Appendix D

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE

DEBRIS SLIDES, DEBRIS FLOODS, AND AFFECTED PROPERTIES

6459, 6488, 6489, and 6500 Goodwin Road, and 6474 Siper Road Whatcom County, Washington

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July 2, 2009

TO: Jeff May
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SUBJECT: **ENGINEERING GEOLOGIC FIELD RECONNAISSANCE**
Debris Slides, Debris Floods, and Affected Properties
6459, 6488, 6489, and 6500 Goodwin Road, and 6474 Siper Road
Whatcom County, Washington

DATE: July 2, 2009

The following Engineering Geologic Field Reconnaissance report presents our findings, a discussion regarding the debris slides and debris floods that affected the residential properties at 6459, 6488, 6489, and 6500 Goodwin Road, and 6474 Siper Road in Whatcom County, Washington. The debris slides and debris floods occurred during the January 2009 storm. 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 and debris flood initiation, and 4) how much did management activities contribute to debris slide and debris flood initiation.

If you have any questions, please call.

Respectfully submitted,

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1.0. INTRODUCTION

We have completed an engineering geologic field reconnaissance of the debris slides and debris floods that affected the above referenced residential properties in northwest 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 area of our geologic field reconnaissance and the affected properties is shown on Figures 1 and 2, an area located about 2⅓ miles north of Nugents Corner. The affected properties (Owners) are located at 6459 (Kitchen), 6488 (Gassman), 6489 (Benson), and 6500 (Franks) Goodwin Road, and 6474 (Soares) Siper Road. The debris slides initiated in the NW¼ of Section 15 and the affected residences are located in the SW¼ Section 10, the NE¼ of Section 16, the NW¼ Section 15, T39N, R4E, (Willamette Base Line &Meridian) in the US Geological Survey 7½-minute Lawrence and Sumas Quadrangles. It should be noted that on the 1952 (revised 1994) edition of the Sumas Quadrangle, Goodwin Road is labeled Stevens Road.

In the DNR 2009 storm tracking database the slides and affected properties that are the subject of this reconnaissance report are referred to as Goodwin Road #1. For purposes of clarity we have chosen to title this report with respect to the addresses of the affected properties.

As shown on Figure 1, the affected properties are located at or near the base of the southwest side of Sumas Mountain. The properties are situated in the Sumas Watershed Administrative Unit (WAU). To date neither watershed analysis nor Landslide Hazard Zonation mapping has been undertaken for this WAU. None of the affected properties are 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. All of the affected properties, save for

Soares, are located on the very lowest slopes of Sumas Mountain; Soares is situated on the adjacent topographic bench that borders portions of the eastern margin of the old Nooksack River flood plain. This bench is mapped by Lapen (2000) to be underlain by glacial-deposits.

The purpose of our geologic field reconnaissance was to locate the point-of-initiation (PI) of the debris slides, observe the site conditions at the PIs, observe the conditions along the flood 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 observed, as to the natural and, if applicable, the anthropomorphic factors that influenced landslide initiation, as well as the triggering event that caused the debris slides and floods.

2.0. SCOPE OF WORK

Our scope of work included the following tasks:

- Review of pertinent published geologic reports and maps in our files
- Review of Whatcom County hazards maps
- 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
- Reconnaissance of the debris-slide PIs and flow tracks
- Reconnaissance of the depositional area of the debris flood
- Review of an Initial Incident Report (IIR) for the area in question on file at the Northwest Region office
- Review of photographs of the event taken by others
- Review of pertinent historical rainfall and snowfall data
- Review of available precipitation data related to the January 4 to 8, 2009 storm
- 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 area is dominated by Sumas Mountain and the old Nooksack River flood plain. The physical setting of the PIs of the debris slides, flow tracks, and the areas of deposition (all collectively referred to as the “Site”) 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 Site is represented by two distinctly different types of terrain (Figures 1 and 2). The PIs (Herein referred to as North PI and South PI) are in an area of steep westerly-facing hillside topography. The affected residences are located on relatively gentle hillside topography or on a slightly elevated topographic bench underlain by glacial deposits that border the east side of the relatively flat plain of the Nooksack River. In the area of the Site the west-facing slopes of Sumas Mountain exhibit an average inclination of about 27%. However, locally bedrock cliffs characterized by essentially vertical inclinations of several tens of feet are present. Overall, on the east side of Goodwin Road the hillside in question exhibits slopes of 60 to 65% in the steep upper portion of the Site and hillsides with inclinations of 25% or less characterize the moderately-steep lower areas of the Site (Figure 2). Goodwin Road and areas to the west of the road are located on a relatively narrow topographic bench that gives way to the west to a steep west-facing slope about 50-feet high and then the generally flat, raised Holocene age surface of the glacial deposits that border the old Nooksack River flood plain. The PIs are situated at elevations of about 1,000 feet. The depositional areas and affected residences are situated on relatively gentle topography, at elevations of approximately 150 (Soares) to about 200 to 235 feet (the other residences). The local relief between the residences on the hillside and the area of the PIs is moderate, up to approximately 800-feet vertical over a horizontal distance of about 2,700 to about 3,000 feet. Above the PIs the topography is characterized by subdued channels in the ground surface and bedrock that direct runoff toward the cliff face. A modestly-well to locally poorly-developed drainage leads down slope from the area of the PIs to Goodwin Road. Locally it is incised in areas of steep hillside topography. Prior to the slides and floods a culvert carried the occupying stream beneath Goodwin Road where upon at the exit the stream made a sharp 90° turn to the south and flowed parallel to Goodwin Road and then, about 100 feet down the road, turned westward again, into a stream channel. The stream continues westward via this channel cut into the narrow topographic bench noted above and then down onto the aforementioned elevated Holocene surface. The depositional area of the stream is characterized by subdued depression-like topography that once filled to a certain unknown elevation, drains to the southwest (Figure 2). A small subdued alluvial fan has developed where the stream debouches onto the Holocene surface and into the subtle depression.

4.2. CLIMATE

The historical climatic record and pertinent details of the recent storm are briefly presented below. Details of the recent storm are as current as possible at the time of preparation of this report. These details 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 15½ miles to the east-northeast of the Site. The Glacier recording station is some distance away but is at an elevation of approximately 1,000 feet, in the range of the elevations of the PIs (1,000 feet) of the debris slides. 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 site of the PIs, which are essentially at the front of the range of the foothills. 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 Site and at the Glacier Recording Station are surely different and the amount of the difference is uncertain, at a minimum 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 PIs is in the rain-dominated zone (below 1,600 feet). The precipitation history is summarized below, keeping in mind that the precipitation history is assumed to be similar, only with likely lower totals at the Site.

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 it 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 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 the lower elevations. We reviewed the available historic climate data 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 we could not be sure how representative these storms would be of the climatic setting leading up to the January 2009 storm. We should be clear that the POR have only monthly totals, not daily totals. As noted above we have only monthly totals, we have no daily totals (the POR summaries only report average rain and snow for any given day of the year), thus we have 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 southwest side of Sumas Mountain received about 8 to 10 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 Sumas Mountain and the slopes above the affected residences 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, 2009). 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 to20 mph were recorded at the weather station during the latter days of the storm (University of Utah, 2009).

4.3. GEOLOGY

The geology of the Site is represented by the underlying Oligocene to Eocene age bedrock and the Quaternary age surficial deposits that overlie the bedrock. Surficial deposits include glacial sediments, soil and colluvium, landslide debris, and alluvial fan deposits. A brief description and general distribution of these earth materials is presented below. The general distribution of these materials is shown on Figure 2.

4.3.1. Bedrock – Lapen (2000) shows the bedrock geology at the Site is represented by the **Huntingdon Formation (Th)**. It is composed of conglomerate and sandstone interbedded with lesser amounts of siltstone and shale. Conglomerate predominates at the Site. The conglomerate is characterized by pebble to cobble size clasts in a medium- to coarse-sand matrix. The sandstone varies from locally laminated to thick bedded. The bedrock exhibits a general northerly strike and a moderately steep (35°) dip to the west (Lapen, 2000). However, due to cross bedding locally bedding can be somewhat variable. Joints are widely spaced. The bedrock crops out in the cliff in the area of the PIs in the upper reaches of the Site and is exposed in the debris-slide track. Huntingdon Formation is assumed to underlie the lower moderately-steep slopes and lower areas of the Site where the bedrock is overlain by a variety of surficial deposits.

4.3.2. Surficial Deposits – Lapen (2000) shows the **glacial sediments (Qg)** at the Site are represented by outwash deposits and undifferentiated deposits (Figure 3). These deposits are characterized by loose, moderately-well to well-sorted gravels with medium to coarse sand and occasional sand and silt beds. These sediments are mapped to underlie the lower moderately-steep slopes, the areas to the west of Goodwin Road, and the Holocene surface upon which the Soares Property is located.

Soils and colluvium are derived from the mechanical and chemical weathering of the underlying bedrock. They are composed of varying amounts of sand, silt, and clay intermixed with blocks of bedrock and organic debris. Soil mapping published by Goldin (1992) classifies the soils underlying the upper slopes of the Site as Blethen gravelly loam, those underlying the lower slopes as Sehome gravelly loam, the soils underlying the Goodwin Road properties are mapped as Squalicum gravelly loam, and the soils at the affected areas of the Soares Property as Hale silt loam, drained. The Blethen gravelly loam is characterized as well drained, moderately permeable, having a high water capacity, medium runoff, and moderate erosion hazard. The Sehome gravelly loam is described as moderately well drained, moderately permeable, but slow permeability in the lower part where glacial till is present, having a high water capacity (perched water conditions in the winter), slow runoff, and slight erosion hazard. The Squalicum gravelly loam is described as well drained and moderately permeable (very slow where dense glacial till is present), having a high water capacity, slow runoff, and slight erosion hazard. The Hale silt loam (drained) is characterized as somewhat poorly drained, moderately permeable (rapid in the substratum), moderate water capacity (a high water table in the winter), slow runoff and ponding, and no 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 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 surfaces noted above. Wolff (2001) estimated soil thickness in the upper areas of the Site to vary from 1- to 4-feet deep.

Landslide debris (Qls) is composed of a mixture of sand, silt, clay, and blocks of bedrock, and sometimes organic debris. The blocks of rock can be quite variable in size. Landslide debris is confined to landslides in the hillside areas, but it is understood that landslide debris can be inter-fingered with sediments in alluvial fans and soil and colluvium on lower slope areas of the Site.

Alluvial fan deposits (Qaf) are composed of interbedded debris-flow deposits and fluvial sediments. They are mapped at the mouth of the drainage where the stream empties on to the relatively flat Holocene surface at the west end of the Site.

4.4. LANDSLIDES

Landslide processes in the area of the Site can be classified into two broad categories: 1) Rotational- or translational-earth/debris flow slides (Complex slides of Cruden and Varnes, 1996) of widely varying size and thickness and 2) debris slides and associated debris flows, and debris floods. In this report we utilize the flow-type landslide-classification system suggested by Hungr and others (2001). Rock fall processes likely also occur at the Site, but are probably very rare and relatively small in scale.

A very large complex slide was observed just south of the Site (Figure 2). A very small rotational slide was noted about mid-slope on the north side of the debris slide track (Figure 2). This slide is judged to be relatively old and, at this time, stable feature. Another slide was noted along the debris flow track in the lower area of the near the aforementioned small rotational slide. It is also relatively small, but is active.

Topographic evidence (e.g., bedrock hollows, convergent topography, and alluvial fans) suggesting past debris slide activity is rare (Figure 2) in the area of the Site. However, the PIs did develop in an area of poorly defined convergence (Figure 2). Our field observations suggest that obviously the base of the rock cliffs can be a PI for these types of slides. Our observations of the debris slide PIs suggest that in the past patches of soil have slipped off the rock faces at the PI sites, but apparently not to the magnitude that characterized the event of early January 2009.

4.5. GROUNDWATER AND PEAK FLOW

Evidence for groundwater at the PI was not abundant. Fractures and joints in the bedrock noted during our reconnaissance are certainly an avenue for groundwater flow through the bedrock. The permeability through the pore spaces of the bedrock is uncertain and could be quite variable, and certainly must account for some groundwater flow, as suggested by the sapping of the bedrock at the South PI. The soil cover on the bedrock above the PIs is likely relatively thin and the contact between the soil and the bedrock likely represents a significant barrier to the rapid movement of groundwater from the soil downward into the bedrock, forcing some flow parallel to the bedrock surface, and at this location toward the bedrock cliff.

An important factor affecting groundwater, especially at the time of the failures, was the January 2009 storm and the associated phenomenon commonly known as rain-on-snow (ROS) precipitation. It should be noted that the PIs of the debris slides in question were all below the 1,600 foot elevation that is often considered to be the lower elevation of the ROS zone. Generally ROS conditions develop most frequently above this elevation, but not exclusively. However, portions of the harvest area up slope of the PIs extend up to about 1,400 feet, and the Site, including the PIs, were covered by snow at the time of the January 2009 rain storm.

The effects of ROS and the change in peak flow with respect to forested and clear-cut areas have been modeled for three watershed analyses 9 to 9½ miles to the southeast: Acme WAU and the Canyon Lake and Kenny Creek watersheds in the Porter Canyon and a portion of Racehorse Creek WAUs, respectively. One aspect of these analyses modeled the percent change in peak runoff after clear-cut harvest as compared to a mature-forest setting. The Acme analysis divided that watershed into two sub-basins. The sub-basin most like the Site is the eastern sub-basin (the Van Zandt Dike area). The five largest historic ROS events were used in both analyses. In both studies the modeling assumed the entire watershed (or sub-basin) to be clear cut and compared the increase in peak flow to that of an entirely forested watershed (or sub-basin). In the Acme watershed the percent increase for the eastern sub-basin for the several storms was estimated to range between 2% and 21%, the average increase in peak discharge was 11%. Stated another way, in the eastern sub-basin of the Acme watershed the magnitude of a peak-flow with a 10-year recurrence interval under fully-forested conditions would increase to that of a 14-year storm event under clear-cut conditions (Beschta, 1995). In the Canyon Lake Creek - Kenny Creek Watershed analysis, modeling predicted a range of increases for the individual storms of 0 to 13%. The overall average was a 6% increase in peak discharge. Stated another way, the magnitude of a peak-flow with a 10-year recurrence interval under fully-forested conditions would increase to that of a 15-year storm event under clear-cut conditions (Beschta and Veldhuisen, 1993).

Though these watershed analyses were carried out for an entire watershed, not a specific portion of it, in our opinion some generalized relationships can be drawn from the aforementioned studies and applied to thinking concerning the development of peak flows at the Site. Peak flow is the sum of the water delivered to a stream via subsurface flow and surface flow. (Surface flow being channelized flow and sheet flow minus that rainfall that falls directly in the surface water.) An increase in peak flow can also signal some increase in channelized and sheet flow, then it becomes a question of how much that increase might be and when it might occur. As noted above the range in the amount of increase could be quite variable, from 0% to 21% in the watersheds modeled. Not all the increase in peak flow is directly related to sheet flow, only some portion of the increase is related to sheet flow. In an extreme storm event, like the early January 2009 storm the soil would likely become saturated at some point during the storm. Up until that time sheet flow would likely not be a fraction of the total peak flow. After the soil becomes saturated, sheet flow would likely become a larger portion of the peak discharge. Unfortunately, when that line is crossed is difficult to know at this level of reconnaissance. However, considering the thin soils at the site, and modeling by Beschta and Veldhuisen (1993) and Beschta (1995), that line is surely crossed at least by the later portion of the storm. In this report we have assumed that an increase in stream flow would also suggest an increase in groundwater.

The above discussion assumes that the applications of the increases in peak flow would be proportional from the entire watershed to a specific site. This is an over simplification of a complex process and we understand that the sub-basin is not uniform and that projection of the results from basin-wide to a localized hillside setting in another watershed needs to be done with some caution. However, the results of the watershed analyses suggest the change in the hydrologic regime (peak flows and, by association, channelized flow and sheet flow) at the Site following the harvest of the Gasping Goodwin Aerial timber sale would likely increase. Based on our understanding of the Site at this time, the amount could vary from minor to significant.

5.0. HISTORICAL SETTING

The historical setting of the Site is briefly summarized below. This includes the past landslide history, and past forest practices and 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 six sets of aerial photographs dating from 1970 to 2001 did not reveal evidence for past slope instability within the area of the Site during that time period. This should not be construed to suggest that landsliding has not occurred; only that such movement or sliding may have been too small to be detectable on 1:12,000 scale aerial photographs, or that shallow landsliding predated 1960 (allowing for a 10-year period preceding the 1970 photographs).

5.2. MANAGEMENT AND LAND-USE HISTORY

The past forest practices history and land-use history is discussed below. The following discussions are based on review of vertical, stereographic aerial photographs dating back to 1970, and review of relevant forest practices applications. The land-use history is derived from review of the same aerial photographs.

5.2.1. Management History – Review of the 1970 aerial photographs showed an irregular canopy of deciduous trees and conifers covering the area of the Site. Large areas to the east of the Site, and topographically separated from the Site, were logged prior to 1970. Comments on the 1983 photographs suggest that the "historic" harvest activity observed on the 1970 photographs in the areas in question took place in the mid-1940s. Based on the aerial photographs, Forest Application 72933 (Gasping Goodwin Aerial, 2001), and the IIR 09/S/ZFX (Hooks, 2009) the next phase of harvest activity was proposed in 2001 and the actual harvest occurred in 2004/2005. That Timber Sale was labeled *Gasping Goodwin Aerial*. It was a clear-cut sale characterized by two yarding methods: generally the lower portions of the sale were cable logged; the upper portions were helicopter yarded. An area of bedrock cliffs, in part, separated the cable yarded area from the helicopter yarded area. The area of the bedrock cliffs was removed from the sale and became essentially a leave tree area, management activities were not conducted in the bedrock-cliff/leave-tree area.

5.2.2. Land-Use History – Goodwin Road is present on the 1970 aerial photographs. The Benson and Gassman residential structures are present. No specific use to perhaps low-intensity agricultural use (grazing) characterized land use during the following couple of decades. From the year of 1970 photographs to the time of the 1995 aerial photographs no new residential structures were observed. The 2001 aerial photography shows residential structures on the May and Soares Properties. There is still no residential structure on the Frank Property. The residential structure on the Frank Property was evidently constructed between 2001 and 2009.

6.0. RECONNAISSANCE OBSERVATIONS

The debris slides and resulting debris floods that affected the Benson, Gassman, Franks, Kitchen, and Soares properties are reported to have occurred around 11:00 PM January 6th (Hooks, 2009). It is thought that later the same night additional flow events followed the initial event (Hooks, 2009). The following discussion presents salient field observations regarding the debris slides that impacted the several residences. The discussion proceeds from the PIs downslope to the areas of deposition. Resulting damage to private property is summarized in the Areas of Deposition discussion.

6.1. POINTS OF INITIATION (PIs)

As Figure 2 shows the slide and associated flood began from two separate PIs about 60 feet apart at the base of the cliff in the leave area of the Gasping Goodwin Aerial timber sale. The debris slides and associated debris flows that originated at the PIs coalesced into a common channel about 550 feet down slope from the PIs. As noted earlier the two PIs are referred to as the North PI and the South PI. They are each discussed in that order below.

6.1.1. North PI – The PI is more-or-less at the base of an approximately 50- to 60-feet high cliff-like landform in the mature timber that stocked the leave-tree area of the sale (Figure 2). The scar at the North PI is estimated to be about 30- to 40-feet wide, and varies in depth from a few feet to about 5- to 6-feet deep. Bedrock is exposed in the scar and it appears the failure was essentially confined to the colluvial deposits that had accumulated at the base of the cliff and the patches of soil that developed on the bedrock surfaces. Inclinations of the adjacent colluvial slopes are steep and range up to about 100%. The inclination of the newly-exposed bedrock surfaces vary from 80% to vertical. Roots from the trees that were lost in the failure do not appear to have penetrated into the bedrock. To the north of the slide scar a ground crack about 10-feet long was observed. The crack was about 4-inches wide. At the time of the January 8th reconnaissance channelized runoff was observed flowing across the rock face (Figure 3). The development of the channel was controlled by bedrock joints and bedding. LiDAR topography suggests some subdued channeling on the westerly-facing hillside above the bedrock cliff.

6.1.2. South PI – As at the North PI, the failure is essentially at the base of the cliff and involved colluvial soils, though in this PI some weathered bedrock may also have been involved. This slide also occurred in mature timber that stocked the leave tree area of the sale. The slide scar is about 75-feet wide, and about 2- to 3-feet deep. The bedrock cliff above the scar is about 20 feet high. Hillside slopes in the adjacent colluvial deposits vary in inclination from about 75% to 90%. Roots from the trees that were lost in the failure do not appear to have penetrated into the bedrock. A smaller shallower scar, about 15- to 20-feet wide and a couple of feet deep was noted extending up the face of the bedrock cliff at the southern edge of the scar. Above the cliff a subdued swale was observed. Right at the top of the cliff this swale exhibited Class IV-Special characteristics as discussed in the guidelines and criteria presented in the Washington State Forest Practices Rules (WAC 222-16-050) and Board Manual Section 16 (e.g., 70% slopes). Sapping of the cliff face was observed above the slide scar. At the time of the initial site (January 8th) channelized water was observed flowing across the rock face. Later, during site reconnaissance in March, water was observed trickling down the face of the cliff. A relatively large ground crack was observed above the scar. Here the soil cover appeared to be "peeling" away from the rock face. The crack is about 10- to 12-feet long and about 1-foot wide.

6.2. DEBRIS-FLOW TRACKS

The debris-flow track extends about 2,900 feet from the PIs to Goodwin Road (Figure 4). Past Goodwin Road the track extends another 800 to 900 feet to the area on the Soares Property where water ponded (Figure 2). As noted above, at a point about 550 feet down slope from the PIs the debris-flow tracks from the North and South PIs merged and became one track from there down slope. The debris scoured the slope and the drainage channel picking up more earth materials and organic debris (Figure 5). Elsewhere, the slide material ran across the ground surface doing little damage except to vegetation (Figure 6). Subsequently running water from the PIs locally eroded narrow gullies up to 7-feet deep and 4- or more feet wide. At a turn in the lower area of the timber sale the debris jumped out of the drainage channel and across a hillside area before being redirected, by the local topography, back into the channel. Before exiting DNR property a small portion of the debris broke away from the main mass and traveled across the hillside to the northwest for a distance of about 350 feet before coming to rest. As shown on Figure 2 the debris-flow track crossed the buried Williams gas pipeline but apparently did no harm (pers. comm; A. Kammereck, P.E.; Golder Associates). On the gentler slopes of the Franks Property the slide debris spread out somewhat before overflowing on to the Franks driveway and also continuing down the drainage onto the Gassman Property. Mud splatter was observed on tree trunks up to 4 feet above the ground surface. At Goodwin Road the fraction on the Franks Property split, some going north along the east side of Goodwin Road for about 400 feet. The remainder either piled up on the road and plugging the culvert along with the fraction that spilled on the Gassman Property, or continued across the Goodwin Road and on the Benson Property, spilling onto the driveway and lawn areas, some splitting off and going a relatively short distance before coming to rest north of the Benson residence. The remainder went down either the driveway and into the garage or was directed southwestward into the old drainage and on down to the subtle depression-like area on the Soares Property.

6.3. AREAS OF DEPOSITION

Areas of deposition were scattered along the way (Figure 2). They included an area of relatively gently slopes on the Franks Property. The driveway of the Franks Property (Figure 7) and side-yard of the Gassman Property (Figure 8) were covered with slide debris along with the intervening stream channel. Debris was deposited on Goodman Road and across the Benson Property (Figure 9). Slide debris was deposited on the front-yard areas of the Benson Property (Figure 9). Slide debris entered the Benson garage (Figure 10). Debris filled the stream channel at the outfall of the culvert and on into the stream channel on the southern area of the Benson Property and spread across portions of the Kitchen Property as the flood spilled down the stream channel. Deposition of finer debris continued down the stream channel and on out into the subdued depression on the Soares Property, where the small-sized debris and the fine-grained fraction of sediment accumulated and water ponded (Figures 11 and 12).

7.0. DISCUSSION

As part of our charge we were asked to determine the following:

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

In this section we provide our observations and opinions with respect to these questions. **Section 7.1.** provides our observations and conclusions with respect to questions 1 and 2 above. **Sections 7.2. to 7.4.** address questions 3 and 4**. Section 7.2.** provides a discussion concerning the likely influence that the January 2009 storm and accompanying ROS conditions might have had on peak flow and groundwater flow from the adjacent Gasping Goodwin Aerial timber sale. **Section 7.3.** summarizes the likely influence that the timber sale might have had on the development of debris slides at the PIs. **Section 7.4** provides a brief discussion regarding our opinion as to the degree of causal influence the management activities may have had in development of the debris slides.

7.1. LOCATION AND MANAGED-LANDS

The two debris slides initiated on DNR-managed lands. Both slides occurred in the unmanaged leave-tree area within the 4- to 5-year old DNR Gasping Goodwin Aerial Timber Sale.

7.2. STORM AND RAIN-ON-SNOW INFLUENCES

The January 2009 storm followed a several-week period of rain, snow, and near freezing to freezing temperatures. A snow pack of up to at least a couple of feet blanketed the PIs prior to arrival of the rains and accompanying winds and warmer temperatures. The PIs are located in the upper portion of the generally accepted rain-dominated zone; however, a classic ROS situation developed anyway. As noted earlier, the area above the cliffs and the PIs was clear cut about 4 to 5 years earlier. Extrapolation of the modeling of peak flow in the two aforementioned watersheds to the east by Beschta (1995) and Beschta and Veldhuisen (1993), to the conditions in the upper portions of the Site suggest a potential to increase peak flows (channelized flow and overland flow) at the Site. Based on the work by Beschta (1995) and Beschta and Veldhuisen (1993) the average increase in peak flow, and by extension channelized flow and sheet flow, could be about 6 to 11% greater than under forested conditions, depending on the watershed. The reported range of magnitudes of increase in peak flow from forested to clear cut conditions for the five storms modeled in the two watershed analyses varied from 0% to 21%. The average increases equates to changing the magnitude of a 10-year peak flow to that of a 14- or 15-year peak flow (Beschta and Veldhuisen, 1993, and Beschta, 1995). Though the average could be considered quite modest, the high individual storm increases could be considered significant. However, as stated in section **4.5 GROUNDWATER AND PEAK FLOW**, caution needs to be exercised when projecting Beschta and Veldhuisen's (1993) and Beschta's (1995) modeling of basin-wide hydrologic changes to localized areas.

The potential for frozen ground to increase runoff could complicate the calculations and we have not tried to account for this condition in this discussion, largely because we do not know if this condition actually existed at the time of the storm. We suspect it not likely. This discussion is further complicated by work of Coffin and Harr (1992). They showed increased outflow from plantation sites in ROS events was somewhat variable and did not always exceed forested sites. Thus it is very difficult to accurately know exactly how much additional groundwater and runoff was actually added to the area of the sale as a result of the January storm and associated ROS conditions.

It appears that the area of the Site has experienced at least two similar weather events in 1970/71 and 1971/72 during a record of 34 years. Review of the 1976 aerial photographs does not show any landslide activity following those weather events, at least any slide activity that could be detected at the scale and resolution of the photographs. During our field reconnaissance of the PIs we did not observe evidence for earlier (particularly 2001 to pre-2009) significant debris slides in the area of the Site, this in spite of the fact that at least eight significant storms have passed through the county, some of which certainly passed over the Site since the time of the 2001 photography, one of those (November 2006) since the 2004/2005 harvest of Gasping Goodwin Aerial timber sale.

7.3. MANAGEMENT AND VEGETATION INFLUENCES

As noted above, the PIs occurred in the leave tree area of the Gasping Goodwin Aerial timber sale. This area is characterized by locally steep colluvial slopes that back up against the essentially vertical bedrock cliffs. Wolff (2001) reports a small slide in a bedrock outcrop, presumably at the base of, or on, the cliff face. Interpretation of LiDAR topography suggests subdued drainages initiating from these locations. Based on our field reconnaissance and review of the LiDAR topography, these sites would not likely have been classified as Class IV-Special (potentially unstable) terrain. However, this area was removed from the sale; it appears because of the possibility of sliding that might result from yarding logs downhill through the area in question (Wolff, 2001). The intent of retaining leave trees is to maintain root strength, to preserve canopy interception and evapotranspiration, and to prevent yarding-related soil compaction, thus reducing the potential for a slope failure to occur in the leave tree area.

7.4. SUMMARY DISCUSSION

At each PI there were several contributory factors to the initiation of the debris slides that are the subject of this reconnaissance. These factors include the topography, geology, groundwater and peak-flow conditions, and harvest history. Of course the triggering factor was the early January storm and associated high volumes of water generated by the rain-on-snow conditions at the Site. It should be noted that both of the slides that are the subject of this reconnaissance occurred in colluvial (surficial) deposits. However, in the case of the South PI, some of the underlying weathered sandstone bedrock may also have been involved. The high elevation and steep slopes at the PIs and locally the steep gradients of the drainage channel provided an environment conducive for rapid down-slope movement once the slides developed.

At the PIs it appears that the westward sloping topography above both PIs and modest-sized channel above South PI collected and directed ground water and peak flow waters from the clear cut area above the cliff toward the face of the cliff. There the water would either surface or, if at the surface, continue flowing down the cliff face at the PIs. It is likely that this surface-runoff drainage-system had been functioning for sometime (perhaps 1,000s of years) creating a stream channel as colluvium accumulated at the base of the cliff. The drainage, evident in the pre-failure LiDAR topography, that extends from the PIs to Goodwin Road and then beyond along with the alluvial fan noted on the east side of the depression where water and debris accumulated provides evidence that such a drainage system had developed over time. The presumed higher than usual volume of water being delivered to the area of the future PIs must have, as it fell and cascaded down and across the bedrock cliff, saturated and eroded the colluvial deposits at the base to a higher degree than likely experienced in the last few hundred years, including a sever storm in November 2006. It would have been the influx of this high volume of water that eroded and destabilized the colluvium, resulting in development of the debris slides that moved down the hillside in the existing drainage that became the debris-slide track, and then the debris slide became a debris flood as the mixture encountered the lower gradient slopes of the Site.

In our opinion, it would be unreasonable to suggest the Gasping Goodwin Aerial timber sale harvest had no effect on the landslides that originated in the un-cut areas. Due to the clear-cut upslope of the bedrock cliff, snow accumulation on the ground was likely greater in these areas as compared with forested areas. Work by Coffin and Harr (1992), Marks and others (1998), Marks and others (2001), and the watershed work done by Beschta and Veldhuisen (1993) and Beschta (1995), while somewhat contradictory on some details and magnitude of increase overall support the conclusion that peak flows (channelized flow and sheet flow) increase when the forest cover is removed. The modeling by Beschta and Veldhuisen (1993) and Beschta (1995) indicate that on average peak flows could increase by 6% to 13% and the range of lows and highs, depending on the storm modeled, could varied from 0% to 21%. When the heavy rainfall and associated warmer temperatures melted the snow it most likely contributed to a greater peak flow and the amount of water being introduced to the areas of the PIs, an amount of water that was likely greater than the areas of the PIs had experienced in a long time (at least the age of the mature timber). This introduction of this additional water could, if enough was added, erode and destabilize the colluvial deposits, triggering the debris slides. However, as noted above, if the results of the ROS analyses by Beschta and Veldhuisen (1993) and Beschta (1995) are reflective of the range in the amount of increase in water that might be expected, then, in our opinion, the degree of contribution of the clear cut to the increase in the amount of runoff delivered to the bedrock cliff and the potential to add to the destabilizing factors that caused the debris slide, is, with the information at hand, extremely difficult to meaningfully quantify.

Conversely, it is also our opinion that it is possible that the landslides originating at the PIs could have occurred even if the area above the cliff was left forested. The early January ROS storm that triggered these landslides appears to have been one of the more extreme weather events for the area when compared to the rainfall and snowfall amounts reviewed for the climate history discussed above (Section 4.2.1.). It is our opinion that, even if the forest was intact above the cliff, it would not be an unreasonable scenario in which the areas of the PIs were on the edge of failure and the volume of water derived from heavy precipitation and rapid snowmelt from the fully-forested area overwhelmed the local site conditions at the PIs and shallow-rapid slope-failures could develop. It should be pointed out that during the January 2009 storm slides occurred elsewhere in unmanaged areas in Whatcom County, even though those areas were likely “tested” by the earlier storm event in November 2006.

With the above discussion in mind it should be noted that in the end the imprecise results of research and contradicting research results make it difficult to draw a conclusive cause-and-effect relationship between management activities and initiation of a specific slide in this case.

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 6459, 6488, 6489, and 6500 Goodwin Road, and 6474 Siper Road 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 areas of recent management activities?
3) Did the management activities contribute to initiation of debris slides?
4) How much did the management activities contribute to debris slide initiation?

In this reconnaissance report we provide our observations and opinions, with respect to these questions, based on our field reconnaissance and review of office derived data. If new information should be become available, our geologic interpretations, and thus, our discussion could require modification.

The signatures and stamp for this engineering geologic field reconnaissance report are 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 stamp or authorized facsimiles of the same.

END

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AERIAL PHOTOGRAPHY REVIEWED

Date	Flight Line/Frames	Approx. Scale	Medium
6/2/70	NW-69 240 45B-110 to -111	1:12,000	B/W
7/15/76	NW-C 76-22B-13 to -14	1:24,000	Color
6-3-78	NW-78 58C-40 to -41	1:12,000	B/W
5/13/83	NW-C-83 8-45-66 to -67	1:12,000	Color
5/27/95	NW-95 29-45-136 to -137	1:12,000	B/W
9/10/01	NW-C-01 73-45-34 to -35	1:12,000	Color

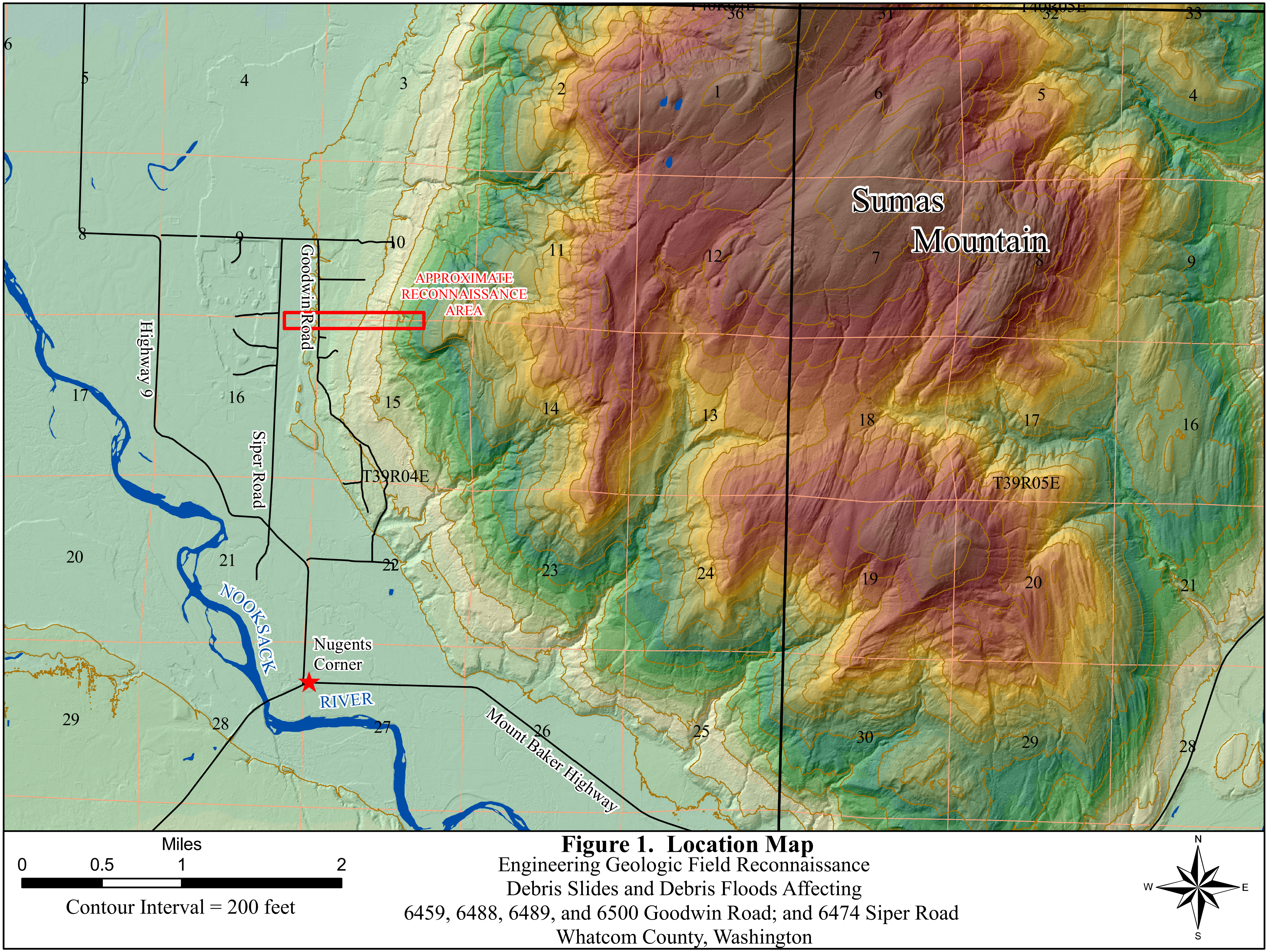


Figure 1. Location Map
Engineering Geologic Field Reconnaissance
Debris Slides and Debris Floods Affecting
6459, 6488, 6489, and 6500 Goodwin Road; and 6474 Siper Road
Whatcom County, Washington

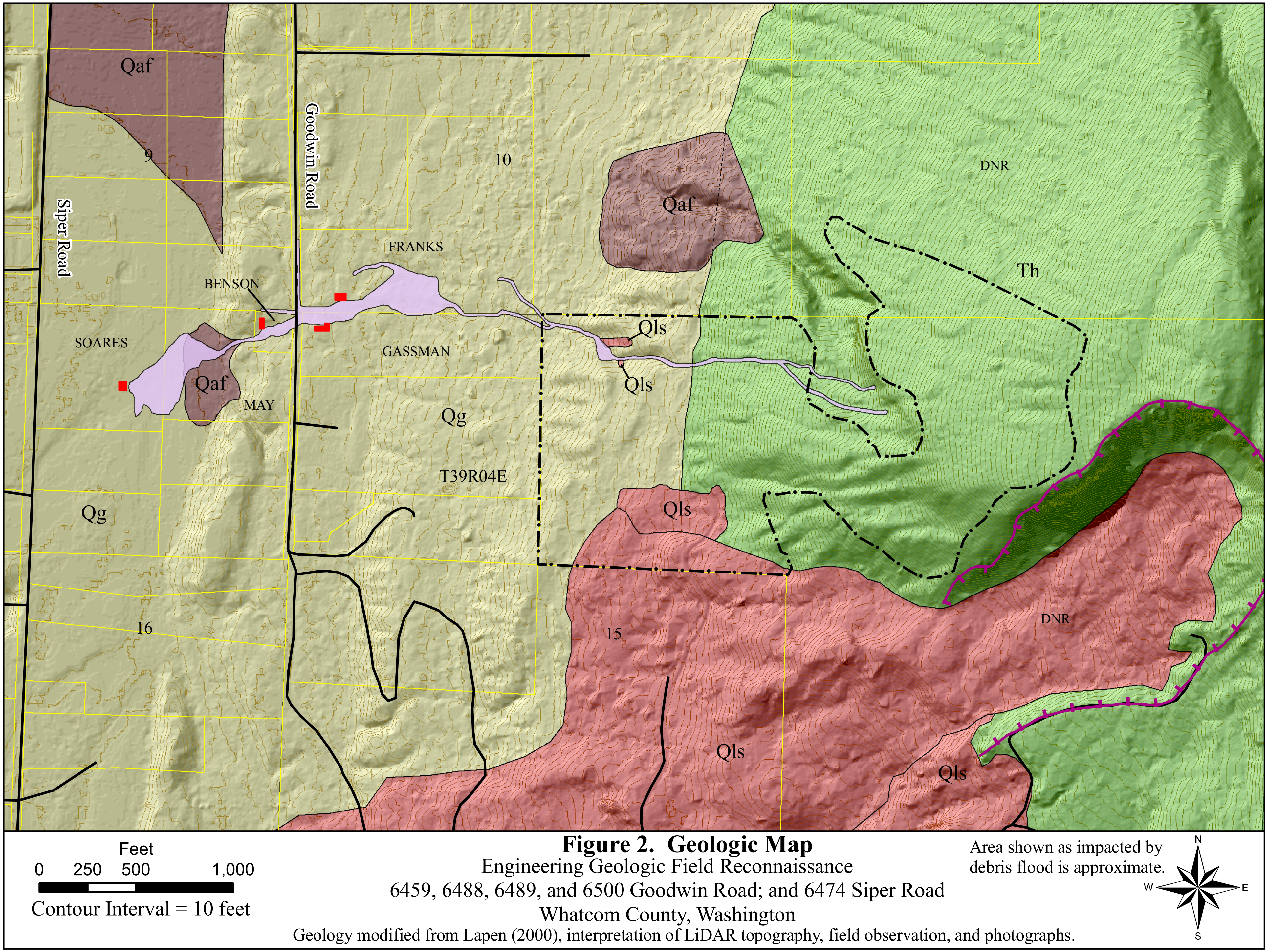


Figure 2. Geologic Map

Engineering Geologic Field Reconnaissance
6459, 6488, 6489, and 6500 Goodwin Road; and 6474 Siper Road
Whatcom County, Washington

Geology modified from Lapen (2000), interpretation of LiDAR topography, field observation, and photographs.

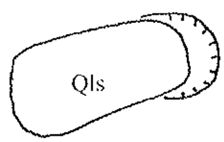
EARTH MATERIALS

Qaf	Alluvial fan deposits
Qls	Landslide debris
Qg	Glacial outwash and undivided deposits
Th	Huntingdon Formation

MAP SYMBOLS

Geologic contact, dotted where concealed

Approximate route of debris slide track and area of ponded water and debris on Soares/May Properties



Landslide, shows crown of scarp of landslide

Approximate boundary of the Gasping Goodwin Aerial timber sale

Property line (in yellow)

Approximate location of residential structures on the affected properties

Approximate location of the Williams gas pipeline

FIGURE 2A. Explanation for Figure 2 Geologic Map

Engineering Geologic Field Reconnaissance
6459, 6488, 6489, and 6500 Goodwin Road, and 6474 Siper Road
Whatcom County, Washington

Figure 3 North PI. Note water flowing across bedrock surface. Photograph taken 1/8/09. View looking east. (Photo by D. Hooks)

Figure 4 Aerial photograph showing debris-flow track (furrow on hillside) from PIs to pipeline right-of-way (grass strip across lower area of photograph). Treeless areas delineate Gasping Goodwin Aerial timber sale. View looking southeasterly. (Photo by D. Hooks)

Figure 5 View looking west and down slope along debris-flow track. Photograph taken 1/8/09 just below junction of debris slide tracks.
(Photo by D. Hooks)

Figure 6 View of debris-flow track in lower area of Gasping Goodwin Aerial timber sale. Note area in left half of photograph where debris passed over hillside area. Photograph take 1/8/09. View looking west.
(Photo by D. Hooks)

Figure 7 View of area at 6500 Goodwin Road blanketed by debris from debris flood. View looking northwesterly. Photograph taken 1/8/09.
(Photo by D. Hooks)

Figure 8 View of area at 6488 Goodwin Road blanketed by debris from debris flood. View looking westerly. Photograph take 1/8/09.
(Photo by D. Hooks)

Figure 9 View of area along Goodwin Road in front of 6488 and 6500. Stream is essentially flowing in same location as prior to debris flood event. However, stream is now several feet above original channel. Residence at 6489 Goodwin Road in background. Debris flowed over surface in front of house and into an area to the right. View looking westerly. Photograph taken 1/8/09. (Photo by D. Hooks)

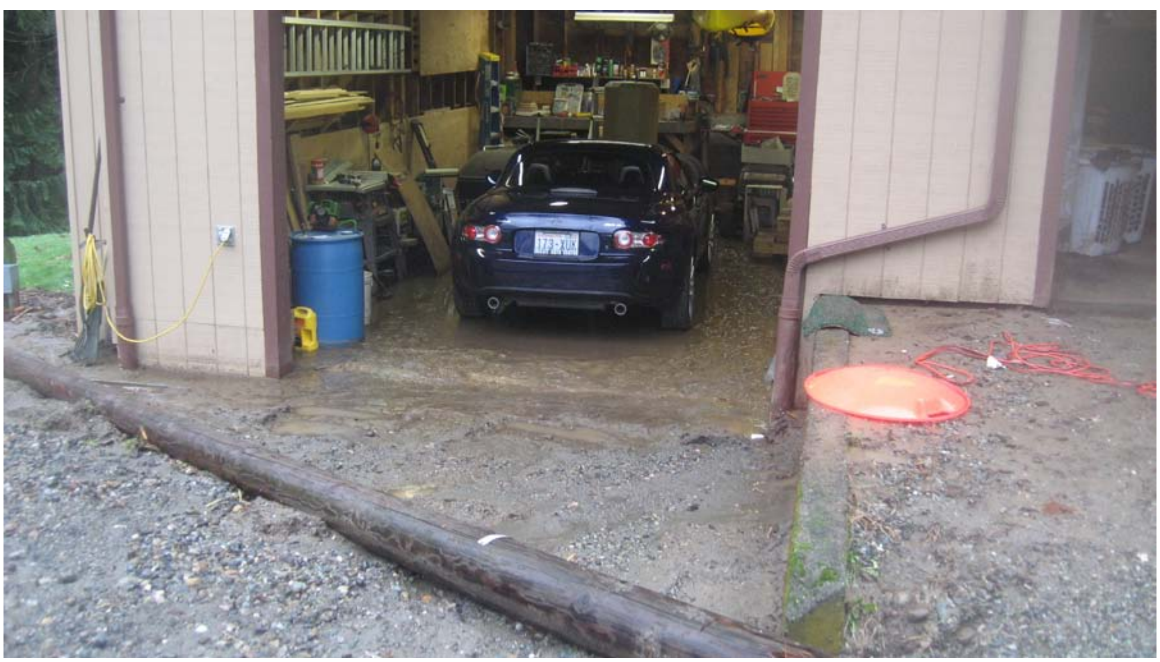


Figure 10 View of garage at 6489 Goodwin Road and pole placed to divert debris. Some debris entered garage before placement of pole. View looking southwest at southeast corner area of garage. Photograph taken 1/8/09. (Photo by D. Hooks)

Figure 11 Water and debris filling subdued depression to east of 6474 Siper Road. Affected residence between water and trees. View looking southwest. Photograph taken 1/8/09. (Photo by D. Hooks)

Figure 12 Aerial photograph of flooded area east of 6489 Siper Road. Residence is structure just to right of ponded water. View looking to south. Photograph take 1/20/09. (Photo by D. Hooks)