including 44 deep-seated landslides that pre-date the photo record) the greatest proportion occurred in association with mature forest (45 percent), and the least proportion occurred in association with immature forest (13 percent). If data on deep-seated landslides that pre-date the photo record are omitted from consideration, an account of the remaining landslides mapped by Koler and Ballerini (1996) still yields more than twice as many landslides associated with mature forest as immature forest (approximately 34 percent versus 15 percent, respectively), indicating a relationship inverse to that reported in this study. The discrepancy results chiefly from mapping errors and omissions in the earlier study. !

The 276 mapped shallow landslides have a total length of 67.3 miles, of which 61.8 miles is from landslides that occurred between 1962 and 1996, yielding 1.8 miles of landslide runout per year, and a landslide runout rate of about 0.02 miles per square mile per year during the 34-year period of record. (As used here, the term landslide runout encompasses the entire length of a landslide downslope of its crown). In the Howard Hanson and Smay Creek WAUs, the length of landslides per unit time ranged from a low of 0.4 miles per year between 1978 and 1989, to a high of 3.4 miles per year between 1962 and 1965. Note that the count and length of landslides per unit time do not correlate well for respective photo intervals (e.g., the period between 1989 and 1996 ranks first in terms of count per year and second in terms of length per year, whereas the period between 1962 and 1965 ranks third in terms of count per year and first in terms of length per year).

The average length of all mapped landslides associated with mature forest (912 feet), immature forest (1,569 feet), and roads (1,240 feet) varies by less than a factor of two. However, the total length of all mapped landslides associated with immature forest and roads exceeds that associated with mature forest by factors of 3.5 and 4.1, respectively. Between 1989 and 1996, the total length of landslides associated with roads was almost nine miles, accounting for about 13 percent of the total length of all mapped shallow landslides during the period of record. Although the length of road-related landslides per unit time was greater between 1965 and 1978 (1.5 miles per year) than between 1989 and 1996 (1.3 miles per year), the length per unit time between 1989 and 1996 exceeded that of the preceding 27 years of record (0.8 miles per year).

The 95.5-square-mile study area has an average density of about 2.9 mapped shallow landslides per square mile, and an average landslide length per unit area of about 3,723 feet per square mile. Average landslide density and length per unit area vary similarly among geographic localities in the study area. However, they do not vary similarly to average landslide length (table 3, and figure 1). These relationships are probably influenced in part by differences in the geomorphology and drainage networks of the geographic areas considered.

The Lower Green area comprises about 12 percent of the study area, encompassing most of the area downstream of the North Fork Green River, except for the Bear Creek drainage. Among the five geographic areas considered, it has the highest spatial density of landslides (5.8 per square mile), the highest length of landslides per unit area (5,419 feet per square mile), and the lowest average landslide length (940 feet). Most of the mapped shallow landslides in the Lower Green area initiated on mountain sides flanking the Green River canyon downstream of Howard Hanson dam. The mountain sides facing the canyon are dissected by many short, steep tributaries (i.e., commonly less than 1.5 miles in length, and predominately greater than 20 percent gradient) that drain steep flanking and upper slopes. The relatively small tributaries to the Green River in the Green River canyon may have experienced greater stream incision than drainages farther upstream in Green River basin. Galster (1989) reports the Green River was pirated from its former outlet through the valley of the North Fork Green River during Pleistocene time, subsequently cutting "its channel about 100 feet deeper than the present valley floor [at Howard Hanson dam], rapidly excavating along the sheared rock of the Green River fault zone" (which roughly parallels the thread of the Green river canyon). The low average landslide length in the Lower Green area, and the high count and length of landslides per unit area, may result in part from a relatively high density of short steep tributaries to the Green River in the Green River canyon, and a legacy of slope development in response to stream incision along the canyon and its tributaries.

The Smay Creek area comprises about 24 percent of the study area, encompassing the entire Smay Creek drainage and a small portion of the Green River valley. Among the five geographic areas considered, it has the second highest spatial density of landslides (4.0 per square mile), the second highest length of landslides per unit area (4,752 feet per square mile), and the second lowest average landslide length (1,175 feet). The relatively high spatial density of landslides in the Smay Creek area, and the relatively low average landslide length, result in part from relatively high numbers of shallow landslides along the toe of the large deep-seated landslide complex in the upper Smay Creek basin (T21N, R10E). The scale of tributaries to Smay Creek and West Smay Creek, which are shorter than most major tributaries to the Green River in the South Green River area, may also contribute to the relatively low average landslide length in the Smay Creek area.

The North Green River area comprises about 13 percent of the study area, encompassing the largest drainages north of the Green River between the Reservoir and Smay Creek areas, including Gale, Boundary, Sylvester, Cougar, "May," and "East Maywood" creeks, as well as portions of the Green River valley. Among the five geographic areas considered, it has the third highest spatial density of landslides (2.7 per square mile), the third highest length of landslides per unit area (3,352 feet per square mile), and the third lowest average landslide length (1,226 feet). The average landslide length in the North Green River and Smay Creek areas differs by less than 5 percent. The moderate spatial density of landslides in the North Green River area result in part from the variability of its terrain, which includes relatively extensive areas with gentle- to moderate-gradient slopes (e.g., lower Sylvester, Cougar, and May creek basins, and north of Humphrey Mountain), in addition to the steeper slopes that predominate elsewhere.

The South Green River area comprises about 44 percent of the study area, encompassing all drainages south of the Green River upstream of the Reservoir area, including Bear, Charley, Elder, Canton, Humphrey, Sweeney, and Gold creeks, as well as smaller drainages located north of the Green River on the south side of Humphrey Mountain, and portions of the Green River valley. Among the five geographic areas considered, it has the second lowest spatial density of landslides (2.0 per square mile), the second lowest length of landslides per unit area (3,338 feet per square mile), and the highest average landslide length (1,698 feet). The length of landslides per unit area in the South Green River and North Green River areas differs by less than 5 percent. The relatively low spatial density of landslides in the South Green River area results in part from low numbers of landslides on the broad, gentle- to moderate-gradient dip slopes that comprise much of the terrain between the major drainages in the area. The relatively high average landslide length in the South Green River area results in part from extensive landslide runout through many of the area's relatively long tributaries to the Green River.

The Reservoir area comprises about 7 percent of the study area, encompassing mostly small drainages in the vicinity of Howard Hanson reservoir, and portions of the Green River valley. However, it also includes the Piling Creek drainage and other relatively small, steep drainages located north of Howard Hanson reservoir and west of Gale Creek. Among the five geographic areas considered, it has the lowest spatial density of landslides (0.6 per square mile), the lowest length of landslides per unit area (892 feet per square mile), and the second highest average landslide length (1,583 feet). The low spatial density of landslides in the Reservoir area results in part from the large expanse of gentle slopes developed on Quaternary deposits in the vicinity of the Howard Hanson reservoir. The high average landslide length in the Reservoir area is an aberration reflecting the influence of one relatively long debris torrent on a landslide population of only four. The aberration is an artifact of "sub-basin" boundaries that were delineated to include Piling Creek and other small, steep drainages north of Howard Hanson reservoir in the Reservoir "sub-basin," rather than an area predominated by similarly steep terrain.

Deep-Seated Landslides

Map A-1 depicts the locations of about 48 deep-seated landslides identified in the study area, including several large landslide complexes. They vary greatly in size, ranging from less than 10 acres to greater than 1,000 acres, and altogether comprise an area of about 14.8 square miles (including head scarps), or about 15.4 percent of the study area. More than half of the total area comprised by deep-seated landslides resides in four large landslide complexes: one north of the Green River near Palmer, one north of the Green River near Cougar Mountain, and one each in the East Smay and Charley creek basins. Relatively large deep-seated landslides or landslide complexes are present in other basins as well, most notably West Fork Smay Creek, Elder Creek, an one located in portions of two unnamed basins south of the Green River about one mile east of Sweeney Creek.

To our knowledge a precise age has not been determined for any deep-seated landslides in the upper Green River basin. All those in the study area pre-date aerial photography flown in 1942. Most we observed supported old stands of forest prior to logging, indicating their minimum age is at least several centuries. In almost all cases, however, we presume they are much older. Evidence of this includes the extent of soil development on head scarps and the degree of stream incision within larger landslides.

We presume almost all the deep-seated landslides in the study area originated since the last major advance of valley glaciers in the upper Green River basin (presumably the Evans Creek stade of the Fraser glaciation), or moved substantially since that time. In some cases this is demonstrated by their encroachment into U-shaped valley segments, such as along the eastern margin of the large landslide complex north of Smay Creek, and in others by their encroachment over late Pleistocene or younger Quaternary deposits, such as north of the Green River near Palmer (Hardman, 1996), south of the Green River about one mile east of Sweeney Creek, and west of Charley Creek in the lower Charley Creek basin.

Three component elements are discernible in most of the deep-seated landslides in the study area: (1) a steep, arcuate head scarp underlain by bedrock, (2) an outwardly convex, irregularly sloping, gently to moderately inclined body bounded laterally in many cases by low-order streams and typically underlain by massive, poorly consolidated, matrixsupported pebble-cobble conglomerate containing clay, and (3) toe slopes underlain by material like that in the landslide body, but located near and inclined more steeply toward the landslide tip. The scarp slopes, bodies, and toe slopes of the landslides identified here comprise areas of about 2.9, 10.7, and 1.2 square miles, respectively. Their dimensions and morphology vary considerably among landslides.

The gross morphology of most deep-seated landslide in the study area suggests deformation occurred by rotational slumping of relatively large, coherent blocks of bedrock in their upper reaches coupled with flow of disaggregated material into areas of mass accumulation below. We suspect initial movement, in most cases, occurred both rapidly and on a large-scale. This is clearly indicated for the deep-seated landslide north of the Green River at Howard Hanson dam where drilling records reveal the topography of the valley bottom prior to landslide movement. Galster (1989) reports the landslide "diverted the river around the landslide toe, 1,300 feet southwest of its former channel." He also indicates it buried a low topographic rise (with relief of about 100 feet) located between the old and new channel sites. Such a large shift in channel position across an intervening topographic rise implies channel movement occurred swiftly in response to rapid introduction of landslide debris on a large scale. In other cases, rapid and large-scale initial movement is suggested by the presence of landslide deposits on the opposite side of a valley from their source area (e.g., Smay Creek valley bottom, sec. 32 and 33, T21N, R10E). Such configurations imply stream incision into landslide deposits after a valley's rapid burial by landslide debris.

The number of shallow landslides generated on slopes within individual deep-seated landslides varied widely during the period of the photo record. This variation may reflect differences in slope morphology and management history on deep-seated landslides, as well as influences of other factors beyond the scope of this analysis, such as differences in their age, mechanics, material properties, and subsurface hydrology. All the deep-seated landslides we observed in the field have old scars from shallow landslides pre-dating the photo record, and locally their slopes exhibit evidence of tension or high rates of creep. Most deep-seated landslides in the study area also include steep, convergent areas (e.g., scarps and stream-adjacent slopes) that are morphologically similar to slopes where shallow landslides originated in terrain underlain by bedrock (e.g., MWMU 9 and 11). Within deep-seated landslides, the spatial density of mapped shallow landslides ranged from 26.6 per square mile along their toe slopes, to only 1.0 per square mile on the generally more moderate slopes developed on their bodies. The spatial density of mapped shallow landslides on scarp slopes of deep-seated landslides (8.7 per square mile for the combined areas of MWMU 6 and 66) is comparable to that for other steep, convergent slopes with bedrock substratum (7.2 per square mile in MWMU 11).

As previously noted, most of the deep-seated landslides identified in this study were previously mapped, either in whole or in part, by Fiksdal and Brunengo (1981), Frizzell and others (1984), or Koler and Ballerini (1996). Newly mapped landslides, as well as others largely reinterpreted here include those (1) located west of Gold Creek in NE 1/4, sec. 23, T20N, R10E, (2) located south of the Green River, in SW 1/4 sec. 18, T20N, R10E, within an unnamed basin, (3) forming a landslide complex at the head of Elder Creek, (4) located south of the Green River, mostly within S1/2 sec. 24, T21N, R07E, (5) located in SE 1/4 sec. 31, T21N, R09E, east of an unnamed tributary to Gale Creek (6) located north of the Green River, mostly within SW 1/4 sec. 6, T20N, R09E, (7) forming a large landslide complex located in the Cougar Creek and Sylvester Creek basins on the southern slopes of Cougar Mountain, (8) forming a landslide complex north of West Smay Creek, mostly within sec. 24, T21N, R09E, and (9) located in SW 1/4 sec. 7, T20N, R10E, north of an unnamed tributary to Smay Creek.

If correct, our interpretation of the large deep-seated landslide complex located on the southern slopes of Cougar Mountain implies the approach used by Koler and Ballerini (1996) to estimate annual sediment yield from sub-basins in the Howard Hanson and Smay Creek WAUs is untenable. The rest of this section examines the basis for our interpretation of this landslide complex and the reliability of values for annual sediment yield estimated by Koler and Ballerini (1996).

The lower portions of the Cougar, Sylvester, and May Creek basins comprise a broad area of low relief. The area forms an anomalous opening along the thread of Green River valley, which is flanked by much steeper slope faces along most of its length upstream of Howard Hanson reservoir. Frizzell and others (1984) mapped deposits of Quaternary alluvium in the portion of the low-relief area formed by the lower Cougar and May creek basins. They also mapped relatively extensive areas of Quaternary alluvium at the mouth of Smay Creek, and at the mouths of Champion and Rock creeks near Lester upstream of the study area. Figure 2 illustrates the extent of Quaternary alluvium in these three areas (i.e., Cougar and May creeks, Smay Creek, and Champion and Rock creeks), as modified after mapping by Frizzell and others (1984).

Our reinterpretation of their mapping in the vicinity of Cougar and May creeks rests largely on the following lines of reasoning. Firstly, one of the authors indicated their control for mapping Quaternary deposits in that area was "not terribly good" (Derrick Booth, personal communication, 1997). Secondly, Fiksdal and Brunengo (1981) identified areas deformed by deep-seated landslides in the upper Cougar and Sylvester creek basins. Slope morphology in areas logged subsequent to their analysis suggests those landslides reside within an extensive deep-seated landslide complex that extends downslope primarily into the lower Cougar and Sylvester creek basins. Thirdly, although exposures of subsurface materials are rare in the low-relief area formed by the lower Cougar, Sylvester, and May creek basins, we observed unstratified, poorly sorted, sub-angular pebble-cobble conglomerate in a low road cut east of Sylvester Creek (SE 1/4 NW 1/4 sec. 10, T20N, R09E). The subsurface material exposed there resembles that exposed within many deep-seated landslides in the study area, but is atypical of alluvial deposits we observed. Additionally, stream-flanking slopes in the lower Sylvester Creek basin locally retain recurved stumps from old-growth trees, suggesting they have experienced relatively high rates of creep for extended periods of time. Creep of this type is evident locally on many deep-seated landslides in the study area.

Lastly, the mapped alluvial deposits in lower Cougar and May creek basins are dissimilar to those in the vicinity of Smay Creek, as well as those in the vicinity of Champion and Rock creeks, in terms of their area relative to upstream basin size, pattern of distribution, and relief above local base level. These dissimilarities suggest there were differences in their modes of emplacement. In proportion to their contributing drainage area, the extent of Quaternary alluvium mapped by Frizzell and others (1984) in the vicinity of Cougar and May creeks is at least four times greater than that of the deposits in the vicinity of either Smay Creek or Champion and Rock creeks (table 4).

Table 4. Area of Quaternary alluvium relative to contributing drainage area.

basins	Qa area (mi.^{2})	Drainage area (mi.^{2})	Qa area / drainage area
Cougar/May	0.44	2.78	0.16
Smay	0.61	22.50	0.03
Champion/Rock	0.56	13.52	0.04

Notes: Quaternary alluvium (Qa) area estimated after 1:100,000-scale mapping by Frizzell and others (1984) transferred to 1:24,000-scale USGS Quadrangles. Area determined from 64-dot per square inch grid. Assumed boundaries for areas of mapped alluvium derived from associated drainage(s): (1) Cougar/May distal boundary at fist contour line north of Green River, lateral boundaries at intersection of mapped geologic contact with first contour line north of Green River, (2) Smay distal boundary at BNRR, east lateral boundary at Section SB-SB' on figure 2, west lateral boundary at East Maywood Creek, upstream boundary at National Forest Boundary, and (3) Champion/Rock distal boundary at BNRR, east lateral boundary at west side of base of knoll east of Rock Creek, west lateral boundary near convergence of BNRR, Green River, and mapped geologic contact. Drainage areas for Cougar/May and Champion/Rock estimated from 1:63,360-scale topographic map of North Bend Ranger District, Mount Baker-Snoqualmie National Forest (1991). Area determined from 64-dot per square inch grid. Drainage area for Smay from WDNR GIS coverage for Howard Hanson and Smay Creek WAUs.

Figure 3-a illustrates geologic contacts for slope profiles along lines of section depicted on figure 2. The mapped distribution of Quaternary alluvium in the Smay Creek and the Champion and Rock creek areas describes patterns typical of alluvial deposition at valley mouths, with deposits extending farther toward the heads of basins along their stream valleys than on flanking slopes (cf. Section SB-SB', and Sections SA-SA' and SC-SC', figure 3-a). These patterns contrast sharply with the mapped distribution of Quaternary alluvium in the lower Cougar and May creek basins, where the deposits extend comparable distances toward the heads of the basins along stream valleys and flanking slopes (figure 2; and figure 3-a, Section CA-CA'). Sections CX-CX' and SX-SX' (figure 3-b) cross Sections CB-CB' and SB-SB', respectively, about 1,400 feet from their intersection with the first contour line north of the Green River, and lie perpendicular to the other lines of section. As illustrated in the cross-slope profiles along Sections CX-CX' and SX-SX' (figure 3-b), mapped alluvial deposits in the lower Cougar and May creek basins rise well above the projected profile of the Green River to stand more than 100 feet higher above local base level than those in the Smay Creek basin, despite having a much smaller drainage area from which to derive such a wealth of alluvium. Their relief above

local base level is similarly anomalous in comparison to alluvial deposits in the Champion and Rock creek area.

Koler and Ballerini (1996) estimated the annual sediment yield from sub-basins in the study area based on the calculated weight of sediment in their alluvial fans:

> Probably the best evidence that numerous failures have occurred in the last several thousand years are the large alluvial fans sitting on the valley floor of the Green River mainstem. The largest fan is located at the mouth of the Cougar Mountain Sub-watershed, and is over 200 acres in size. A quick calculation shows that this fan has 70 *million* tons [emphasis as written] (assuming a soil unit weight of 100 pcf) of deposition since glacial activity ended approximately 10,000 years ago. Therefore, an approximate average of 7,000 tons/year of sediment was delivered from this drainage. Other alluvial fans and colluvial aprons located within the Green River and its tributaries, are similar in area and range from 150 to just under 200 acres. An average of approximately 5,000 tons/year of delivered sediment were deposited in these areas. Therefore, the average for the Howard Hanson - Smay Creek WAUs is most likely somewhere between 5,000 and 7,000 tons/year. The estimated sediment yield of 7,000 tons/year is probably not an unreasonable rate for "background-" or "natural-" levels...Again this is only an estimate, but one that is probably reasonable and can be used for comparing mass-wasting by management activities in the study area with natural events.

The following reasons, among others, suggest their estimates are unreliable. Clearly no long-term estimates of annual sediment yield for the Cougar Creek basin can be derived from a volume or weight of material comprised primarily by deep-seated landslide deposits rather than alluvium or shallow landslide deposits accumulated incrementally over time. As discussed above, several lines of complimentary evidence support our interpretation that deep-seated landslide deposits, rather than alluvial deposits derived from their upper basins, underlie much of the low-relief area in the lower Cougar, Sylvester, and May creek basins. Even if this interpretation is incorrect, sediment yield must account for the volume or weight of sediment transported out of basins by their streams. Under present climate conditions, this fraction appears to comprise the bulk of the sediment yield for most major tributaries to the Green River in the study area. Estimates of annual sediment yield based solely on the volume or weight of material stored in an alluvial fan will discount this fraction of a basin's sediment yield. Furthermore, the reported extent of post-Pleistocene alluvial deposits near the mouths of major tributaries to the Green River within the study area (i.e., 150-200 acres) appears excessive. With the exception of Howard Hanson Reservoir, lower Smay Creek, and the channel and floodplain of the Green River, the areas of locations where we observed evidence of post-Pleistocene alluvial deposition (e.g., lower Bear Creek, lower Sweeney Creek, and lower Bear Creek) were much less extensive than the low-relief terrain at the mouth of Cougar Creek. These observations suggest the inferred basis for extrapolation of an estimated "background" or "natural" sediment yield for the Cougar Creek basin to other major tributaries to the Green River in the study is unsound.

APPROACH TO LANDSLIDE HAZARD ZONATION

We evaluated the landslide history of eleven different types of terrain distinguished by variations in selected slope characteristics to gage their relative potential to yield landslide runout to streams in association with logging and logging roads. The different types of terrain are called mass wasting map units, or MWMUs. The products of the assessment include (1) a landslide-hazard map showing the distribution of MWMUs within the study area (Map A-2), (2) descriptions of the slope characteristics and landslide history of individual MWMUs (Form A-2), and (3) reports on predicted landslide "triggering mechanisms" for MWMUs classified here as having either a moderate or high delivered hazard rating (see attached Causal Mechanism Reports). Table 5 lists the MWMUs for the Howard Hanson and Smay Creek WAUs depicted on Map A-2, and described in Form A-2 and the attached Causal Mechanism Reports.

Table 5. Mass-wasting map units for the Howard Hanson and Smay Creek WAUs.

MWMU number	MWMU description	MWMU area (mi.^{2})	delivered hazard rating
1	ridges, spurs, gentle slopes, etc.	47.13	low
2	floodplains and low alluvial terraces	4.37	low
3	steep slopes on Tertiary intrusive rocks	0.59	high
4	steep slopes along earthflow toes	1.24	high
5	earthflow bodies	10.65	moderate
6	earthflow scarps	2.63	moderate
66	earthflow scarps akin to MWMU 11	0.23	high
7	gentle slopes on older Quaternary deposits	5.50	low
8	steep slopes on older Quaternary deposits	1.26	high
9	inner gorges	1.54	high
10	(not used in this analysis)		
11	steep slopes on Tertiary volcanic rocks	20.32	high

Following the conceptual approach illustrated in figure 4, we distinguished MWMUs primarily on the basis of four slope characteristics: slope inclination, topographic convergence, geologic substrate, and slope position relative to downslope features enhancing or diminishing potential for landslide runout (e.g., confined channels or topographic benches). These variables were practical to use because they are generally discernible from available aerial photos and USGS 1:24,000-scale topographic maps. The following discussion summarizes the applicability of these variable to analysis and classification of landslide hazards in the Howard Hanson and Smay Creek WAUs.

Soil mechanics indicate slope inclination fundamentally influences the shear stress acting on the basal zones of shallow landslides. As articulated by Swanston (1974), "increases in shear stress result from increasing slope of the failure surface," and "[a]ny increases in the tangential component of gravitational stress [i.e., shear stress] will increase the tendency for the soil to move downslope." Benda and others (1991) note that shallow landslides commonly initiate on steep slopes in the southern portion of the Cascade Range (i.e., south of Snoqualmie Pass), and detailed inventories of landslide activity within this region have demonstrated a strong correlation between slope inclination and sites of shallow landsliding (e.g., Dragovich et al., 1993).

Areas of convergent topography on unchanneled slopes (now widely referred to as hollows) are sites prone to shallow landsliding (Dietrich et al., 1987; Reneau and Dietrich, 1987a; Reneau and Dietrich, 1987b; Benda, 1990; Montgomery et al., 1991; Montgomery and Dietrich, 1994). Reneau and Dietrich (1987a) describe hollows as the concave-out portions of unchanneled hillslopes, and note that "topographic convergence in hollows forces colluvial debris to accumulate and causes shallow subsurface runoff to be concentrated during storms." Based on studies of water levels in two-first order basins in New Zealand, Petch (1988) determined that topographic convergence increased the probability of soil saturation in the steep, unchanneled, strongly convergent portions of the basins, *as well as* in their riparian areas. As noted by Montgomery and Dietrich (1994), "debris flow source areas are, in general, strongly controlled by surface topography through shallow subsurface flow convergence, increased soil saturation, and shear strength reduction."

Recent models for predicting sites of slope instability relate the potential for shallow landsliding to aspects of topographic convergence. Montgomery and Dietrich (1994) developed a model that essentially "holds all soils properties constant in space and then defines the topographic control on the location of shallow landsliding" based on a site's slope inclination and contributing area per unit contour length. Another model developed by Shaw and Johnson (1995) predicts areas of potential instability based on variations in slope inclination and curvature. Figure 5 illustrates the spatial association between the drainage network (including both channels and hollows) and sites prone to colluvial accumulation, soil saturation, and shallow landsliding in a relatively small basin analyzed in detail by Dietrich and others (1993). It exemplifies our conceptual basis for relating topographic convergence to landslide potential in the study area, where mapped landslide hazards on slopes with mature and immature forest primarily coincide with steep, topographically convergent portions of drainages (cf. Map A-2 and figure 5).

The structural orientation of geologic substrate can influence the development of landforms. Fiksdal and Brunengo (1981) relied in part on differences in the geometric relationship between bedding surfaces and slope faces to delineate landforms in portions of the upper Green River basin and describe variations in their relative potential for landsliding. Others studies of different areas in western Washington have determined (Dragovich et al., 1993) or alluded (Clark, 1996) there is some correlation between the spatial density of mapped landslides and the orientation of bedding relative to slope faces.

In this study we have not specifically analyzed or delineated landslide hazards on the basis of bedding structure or its orientation relative to slope faces. We merely used previously mapped variations in geologic substrate as the basis for subdividing broader MWMUs we might otherwise have delineated solely on the basis of topographic convergence and slope inclination into smaller units with distinct geologic substrates and fewer internal variations in landform. The use of variations in geologic substrate to segregate MWMUs also facilitates assessment of the relative potential for landslide runout to reach streams or public resources. For example, we distinguished alluvial floodplains and low terraces in the Green River and Smay Creek valleys (MWMU 2) from other areas with little potential for generating landslide runout to streams, such as gentle slopes developed on older deposits of Quaternary alluvium (MWMU 7), and selected slopes developed on Tertiary volcanic rocks (MWMU 1). Similarly, we distinguished steep, topographically convergent slopes developed on Tertiary volcanic rocks (MWMU 11) from steep, topographically convergent slopes developed on Tertiary intrusive rocks (MWMU 3) because of apparent differences in their relative degree of dissection by streams and hollows, and potential differences in their soil properties. Refining the physical basis for delineating MWMUs to accord with mapped variations in geologic substrate effectively reduces the size of some polygons (e.g., MWMU 11) by segregation of others with similar slope morphology (e.g., MWMU 3, and MWMU 8).

The composition of geologic substrate can also influence the properties of residual soils. We observed soils are locally less cohesive and more well drained in MWMUs underlain by Tertiary bedrock (e.g., MWMUs 1, 3, 6, 66, 9, and 11) than in MWMUs underlain by younger, less consolidated materials (e.g., MWMUs 2, 4, 5, 7, and 8). However, because we could not reference and did not collect data on such relevant properties as porosity, permeability, transmissivity, cohesion, or angle of internal friction of soils within the study area, we merely assumed that mapped variations in geologic substrate may impart some degree of variation to the properties of overlying soils. We elected to delineate MWMUs partially on the basis of variations in geologic substrate so they would reflect correlative variations in soil properties, whatever they may be.

The relative potential for landslides to harm aquatic or other public resources depends not only on the influence of site conditions such as slope inclination, topographic convergence, and soil properties on the potential for landslide initiation, but also on the potential for landslide runout to reach and travel along stream courses. Fannin and Rollerson (1996) suggested the relative potential for landslide runout to reach streams decreases as the distance across open slopes below landslide source areas increases. Based on field observations of debris flows in the Queen Charlotte Islands, British Columbia, Canada, they determined the average total length of 158 landslides that deposited on open slopes without reaching channels was 122 meters (400 feet), but reported a high standard deviation of 99 meters (325 feet). They noted that in most cases "the onset of terminal deposition for a debris flow on an open slope is associated with a change in slope gradient," with deposition occurring at gradients within 14 percent slope of 27 percent slope. For debris flows that initiated on open slopes and continued down steep (>27 percent), or gentle (9-27 percent) channels, they reported progressively greater average total lengths of 177 m (580 feet) and 668 m (2,192 feet), respectively, noting such debris flows "will often travel the complete length of the confined channel, at which point the onset of terminal deposition is then triggered by the loss of confinement." As suggested by Benda and Cundy (1990), deposition of debris flows entering confined channels is not likely to occur until the they encounter a high-angle tributary junction, or until channel gradient drops below about 6 percent. Johnson (1991) and Coho and Burgess (1993) reported that deposition of debris flows in confined channels can cause dam-break floods that are capable of conveying debris to more gently sloping channel segments with gradients as low as about 2 percent.

The conceptual approach used to delineate MWMUs for the Howard Hanson and Smay Creek WAUs (i.e., on the basis of slope inclination, topographic convergence, geologic substrate, and potential for landslide runout to reach and travel along stream courses) is similar to that employed by Reynolds (1996) and Krogstad and Reynolds (1997) for other WAUs in the upper Green River basin. The numeric symbols identifying the MWMUs delineated in this report largely correspond to the symbols for MWMUs delineated in those earlier studies. However, the MWMUs delineated in this report include some combinations and refinements of map units delineated for other WAUs in the upper Green River basin. For example, MWMU 11 encompasses all terrain like that Reynolds (1996) delineated as MWMU 12 and MWMU 13 in the Lester WAU, as well as portions of terrain like that delineated as MWMU 10. Other MWMUs delineated in this report constitute new map units differentiated on the basis of geologic substrate not widely represented in the WAUs located farther upstream in the Green River basin (e.g., MWMU 7 and MWMU 8).

BASIS FOR LANDSLIDE HAZARD ZONATION

Landslide Initiation

Most shallow landslides initiate on steep slopes. About 57 percent of all mapped shallow landslides in the study area initiated at mapped slope gradients greater than or equal to 65 percent. However, the percentage of landslides that initiated at slope gradients greater than or equal to 65 percent as measured in the field is probably much greater. Field observations indicate many of the landslides listed in Form A-1 as initiating at mapped slope gradients less than 65 percent actually initiated on steeper slopes beyond the resolution of the 1:24,000-scale USGS topographic maps used to estimate slope gradients at landslide initiation sites. In particular, the toe slopes of deep-seated landslides (MWMU 4), and steep slopes formed on older Quaternary deposits (MWMU 8) are commonly steeper than indicated on USGS topographic maps.

Tables 6, 7, and 8 list the number of mapped landslides per slope class by landslide type, land-use association, and MWMU, respectively. A greater proportion of shallow-rapid landslides (52 percent) initiated at mapped slope gradients less than 65 percent than debris torrents (38 percent). This disparity probably results in part from the relatively high proportion of shallow-rapid landslides relative to debris torrents in MWMUs 4 and 8, and the tendency for 1:24,000-scale USGS topographic maps to mask steep slopes in those areas. With respect to variations in land-use association, there is less disparity among the proportion of landslides that initiated at mapped slope gradients less than 65 percent, ranging only from 40 percent for roads and mature forest, to 47 percent for immature forest, roughly bracketing the proportion for all mapped shallow landslides (43 percent). Although this difference in the populations is relatively small, it suggests the possibility that shallow landslides may initiate on somewhat gentler slopes in immature forest than mature forest. For all MWMUs with non-bedrock substrate (except MWMU 2, which had no mapped landslides), more than half of all mapped shallow landslides initiated at mapped slope gradients less than 65 percent. (Note that the proportion for both the toe slopes and bodies of deep-seated landslides exceeds 70 percent). In contrast, less than half of all mapped shallow landslides originating within MWMUs with bedrock substrate (i.e., MWMU 1, 3, 6, 66, 9, and 11) initiated at mapped slope gradients less than 65 percent, with the proportion ranging below 30 percent for MWMUs 3 and 11. These data suggest shallow landslides may initiate at lesser slope gradients in areas with non-bedrock substrate. However, as noted previously, the 1:24,000-scale USGS topographic maps used to estimate slope gradient commonly fail to resolve small areas of steep slope in terrain with non-bedrock substrate.

Slope form also exerts a strong influence on landslide initiation in the study area, where at least 93 percent of all mapped shallow landslides originated on planar or convergent slopes (table 9).

Classification of form depends partially on the scale at which it is considered. As classified here, the slope form at a landslide initiation site refers to the cross-slope profile typically across distances of about two to five times landslide width. As a consequence, the landslide inventory lists the slope form as planar for many landslides that originated on lower slopes along stream courses. At the coarser scale of a slope profile across the stream course, the slope form at these sites is topographically convergent. At either scale, landslides occurred infrequently on divergent slopes along spurs or ridges. The sites where landslides initiated on convergent or planar slopes predominately range from lower slope positions marginal to stream courses, to middle slope positions between streams and spurs or ridges.

Delivery and Routing

The classification of landslide hazards presented in this report (Map A-2, Form A-2, and attached Causal Mechanism Reports) considers the potential for delivery of landslide debris to public resources following landslide initiation at a given site. This approach provides finer resolution of risks to public resources than would a classification of landslide hazards based solely on the potential for landslide initiation. In the context of this report, the term delivery means direct conveyance of landslide debris to surface waters or other public resources. Delivery potential describes the relative likelihood that landslide debris will be conveyed directly to public resources as the result of landslide initiation at a given site. Channelization tends to conserve the mobility of landslide debris delivered to streams, enabling relatively small parent landslides (on the order of hundreds of cubic yards) to foster extensive landslide runout through streams (exceeding two miles in some cases, e.g., landslides 65-7 and 78-33). Routing describes the path a landslide travels through a drainage system in terms of landslide length per stream class. This section describes observed relationships between landslide delivery and routing and (1) landslide types (2) land use at landslide initiation sites, and (3) MWMUs. These relationships illustrate the associated extent of landslide disturbance to streams and indicate how relative vulnerability to such disturbance varies among stream types.

Delivery ratios describe the fraction of landslides in a given population that deliver landslide debris to streams. They provide an empirical basis for evaluating variation in delivery potential among different landslide populations. The delivery ratio for debris torrents exceeds that for shallow-rapid landslides (table 10). With respect to land-use association, the delivery ratio for landslides originating on slopes with either mature or immature forest exceeds that for landslides associated with roads (table 11). The lower delivery ratio for road-related landslides is not attributable to a higher percentage of shallow-rapid landslides, which occurred in similar proportion on slopes with immature forest, and still greater proportion on slopes with mature forest (table 12). It may result from the variable distance between streams and roads, which can exceed distances typically traveled by unchannelized runout from shallow-rapid landslides. In contrast, the distribution of landslide initiation sites on slopes with mature or immature forest more closely follows that of the drainage network (i.e., channels and hollows), and their proximity to the drainage network probably contributes to their higher delivery ratios. It may result in part from a greater likelihood for slopes along stream courses to become saturated during storms, as suggested by the pattern of ground saturation illustrated in figure 5.

The variation in delivery ratios among MWMUs (table 13) is greater than that between shallow-rapid landslides and debris torrents, and greater than that among all land-use associations, ranging from 0.36 for MWMU 1 (ridges, spurs, low-gradient slopes, etc.) to 1.00 for MWMU 9 (inner gorges). Delivery ratios are equal to or greater than 0.90 for all but one of the six MWMUs classified as having a high delivered hazard rating. The range of delivery ratios correlates well with the hazard classifications assigned to individual MWMUs, generally decreasing with diminishing levels of hazard. Where landslide source areas exist within MWMUs classified as having a moderate or low delivered hazard rating, (i.e., MWMUs 1, 5, 6, and 7), the features limiting delivery potential include (1) extensive lengths of intervening slope lacking convergent elements such as hollows or low-order streams, and (2) broad low-gradient benches or abrupt decreases in slope gradient between landslide source areas and potential receiving channels. MWMUs classified as having a high delivered hazard rating (i.e., MWMU 3, 4, 66, 8, 9, and 11) exclude such features. They have a high potential for delivery of landslide debris to streams from slopes throughout their boundaries.

Delivery potential is high for some MWMUs because they chiefly encompass short lengths of steeply inclined slopes near streams (e.g., MWMUs 4, 8, and 9). For MWMUs with more extensive lengths of steeply inclined slope (e.g., MWMUs 3 and 11), data on lengths of shallow-rapid landslides constrain estimates of the potential for delivery of unchannelized runout from more distal sources. However, because many mapped shallow-rapid landslides terminate at streams, their lengths commonly indicate the minimum distances they can travel across slopes. The 100 shallow-rapid landslides mapped in the study area range from 30 to 900 feet in length. Their average and median lengths are 174 feet and 125 feet, respectively, and their standard deviation is 148 feet. The unit boundaries for MWMUs 3 and 11 are not determined by any fixed algorithm for predicting delivery potential, but generally encompass all continuos moderate and steep gradient terrain located within 400 feet of mapped stream courses, a distance about equal to the median length of the 100 mapped shallow-rapid landslides plus two standard deviations.

The median length of mapped shallow landslides is less than the average length for each MWMU (table 14), reflecting the influence of inferior numbers of relatively long landslides on the average length of the population. MWMUs 3, 66, 9, and 11 exhibit the greatest difference between median and average landslide lengths, which suggests the configuration of slopes and channels in bedrock terrain dissected by stream incision is conducive to generating landslide runout of relatively great length.

Altogether the mapped shallow landslides have disturbed more than 60 miles of stream length, including almost 11 miles of fish-bearing streams. Debris torrents account for almost all the mapped landslide runout through streams (table 10). The most extensive direct impacts to fish-bearing streams have resulted from long debris torrents moving through the valleys of Bear Creek, Charley Creek, Sweeney Creek, Gold Creek, West Smay Creek, and May Creek. The total length of mapped landslide runout through non-fish-bearing streams is about 4.6 times greater than the total length of runout through fish-bearing streams. Landslide runout through non-fish-bearing streams can directly affect segments of fish-bearing streams by conveying debris to them. In some cases the runout reaches fish-bearing streams without progressing much farther (e.g., landslides 78-27 in Sweeney Creek, 78-65 in Smay Creek, and 96-39 in West Smay Creek), while in others it continues for even greater distances through fish-bearing streams (e.g., landslides 65-7 in Charley Creek, and 96-35 in East Maywood Creek). In other cases landslide runout through non-fish-bearing streams may indirectly affect fish-bearing streams by depositing debris within supply-limited channel segments upstream (e.g., landslides 78-15 in the Green River canyon area, and 96-119 in the West Smay Creek basin).

About 89 percent of the total length of mapped landslide runout through streams is attributable to either road-related landslides, or landslides that originated on slopes logged less than 20 years prior to landslide initiation (table 11). The total contribution from both populations is similar. Landslides that initiated on slopes with mature forest only account for about 11 percent of the total length of mapped landslide runout through streams. Among the mapped shallow landslides that delivered debris to streams, the average length of runout through streams was almost twice as great for landslides that initiated on slopes with immature forest (1,607 feet) as for landslides that initiated on slopes with mature forest (870 feet). Assuming the total area of mature forest in the study area was greater than the total area of immature forest throughout the period of the photo record (as suggested by visual estimates from aerial photographs listed in table 1), the total rate of runout through streams was at least 3.7 times higher for landslides that initiated on slopes with immature forest than for landslides that initiated on slopes with mature forest.

The gradient and confinement of a channel constrain its vulnerability to landslide runout (Coho and Burgess, 1993; Kennard, 1994). Figure 6 illustrates the differences among the total length of runout attributed to landslides that originated in association with roads, and on slopes with mature or immature forest. In each case, the greatest length of landslide runout occurred in Type-4 streams, despite the greater total length of Type-5 streams in the study area. These data indicate confined segments of Type-4 streams downslope of landslide initiation areas are particularly vulnerable to disturbance by landslide runout. Following the practice employed by Reynolds (1996) for the Lester WAU, confined segments of Type-4 streams, and confined segments of fish-bearing streams located downslope of MWMU polygons with a high delivered hazard rating are classified as channel disturbance zones because they have a high vulnerability to disturbance by landslide runout (e.g., Type-4 streams), or support public resources vulnerable to such disturbance (e.g., fish-bearing streams). For channel segments flanked by mountain sideslopes, disturbance of riparian vegetation by landslide runout commonly spans the entire width of the alluvial valley bottom and rises onto adjoining sideslopes where the valley bends or narrows.

Figure 7 illustrates the contributions of different land-use associations and MWMUs to the extent of mapped landslide runout through fish-bearing and non-fish-bearing streams. More than 60 percent of all mapped landslide runout through streams is the result of landslides that originated in MWMU 11 (table 13). MWMUs 4, 6, and 9 together contributed about 28 percent of the total.

Seven MWMUs comprising about 29 percent of the study area account for about 91 percent of all mapped landslides (figure 8), and about 96 percent of the total mapped landslide length (figure 9). These data indicate landslide hazards are largely concentrated in terrain encompassing less than one third of the study area. Land managers should anticipate that landslide hazards associated with roads extend throughout all portions of this terrain where slope gradients exceed those described in the attached Causal Mechanism Reports. However, landslide hazards associated with logging probably encompass only a fraction of this terrain, particularly that in the vicinity of hollows, channel heads, and lower slopes along stream courses.

CONFIDENCE

The Howard Hanson and Smay Creek WAUs, like the "Hemlock watershed" referred to in Washington Forest Practices Board (1997), is "very complex, containing broad alluvial valleys, deeply and freshly incised tributaries, and rolling upland plateaus," where "a mixture of volcanic bedrock and glacial deposits complicates the geologic history."

We assume the landslide history of a large area provides a sound basis for interpreting the relative potential for landslides to initiate on different types of terrain (given similar climate conditions), as well as the relative potential for those landslides to deliver and route debris to public resources.

This study relies primarily on interpretation of aerial photos to ascertain landslide history. Both authors have experience in photo interpretation from studies of other relatively large areas in the Cascade Range, including the Lester WAU (Reynolds, 1996), the Upper Green WAU (Krogstad and Reynolds, 1997), and the Greenwater WAU (USDA Forest Service, 1998). The quality, scale, and available coverage from the NW-78, SP-89, and SCC-P-96 aerial surveys enabled us to compile a relatively comprehensive inventory of more recent landslide activity in the study area. The portion of the inventory compiled from those aerial surveys likely includes almost all the large landslides that occurred in the study area since about the early 1970s, but inevitably misses some smaller ones. The earlier portion of the landslide inventory compiled from the ELC (1962), WF (1965), and KP-70 aerial surveys provides a less comprehensive account of landslide history because of the inferior quality (e.g., ELC), smaller scale (i.e., WF), or limited available coverage (e.g., KP-70) of the surveys. The shortcomings in quality and scale diminished either our ability or confidence in resolving smaller landslides particularly in association with roads and dense forest canopy. Similarly, gaps in available coverage, and long periods of time between successive photo intervals (e.g., 1965 to 1978, and 1978 to 1989), reduced our confidence in landslide identification (particularly for smaller landslides) because of more extensive revegetation of disturbed areas during the longer periods between available images.

The breadth of the landslide inventory presented in Form A-1 and Map A-2 is comparable to that of others compiled for western Washington WAUs using methods outlined by the Washington Forest Practices Board since 1992. Despite its inherent shortcomings as a comprehensive historical account, the landslide inventory provides a large set of reproducible data on landslide history that is pertinent to classification of landslide hazards in the study area.

The conceptual approach used to distinguish the eleven MWMUs in the study area reflects that employed by Fiksdal and Brunengo (1981) to distinguish landforms in portions of the upper Green River basin, and is consistent with cited research on slope characteristics conducive to landslide initiation and runout. The delineation of the MWMU boundaries depicted on MAP A-2 is constrained by available maps of geologic substrate in the study area (Hammond, 1963; and Frizzell et al., 1984), and slope morphology depicted on 1:12,000-scale aerial survey projects listed in table 1, and 1:24,000-scale USGS topographic maps.

The relatively large scale of the controls for mapping polygon boundaries obscure resolution of small-scale variations in slope morphology at the 1:24,000 mapping scale. Because the controls for mapping polygon boundaries may mask small-scale areas of convergent topography likely to enhance potential for landslide runout, MWMU 1 polygons bounding areas with steep slopes may include some sites that should be reclassified as MWMU 3, 9, or 11. The delineated boundaries of MWMU 2 and 7 likely include few sites with potential for delivering landslide runout to streams or other public resources because they generally bound areas with uniformly low or gentle slopes.

MWMUs classified as having a moderate or high delivered hazard rating include areas with moderate or gentle slopes where landslides are unlikely to initiate. The inclusion of such areas within these MWMUs is not a mapping error. The delineated boundaries for these MWMUs enclose areas with the same type of geologic substrate that have internally consistent variations in slope morphology and include sites with a high potential for delivering landslide runout to streams or other public resources.

The variation among the delivered hazard ratings assigned to the eleven MWMU distinguished in this report chiefly reflects differences in the identified landslide history of the MWMU polygons depicted on Map A-2 and described on Form A-2.

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Form A-1. Landslide inventory database.

REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING									
ID NUMBER	PHOTO YEAR	[illegible]	USGS QUAD	"SUB-BASIN"	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	[illegible]	ID VERITY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN or SMAY
[82]-4	1980	24-06-02	FL	ES	21	10	36	sw	DT	q	d	p	0	0	800	20	800	40	22	P		F	9	Y								
[96]-230	1996		EG	LG	21	7	34	se	SR	q	p	d					200	62	32	?		RR	11	Y		x						
63-1	1962	36-92	CY	CC	20	8	17	nw	SR	p	d	p	50	50	0	0	60	80	27	P	stream-marginal slope	F	11	Y				x				
63-10	1962	14-190	CM	RES	21	8	25	ne	DT	p	d	p	0	0	1,000	50	1,000	80	42	C	convergent, dissected slope	F	11	Y			1,000	x				
63-11	1962	14-190	CM	RES	21	8	26	ne	DT	p	d	p	0	0	5,000	50	5,000	80	42	C	convergent, dissected slope	F	11	Y			1,800	2,000	1,200			
63-12	1962	14-164	CM	GC	21	9	19	sw	DT	p	d	d	0	0	700	25	700	44	24	C	convergent, dissected slope	F	11	Y			700					
63-13	1962	14-164	CM	GC	21	9	19	sw	DT	p	d	d	0	0	800	25	800	80	27	C	convergent, dissected slope	RR	11	Y			x					
63-14	1962	14-164	CM	GC	21	9	30	nw	DT	p	p	d	0	0	300	25	300	80	42	P	stream-marginal slope	MF	11	Y			300	x				
63-15	1962	8-250	CM	CM	21	9	34	sw	DT	p	d	d	0	0	300	25	300	40	22	C	convergent, dissected slope	F	5	Y			300					
63-16	1962	8-214	FL	WS	21	9	26	nw	DT	p	p	p	0	0	8,400	50	8,400	44	24	C	convergent, dissected slope	F	3	Y				400	8,000			
63-17	1962	8-214	FL	WS	21	9	25	ne	DT	p	p	p	0	0	4,800	50	4,800	67	34	P	stream-marginal slope	MF	3	Y					4,800			
63-18	1962	8-163	FL	ES	21	10	31	ne	DT	p	p	d	0	0	600	25	600	40	22	P	stream-marginal slope	RR	3	Y			600					
63-2	1962	36-92	CY	CC	20	8	17	sw	DT	p	d	p	0	0	1,400	25	1,400	44	24	P	stream-marginal slope	F	11	Y			100	1,200				
63-20	1962	7-66	FL	ES	21	10	31	se	SR	d	d	d	150	60	0	0	150	80	30	P	planar slope	RR	3	Q	x							
63-21	1962	7-66	FL	ES	21	10	31	se	SR	p	p	d	250	75	0	0	250	80	30	P	planar slope	RR	3	Q	x							
63-22	1962	7-66	FL	ES	21	10	31	se	SR	p	p	d	150	40	0	0	150	25	14	P	planar slope	RCB	1	N	x							
63-23	1962	7-66	FL	ES	21	10	32	nw	SR	d	p	d	150	75	0	0	150	133	53	P	planar slope	RR	3	Y							x	
63-24	1962	7-67	FL	ES	21	10	32	ne	DT	d	d	d	0	0	600	50	600	66	33	P	stream-marginal slope	F	4	Y				600			x	
63-25	1962	14-110	CM	GC	21	9	32	ne	DT	d	d	d	0	0	400	50	400	57	30	C	convergent, dissected slope	RF	11	Y				400				
63-26	1962	8-212	FL	WS	21	9	36	ne	SR	q	q	p	100	175	0	0	100	114	49	C	head scarp	F	6	Q			x					
63-3	1962	36-92	CY	CC	20	8	17	se	DT	p	d	p	0	0	800	25	800	90	42	P	stream-marginal slope	RR	11	Y			800	x				
63-4	1962	36-92	CY	CC	20	8	16	nw	DT	p	d	p	0	0	600	25	600	80	30	P	stream-marginal slope	RR	11	Y			600	x				
63-5	1962	36-96	EG	CC	21	8	33	sw	DT	p	d	p	0	0	800	25	800	63	28	C	convergent, dissected slope	F	11	Y			800					
63-6	1962	36-101	EG	CC	21	8	33	sw	DT	p	d	p	0	0	1,400	25	1,400	80	30	P	stream-marginal slope	F	11	Y			1,400					
63-7	1962	36-101	EG	BC	21	8	33	nw	DT	p	d	p	0	0	1,200	25	1,200	80	30	C	convergent, dissected slope	F	11	Y		1,200				x		
63-8	1962	36-101	EG	BC	21	8	33	nw	DT	p	d	p	0	0	1,000	25	1,000	80	30	C	convergent, dissected slope	F	11	Y			1,000			x		
63-9	1962	36-101	EG	BC	21	8	33	nw	DT	p	d	p	0	0	2,000	25	2,000	67	34	P	stream-marginal slope	F	11	Y			2,000			x		
65-1	1965	11-41	EG	LG	21	8	10	se	DT	d	d	p	0	0	4,600	40	4,600	90	30	P	stream-marginal slope	F	9	Y				3,000	1,000			x
65-12	1965	14-44	FL	ES	21	10	33	se	SR	d	d	d	200	100	0	0	200	25	14	C	earthflow toe	MF	4	Y					x			
65-13	1965	11-41	EG	LG	21	8	20	sw	SR	d	q	d	250	75	0	0	250	73	36	C		F	11	Y								x
65-14	1965	12-42	CY	CC	20	8	8	sw	SR	d	q	d	600	75	0	0	600	69	42	C		MF	11	Y				x (250)				
65-15	1965	12-43	CY	CC	20	8	10	ne	DT	d	p	p	0	0	3,000	20	3,000	67	30	C		RR	9	Y				3,000				
65-16	1965	11-41	EG	LG	21	8	10	nw	DT	p	p	d	0	0	600	30	600	80	30	P?		MF	11	Q								
65-17	1965	11-41	EG	LG	21	8	16	nw	DT (SR)	d	d	d	200	80	1,000	30	1,000	67	34	C		RR	11	Y								
65-18	1965	11-41	EG	LG	21	7	13	ne	DT	d	p	d	0	0	560	30	560	80	30	C		F	11	Y								
65-2	1965	11-41	EG	LG	21	8	10	se	DT	d	d	p	0	0	1,200	50	1,200	73	36	P	stream-marginal slope	MF	11	Y		1,200			x			
65-3	1965	12-42	EG	BC	21	8	31	sw	DT	d	d	p	0	0	16,400	50	16,400	67	30	C	convergent, dissected slope	F	11	Y				8,000		7,400		
65-4	1965	12-42	EG	BC	21	8	32	sw	DT	d	d	p	0	0	1,000	50	1,000	73	36	C	convergent, dissected slope	MF	11	Y			600	400				
65-6	1965	12-42	EG	BC	21	8	29	ne	DT	d	d	d	0	0	2,000	25	2,000	67	34	P	stream-marginal slope	RR	11	Y			2,000				x	
65-7	1965	12-43	CY	CC	20	8	30	ne	DT	d	d	d	0	0	20,200	40	20,200	44	24	P	stream-marginal slope	F	11	Y				6,000	2,800	6,600	6,000	x

Form A-1. Landslide inventory database.

REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING								
ID NUMBER	PHOTO YEAR	PHOTO NUMBER	USGS QUAD	SUB-BASIN	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	LANDSLIDE TYPE	ID VERIFY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N/?)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN or SMAY
65-8	1965	12-42	CM	GC	21	9	32	ne	SR	d	q	d	100	100	0	0	100	65	33	C	convergent, dissected slope	F	11	Y			x					
65-9	1965	12-42	CM	GC	21	9	32	sw	DT	d	d	q	0	0	2,800	40	2,800	80	38	P?	stream-marginal slope	MF	9	Y			400	2,400	x			
70-1	1970	17-40C-6	EG	LG	21	8	21	nw	DT	d	d	q	0	0	2,600	20	2,600	73	36	C		MF	9	Y			2,600					x
70-2	1970	17-40C-6	EG	LG	21	8	20	ne	SR	d	p	d	300	40	0	0	300	80	38	C		RR	11	?	x							
70-3	1970	17-40C-6	EG	LG	21	8	20	ne	DT	d	p	d	0	0	800	25	800	80	38	P		RR	11	Y			800					
70-4	1970	17-40C-6	EG	LG	21	8	20	ne	SR	p	p	d	100	30	0	0	100	44	24	P		RR	11	Y				x				
70-5	1970	17-40C-6	EG	LG	21	8	20	se	SR	d	p	d	150	40	0	0	150	80	38	P		RR	11	Y							x	
70-6	1970	17-40C-6	EG	LG	21	8	20	se	DT	p	d	p	0	0	1,300	25	1,300	67	34	P		RR	11	Y				x				
70-7	1970	27-40B-30	EG	LG	21	8	10	se	SR	d	q	d	0	0			200	57	30	P	rim of stream-marginal slope	F	11	Y				x				
70-10	1970	81B-16	CY	CC	20	8	3	sw	SR	d	d	d	100	100	0	0	100	65	33	P	stream-marginal slope	F	11	Y					x			
70-11	1970	81B-20	EG	CC	21	8	33	se	DT (SR)	d	d	d	300	100	2,300	50	2,600	62	32	C	convergent, dissected slope	RR	4	Y				1,800	800			
70-12	1970	80B-23	EG	BC	21	8	28	nw	SR	q	q	d	200	50	0	0	200	80	38	P	planar slope	RR	8	Y							x	
70-13	1970	80B-23	EG	LG	21	8	20	ne	DT (SR)	d	d	d	100	50	1,200	25	1,300	80	38	P	stream-marginal slope	RR	9	Y				1,200				
70-14	1970	80B-23	EG	LG	21	8	20	nw	DT (SR)	p	p	p	75	100	1,200	25	1,275	80	38	P	stream-marginal slope	RR	11	Y			1,200					x
70-15	1970	80B-23	EG	LG	21	8	20	ne	DT (SR)	d	d	d	175	100	2,600	25	2,775	80	38	P	stream-marginal slope	RF	11	Y			1,800	1,600				x
70-16	1970	81B-20	EG	CC	21	8	34	sw	SR	d	d	d	50	50	0	0	50	80	38	P	planar slope	RR	8	Y							x	
70-17	1970	84B-17	GW	CAN	20	9	10	nw	DT	d	d	d	0	0	2,800	25	2,800	73	36	C	convergent, dissected slope	RR	11	Y			2,800	x				
70-19	1970	86A-17	GW	SC	20	9	10	ne	DT	p	d	d	0	0	1,000	25	1,000	80	38	P	stream-marginal slope	RR	11	Y			1,000					
70-2	1970	80B-16	CY	CC	20	8	17	ne	DT (SR)	d	d	d	200	75	500	50	700	73	36	P	planar slope	RR	11	Y			700	x				
70-20	1970	85A-24	CM	GC	21	9	19	sw	DT (SR)	d	d	p	50	50	4,200	50	4,250	80	38	C	convergent, dissected slope	RR	11	Y			1,650	2,200	400			
70-22	1970	86A-16	GW	SC	20	9	29	nw	DT	d	d	d	0	0	2,200	50	2,200	67	34	C	convergent, dissected slope	RF	11	Y			2,200	x				
70-23	1970	86A-16	GW	SC	20	9	29	ne	DT	d	d	d	0	0	1,800	50	1,800	80	38	C	convergent, dissected slope	RF	11	Y		1,800	x					
70-24	1970	86A-16	GW	SC	20	9	29	ne	SR	p	p	p	100	100	0	0	100	80	38	C	convergent slope	RCB	11	?	x							
70-25	1970	86A-16	GW	SC	20	9	29	ne	DT (SR)	d	d	d	200	100	11,800	50	12,000	73	36	C	convergent, dissected slope	RF	11	Y			3,200	7,400	1,200			x
70-26	1970	86A-17	GW	SC	20	9	17	se	SR	d	d	d	100	100	0	0	100	50	27	P	earthflow toe	F	4	Y				x				
70-27	1970	86A-17	GW	SC	20	9	17	se	DT	d	q	q	0	0	400	25	400	73	36	C	convergent, dissected slope	F	4	Y				400				
70-28	1970	88A-19	GW	HR	20	9	16	nw	DT	d	d	d	0	0	400	25	400	67	30	P	stream-marginal slope	RF	4	Y			400					
70-29	1970	88A-19	GW	HR	20	9	16	nw	DT	q	q	q	0	0	1,200	50	1,200	26	14	C	stream-marginal slope	F	4	Y					1,200			x
70-3	1970	79B-30	EG	LG	21	8	19	se	DT (SR)	d	d	d	200	100	1,200	25	1,400	73	36	P	stream-marginal slope	RF	11	Y			600	600				
70-30	1970	86A-19	GW	SC	20	9	9	se	SR	d	q	d	100	700	0	0	100	50	27	P	stream-marginal slope	RR	4	Y								x
70-32	1970	89A-16	NAG	HR	20	9	23	se	DT	d	d	d	0	0	1,500	40	1,500	40	22	P	stream-marginal slope	RF	9	Y			1,500	x				
70-33	1970	89A-16	NAG	HR	20	9	25	sw	DT	d	d	q	0	0	12,200	50	12,200	80	38	C	stream-marginal slope	MF	9	Y			3,200	8,000	1,000			x
70-34	1970	89A-16	NAG	HR	20	9	23	ne	DT	d	d	p	0	0	1,600	50	1,600	67	34	P	stream-marginal slope	F	4	Y				1,600				
70-35	1970	89A-23	CM	CM	21	9	34	ne	DT	d	d	d	0	0	11,200	50	11,200	80	38	C	convergent, dissected slope	RR	11	Y			2,200	9,000				
70-37	1970	90A-22	FL	WS	21	9	36	ne	SR	p	p	d	150	75	0	0	150	44	24	P	planar slope	MF	4	Y					x			
70-38	1970	90A-22	FL	WS	21	9	25	se	SR	p	p	d	250	100	0	0	250	57	30	C	convergent slope	MF	4	Y					x			
70-39	1970	90A-22	FL	WS	21	9	36	ne	SR	d	d	d	75	50	0	0	75	73	36	P	stream-marginal slope	MF	9	Y			x					
70-4	1970	79B-31	EG	LG	21	8	7	se	SR	d	p	d	300	50	0	0	300	67	34	C	convergent, dissected slope	RF	11	Y			x					
70-40	1970	90A-22	FL	WS	21	10	31	nw	DT	d	d	p	0	0	5,300	50	5,300	73	36	C	convergent, dissected slope	F	11	Y			1,400	900	3,000			
70-41	1970	90A-22	FL	WS	21	10	31	nw	DT	d	d	p	0	0	800	50	800	73	36	C	convergent, dissected slope	F	11	Y		800						

Form A-1. Landslide inventory database.

REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING								
ID NUMBER	PHOTO YEAR	PHOTO NUMBER	USGS QUAD	"SUB-BASIN"	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	LANDSLIDE TYPE	ID VERIFY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN or SMAY
70-42	1970	90A-22	FL	WS	21	9	25	se	SR	p	p	p	80	75	0	0	80	67	34	P	stream-marginal slope	MF	4	Y					x			
70-43	1970	90A-22	FL	WS	21	9	25	sw	DT	d	d	p	0	0	2,200	50	2,200	44	24	?		MF	4	Y					2,200			
70-44	1970	91A-23	FL	ES	20	10	6	ne	DT	p	p	p	0	0	2,500	50	2,500	90	42	C	rocky, converg., dissected slope	MF	3	Q		2,500					x	
70-45	1970	91A-23	FL	ES	21	10	31	nw	DT	p	d	p	0	0	1,800	50	1,800	44	24	?		RL	11	Y			1,800					
70-46	1970	91A-23	FL	ES	21	10	31	nw	DT (SR)	d	d	p	200	75	600	50	600	42	23	?		RL	11	Y		600	x					
70-47	1970	91A-23	FL	ES	21	10	31	nw	DT (SR)	d	d	d	100	50	3,000	50	3,100	100	45	C	convergent, dissected slope	RF	11	Y			2,000					
70-48	1970	92A-22	NAG	ES	20	10	5	sw	DT	d	d	d	0	0	800	40	800	58	30	C	convergent, dissected slope	RR	11	Y			600	x				
70-49	1970	92A-22	NAG	ES	20	10	5	se	DT	d	d	d	0	0	3,800	40	3,800	57	30	C	convergent, dissected slope	RR	9	Y			400	2,000				
70-5	1970	91B-14	CY	CC	20	8	16	sw	DT	d	d	d	0	0	800	25	800	90	42	P	stream-marginal slope	RR	11	Y		800		x				
70-50	1970	92A-22	NAG	ES	20	10	5	sw	DT	d	d	d	0	0	800	25	800	67	34	C	hollow	IF	11	Y			800	x				
70-51	1970	92A-22	NAG	ES	20	10	5	se	SR	d	d	d	250	150	0	0	250	58	30	C	convergent slope	RF	11	Y				x				
70-52	1970	92A-22	NAG	ES	20	10	5	sw	DT	d	p	d	0	0	600	50	600	67	34	C	convergent, dissected slope	RF	6	Q		600						
70-53	1970	92A-22	NAG	ES	20	10	5	sw	DT (SR)	d	d	p	100	50	2,400	50	2,500	58	30	P?	stream-marginal slope	RF	11	Y				2,400				
70-54	1970	92A-22	FL	ES	20	10	5	ne	DT (SR)	d	d	d	100	100	1,200	50	1,300	62	32	C	convergent, dissected slope	RF	9	Y				1,300				
70-55	1970	92A-22	FL	ES	20	10	5	ne	DT	p	p	p	0	0	3,200	50	3,200	44	24	C	convergent, dissected slope	RR	9	Y				1,800	2,200		x	
70-56	1970	92A-24	FL	ES	20	10	29	se	DT	d	d	p	0	0	4,200	50	4,200	25	14	C	convergent, dissected slope	RR	4	Y			1,300	2,900			x	
70-57	1970	93A-25	FL	ES	21	10	33	ne	SR	p	p	d	100	200	0	0	100	25	14	C	earthflow toe	IF	4	Y					x			
70-58	1970	92A-24	FL	ES	21	10	30	se	SR	d	d	p	100	50	0	0	100	50	27	C	convergent, dissected slope	IF	11	N	x							
70-59	1970	92A-24	FL	ES	21	10	32	nw	SR	d	d	d	100	50	0	0	100	40	22	P	planar slope	RCB	6	Q	x							
70-6	1970	91B-14	CY	CC	20	8	21	ne	DT	d	d	d	0	0	800	50	800	40	22	C	convergent, dissected slope	RR	11	Y				800				
70-60	1970	92A-24	FL	ES	21	10	29	sw	DT (SR)	d	d	d	200	100	3,800	50	4,000	44	24	P	stream-marginal slope	RF	66	Y			1,000	3,800			x	
70-61	1970	92A-24	FL	ES	21	10	29	ne	DT	d	d	d	0	0	2,000	50	2,000	58	30	C	convergent, dissected slope	IF	6	Y		2,000						
70-62	1970	86A-24	CM	GC	21	9	32	nw	SR	p	q	p	300	50	0	0	300	67	34	P	stream-marginal slope	RR	11	Y		x	300					
70-63	1970	92A-24	FL	ES	21	10	29	sw	DT	d	d	p	0	0	700	25	700	50	27	P	planar slope	RR	6	Y		x						
70-64	1970	92A-24	FL	ES	21	10	33	se	DT	d	d	q	0	0	1,500	50	1,800	50	27	P	stream-marginal slope	RR	9	Y				1,500			x	
70-65	1970	93A-25	FL	ES	21	10	33	se	DT	d	d	d	0	0	2,000	25	2,000	58	30	C	convergent, dissected slope	RR	9	Y			200	1,800			x	
70-66	1970	93A-25	FL	ES	21	10	33	se	DT	d	d	d	0	0	1,800	25	1,800	58	30	C	convergent, dissected slope	IF	9	Y			300	1,300	x			
70-67	1970	93A-26	FL	ES	21	10	27	nw	DT	p	q	d	0	0	600	50	600	114	49	C	rocky, converg., dissected slope	IF	6	Q			600					
70-68	1970	94A-22	FL	ES	20	10	3	ne	DT	d	d	q	0	0	6,100	25	6,100	40	22	P	stream-marginal slope	RR	9	Y			1,100	5,000	x			
70-69	1970	94A-22	FL	ES	20	10	3	nw	DT	d	d	d	0	0	400	25	400	57	30	P	stream-marginal slope	RF	9	Y				400	x			
70-7	1970	91B-14	CY	CC	20	8	16	se	DT	d	d	p	0	0	5,000	50	5,000	62	32	C	convergent, dissected slope	RR	11	Y				1,000	4,000			
70-70	1970	95A-26	FL	ES	21	10	34	se	DT	d	d	d	0	0	2,500	50	2,500	36	20	C	convergent, dissected slope	IF	4	Y				2,500				
70-71	1970	95A-26	FL	ES	21	10	34	ne	DT	p	p	p	0	0	200	25	200	67	34	P	stream-marginal slope	IF	11	Y				x				
70-72	1970	95A-26	FL	ES	21	10	34	ne	SR	p	p	p	200	100	0	0	200	90	42	P	stream-marginal slope	IF	11	Y				x				
70-73	1970	95A-26	FL	ES	21	10	36	nw	DT	d	d	d	0	0	800	25	800	73	36	P	stream-marginal slope	RF	11	Y				800	x			
70-74	1970	95A-26	FL	ES	21	10	36	nw	DT	d	d	p	0	0	1,200	25	1,200	80	39	C	convergent, dissected slope	RR	9	Y				1,200				
70-75	1970	95A-26	FL	ES	21	10	36	nw	DT	d	d	p	0	0	900	25	900	73	36	?		IF	11	Y		900		x				
70-76	1970	95A-26	LL	ES	21	10	36	ne	SR	d	d	d	300	50	0	0	300	40	22	P	planar slope	RF	11	N	x							
70-77	1970	95A-26	LL	ES	21	10	36	ne	SR	d	d	d	300	50	0	0	300	50	27	P	planar slope	RF	11	Q		x						
70-78	1970	95A-26	LL	ES	21	10	36	sw	DT	p	p	p	0	0	4,600	25	4,600	50	27	C	convergent, dissected slope	IF	9	Y			1,600	3,000				

Form A-1. Landslide inventory database.

REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING								
ID NUMBER	PHOTO YEAR	PHOTO NUMBER	USGS QUAD	"SUB-BASIN"	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	LANDSLIDE TYPE	ID VERIFY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN or SMAY
70-79	1970	96A-26	LL	ES	21	10	26	ne	SR	p	p	p	100	100	0	0	100	67	34	P	stream-marginal slope	IF	9	Y				x				
70-8	1970	81B-10	CY	CC	20	8	3	sw	DT	d	d	d	0	0	50	50	50	66	33	P	stream-marginal slope	RR	11	Y					x			
70-60	1970	96A-26	FL	ES	21	10	27	se	DT	p	d	d	0	0	800	25	800	73	36	C	convergent, dissected slope	IF	11	Y		800						
70-61	1970	96A-26	FL	ES	21	10	27	se	DT	d	d	d	0	0	1,200	50	1,200	50	27	P	stream-marginal slope	RR	11	Y			1,200	x				
70-62	1970	96A-26	FL	ES	21	10	26	sw	DT	d	d	q	0	0	800	25	800	40	22	C	convergent, dissected slope	RR	11	Y		800		x				
70-63	1970	96A-26	FL	ES	21	10	26	sw	DT	d	d	d	0	0	800	25	800	37	20	C	convergent, dissected slope	RR	9	Y			800					
70-64	1970	96A-26	LL	ES	21	10	26	ne	DT	d	d	d	0	0	1,300	25	1,300	58	30	P	stream-marginal slope	RR	9	Y			1,300					
70-65	1970	79B-30	EG	LG	2	8	19	sw	SR	q	p	d	80	40	0	0	80	100	45	P	stream-marginal slope	MF	1	Y								
70-66	1970	96A-26	LL	ES	21	10	26	sw	DT	d	d	p					1,100	58	30	C	stream-marginal slope	RR	9	Y			1,100					
70-67	1970	96A-26	LL	ES	21	10	26	sw	DT	p	d	p	0	0	1,800	25	1,800	58	30	P	stream-marginal slope	RR	11	Y		1,800						
70-8	1970	81B-10	CY	CC	20	8	3	sw	SR	d	d	d	100	50	0	0	100	66	33	P	stream-marginal slope	IF	11	Y					x			
90-1	1990	33-79-206	EG	LG	21	7	34	se	SR	d	p	d	100	50	0	0	100	58	30	P	landing	RR	11	N	x							
90-10	1990	92-191	CY	CC	20	8	22	ne	DT	p	p	d	0	0	1,200	25	1,200	50	27	C	hollow	IF	11	Y			1,200					
90-11	1990	86-86	GW	SC	20	9	10	se	DT	p	d	p	0	0	1,800	25	1,800	73	36	C	convergent, dissected slope	RR	5	Y				1,800				
90-13	1990	90-86	FL	WS	21	9	25	sw	DT	d	d	d	0	0	800	50	800	133	53	C	convergent, dissected slope	RF	11	Y		800	x					
90-14	1990	90-246	FL	ES	21	10	29	sw	DT	d	d	d	0	0	1,800	25	1,800	40	22	P	stream-marginal slope	IF	86	Y		1,800	x					
90-16	1990	92-246	FL	ES	21	10	29	se	DT	d	d	d	0	0	1,800	50	1,800	40	22	C	convergent, dissected slope	IF	6	Y			1,800	x				
90-18	1990	90-246	FL	ES	21	10	29	ne	DT	d	d	d	0	0	800	50	800	90	42	C	convergent, dissected slope	RR	6	Y		100						
90-19	1990	90-246	FL	ES	21	10	29	ne	SR	d	d	d	50	50			50	114	49	P	stream-marginal slope	RR	6	Y		x						
90-2	1990	79-206	EG	LG	21	7	34	se	DT (SR)	d	d	p	400	50	300	50	700	50	27	C	hollow	RR	11	Y			700					
90-20	1990	92-246	FL	ES	21	10	29	ne	DT	p	p	d	0	0	600	25	600	100	45	P	stream-marginal slope	IF	6	Y			600					
90-21	1990	94-136	FL	ES	21	10	34	ne	DT	d	d	d	0	0	600	25	600	67	34	P	stream-marginal slope	RR	11	Y		600		x				
90-23	1990	93-191	FL	ES	21	10	33	sw	SR	p	p	p	100	25	0	0	100	40	22	?	earthflow toe	RCB	4	Q							x	
90-24	1990	79-206	EG	LG	21	8	19	sw	SR	d	p	d	250	75	0	0	250	58	30	P	planar slope	RF	11	Y			x					
90-25	1990	34-87-168	GW	SC	20	9	9	se	SR	p	p	d	500	50	0	0	500	58	30	P	planar slope	RR	11	Q								
90-26	1990		CM	CM	20	8	4	ne	SR	d	d	d					100	73	36	?		MF	6	Y		?						
90-27	1990	92-246	FL	ES	21	10	29	ne	DT	d	d	d	0	0	250	50	250	40	22	C	convergent, dissected slope	IF	6	Y		250	x					
90-28	1990	93-191	FL	ES	21	10	33	se	SR	d	d	d	50	250	0	0	50	25	14	C	earthflow toe	IF	4	Y					x			
90-29	1990	86-182	CM	CM	20	9	3	nw	DT (SR)	d	p	p	200	100	2,800	50	2,800	58	30	C	convergent, dissected slope	IF	6	Y		200		2,800				
90-3	1990	79-206	EG	LG	21	8	19	sw	SR	q	d	p	200	50	0	0	200	58	30	C	hollow	IF	11	Y				x				
90-30	1990	86-182	GW	CM	20	9	3	se	DT	d	d	p	0	0	1,400	50	1,400	73	36	C	convergent, dissected slope	IF	6	Y			1,400	x				
90-31	1990	86-182	GW	CM	20	9	10	nw	DT	p	p	p	0	0	500	20	500	58	30	P	convergent, dissected slope	RR	11	Y		500						
90-32	1990	86-183	CM	GC	21	9	30	se	DT	d	d	q	0	0	4,450	50	4,450	42	23	P	stream-marginal slope	RR	11	Y			450	4,000		x		
90-33	1990	86-183	CM	GC	21	9	30	se	SR	d	p	p	400	50	0	0	400	58	30	?		RR	11	Y		400		x				
90-34	1990	80-25	EG	LG	21	8	29	se	SR	q	p	d	50	50	0	0	50	47	25	P		RR	11	Y			x					
90-35	1990	80-28	EG	LG	21	8	29	se	SR	d	d	d	100	50	0	0	100	67	34	P		RR	11	Y				x				
90-36	1990	80-26	EG	LG	21	8	28	nw	SR	d	p	d	100	40	0	0	100	36	20	C		RR	7	Y			x					
90-37	1990	80-25	EG	LG	21	8	20	nw	DT	d	q	d	0	0	125	20	125	47	25	P		IF	7	N	x							
90-38	1990	80-27	EG	LG	21	8	19	se	SR	d	d	p	150	40	0	0	150	40	22	P		RR	11	Y			x					
90-39	1990	80-29	EG	LG	21	8	17	ne	DT	d	p	d	0	0	450	25	450	73	36	P		RL	11	Q			x					

Form A-1. Landslide inventory database.

REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING								
ID NUMBER	PHOTO YEAR	PHOTO NUMBER	USGS QUAD	"SUB-BASIN"	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	LANDSLIDE TYPE	ID VERIFY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN or SMAY
80-4	1980	80-28	EG	LG	21	8	21	sw	DT	d	p	d	0	0	400	35	400	80	42	P	stream-marginal slope	RF	11	Y				x				
80-40	1980	83-270	GW	CAN	21	8	11	se	SR	d	p	d	100	80	0	0	100	80	38	P		MF	11	Q	x							
80-5	1980	80-29	EG	LG	21	8	17	sw	DT (SR)	p	p	p	100	100	400	35	500	80	38	P	stream-marginal slope	RF	11	Y				500				
80-6	1980	81-160	CY	CC	20	8	16	nw	DT	p	p	p	0	0	600	40	600	133	53	C	stream-marginal slope	IF	11	Y				600				
90-1	1995	34-05-163	EG	LG	21	8	7	se	DT	d	d	d	0	0	7,000	72	7,000	67	34	C	convergent, dissected slope	RF	11	Y			2,000	3,000	1,200			x
96-101	1996	1-8-163	EG	LG	21	8	17	se	DT	p	d	d	0	0	500	40	500	73	36	C	convergent, dissected slope	RR	11	Y			800					
96-102	1996	2-10-23	EG	RES	21	8	35	sw	SR	d	p	d	300	300			300	44	24	?	escarpment	NF	6	Y							x	x
96-103	1996	1-8-213	EG	LG	21	8	21	se	DT	d	d	d	0	0	600	40	600	80	42	P	stream-marginal slope	RF	11	Y			800					
96-104	1996	1-8-205	CY	CC	20	8	21	nw	DT	d	d	d	0	0	400	25	400	57	30	C	convergent, dissected slope	RR	11	Q	x							
96-108	1996	3-16-300	CM	CM	20	9	2	nw	SR	d	d	d	80	80	0	0	80	40	22	C	convergent, dissected slope	IF	5	Y				x				
96-113	1996	2-14-161	GW	SC	20	9	8	se	DT	d	d	d	0	0	300	80	300	67	30	P	planar slope	RF	11	Y			300					
96-114	1996	2-15-100	GW	SC	20	9	9	sw	DT	d	d	d	0	0	150	80	150	67	34	P	planar slope	RF	1	Y		x						
96-115	1996	2-14-161	GW	SC	20	9	17	ne	SR	d	p	d	350	100	0	0	350	67	30	C	convergent slope	RF	8	Y								x
96-116	1996	3-21-130	FL	ES	21	10	27	nw	SR	d	d	d	200	100	0	0	200	40	22	C	convergent, dissected slope	RF	5	N	x							
96-119	1996	3-10-63	FL	WS	21	9	26	se	DT	d	d	d	0	0	3,400	80	3,400	73	36	P?	stream-marginal slope	IF	9	Y			200	3,200				
96-120	1996	3-10-63	FL	WS	21	9	26	se	DT	d	d	d	0	0	1,000	50	1,000	57	30	P?	stream-marginal slope	RF	11	Y			1,000	x				
96-122	1996	3-10-80	NAG	ES	20	10	7	sw	DT	d	d	d	0	0	2,200	50	2,200	40	22	C	convergent, dissected slope	IF	4	Y				1,200	1,800			
96-123	1996	3-19-87	FL	ES	21	10	32	sw	DT	d	d	d	0	0	400	50	400	58	27	?		MF	11	Y					x			
96-127	1996	3-21-130	FL	ES	21	10	33	se	SR	d	p	d	100	300	0	0	100	25	14	P	earthflow toe	MF	4	Y					x			
96-128	1996	3-21-130	FL	ES	21	10	34	nw	SR	d	p	d	100	100	0	0	100	25	14	P	earthflow toe	MF	4	Y					x			
96-129	1996	3-21-130	FL	ES	21	10	34	nw	SR	p	p	p	80	80	0	0	80	25	14	P	earthflow toe	MF	4	Y					x			
96-130	1996	1-7-161	EG	LG	21	8	19	ne	DT	p	p	p	0	0	800	60	800	33	18	?		MF	11	Y				500				
96-131	1996	1-7-161	EG	LG	21	8	19	ne	DT	p	p	p	0	0	200	25	200	80	27	?		MF	11	N	x							
96-132	1996	3-16-104	CM	CM	21	9	34	sw	DT	p	d	q	0	0	2,000	40	2,000	67	34	P	stream-marginal slope	RR	5	Y		2,000		x				
96-133	1996	2-14-161	GW	SC	20	9	8	se	DT	p	p	p	0	0	200	25	200	67	34	?		RR	11	Q	x							
96-134	1996	2-13-123	CM	GC	21	9	30	ne	SR	p	p	p	100	80	0	0	100	80	38	C	convergent, dissected slope	MF	11	Y			x					
96-135	1996	2-16-205	GW	HR	20	9	22	nw	SR	p	q	p	250	75	0	0	250	44	24	P	head scarp	IF	6	Q			x					
96-136	1996	2-16-205	GW	HR	20	9	22	nw	SR	p	q	q	150	50	0	0	150	40	22	P	head scarp	IF	6	Q	x							
96-137	1996	2-15-100	GW	SC	20	9	9	se	ES	d	p	d	100	75	0	0	100	50	27	C?	earthflow toe	IF	4	Y								x
96-138	1996	2-14-149	GW	SC	20	9	17	se	SR	d	p	p	400	25	0	0	450	80	38	C	hollow	IF	11	Y				x				
96-139	1996	2-12-83	GW	CAN	20	8	12	sw	SR	d	d	d	100	30	0	0	100	53	28	P	approx. 50 feet below road	IF	11	Q	x							
96-140	1996	2-12-83	GW	CAN	20	8	12	se	SR	d	q	d	350	10	0	0	350	50	27	C	hollow?	IF	1	Q	x							
96-141	1996	2-12-83	GW	CAN	20	8	12	se	SR	p	p	d	75	40	0	0	75	50	27	C?	stream-marginal slope	MF	8	Y					x			
96-142	1996	2-12-83	GW	CAN	20	9	7	sw	SR	d	p	d	50	100	0	0	50	50	27	P?		MF	8	Y								x
96-143	1996	2-11-60	CY	CAN	20	8	11	sw	SR	d	p	d	50	75	0	0	50	44	24	P?	earthflow toe	IF	4	Y				x				
96-144	1996	2-11-60	CY	CAN	20	8	11	sw	SR	d	p	d	50	250	0	0	50	50	27	P?	earthflow toe	IF	4	Y				x				
96-145	1996	2-11-47	GW	CAN	20	8	24	nw	SR	d	d	d	200	50	0	0	200	50	27	P?	planar slope	RL	11	Q			x					
96-146	1996	2-11-84	EG	RES	21	8	35	sw	SR	d	p	d	30	50	0	0	30	44	24	P	planar slope	MF	8	Y								x
96-147	1996	2-10-19	CY	CAN	20	8	14	nw	SR	d	q	d	150	25	0	0	150	50	27	C		IF	4	Y				x				
96-148	1996	1-8-101	EG	LG	21	8	29	se	DT	d	p	p	0	0	1,000	10	1,000	73	36	C		MF	11	Y			1,800	x				

Form A-1. Landslide inventory database.

REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING								
ID NUMBER	PHOTO YEAR	PHOTO NUMBER	USGS QUAD	"SUB-BASIN"	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	LANDSLIDE TYPE	ID VERIFY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN or GRAY
96-140	1996	1-8-213	EG	LG	21	8	20	nw	SR	d	p	d	75	75	0	0	75	90	42	P?		MF	8	Y								x
96-160	1996	1-8-101	EG	LG	21	8	20	sw	SR	d	p	d	100	10	0	0	100	44	24	C		IF	8	Y				x				
96-161	1996	1-8-102	EG	LG	21	8	20	se	SR	d	d	d	100	25	0	0	100	50	27	?		NF	11	Y				x				
96-162	1996	1-7-146	EG	BC	21	8	31	se	SR	q	p	d	80	40	0	0	80	73	36	P	stream-marginal slope	MF	9	Y				x				
96-163	1996	1-7-161	EG	LG	21	8	10	ne	SR	p	q	d	800	40	0	0	800	60	30	P	planar slope	RR	11	Q			300					
96-164	1996	1-6-116	EG	LG	21	7	24	ne	SR	p	p	d	200	100	0	0	200	73	36	C	convergent slope	RR	8	Q			x					
96-165	1996	1-6-116	EG	LG	21	7	24	ne	DT	d	p	p	0	0	900	20	900	67	34	C	stream-marginal slope	RR	11	Y			900	x				
96-166	1996	3-17-21	CM	CM	21	9	36	sw	SR	d	d	d	100	75	0	0	100	73	36	P	head scarp	RL	6	Q				x				
96-167	1996	3-17-21	NAG	CM	20	9	12	nw	SR	d	p	d	100	25	0	0	100	90	42	P	stream-marginal slope	IF	11	Y					x			
96-168	1996	2-16-210	CM	CM	21	9	33	se	SR	d	q	d	100	80	0	0	100	44	24	P		IF	6	Q				x				
96-169	1996	2-11-47	GW	CAN	20	8	23	se	SR	d	p	d	100	25	0	0	100	67	30	C	hollow	IF	11	Q		x						
96-23	1996	2-13-119	GW	CAN	20	9	8	nw	DT	p	p	d	0	0	1,400	12	1,400	60	30	P	stream-marginal slope	IF	11	Y			1,400					
96-25	1996	2-14-151	GW	SC	20	9	8	ne	DT	d	d	p	0	0	2,000	25	2,000	73	36	C	convergent, dissected slope	IF	11	Y			400	2,200				
96-28	1996	2-16-200	GW	CM	20	9	3	nw	SR	d	q	d	50	50	0	0	50	40	22	P	undissected slope	IF	6	Y				x				
96-30	1996	2-16-200	GW	CM	20	9	4	nw	SR	d	p	d	80	80	0	0	80	60	30	P	stream-marginal slope	IF	6	Y				x				
96-31	1996	2-16-210	CM	CM	21	9	34	ne	DT	q	q	q	0	0	800	25	800	44	24	P	stream-marginal slope	MF	1	Q		800						
96-32	1996	3-17-16	GW	HR	20	9	23	sw	DT	q	p	p	0	0	2,200	25	2,200	50	27	C	convergent, dissected slope	IF	4	Y			1,800	400				
96-35	1996	3-17-20	NAG	CM	20	9	1	se	DT	d	d	p	0	0	5,000	50	5,000	73	36	C	convergent, dissected slope	IF	11	Y				800	4,200			
96-36	1996	3-17-20	NAG	CM	20	9	2	se	DT	d	d	d	0	0	800	25	800	40	22	C	convergent, dissected slope	IF	11	Y		x						
96-39	1996	3-18-84	FL	WS	21	9	24	se	DT	d	d	d	0	0	2,100	25	2,100	40	22	C	convergent, dissected slope	RR	5	Q			800	1,300	x			
96-40	1996	3-19-80	FL	ES	21	10	20	sw	DT	p	p	d	0	0	1,800	25	1,800	67	30	P	stream-marginal slope	IF	6	Y		1,800						
96-41	1996	1-6-81	CUM	LG	21	7	2	se	DT (SR)	d	d	d	150	50	2,000	25	2,150	40	22	C	hollow	IF	5	Y			2,150					
96-42	1996	1-6-116	EG	LG	21	7	24	se	DT (SR)	d	d	d	400	100	3,600	50	4,000	100	45	C	convergent, dissected slope	RF	11	Y			1,400	2,200				x
96-43	1996	1-6-116	EG	LG	21	7	24	sw	DT (SR)	d	d	d	100	50	1,800	40	1,900	50	27	C	convergent, dissected slope	RR	11	Y			700	1,800				
96-44	1996	1-6-116	EG	LG	21	7	24	ne	SR	p	q	d	200	50	0	0	200	60	30	C	convergent, dissected slope	RF	8	Y			x					
96-45	1996	1-6-116	EG	LG	21	7	24	ne	DT	d	p	d	0	0	200	25	200	60	30	C	convergent, dissected slope	RF	8	Q			x					
96-46	1996	1-6-116	EG	LG	21	8	19	sw	RF	d	p	q	0	0	300	40	300	90	42	C	rocky upper slope	RR	11	Q	x							
96-47	1996	1-6-116	EG	LG	21	8	30	nw	DT	d	p	d	0	0	600	40	650	90	42	C	rocky upper slope	MF	1	N	x							
96-48	1996	1-6-116	EG	LG	21	8	30	nw	RF	p	p	p	250	80	0	0	250	100	45	C	rocky upper slope	RL	11	N	x							
96-49	1996	1-6-116	EG	LG	21	8	19	sw	SR	p	p	p	200	80	0	0	200	44	24	P	planar slope	RR	1	N	x							
96-50	1996	1-7-142	CY	CC	20	8	7	nw	DT (SR)	d	d	d	50	25	600	40	600	60	30	P	stream-marginal slope	MF	11	Y			600		x			
96-51	1996	1-7-142	CY	CC	20	8	6	se	DT (SR)	d	d	d	250	175	3,800	50	4,050	60	30	C	convergent, dissected slope	IF	11	Y			250	2,500	x			
96-52	1996	1-7-142	CY	CC	20	7	12	ne	DT	d	d	p	0	0	1,800	40	1,800	73	36	C	convergent, dissected slope	IF	11	Y			800	1,000				
96-53	1996	1-7-149	EG	LG	21	8	20	sw	DT	p	q	d	0	0	1,000	75	1,000	50	27	P	stream-marginal slope	RF	11	Y			800	200				
96-54	1996	1-7-152	EG	LG	21	8	7	se	DT	d	d	d	0	0	5,600	50	5,600	67	34	C	convergent, dissected slope	IF	11	Y			2,000	3,600				
96-55	1996	1-7-152	EG	LG	21	8	7	se	DT	d	d	d	0	0	700	25	700	60	30	C	convergent, dissected slope	IF	11	Y			700	x				
96-56	1996	1-7-152	EG	LG	21	8	7	se	SR	d	p	d	350	25	0	0	350	73	36	C	convergent, dissected slope	RF	11	Q	x							
96-57	1996	1-8-182	EG	LG	21	8	21	sw	DT	d	d	p	0	0	1,500	30	1,500	67	34	C	stream-marginal slope	MF	9	Y		1,000	500					x
96-58	1996	1-8-179	EG	BC	21	8	32	se	DT	d	d	q	0	0	1,000	25	1,000	60	30	C	convergent, dissected slope	MF	11	Y			500	500				
96-59	1996	1-9-200	CY	CC	20	8	16	nw	DT	q	d	q	0	0	700	40	700	114	49	C	convergent, dissected slope	IF	11	Y				700				

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REFERENCE									MAPPING				DIMENSIONS (feet)					SLOPE CHARACTERISTICS						DELIVERY AND ROUTING								
ID NUMBER	PHOTO YEAR	PHOTO NUMBER	USGS QUAD	"SUB-BASIN"	TOWNSHIP (N)	RANGE (E)	SECTION	1/4 SECTION	LANDSLIDE TYPE	ID VERIFY	ID TYPE	ID ORIGIN	SR LENGTH	SR WIDTH	DT LENGTH	DT WIDTH	TOTAL LENGTH	GRADIENT (%)	ANGLE (degrees)	FORM	ATTRIBUTES	LAND USE	MWMU	DELIVERY (Y/N)	NO DELIVERY	TYPE 9 (feet)	TYPE 5 (feet)	TYPE 4 (feet)	TYPE 3 (feet)	TYPE 2 (feet)	TYPE 1 (feet)	GREEN 1st SMAY
96-60	1996	1-9-213	EG	BC	21	8	28	sw	SR	p	p	d	100	25	0	0	100	73	36	P	stream-marginal slope	MF	8	Y						x		
96-61	1996	1-9-213	EG	BC	21	8	28	sw	SR	p	p	d	150	25	0	0	150	50	27	P	stream-marginal slope	MF	8	Y						x		
96-62	1996	1-9-213	EG	BC	21	8	33	nw	DT	d	d	d	0	0	560	40	560	60	30	C	stream-marginal slope	MF	11	Y			560			x		
96-63	1996	1-9-213	EG	BC	21	8	33	nw	DT	d	q	q	0	0	350	40	350	25	14	C	stream-marginal slope	MF	11	Y						300		
96-64	1996	1-9-213	EG	LG	21	8	27	nw	DT	d	p	d	0	0	600	60	600	90	42	P	planar slope	RF	1	Q	x							
96-66	1996	2-11-61	CY	CC	20	8	11	sw	DT	d	d	p	0	0	3,200	80	3,200	50	27	C	convergent, dissected slope	IF	4	Y				3,200				
96-67	1996	2-15-101	GW	CM	20	9	10	nw	SR	d	p	d	100	75	100	10	200	67	34	P	steep planar slope	RF	11	Q		x						
96-68	1996	2-12-82	GW	CAN	20	8	24	se	DT	d	d	q	0	0	4,200	60	4,200	60	30	C	convergent, dissected slope	IF	11	Y			800	3,400				
96-69	1996	2-12-86	GW	CAN	20	8	1	sw	DT (SR)	d	d	d	80	25	200	25	300	67	30	?	escarpment	RF	8	Y								x
96-70	1996	2-13-116	GW	SC	20	9	10	nw	DT (SR)	d	d	d	100	25	6,000	60	6,100	67	34	C	convergent, dissected slope	RR	11	Y			3,800	3,400				
96-71	1996	2-16-208	GW	CM	20	9	11	nw	DT	d	d	d	0	0	600	25	600	60	30	P	stream-marginal slope	IF	1	Q	x?	x						
96-72	1996	2-16-208	GW	CM	20	9	11	nw	SR	p	p	p	100	25	0	0	100	44	24	C	convergent, dissected slope	RCB	6	O			x					
96-73	1996	3-17-20	NAG	CM	20	9	11	ne	DT (SR)	d	d	d	150	25	1,250	60	1,400	62	32	P	stream-marginal slope	RR	11	Y			1,200		200			
96-74	1996	3-17-22	CM	CM	21	9	35	sw	SR	d	p	d	400	25	0	0	400	133	53	D	divergent slope	RR	1	N	x							
96-75	1996	2-16-210	CM	CM	21	9	34	sw	SR	d	q	d	50	50	0	0	50	53	28	P		IF	6	Y		x						
96-76	1996	2-16-209	GW	CM	20	9	3	se	DT	d	d	d	0	0	350	25	350	67	34	P	stream-marginal slope	IF	1	Y			350					
96-77	1996	2-16-209	GW	CM	20	9	11	nw	SR	d	d	d	50	50	0	0	50	67	34	P	stream-marginal slope	RCB	11	Y			x					
96-79	1996	3-16-85	FL	WS	21	9	24	ne	DT	d	d	d	0	0	1,800	25	1,800	60	30	P	stream-marginal slope	RR	11	Q			1,800					
96-80	1996	3-20-114	FL	ES	21	10	29	sw	DT (SR)	d	d	d	100	60	500	40	600	57	30	C	convergent, dissected slope	IF	66	Y		600	x					
96-81	1996	3-20-114	FL	ES	21	10	29	se	DT	d	d	d	0	0	1,000	25	1,000	62	32	C	hollow	RR	6	Y			1,800					
96-82	1996	3-20-114	FL	ES	21	10	29	ne	SR	d	p	d	400	25	500	75	900	60	30	P	head scarp	IF	6	Q	x							
96-83	1996	3-20-114	FL	ES	21	10	29	ne	DT	d	d	d	0	0	1,000	40	1,000	60	30	C	convergent, dissected slope	IF	6	Y		1,000						
96-84	1996	3-19-67	FL	ES	21	10	31	nw	DT	d	d	d	0	0	3,000	80	3,000	67	34	C	convergent, dissected slope	RR	11	Y			2,400	600			x	
96-85	1996	3-21-137	FL	ES	21	10	33	sw	SR	p	p	d	100	25	0	0	100	25	14	D	earthflow toe	RCB	4	N	x							
96-86	1996	3-21-137	FL	ES	21	10	33	sw	SR	p	p	d	100	25	0	0	100	25	14	D	earthflow toe	MF	4	Y							x	
96-87	1996	3-21-137	FL	ES	21	10	33	sw	SR	p	p	d	100	25	0	0	100	25	14	C	earthflow toe	RF	4	Y							x	
96-88	1996	3-21-137	FL	ES	21	10	33	sw	SR	p	p	d	100	50	0	0	100	25	14	C	earthflow toe	RF	4	Y							x	
96-89	1996	3-21-137	FL	ES	21	10	33	sw	SR	p	p	d	100	25	0	0	100	25	14	C	earthflow toe	RF	4	Y							x	
96-91	1996	1-7-142	CY	CC	20	8	8	nw	DT	d	p	d	0	0	450	25	450	50	27	P	stream-marginal slope	MF	11	Y		250			200			
96-92	1996	1-7-149	EG	LG	21	8	19	se	DT (SR)	d	d	d	100	50	1,500	40	1,600	62	32	C	convergent, dissected slope	RR	11	Y				1,500				
96-93	1996	2-14-151	GW	SC	20	9	8	se	SR	d	d	d	175	50	0	0	175	60	30	P	stream-marginal slope	RR	11	Y			x					
96-94	1996	2-14-151	GW	SC	20	9	8	se	DT	d	d	d	0	0	1,400	12	1,400	60	30	P	stream-marginal slope	RR	11	Y			1,400					x
96-96	1996	1-6-117	EG	LG	21	7	13	ne	DT	d	d	d	0	0	700	50	700	60	30	P	stream-marginal slope	MF	11	Y		700						x
96-97	1996	1-7-150	EG	LG	21	8	18	se	DT	d	d	d	0	0	300	40	300	73	36	P	stream-marginal slope	MF	11	Y					300			x
96-98	1996	1-7-152	EG	LG	21	8	7	se	DT	d	d	d	0	0	400	25	400	53	28	C	convergent, dissected slope	RF	11	Y		400						
96-99	1996	1-7-152	EG	LG	21	8	7	se	DT	d	d	d	0	0	500	75	500	60	30	C	convergent, dissected slope	RR	11	Y			500					