Appendix H

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE

DEBRIS SLIDES, DEBRIS FLOODS, AND AFFECTED PROPERTIES

Nelson Road and North Fork Road
Whatcom County, Washington

Prepared for:

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Washington Department of Natural Resources
Land Management Division

October 12, 2009

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Caring for
your natural resources
... now and forever

TO: Jeff May
Baker District Manager
Department of Natural Resources
919 Township Street
Sedro-Woolley, Washington 98284

SUBJECT: **ENGINEERING GEOLOGIC FIELD RECONNAISSANCE**
Debris Slides, Debris Floods, and Affected Properties
Nelson Road and North Fork Road
Whatcom County, Washington

DATE: October 12, 2009

The following Engineering Geologic Field Reconnaissance report presents our findings and a discussion regarding the debris slides and debris floods that affected several residential properties on Nelson Road and North Fork Road in Whatcom County, Washington. This reconnaissance report addresses the following issues: 1) Were the points-of-initiation of the debris slides on DNR-managed lands? 2) Were the points-of-initiation in areas of recent management activities? 3) Did the management activities contribute to debris slide initiation? and 4) How much did management activities contribute to debris slide initiation?

If you have any questions, please call.

Respectfully submitted,

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WASHINGTON STATE DEPARTMENT OF
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1.0. INTRODUCTION

At your request we have completed an engineering geologic field reconnaissance of the debris slides and debris floods that affected several residential properties in west-central and north-central Whatcom County. The debris slides and debris floods that are the subject of this field reconnaissance report occurred during the early January 2009 rain storm. The general areas of our geologic field reconnaissance and the affected properties are shown on Figure 1. This reconnaissance report addresses four sites on Nelson Road not covered by reconnaissance reports issued earlier this year that address several other sites on Nelson Road, and this report addresses a site on North Fork Road. Please see the back of this reconnaissance report for a list of those earlier Nelson Road reports. The addresses and owners of the affected properties are listed below. The five sites addressed in this reconnaissance report are grouped by location and the individual slide that affected each group of properties. They are, from south to north:

3608 Nelson Road; Syre; herein referred to as the 3608 NR Site

3810 Nelson Road; Fitch &
3825 Nelson Road; Fox; herein collectively referred to as the 3810 NR Site.
(In the DNR Storm tracking system this site is referred to as Nelson Road #3)

3830 Nelson Road; Malec; herein referred to as the 3830 NR Site

4076 Linnel Road; Digby/Hildt; herein referred to as the Linnel Road (LR) Site

6104 North Fork Road; Kirkwood
6108 North Fork Road; Severson
6130 North Fork Road; Bell; herein referred to as the North Fork Road (NFR) Site

(In the DNR Storm tracking system this site is referred to as CL-1000 Mainline)

The distribution of the several properties and the general direction of debris-flood run-out are shown on Figures 1, 2, and 3. The Nelson Road debris slides initiated in various areas of Sections 16 and 21, T38N, R5E, (Willamette Base Line &Meridian) and the impacted areas of the affected properties are located in the western portion of Section 16 or the eastern portions of Sections 17 and 20, of the same Township, in the US Geological Survey 7½-minute Deming Quadrangle. At the NFR Site the debris slide initiation sites and affected properties are both in the eastern half of Section 15, T39, R5E, same base line/meridian and quadrangle noted above.

The slides and resultant debris floods that impacted the 3608 NR site (Syre) were included in the reconnaissance report for the 3506, 3600, 3618, 3633, and 3652 Nelson Road properties, issued May 6, 2009 by Hanell and Coyle (2009). For details please see that reconnaissance report. For the remainder of this reconnaissance report, detailed discussion of the 3608 NR site (Syre) will not be included as part of the NR Sites. However, Figure 2 shows the general course of the debris floods that impacted that property.

The Nelson Road sites are situated in the Acme Watershed Administrative Unit (WAU). To date Landslide Hazard Zonation mapping has not been undertaken for this area. However, watershed analysis for the Acme WAU was released in 1999 by Trillium Corporation. Save for the LR Site (the northern most Nelson Road addressed in this report) the debris slides originated in the Acme Watershed Mass Wasting Map Unit (MWMU) #7. This MWMU is described as a “conditionally high hazard” area. In this MWMU slope processes are characterized as predominately shallow landslides, small debris slides, and possibly bedrock-slab failures. This area is designated as Area of Resource Sensitivity Mass Wasting Unit 1 (ARS MW-1). This ARS is accompanied by an involved set of landform descriptions, resource concerns, linkages, and prescriptions. Please see the Acme Watershed Analysis for details. The northern-most slide originated in MWMU #6. This MUMW is mapped to be associated with Devils Slide. The watershed analysis reports the predominate landslide process in this MWMU is judged to be bedrock slab failures, but can include debris flows and shallow colluvial failures. The slopes included in the Devils Slide MWMU are designated as Area of Resource Sensitivity Mass Wasting Unit 2 (ARS MW-2). As is the case with ARS-1, this ARS is accompanied by an involved set of landform descriptions, resource concerns, linkages, and prescriptions. Please see the Acme Watershed Analysis for details.

The NFR Site is located in the Racehorse Creek WAU. To date watershed analysis has not been undertaken for this WAU. However, Landslide Hazard Zonation (LHZ) mapping was released in 2006 by Cashman and Brunengo. Potential slope stability hazards on these slopes varies greatly with the topography and range from low hazards on gentle slopes to moderate on moderately steep slopes, to very high hazards in areas of steep (>75%) convergent topography.

As shown on Figure 1, all the affected properties are located at or near the base of westward-facing steep slopes. The Nelson Road sites are located along the base of a steep slope that marks the west side of a plateau-like topographic high known as Van Zandt Dike; the NFR Site is at the base of the western margin of the mountains of the Racehorse Creek WAU. Only the 3608 NR Site is located within an alluvial fan hazard zone as shown on the *Geologically Hazardous Areas* map of the Whatcom County Critical Areas Ordinance prepared in 2006 for Whatcom County Planning & Development.

The purpose of our geologic field reconnaissance was to locate the points-of-initiation (PI) of the several debris slides, observe the site conditions at the PIs, observe the conditions along the debris-flow tracks, and note conditions in the areas of deposition. In addition, we were asked to provide a professional opinion, based on the office data reviewed and field evidence we observed, as to the natural and, if applicable, the anthropomorphic contributory factors that influenced landslide initiation, as well as the triggering event that caused the debris slides and flows.

2.0. SCOPE OF WORK

Our scope of work included the following tasks:

- Review of pertinent published and unpublished geologic reports and maps in our office files
- Review of a pertinent 2001 topographic map prepared by DNR Division of Engineering, Resource Map Section
- Review of a pertinent property boundary map of the North Fork Road area prepared by Whatcom County
- Review of Whatcom County hazards map
- Review of pertinent sections of the Acme Watershed Analysis report
- Review of the landslide hazards zonation report for Racehorse Creek WAU
- Review of pertinent data files in the DNR electronic database
- Review of pertinent LIDAR imaging in the DNR electronic database
- Review of pertinent aerial photographs in the DNR files at the Northwest Region office
- Review of available pertinent past Forest Practices Applications
- Review of the Initial Incident Reports (IIR) for the several sites
- Review of photographs taken shortly after the failures
- Reconnaissance of the debris-slide points-of-initiation and flow tracks
- Reconnaissance of the depositional area of the debris flows
- Photographing pertinent aspects of the debris slides, flow tracks, and depositional areas
- Review of pertinent historical rainfall and snowfall data

- Review of available rainfall and snowfall data related to the January 4 to 8, 2009 storm
- A brief discussion with Ms. Digby and Mr. Hildt
- A brief discussion with Mr. Fitch
- A brief discussion with Mr. Malec
- A brief discussion with Mr. Syre
- Analysis of the resulting data
- Preparation of this field reconnaissance report and accompanying illustrations

In addition there was one meeting with the Northwest Regional Manager and selected assistant Northwest Regional staff, geologists from Washington Division of Geology and Earth Resources, and geologists from the DNR Land Management Division (LMD) Earth Sciences Program in which the general nature of the proposed reports for the slides related to the January storm and estimated schedule of field work and report completion were discussed. No specific site was discussed in any detail.

3.0. LIST OF ILLUSTRATIONS

The following illustrations are attached to the back of this report:

4.0. PHYSICAL SETTING

The Nelson Road and North Fork Road sites (NR Sites and NFR Site, respectively) are dominated by high steep topographic relief and essentially flat river valleys. The physical setting of the PIs of the debris slides, flow tracks, and the areas of debris flood deposition are characterized by the topography, climate, geology, landslides, and groundwater. Each of these attributes is briefly discussed below.

4.1. TOPOGRAPHY

The topography of the **Nelson Road sites** is represented by two distinctly different types of terrain (Figures 1 and 2). The area is dominated by the Van Zandt Dike, a plateau-like topographic high and the South Fork Nooksack River Valley (aka the Acme Valley). At the Nelson Road sites the PIs are in an area of steep hillside topography. The affected areas of the impacted properties are located on relatively gentle to flat hillside topography. The west-facing slopes of Van Zandt Dike exhibit an average inclination of about 85%. However, locally bedrock cliffs, characterized by essentially vertical inclinations, are present. Between the cliffs, “benches” characterized by relatively gentler slopes can be found. Locally, cascades and waterfalls up to several tens of feet high are present where streams flow across the cliffs. The bench and cliff topography creates a subtle “ribbed” effect that sweeps downward across portions of the hillside area. The PIs are situated at elevations that vary from about 1,100 to 1,330 feet. The depositional areas and affected residences are situated on relatively gentle topography, at elevations of approximately 300 to about 340 feet. The local relief between the areas of deposition and the PIs is high, and ranges from approximately 785 to 960 feet vertical over a horizontal distance of between about 950 to 1,000 feet, measured from the base of the slope. Several relatively significant drainages can be observed incised into the west-facing slopes above the Nelson Road area. Most of the streams in these drainages head near the top of the slope; however, one extends eastward and southward into the plateau area of Van Zandt Dike (Figure 1 and 2). Some of these streams, at least during periods of high flow, empty into Black Slough (Figure 1) and the water then flows northward into the northward-flowing South Fork Nooksack River. The residential structures at the 3810 NR site and the 3830 NR site are situated on alluvial fans; those at the 3608 and 4076 site are not on alluvial fans, but portions of the properties at those sites are on alluvial fans.

The topographic setting of the **NFR Site** is dominated by the west side of Slide Mountain and the North Fork Nooksack River Valley (Figures 1 and 3). At the NFR Site the PIs are in an area of steep hillside topography. The affected areas of the impacted properties are located on relatively gentle to flat topography. The west-facing slopes above the affected areas exhibit an average inclination of about 80% to 100%. However, locally bedrock cliffs, characterized by essentially vertical inclinations, are present. Between the cliffs “benches” characterized by relatively gentler slopes can be found. The cliffs and benches impart a stair-step like effect to the appearance of the hillside. Locally cascades and waterfalls up to several tens of feet high are present where streams flow across the cliffs. The PIs are situated at elevations that vary from about 700 to 810 feet. The depositional areas and affected residences are situated on relatively gentle topography, at elevations of approximately 50 to 60 feet. The local relief between the areas of deposition and the PIs varies from approximately 300 to 410 feet vertical over a horizontal distance of between about 650 to 750 feet measured from the base of the slope. Three westward drainages can be observed on the west-facing slopes at the NFR Site. Two are relatively short and extend only partially up slope (Figure 3). The other extends further eastward and heads further up slope. Apparently the streams when flowing in these drainages sink into the subsurface upon reaching the valley floor. From there subsurface flow most likely delivers water to the North Fork Nooksack River. The CL-1000 Mainline forest road traverses the hillside area above the NFR Site (Figure 3).

4.2. CLIMATE

The historical climatic record and pertinent details of the recent storm are briefly presented below. The rainfall data pertinent to the January 2009 storm is generalized with few details. This could change as more information becomes available.

4.2.1. Historic Record – The area of the Site is influenced by a predominantly maritime-type climate with mild wet winters and cool dry summers. The area receives frequent and sometimes intense storms that approach from the Pacific Ocean, about 120 miles to the west.

The nearest weather recording station with a lengthy historic record is located at the Glacier Ranger Station (Western Region Climate Center (WRCC), 2008), about 8¾ to 12½ miles to the northeast of the Nelson Road and NFR sites, respectively. The Glacier recording station is some distance away but is at an elevation of approximately 1,000 feet, near the elevations of the PIs of the Nelson Road sites (1,100 and 1,330 feet), but well above the PIs at the NFR Site. The generally accepted zone of greatest or most frequent rain-on-snow influence in this portion of the Cascades is from 1,600 to 4,000 feet (Trillium Corporation, 1993). The Glacier Ranger Station is well into the foothills of the Cascade Mountains, unlike the sites of the slides in question, which are essentially in the foothills of the front of the ranges. These geographic disparities are important and do not allow a simple inference of the climatic history from one site to the other. However, it appears to be the closest weather station with a historic record of significant length. Though totals at the sites and at the Glacier Recording Station are surely likely to be different (if totals for the sites were available) and the amount of the difference uncertain; it is probably safe to assume that if a large storm resulted in significant precipitation at the Glacier Station then the same storm likely resulted in significant precipitation at the Site. The area of the slides in question is in the rain-dominated zone (1,600 feet or less). The precipitation history is summarized below, keeping in mind that the precipitation history is assumed to be similar, only with likely somewhat lower totals at the sites.

The three periods-of-record (POR) for the Glacier Ranger Station include the following: 1949-1983, 1961-1990, and 1971-2000; in total a 51-year record. (In the station database the tabulated data is reported in this manner.) The WRCC (2008) reports the annual average rainfall at the Glacier Ranger Station varies from about 68⅔ and 71 inches, for PORs 1961 – 1990 and 1971 – 2000, respectively. The mean annual for the 1949 to 1983 POR is 66⅔ inches of rain, with a yearly standard deviation of about 12 inches. The highest recorded January rainfall for the POR was 19½ in 1974; for a December it was 21 inches in 1979. The mean January and December rainfalls are 9⅓ and 10½ inches, respectively. Average daily precipitation in January and December is about ⅓ of an inch, within a daily range that varies from about one-eight inch to five-eights inches for both months. However, the maximum one-day total in January during the POR is about 3½ inches, while in December it is about 4⅔ inches. It appears that during one very unusual December storm event the daily average rainfall was exceeded by about 1,225%. The mean average snowfall is about 51¾ inches per year over the 1948 to 1982 POR for snowfall. The greatest snowfall in January was 73¾ inches in 1954; in December, 25 inches in 1971. The monthly mean snowfall is about 17 and 8 inches for January and December, respectively. Daily average snowfall for January and December has varied from 0 to about 1¾ inches; however, during extreme events up to at least 17 inches of snow has fallen in a single day. Snow depths at the Glacier station during January average between about 1 and 6⅓ inches over the POR; in December the average for the POR is between 0 to about 1 inch. Over the POR, snow-depth extremes for January range from about 11 inches to about 37¼ inches; for December, the range is from 0 to about 11 inches.

Since 2000 (the end of the POR) the National Climatic Data Center (2009) reports that Whatcom County has experienced one heavy snow event in February 2001, three heavy snow events in January and February of 2002, one heavy rain event in October 2003, a winter-weather mix event in January 2004, heavy rains in November and December 2004, one heavy snow event followed by a flood (heavy rain?) event in January 2005, and finally a flood (heavy rain?) event in November 2006. In December 2008, the area experienced a prolonged period of severe winter weather during which snow accumulations reached about a foot-and-a-half in the low lying areas.

The January 2009 storm followed a several-week period of snow storms, prolonged freezing temperatures, and thick accumulations of snow, even at lower elevations. The available historic climate data were reviewed to determine how often such a sequence of weather events has occurred in the area of the Site. Only the data for the years 1949 to 1983, a 34 year period, from the WRCC contained totals for monthly accumulations of snow and rain. We arbitrarily chose months where the December snowfall equaled or exceeded about 24 inches, and the January rainfall equaled or exceeded 10 inches, attempting to match the snow conditions leading up to the January 2009 storm and the rainfall of that storm. For the time period reviewed there were only two periods that matched these criteria: December/January 1970/71 (snow 30”/rain 13”, respectively) and December/January 1971/72 (snow 45”/rain 13” respectively). It should be noted that in both Januarys there was significant snowfall in addition to the rainfall. It should also be noted that there were several January snowfall and rainfall totals that came close or exceeded the 10-inch minimum (January 1954, ’60, ’68, ’70, ‘74, ‘76, and ’82), but because it is uncertain whether the rain followed the snow or vice-versa it is difficult to be certain how representative these storms would be of the climatic setting leading up to the January 2009 storm. This is because the POR has only monthly totals, not daily totals. Because there are only monthly totals, no daily totals (the POR summaries only report average rain and snow for any given day of the year), it is assumed that from the monthly December snowfall totals, at least about 1½ to 2 feet of snow was present at the end of

December, and that a large portion of the January rain fell on the December snow during a several-days storm, in effect a worse-case scenario.

4.2.2. January 2009 Storm – The damaging storm in question began about January 4 and continued to about January 8, 2009, and followed on the heels of the December 2008 snow storms mentioned above. No recording stations are located at the Site. However, interpretation of Doppler-radar imaging of the four day period of rain bracketed above (National Weather Service, 2009) suggests that the area of the sites received about 9 to 11 inches of rain during that period. The January 4 to 8 period was preceded and followed by showers and light rain and snow so that the actual total could be somewhat greater. The time-intensity relationships are uncertain, but likely were characterized by periods of heavy rainfall interspersed with periods of lighter to no rainfall. The amount of snowfall on Van Zandt Dike and the slopes above the affected properties is also uncertain. However, based on the IIR, it appears that the snow pack was about two, and maybe as much as three feet thick (Hooks, 2009a, b, c). Temperature and wind data from University of Utah TSUNA weather station east of Deming near the base of Sumas Mountain recorded almost three weeks of below or just above freezing temperatures prior to the January 4 to 8 storm. During the storm, temperatures rose over the four day period from below freezing to almost 50°F during the last couple of days of the storm. Also, wind speeds between 20 to 30 mph from the SSW with sustained speeds of 15 to 20 mph were recorded at the weather station during the latter days of the storm (University of Utah, 2009). Recently obtained information from Miller (1964) suggests a 48-hour rainfall total of 8 inches equates to a storm with a return interval of 100 years. Based on the Doppler data the January storm would approximate at least a 50- to 100-year storm event.

4.3. GEOLOGY

The geology of both sites is represented by the underlying Eocene age bedrock and the Quaternary age surficial deposits that overlie the bedrock. Surficial deposits include glacial sediments, soil and colluvium, landslide debris, alluvial fan deposits, alluvial deposits, and artificial fill. A brief description and general distribution of these earth materials is presented below, their general distribution is shown on Figures 2 and 3.

4.3.1. Bedrock – Dragovich and others (1997) map the bedrock geology at both sites as the Chuckanut Formation (**Tec**). It is composed of sandstone interbedded with lesser amounts of siltstone and shale. The sandstone varies from locally laminated to very thick bedded and exhibits a general east-west strike and a moderate (40°) to steep (70°) northerly dip. Locally the bedrock is broken by sets of generally steeply dipping joints. The bedrock crops out in the upper reaches of the sites and is assumed to underlie the surficial deposits from the mid-slope areas downward where the bedrock is overlain by a variety of surficial deposits.

4.3.2. Surficial Deposits – The **glacial sediments** (**Qg**) where present are represented by accumulations of poorly stratified sand and gravel, with some minor amounts of finer-grained sediments. These sediments inter-finger with alluvial deposits in the valley floor. They occur as isolated patch in the upper areas of the sites and are likely present on topographic benches of the sites (Figure 3), though they may not be mapped. Also they are present underlying the Acme Valley floor (Figure 2) and may underlie the valley filling alluvial deposits.

Soils and colluvium are derived from the mechanical and chemical weathering of the underlying bedrock. These deposits are composed of varying amounts sand, silt, and clay intermixed with blocks of bedrock and organic debris. In the **Nelson Road** area soil mapping published by Goldin in 1992 classifies the soils underlying the lower portions of the Site as Chuckanut loam and those underlying the mid- and upper slopes as Andic Xerochrepts on 60% to 90% slopes. The Chuckanut loam is characterized as well drained, moderately permeable, having a high water capacity, moderate runoff, and moderate erosion hazard. The Andic Xerochrepts soil is described as a loam intermixed through the area with bedrock outcrops. The loam component is characterized as well drained, moderately permeable, having a high water capacity, moderate runoff, and moderate erosion hazard. At the **North Fork Road Site** the mid- and upper slopes are blanketed by Andic Xerochrepts soils were bedrock does not crop out. This soil is described above. The valley floor soils are mapped as the Puyallup fine sandy loam, and are characterized as well drained and having a moderate water capacity, moderate permeability, slow runoff, and no erosion hazard. Between these two soils Goldin (1992) maps Nati loam. It is characterized as well drained, moderately permeable, having a moderate water capacity, slow runoff, and slight erosion hazard.

The soils form more or less in-place; however, the colluvial deposits are formed by the accumulation of soil moved down slope in response to gravity driven processes (e.g., soil creep, etc.). Herein, colluvial deposits (**Qc**) are considered to be soil deposits thicker than about 3 to 4 feet. The soils occur in patches and discontinuously across the upper areas of the site including the bedrock benches noted above. Colluvium blankets the mid- and lower slopes of the sites, but also has accumulated locally on topographic benches and at the base of most of the bedrock cliffs.

Landslide debris (**Qls**) is composed of a mixture of sand, silt, clay, and blocks of bedrock. The blocks of rock can be quite variable in size. Landslide debris is confined to landslides in the hillside areas, but is understood to be inter-fingered as debris slide and debris-flood deposits within alluvial fans and colluvial deposits on lower-slope areas of the sites.

Alluvial fan deposits (**Qf**) are composed of interbedded debris flow and debris flood deposits and fluvial sediments. The debris-flow deposits, where exposed, are poorly-stratified, poorly-sorted deposits of coarse angular accumulations of bedrock debris and soil in a matrix of finer-grained earth materials. They are mapped at the mouths of the various drainages at the sites.

Alluvial deposits (Old and young; **Qoal** and **Qa**, respectively) are composed of stratified gravel, sand, silt, and clay. They underlie the valley floor areas of the sites, and can be interfingered with glacial and alluvial fan deposits.

Artificial fill is composed of sand, silt, clay, and soils and rock debris derived from local road grading and landing construction. Though not shown on any of the figures its presence should be assumed along the outside margins of roads and landings.

4.4. LANDSLIDES

Landslide activity at the Nelson Road sites is essentially confined to debris slides, small-scale landslides, and avalanches (save for Devils Slide - a very large, prehistoric collapse of a portion of the west-facing slopes of Van Zandt Dike (Brunengo, 2001)). These slides fail from the steep slopes that parallel the many drainages that have been eroded into the west-facing slopes of the Dike. They can be quite variable in size and are composed of rock and soils debris, and organic debris of varying amounts. These landslide events occur sporadically, and can be associated with heavy rainfall events, but not always. Some of these failures travel down the entire length of the steep drainage channel to the valley floor. Upon reaching the valley floor, the debris is deposited, accumulates, and contributes to the development of alluvial fans at the base of the slopes.

4.5. GROUNDWATER

Evidence for groundwater at both sites was not abundant. This may, in part, be due to the time of the year of our reconnaissance. It may also be due to the locally thin soils and locally relatively impermeable bedrock at some of the PIs. Locally groundwater seeps on the sides of several drainages were observed here and there during our reconnaissance. Even though it was relatively late in the year at the time of our reconnaissance, many of the drainages still had running water, regardless of whether bedrock or soil was exposed in the bottom of the channel. However, running water was more common in bedrock channels.

5.0. HISTORICAL SETTING

The historical setting of the sites is briefly summarized below. This includes the past landslide history and past forest practices and adjacent land-use history. Interpretation of stereoscopic aerial photography was relied upon for preparation of this section. For a complete list of aerial photography reviewed please see **AERIAL PHOTOGRAPHS REVIEWED** in the back of this report.

5.1. LANDSLIDE HISTORY

Review of 12 sets of aerial photographs dating from 1947 to 2001 (1970 to 2001 for the NFR Site) revealed only a few debris slides originating during that time period on slopes above the properties that are the subject of this reconnaissance report, at either the NR Site and NFR Site. The 1947 aerial photographs show a relatively large debris slide occurred on the large north-facing slope in the southern portion of the NR Site. During the following years the aerial photography records several debris slides originating near, if not at the top, of the drainages that characterize the west-facing slopes of the NR Site; three showing on the 1983 aerial photography; and one each showing on the 1955 and 1987 coverage. In addition, Landslide Hazard Zonation mapping prepared by Cashman and Brunengo (2006) shows three debris slides originating on slopes above the NR Site. The 2001 coverage did not show any evidence of recent (to the time of the photographs) debris slide activity at the NR Site, but at the NFR Site the three debris slides of Cashman and Brunengo (2006) were observed at or just to the north of that Site. It should be noted that evidence for movement of large, deep-seated landslides was not observed on the photographs reviewed. This should not be construed to suggest that movement has or has not occurred; only that such movement may have been too small to be detectable on 1:12,000 (or smaller) scale aerial photographs.

5.2. FOREST PRACTICES AND LAND-USE HISTORY

The following discussions are based on review of vertical, stereographic aerial photographs dating back to 1947, review of relevant forest practices applications, and discussions with home owners of the affected properties.

5.2.1. Forest Practices – The 1947 aerial photographs show that by that time large areas on the top of the Dike had been clear cut. Based on the appearance of the regeneration, the clear cut may date to 20 years earlier. On the 1947 aerial photographs the slopes in question above the NR Sites are in very dark shadows and it is very difficult to see any details and only vague suggestions of any activity in the area in question. However, the 1955 aerial photographs suggest no harvest activity on the slopes in question for quite some time. From the 1955 photographs to the 2001 coverage no harvest activity is observed on the DNR slopes above the NR Sites. During our reconnaissance we did not observe any post-2001 harvest activity on DNR property on the slopes in question. At the NFR Site no harvest activity in the immediate areas of the PIs was observed during the time period recorded by the aerial photography (1970 to 2001), and up to the date of our reconnaissance; September 8, 2009. However, the nature of the canopy observed on the 1970 aerial photographs suggest harvest activities on the slopes above the NFR site; likely several decades earlier.

5.2.2. Land-Use History – Nelson Road is present on the 1947 aerial photographs. Its configuration is essentially the same as today with the 90° turn that directs the road west to its intersection with Washington State Route 9, about 1¼ miles south of Van Zandt (Figure 1). North of the 90° turn, Nelson Road is characterized by three relatively gentle bends. After the northernmost of these bends the road continues straight northward to a "T"-intersection with Potter Road, which extends eastward from Van Zandt in the same configuration as today. Linnel Road can be seen going east from the intersection of Nelson and Potter Roads.

Review of the 1947 photography shows no residential structures, save for the LR residence, east of Nelson Road from the 90° turn northward. In 1947, land use was solely agricultural, and arguably some timber production along the lower slopes of the Dike. With respect to the properties and associated structures that are the subject of this reconnaissance no new construction east of Nelson Road was observed until the 1976 aerial photography when the structure at the 3810 NR site is first observed. The structures 3830 NR site are not present on the 2001 aerial photographs, however the workshop at the same address is present on the DNR database 2003 to 2005 orthophotographs. Likewise, neither is the residence at the 3608 NR site. These sites were developed between 2003/2005 and January 2009. The 1947 aerial photography shows a presumed residence and associated out-buildings on the Fox Property. By 1970 additional out-buildings are present.

At the NFR Site the North Fork Road is present on the 1970 aerial photographs; however no structures are present at the NFR Site. The 1970 aerial photographs show quarry operation on the Bell and Severson properties. The 1976 photography shows a structure where the current Kirkwood garage/shop is and a presumed residential structure, but not where the current Kirkwood residential structure is now located. By the time of the 1983 aerial photography the current Kirkwood residence is present, and by 1995 the current addition to that same residence is visible. The residence at the Severson property is not present on the 2001 aerial photographs, nor is that same residence present on the DNR database 2003/2005 orthophotographs. This site was apparently developed between 2003/2005 and January 2009. It appears quarry operations and residential occupation continued at the Bell property until about sometime between 1983 and 1995 aerial photography. By the time of the 2001 aerial photography it is clear that quarry operations had ceased; however, residential use continued.

6.0. RECONNAISSANCE OBSERVATIONS

The debris slides and debris flood that affected the several properties that are the subject of this reconnaissance report occurred during the January 2009 storm. As noted earlier, four of the sites are located in the Nelson Road area; the other site is located on North Fork Road. The Nelson Road sites are herein referred to, from south to north, as: the

3608 NR Site, the 3810 NR Site, the 3830 NR Site, and the Linnel Road (LR) Site; the North Fork Road Site as, simply, the North Fork Road (NFR) Site. The locations of these sites are shown on Figure 1. The following discussion presents salient field observations regarding the debris slides and associated debris floods that impacted the several sites. The discussion proceeds from the PI downslope to the areas of deposition. Resulting damage to private property is summarized in the discussion. The debris slides and debris floods discussed in this report are classified using criteria advanced by Cruden and Varnes (1996) and Hungr and others (2001).

As noted in section 1.0. of this reconnaissance report, during field reconnaissance it was observed that the debris floods that affected the 3608 NR Site were part of the debris floods that originated from debris slides that were discussed in our earlier report addressing the 3506, 3600, 3618, 3633, and 3652 Nelson Road properties, issued May 6, 2009 (see references, Hanell and Coyle, 2009). For additional information please see that report and the discussion regarding Knutzen Drainage. The general course of the debris flood at the 3608 NR Site is shown on Figure 2 of this report. Essentially, damage at the 3608 NR Site was confined to debris floods that spread across lawn and driveway areas (Hooks, 2009a). No further discussion of this site will be presented in this section.

3810 NR Site – This slide is reported to have occurred at an undetermined time on January 7th (Hooks, 2009b). The debris slide originated in colluvium (Figure 4) at an elevation of about 1,330 feet in an area of convergent topography characterized by 85% to 90% slopes (Figure 2). Field reconnaissance suggests that possibly two spatially close PIs could have been involved in the development of this event; however, this could not be confirmed. A mature stand of trees populate the area of the PI. The debris slide scoured the channel from the PI down slope (Figure 5) to the residence on 3810 Nelson Road (Fitch). The course of the debris slide near the bottom was in part influenced by an old logging road that helped to direct the flow toward the Fitch residence. Upon reaching the gentler slopes at the bottom of the hillside, the flow became a debris flood as it spread out over the yard area of the Fitch property. Some debris piled up around the Fitch residence (Figures 6 & 7) and did some damage to the backyard gazebo-like structure. The debris flowed northwestward (Figure 8) across Nelson Road and well into the Fox property (Figure 9).

3830 NR Site – This event occurred at an undetermined time on January 7th (Hooks, 2009c). The PI of this debris slide occurred in colluvium at an elevation of about 1,100 feet in subdued bedrock hollow-type topography characterized by 80% to 85% slopes (Figure 10). Loose blocks of colluvium were observed on the south side of the PI scar. The PI is in an area populated by a mature stand of trees. The debris slide scoured the channel from the PI down slope (Figure 11, 12, & 13) on to the 3830 NR Site (Malec). As the debris flowed down slope in the drainage channel it crossed the northeast corner of the 3810 NR Site (Figure 2). At the bottom of the slope the debris slide became a debris flood. Debris impacted the southeast and northeast side of the workshop at the 3830 NR Site and the area in front (Figure 14). Debris coursed down the driveway to

Nelson Road and eroded portions of the driveway. The Malec residence was apparently unaffected (Figure 15). Debris also flowed on to the adjacent property to the north (Moceri & Porter, see Figure 16). Some debris crossed Nelson Road and on to the Fox property just west of Nelson Road.

Linnel Road (LR) Site – This event occurred at an undetermined time on January 7th (Hooks, 2009d). The PI of this debris slide occurred in a wedge of colluvium at an elevation of about 1,310 feet at the base of an approximately 80-foot-high bedrock cliff (Figure 17) in inner-gorge like topography. The PI is high on the scarp of the very large Devils Slide landslide (Figure 2) and is in an area populated by a mature stand of trees. The channel above the PI does not show evidence of scour. The debris slide scoured the channel from the PI down slope (Figure 18) and into the landslide debris at the base of the Devils Slide scarp. In the lower reaches of the debris-flow track subsequent erosion by running water carved a channel up to an estimated 60-feet deep and 40-feet wide (Figure 19 & 20). Where the debris exited the channel, large organic debris was caught in trees (Figure 21). The debris slide became a debris flood. As shown on Figure 2, the debris flood split (Figure 22) and flowed over the field to the south of the Digby/Hildt residence. It appears water may have continued to flow westward on to the Harkness Property (Figure 2 & 23). Some water may have also flowed on to the Meeker & Tefft Property, but this is uncertain (Figure 2).

North Fork Road (NFR) Site – The NFR Site slides occurred on January 7th. Two events were observed; one about 5:30 AM and the other during the late morning hours (Penny, 2009; and pers. comm. Ms. Kirkwood, 2009). There are three PIs at this Site: two associated with steep bedrock slopes and cliffs (the Middle and South PIs, Figures 24 & 25) and the other (the North PI) in an area of essentially planar slopes characterized by inclinations of about 70% (Figure 26). The Middle and South PI slide scars expose bedrock and soil overlying soils. These slide scars vary from 30- to 40-feet wide and from about ½-foot to 3-feet deep (measured perpendicular to the ground surface). Debris from the Middle and South debris slides moved down the drainages to the valley floor in the channels that had developed on the slopes below the areas of the PIs (Figures 27, 28, 29, 30, & 31). These drainages cross the eastern, or hillside, portions of the Kirkwood and Bell properties (Figure 3). Generally the drainages were scoured down to bedrock. The debris from the North PI moved down slope and into the debris-flow track of the Middle PI, and then on to the valley floor.

It is our opinion that the Middle and South debris slides were initiated by concentrated runoff (overland flow) that, at the PIs, saturated the thin veneer of soil that on the bedrock slopes and saturated the colluvial deposits at the base of the slopes at the PIs. At the North PI concentrated overland flow was not readily apparent.

Evidence (lack of leaf litter, twigs and small rocks piled up behind vegetation, freshly-eroded channels, etc.) for concentrated overland flow could be observed leading up slope to the east, away from the Middle and South PIs. The evidence could be followed for a distance of about 300 feet before being lost in freshly fallen trees of a current (being undertaken at the time of our reconnaissance) timber sale (the Mapleyard Timber Sale).

Damage to the NFR Site consisted of debris being deposited in the wooded areas (Figure 32 & 33) on the valley floor between the hillside and the residential structures. Sediment spread out across the valley floor, flooding areas of the Kirkwood Property (Figures 34, 35, & 36) and on to the Severson Property (Figure 3), locally accumulating in a vineyard to thicknesses of a couple of feet (Figure 37). Finally, water partially filled the old abandoned quarry to the west of the Severson residence.

It is likely that water from a slide (herein referred to as the Cliff Slide) that originated above the CL-1000 Mainline Road on DNR-managed lands (Figure 3) provided a large source of the water that was a factor in the initiation of the slides at the Middle and South PIs. The Cliff Slide originated in an unmanaged area (Figure 38), about 1,100 feet east of the PIs (Figure 3). Other water sources were likely the rain and melting snow from the slopes above the PIs and redirected runoff from the CL-1000 Mainline Road inboard ditch. This ditchwater was delivered to the slopes between the road and the PIs. A small cut slope failure (Figure 39) about 300 feet up the road from the debris of the Cliff Slide limited the length of inboard ditch, and thus the "collection" area of the ditch.

It must be noted that the debris from the Cliff Slide did not travel much farther than the CL-1000 Mainline Road (Figure 40). We did not observe evidence that would suggest that debris from the Cliff Slide reached the PIs of the slides that impacted the properties at the NFR Site. The slide debris blocked the inboard ditch (Figure 41) and diverted water (Figures 42 & 43). The cut slope slide diverted water on to slopes that are not above the area of the PIs. The water from the 300-foot stretch of inboard ditch between the cut slope slide deposit and the Cliff Slide deposit would likely have been added to the water from the Cliff Slide. The length of the inboard ditch, road surface, and the immediate contributing area up slope of the 300-foot segment of the ditch is relatively small and likely would have contributed comparatively small volumes of water as compared to the volumes of water that apparently issued from the Cliff Slide PI.

Observation of the Cliff Slide site and the road made within a few days after the slides occurred (D. Robson, pres. comm., 2009) suggested that the volume of water that flowed over the road from the inboard ditch was not large. In addition, the narrow, shallow channel eroded through slide debris along the margin of the slide deposit (Figure 42 & 43) also suggests that the amount of water from the inboard ditch was not great. It is our opinion that compared to the amount of water likely delivered by the Cliff Slide, the total contribution of water diverted from the inboard ditch due to blockage by the Cliff Slide deposit was likely relatively modest, at best.

During our preparation of Figure 3 of this report, it came to our attention that the property lines between DNR-managed lands and private lands, as stored in the Whatcom County database, do not coincide with the property lines in the DNR-Managed (surface) Lands

Layer in the DNR GIS database. After careful review of the discrepancies we chose to rely on the DNR property lines as depicted in the DNR database. The discrepancy appears to be due to a location problem with respect to the SW corner of Section 15 in the Whatcom County database.

7.0. SUMMARY

The purpose of this reconnaissance was to develop a preliminary opinion with respect to the following questions for each site at the Nelson Road area and the North Fork Road area:

1) Were the PIs of the debris slides on DNR-managed lands?
2) Were the PIs in an area of recent management activity?
3) Did the management activity contribute to debris slide initiation and subsequent debris flood?
4) How much did management activity contribute to debris slide initiation?

The debris slides and resulting debris floods that affected the 3608 NR Site, the 3810 NR Site, the 3830 NR Site; the LR Site, and, apparently, the NFR Site originated on DNR-managed lands.

Save for the PIs that affected the 3608 NR Site (Syre), none of the PIs developed in an area of recent land-management activity. In fact, the historic aerial photography suggests that it has been decades to almost a lifetime, if ever, since the areas of the PIs had been subjected to timber harvest activities. With respect to the 3608 NR Site, please see the May 6, 2009 report (Hanell and Coyle, 2009) for 3506, 3600, 3618, 3633, and 3652 Nelson Road properties for a full discussion of the debris slide and debris flood that affected the 3608 NR Site.

Except for the 3608 NR Site, there has been no management of the areas of the PIs in recent history. Thus, management activities were not a factor influencing the development of the PIs of the debris slides that affected the 3810 NR site, the 3830 NR site, or the LR site. The PIs of the NFR Site also developed in an unmanaged area, however, the NFR PIs apparently developed, in part, in response to overland flow from water sources up slope. Specifically, this source was the overland flow from the water flowing from the Cliff Slide (that also developed in an unmanaged area). This flow was likely added to by water from the blocked inboard ditch of the CL-1000 Mainline Road. Though diverted water from the CL-1000 Mainline Road was likely part of this overland flow, in our opinion it did not likely make a significant contribution to the total volume of overland flow that was a factor in the development of the PIs at the NFR Site, because the road segment that delivered water to the slope above the PIs was relatively short, and the flow channel eroded in the slide debris across the road was relatively shallow, suggesting a lack of significant flowing water.

In our opinion, the debris slides occurred in response to very local conditions, save for the 3608 NR Site. The weak colluvial soils on steep slopes were likely already close to failure. Review of the climate history suggests the early January storm was a comparatively extreme event. The water introduced by the rainfall, accompanying melting snow, and overland flow on a likely already weak slope provided the proverbial "straw that broke the camels' back" and triggered the slope failures and subsequent debris floods. As noted above, please see our the May 6, 2009 report for 3506, 3600, 3618, 3633, and 3652 Nelson Road properties for a full discussion of the Knutzen Drainage debris slides and debris floods that affected the 3608 NR Site.

8.0. RECONNAISSANCE LIMITATIONS

This reconnaissance report presents a qualitative assessment of the debris slides and associated debris floods that impacted the properties located at the 3608 NR site, the 3810 NR site, the 3830 NR site, the LR site, and the NFR Site in Whatcom County as a result of the early January 2009 storm. The charge of this reconnaissance was to develop an opinion with respect to the following questions:

1) Were the PIs of the debris slides on DNR-managed lands?
2) Were the PIs in an area of recent management activity?
3) Did the management activity contribute to debris slide initiation?
4) How much did the management activities contribute to the initiation of the debris slides?

This reconnaissance report provides observations and opinions, with respect to these questions, based on field reconnaissance and review of office derived data. Should new information become available, our geologic interpretations, and thus, the discussion presented in this report could require modification.

The signature and stamp for this engineering geologic field reconnaissance report is on the cover letter that accompanies this report; just behind the title page. This report, or any copy, shall not be considered complete without the cover letter signed with original signatures and stamps, or authorized facsimiles of the same.

END

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AERIAL PHOTOGRAPHY REVIEWED

Nelson Road Sites

Date	Flight Line/Frames	Approx. Scale	Medium
8/24/47	BBK – 5B – 101 to 103	1:24,000	B/W
8/6/55	BBK – 2P – 167, 168	1:24,000	B/W
7/8/61	F.35 – 19 to 21, 23, 24	1:12,000	B/W
6/5/70	NW-69 228 49C-27 to -29	1:12,000	B/W
6/5/70	NW-69 228 50B-30 to -32	1:12,000	B/W
6/5/70	NW-69 228 51B-52 to -54	1:12,000	B/W
7/14/71	NW-H-71 351 – 11B – 13, 14	1:80,000 (?)	B/W
7/15/76	NW-C 76-25-129 to -132	1:24,000	Color
6-3-78	NW-78 62A-229 to -233	1:12,000	B/W
6-3-78	NW-78 63C-46 to -50	1:12,000	B/W
5/23/83	NW-C-83 13-49 379 to 384	1:12,000	Color
5/23/83	NW-C-83 13-50 418 to 422	1:12,000	Color
6/26/87	NW87 11-50-69 to -72	1:13,400	B/W
7/8/91	NW91 14-49-25 to -28	1:13,000	B/W
7/8/91	NW91 14-50-179, -181 to -183	1:13,000	B/W
5/27/95	NW-95 30-50-38 to -41	1:12,000	B/W
7/9/01	NW-C-01 13-49-147 to -148	1:12,000	Color
8/26/01	NW-C-01 58-50-39 to -41 & -50-43 to -45	1:12,000	Color

North Fork Road Site

Date	Flight Line/Frames	Approx. Scale	Medium
6/5/70	NW-69 228 51B-61 to -63	1:12,000	B/W

7/15/76	NW-C 76-25-135 to -136	1:24,000	Color
6-3-78	NW-78 64D-39 to -40	1:12,000	B/W
7/18/83	NW-C-83 19-51 190 to 191	1:12,000	Color
5/27/95	NW-95 30-51-90 to -92	1:12,000	B/W
8/26/01	NW-C-01 58-51-161 to 162	1:12,000	Color

OTHER NELSON ROAD RECONNAISSANCE REPORTS

(Prepared by Hanell and Coyle in 2009)

On file at Northwest Region Office, Washington Department of Natural Resources, Land Management Division.

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE; DEBRIS SLIDES, DEBRIS FLOWS, AND AFFECTED PROPERTIES; 3506, 3600, 3618, 3633, and 3652 Nelson Road; Whatcom County, Washington; dated May 6, 2009.

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE; DEBRIS SLIDE AND DEBRIS AVALANCHE; VAN DEN HEUVEL PROPERTY; 3800 Nelson Road, Whatcom County, Washington; dated May 29, 2009.

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE; DEBRIS SLIDES, DEBRIS FLOODS, AND AFFECTED PROPERTIES; 3858, 3913 & 3912, and the Fox Property, Nelson Road; Whatcom County, Washington; dated October 2, 2009.

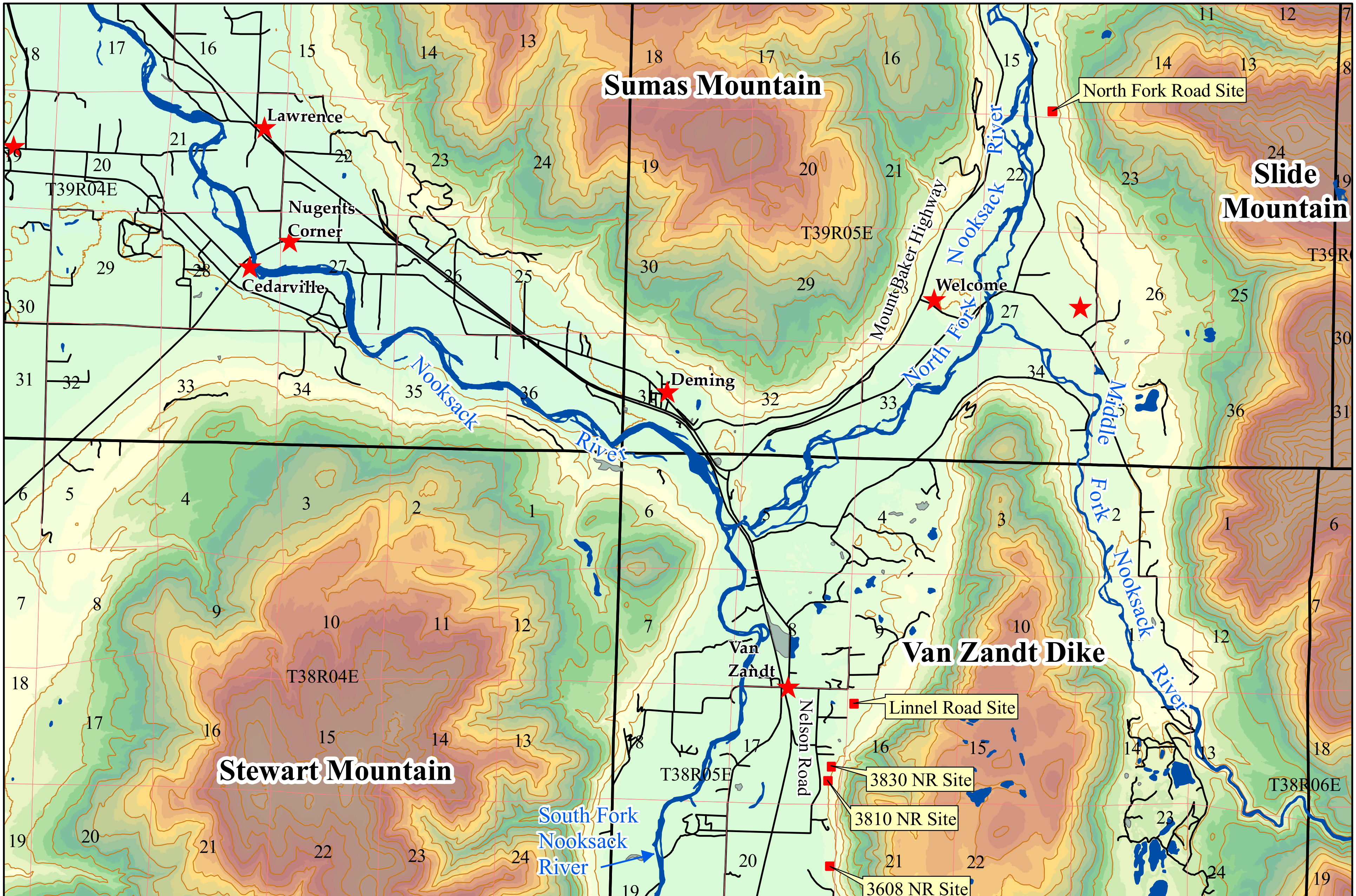


Figure 1. Location Map

Engineering Geologic Field Reconnaissance
Debris Slides, Debris Floods, and Affected Properties
Nelson Road and North Fork Road
Whatcom County, Washington

Miles
0 0.5 1 2

Contour interval = 200 feet

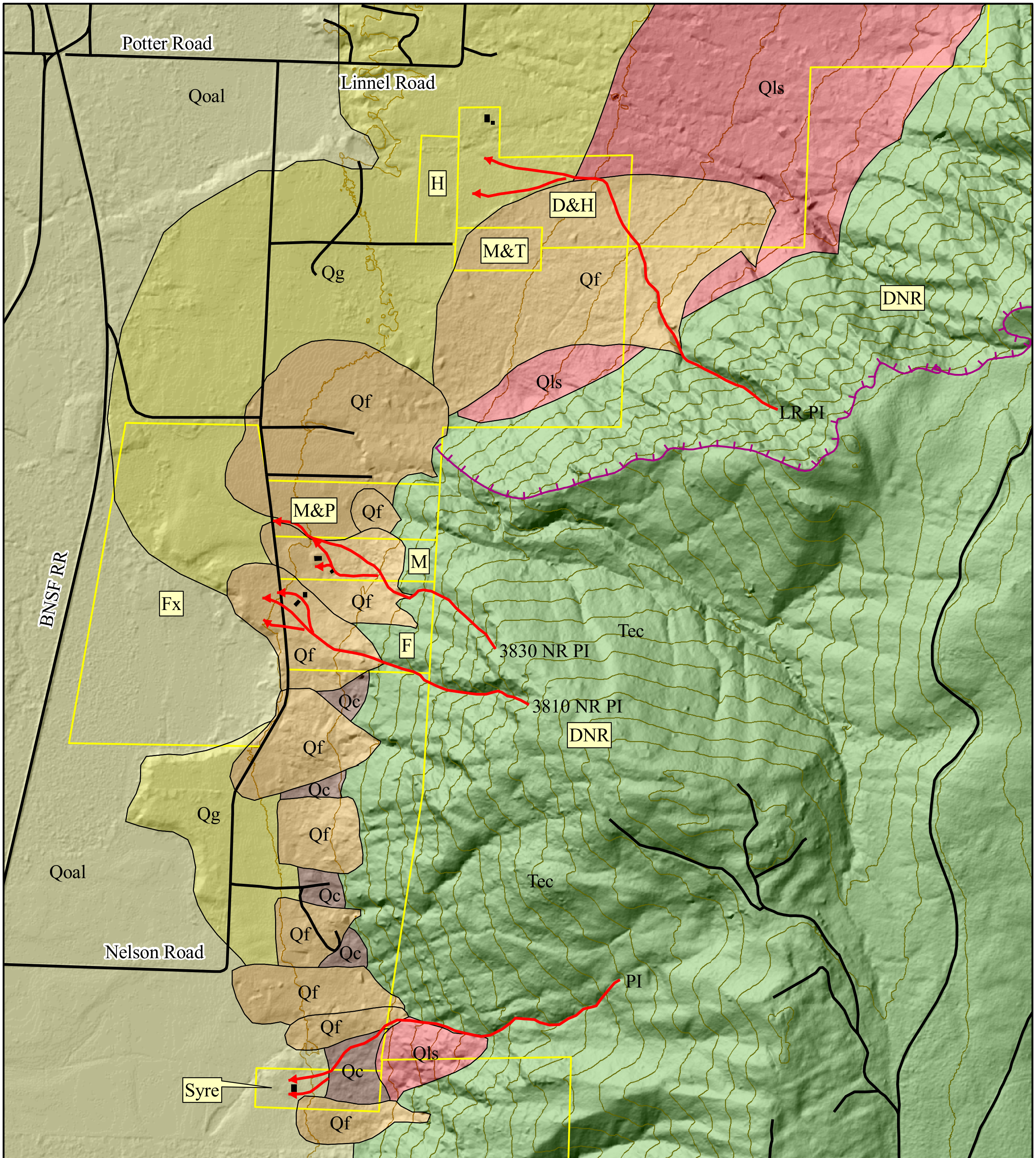


Figure 2. Simplfied Site Geology Map Showing Affected Property Owners, PIs, and Debris Flow/Debris Flood Tracks.

Debris Slides, Debris Floods, and Affected Properties
Nelson Road and North Fork Road
See Figure 3A for explanation.

Property lines approximated from DNR GIS database. Ownership verified on Whatcom County Assessor's website, September 2009. Site scale geology mapped from field observations, DNR GIS digital geology database, and interpretation of DNR LiDAR database.

Feet
0 500 1,000

Contour Interval = 100 ft.

N
W E
S

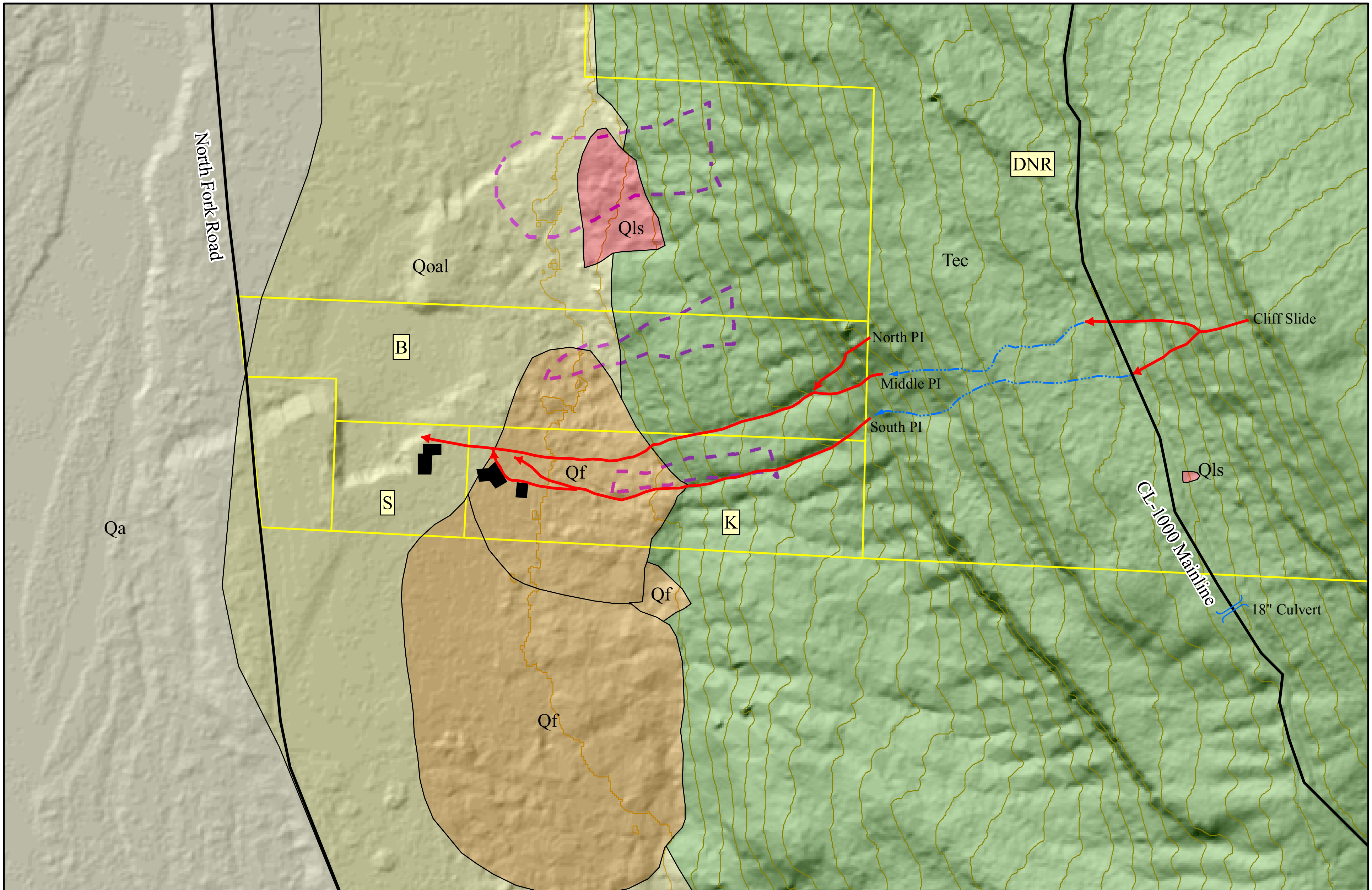


Figure 3. Simplfied Site Geology Map Showing Affected Property Owners, PIs, and Debris Flow/Debris Flood Tracks.

Feet
0 200 400
Contour Interval = 40 ft.

Debris Slides, Debris Floods, and Affected Properties Nelson Road and North Fork Road
See Figure 3A for explanation.
Property lines approximated from DNR GIS database. Ownership verified on Whatcom County Assessor's website, September 2009.
Site scale geology mapped from field observations, DNR GIS digital geology database, and interpretation of DNR LiDAR database.

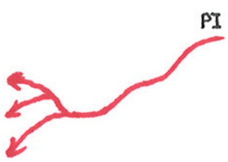
N W E S

EARTH MATERIALS

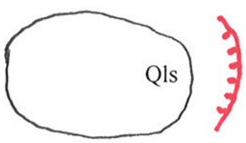
Qa	Alluvium
Qoal	Old alluvium-
Qf	Alluvial fan deposits
Qls	Landslide debris
Qc	Colluvium
Qg	Glacial deposit
Tec	Chuckanut Formation

MAP SYMBOLS

Geologic contact, locally approximate



Debris slide IP (Point-of-Initiation) and flow track. At bottom of slope arrows show general path of debris-flood as it spread out across alluvial fan and valley floor.



Landslide (Devils Slide), hauchers show crown of scarp of Devils Slide

Landslide from Racehorse Creek LHZ (Cashman and Brunengo, 2006)

Presumed path of concentrated overland flow

Property line

Residential structures and selected outbuildings (locations approximate)

B

Initial of affected property owner: B=Bell, D&H=Digby & Hildt, F=Fitch, Fx=Fox, H=Harkness, K=Kirkwood, M=Malec, M&P=Moceri & Porter; M&T=Meeker & Tefft, S=Severson; DNR=Department of Natural Resources

FIGURE 3A. Explanation for Figures 2 and 3

Engineering Geologic Field Reconnaissance
Nelson Road and North Fork Road
Whatcom County, Washington

Figure 4 PI of 3810 NR site debris slide (Fitch). Photograph taken in Spring 2009. View looking northeast. (Photo by C. Hanell)

Figure 5 Scour of lower reaches of debris flow track at 3810 NR site. Photograph taken in Spring 2009. View looking northwest. (Photo by C. Hanell)

Figure 6 Debris flood across back of 3810 NR site. View looking northwest toward back of Fitch house. Photograph taken early January 2009. (Photo by D. Hooks)

Figure 7 Debris at back of Fitch house. Photograph taken early January 2009. (Photo by D. Hooks)

Figure 8 Debris on south side of Fitch residence. Debris went westward across Nelson Road and on to Fox property in background. Photograph taken early January 2009. View looking northwest. (Photo by D. Hooks)

Figure 9 Sediment on Fox property. Photograph taken early January 2009. View looking westerly. (Photo by D. Hooks)

Figure 10 PI of the 3830 NR site (Malec). Photograph taken in Fall 2009. View looking east. (Photo by J. Coyle)

Figure 11 Scoured channel of 3830 NR site debris-flow track. Photograph taken in Fall 2009. View looking east. (Photo by J. Coyle)

Figure 12 Scour along mid-reach of debris-flow track of 3830 NR site debris slide. Photograph take fall of 2009. View looking northwest. (Photo by J. Coyle)

Figure 13 Debris on slope above garage/workshop at 3830 NR site. East corner of building can be seen in distance, with debris pointed toward corner. Photograph taken in early January 2009. View looking northwest. (Photo by D. Hooks)

Figure 14 Garage/workshop at 3830 NR site. Debris hit far corner and then came toward viewer, some also came over slope in left of photograph. Photograph taken early January 2009. View looking south. (Photo by D. Hooks)

Figure 15 View of debris paths around house at 3830 NR site. Some debris reported to have gone down driveway and other debris into to field of to right of photograph. Photograph taken early January 2009. View looking west. (Photo by D. Hooks)

Figure 16 Aerial view of 3830 NR site. North to right, view looking west. Grayish area in field to north of Malec house is debris-flood sediment. White roof in center of photograph is garage/workshop. Photograph taken January 2009. (Photo by D. Hooks)

Figure 17 PI of debris slide of LR site (Digby & Hildt). Bedrock cliff begins at top of slide scarp. Photograph taken Fall 2009. View looking northeast. (Photo by J. Coyle)

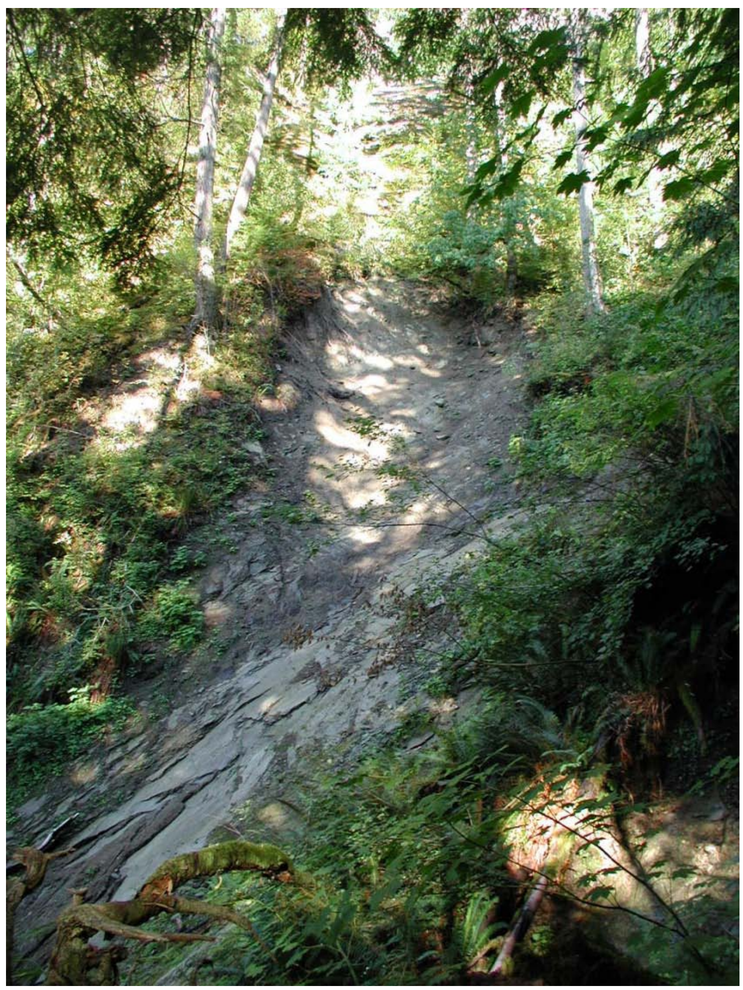


Figure 18 Scoured channel of debris-flow track of debris slide at LR site (Digby & Hildt). Photograph taken in Fall 2009. View looking southeast. (Photo by J. Coyle)

Figure 19 Scoured channel of debris-flow track of debris slide at LR site (Digby & Hildt). Earth slope in background is bank of deeply eroded channel. Photograph taken in Fall 2009. View looking northwest. (Photo by J. Coyle)

Figure 20 Scoured and eroded channel of debris-flow track in colluvium and landslide debris at LR site. Photograph taken in Fall 2009. View looking southeast. (Photo by J. Coyle)

Figure 21 Organic debris deposited in area of trees on upper reaches of alluvial fan. Photograph taken early January 2009. View looking southeast. (Photo by J. May)

Figure 22 Mud and debris spread out over field to south of Digby & Hildt residence. Photograph taken early January 2009. View looking west. (Photo by J. May)

Figure 23 Water flowing across Digby & Hildt field from area of Figure 22. Photograph taken in early January 2009. View looking south. (Photo by J. May)

Figure 24 South PI of debris slides at NFR site (Kirkwood). Photograph taken Fall 2009. View looking northeast. (Photo by C. Hanell)

Figure 25 Middle PI of debris slides at NFR site (Kirkwood). Photograph taken Fall 2009. View looking southeast. (Photo by C. Hanell)

Figure 26 North PI of debris slides at NFR site (Kirkwood). Photograph taken Fall 2009. View looking east. (Photo by J. Coyle)

Figure 27 Scoured channel below South PI at the NFR Site. Photograph taken Fall 2009. View looking westerly. (Photo by J. Coyle)

Figure 28 Scoured slopes and channel below north PI At the NFR Site. Photograph taken Fall 2009. View looking westerly. (Photo by J. Coyle)

Figure 29 Scoured slopes and channel below Middle PI. Photograph taken Fall 2009. View looking easterly. (Photo by J. Coyle)

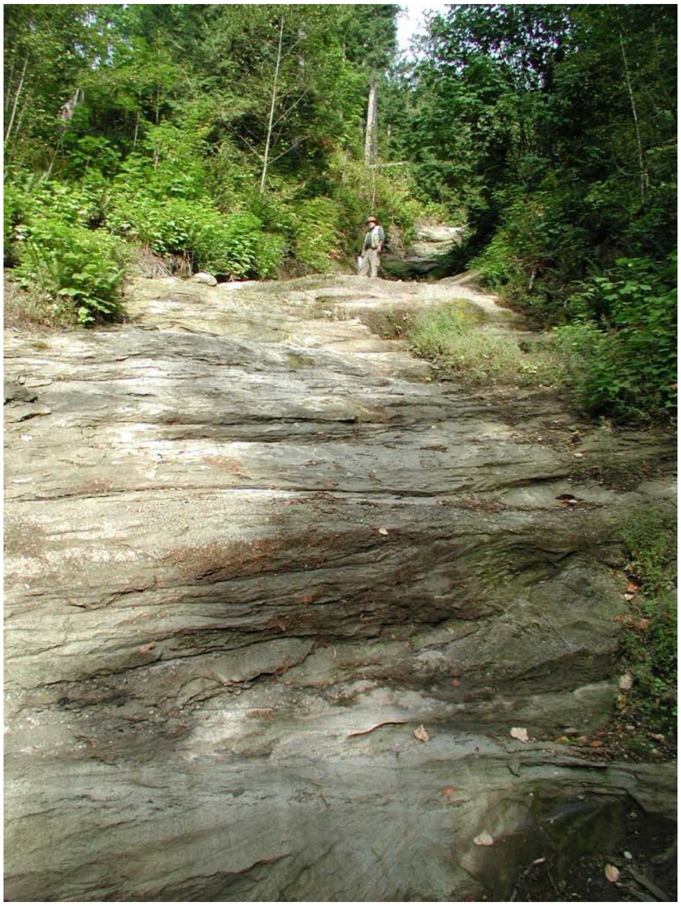


Figure 30 Channel cascade on bedrock on south debris-flow track This is at bottom of track. Photograph taken Fall 2009. View looking east. (Photo by C. Hanell)

Figure 31 Channel cascade on bedrock on the combined middle/north debris-flow track. This is at the bottom of track. Photograph taken Fall 2009. View looking east. (Photo by C. Hanell)

Figure 32 Debris deposited in trees at upper area of the alluvial fan. Kirkwood home in background through trees. Photograph taken in January 2009. View looking west. (Photo by M. Penney)

Figure 33 Downed trees deposited in standing trees. Kirkwood home in background on left. Photograph taken in January 2009. View looking west. (Photo by M. Penney)

Figure 34 View of backyard of NFR site (Kirkwood). Debris and sediment spread outward over backyard. Photograph taken January 2009. View looking west. (Photo by M. Penney)

Figure 35 Sediment at back of Kirkwood home. Photograph taken January 2009. View looking southeast. (Photo taken by M. Penney)

Figure 36 Path of debris flood around north end of Kirkwood home. Severson home in back ground. Photograph taken January 2009. View looking northwest. (Photo by M. Penney)

Figure 37 Inundated vineyard at Severson. Severson house in left margin of photograph. Photograph taken in January 2009. View looking to the northwest. (Photo by M. Penney)

Figure 38 Cliff Slide site. Slide began at base of bedrock cliff about 400-feet up slope. Photograph looking east and upslope from CL-1000 Mainline Road. Photograph taken January 2009. (Photo by M. Penney)

Figure 39 Cut slope slide. Photograph taken standing on CL-1000 Mainline Road. Photograph taken in January 2009. View looking east. (Photo by M. Penney)

Figure 40
Debris from the Cliff Slide deposited on the CL-1000 Mainline Road. Photograph taken January 2009. View looking northwesterly. (Photo by M. Penney)

Figure 41
Slide debris from the cut slope slide deposited on the CL-1000 Mainline Road. Debris from Cliff Slide can be seen on road in background. Photograph taken January 2009. View looking north. (Photo by M. Penney)

Figure 42 Diversion channel at Cliff Slide deposit. Water collected by slide debris diverted through the channel eroded along edge of slide debris and directed over outboard edge of road fill. Photograph taken in January 2009. View looking northwest. (Photo by M. Penney)

Figure 43 Channel eroded when water from inboard ditch was diverted by deposit from cut slope slide. Water was directed over outboard edge of road fill. Photograph taken in January 2009. View looking northwest. (Photo by M. Penney)