Appendix E

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE

DEBRIS SLIDE, DEBRIS FLOOD, AND AFFECTED PROPERTY

6578 Goodwin Road
Whatcom County, Washington

Prepared for:

Jeff May
Baker District Manager

Washington Department of Natural Resources

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Washington Department of Natural Resources
Land Management Division

July 17, 2009

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

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

SUBJECT: **ENGINEERING GEOLOGIC FIELD RECONNAISSANCE**
Debris Slide, Debris Flood, and Affected Property
6578 Goodwin Road
Whatcom County, Washington

DATE: July 17, 2009

The following Engineering Geologic Field Reconnaissance report presents our findings, and a discussion regarding the debris slide and debris flood that affected the residential property at 6578 Goodwin Road in Whatcom County, Washington. The debris slide and debris flood occurred during the January 2009 storm. This reconnaissance report addresses the following issues: 1) was the point-of-initiation of the debris slide on DNR-managed lands, 2) was the point-of-initiation in an area of recent management activity, 3) did the management activity contribute to debris slide initiation and the subsequent debris flood, and 4) how much did management activity contribute to initiation of the debris slides and debris flood.

If you have any questions, please call.

Respectfully submitted,

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1.0. INTRODUCTION

This report presents an engineering geologic field reconnaissance of the debris slide and debris flood that affected the above referenced residential property in northwest Whatcom County. The debris slide and debris flood 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 property is shown on Figures 1 and 2. The area is located about 2½ miles north of Nugents Corner. The affected property (Owner) is located at 6578 (Jones) Goodwin Road. The debris slide initiated in the SE¼ of Section 10 and the affected residence is located in the SW¼ Section 10, T39N, R4E (Willamette Base Line &Meridian) in the US Geological Survey 7½-minute Sumas Quadrangle. 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 slide and affected property that is the subject of this reconnaissance report is referred to as Goodwin Road #2. For purposes of clarity we have chosen to title this report with respect to the address of the affected property.

As shown on Figure 1, the affected property is located near the base of the southwest side of Sumas Mountain. The property is situated in the Sumas Watershed Administrative Unit (WAU). To date neither watershed analysis nor Landslide Hazard Zonation mapping has been undertaken for this WAU. The affected property is not 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 property in question is located on the very lowest slopes of Sumas Mountain.

The residence and outbuildings are located at the end of a 1,300-foot long one-lane-wide gravel road that extends eastward from Goodwin Road (Figures 1 and 2), and then a 350-foot long curving driveway that trends southeast of the gravel road and up to the existing residence. Several outbuildings are located in the vicinity of the residence, including a workshop about 500 feet to the south of the residence.

The purpose of this geologic field reconnaissance was to locate the point-of-initiation (PI) of the debris slide, observe the site conditions at the PI, observe the conditions along the flow track, and note conditions in the areas of deposition. In addition, I have been 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 slide and flood.

2.0. SCOPE OF WORK

The scope of work included the following tasks:

- Review of pertinent published geologic reports and maps in our files
- Review of Whatcom County hazards map
- 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 (FPA)
- Review of an unpublished geologic report pertinent to the FPA
- 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 the western side of Sumas Mountain. The physical setting of the PI of the debris slide, flow track, 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). One is the area of steep westerly-facing hillside topography that includes the mountain side and the drainage in which the debris slide occurred and the other is an area of relatively gentle hillside topography on which the affected property and associated structures are situated. The drainage in which the debris slide occurred is, herein, informally named Jones Creek.

In the area of the Site the west-facing slopes of Sumas Mountain exhibit inclinations that vary from 35% to 65%. However, along Jones Creek inner-gorge topography prevails. Slopes along most of the creek vary from 70% to 90% and greater. Locally bedrock cliffs characterized by essentially vertical inclinations of several tens of feet are present. The lower area of the Site (and the property) is characterized by slopes of 25% or less, with minor areas of 25% to 65% slopes for very short pitches. The PI is situated at elevation of about 850 feet (Figure 2). The depositional areas and affected residential structure and outbuildings are at elevations of approximately 350 feet. The local relief between the residence and associated outbuildings and the PI is about 500-feet vertical over a horizontal distance of about 1,600 feet. Above the PI the hillside is characterized by very steep topography and bedrock cliffs (Figure 2). From the PI to the mouth of Jones Creek the creek exhibits a steep gradient and can be characterized as a relatively narrow and steep-walled drainage. In the upper reaches of Jones Creek the drainage splits (Figure 2). One branch extends to the east into a very steep-walled drainage that ends in "box-canyon" like topography. The other branch extends to the south into relatively broad swale-like topography paralleling the base of the bedrock cliff. The existing residential structure and out-buildings are located on the middle area of a modest-size alluvial fan (Figure 2) that has developed at the mouth of Jones Creek.

It appears that at sometime in the past Jones Creek was diverted from where ever its "original" course was, to flow to the south, away from the area of the residential structure. The creek was placed in a ditch-like watercourse that took it to the south, around the residence and the workshop, that is south of the residence, and then down slope to the west.

4.2. CLIMATE

The historical climatic record and pertinent details of the recent storm are briefly presented below. The rain fall 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 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 PI, which is 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 PI 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. 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 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 overlying Quaternary age surficial deposits. 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 aerial 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 moderately-wide to widely spaced. The bedrock crops out in the cliff, in the area above the PI in the upper reaches of the Site, and is exposed in the debris-flow track. Huntingdon Formation is assumed to underlie the lower slopes and lower areas of the Site where the bedrock is overlain by the various 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 2). 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 slopes of the property and on down to Goodwin Road and past there.

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 and the area of the residence as Sehome gravelly loam, and the soils underlying the area about Goodwin Road are mapped as Squalicum gravelly loam. 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.

Soil forms more or less in-place; however, the colluvial deposits are formed by the accumulation of soil and rock 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. Soil occurs in patches and discontinuously across the upper areas of the site, including the bedrock surfaces of the cliffs noted above. Wolff (2001) estimated soil thickness in upper areas of the Site, areas that are within the Gasping Goodwin Aerial timber sale (Figure 2), to vary from 1 to 4 feet. Based on field observations made in the upper reaches of Jones Creek, thick accumulations of colluvium are present (at least locally) along the base of the bedrock cliff and along the inner-gorge slopes of Jones Creek.

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. In the area of the Site landslide debris is confined to inner-gorge slopes of Jones Creek, but it is understood that landslide debris (debris slide/flood deposits) 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 and flood deposits and fluvial sediments. They are mapped at the mouth of Jones Creek where the stream empties on to lower gradient slopes that underlie the areas where the existing residence and outbuildings are located.

4.4. LANDSLIDES

In the area of the Site landslide processes are essentially confined to debris slides (Cruden and Varnes, 1996) and associated debris flows and debris floods of Jones Creek. 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.

Topographic evidence (e.g., bedrock hollows, convergent topography, and alluvial fans) suggesting past debris slide activity is present (Figure 2) in the area of the Site. The PI developed on steep slopes in an area of planner topography (Figure 2).

Several debris slide scars predating the early January storm were observed during our field reconnaissance of Jones Creek (Figure 2). These scars varied from shallow (est. < 1 ft. thick) soil slips occurring on steep bedrock surfaces to modest-size failures on inner-gorge slopes. These failures varied in length from 20 to 60 feet and width up to about 20 feet. All involved the soil cover and locally underlying weathered bedrock.

4.5. GROUNDWATER AND PEAK FLOW

Evidence for groundwater at the PI was scarce. A debris slide scar that is part of the PI showed evidence for running water (a somewhat eroded channel), suggesting that groundwater was issuing from the area exposed in the scar. 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, but must certainly account for some groundwater flow.

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 PI of the debris slide in question was 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. Portions of the harvest area up slope of the PI extend up to about 1,400 feet. The Site, including the PI, was likely covered by a blanket of 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 9¼ to 9¾ 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 my 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 it is 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 it is understood 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 revealed evidence for past slope instability (debris slides) on the inner-gorge slopes of Jones Creek within the area of the Site during that time period covered by the photography. The approximate location of these debris slides are shown on Figure 2. Evidently once in the creek the slides were not mobilized enough to travel down creek to the mouth, for no evidence that slide debris exited the mouth of the drainage was noted during review of the aerial photographs. In addition to the debris slides noted, evidence for a possible larger slide was also observed. This possible landslide was mapped at the base of the bedrock cliff to the south of the east-trending branch of Jones Creek. This slide may not have been a debris slide, but more appropriately characterized as a complex (rotational-translational) type slide. However, during field reconnaissance of the area of this possible slide, the existence of this slide could not be confirmed.

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 to the east of the Site on the 1970 photographs took place in the mid-1940s. The pattern of the tree cover observed on the 1970 aerial photographs in the area of the Site looks similar to the mid-1940s harvest canopy cover suggesting that harvest activities within the Site at about the same time. Between 1983 and 1995 it appears that some thinning and “patchy” clear-cut harvest activity occurred on the slopes above the residence and outbuildings. 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 designated *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 and the inner gorge of Jones Creek separated the cable yarded area from the helicopter yarded area. The area of the bedrock cliffs and the inner gorge were removed from the sale and management activities were not conducted in these areas. A narrow band of trees was retained between the top of the cliff and the harvest area.

5.2.2. Land-Use History – Goodwin Road is present on the 1970 aerial photographs, and so is the Jones residential structure and outbuildings. No specific use to perhaps low-intensity agricultural use (grazing) characterized land use during the following couple of decades. No substantial changes at the Jones property were noted from 1970 to the present.

6.0. RECONNAISSANCE OBSERVATIONS

The debris slide and resulting debris floods that affected the Jones property are reported to have occurred on January 7th, the time is uncertain (Hooks, 2009). The following discussion presents salient field observations regarding the debris slide that impacted the Jones property. The discussion proceeds from the PI downslope to the area of deposition. Resulting damage to private property is summarized in the Areas of Deposition discussion.

6.1. POINT OF INITIATION (PI)

As Figure 2 shows the debris slide and associated flood began on a west-facing slope in the upper reaches of Jones Creek. It appears that two separate debris slides, that are in close proximity of each other, were the causative slides. It is uncertain if the slides failed at essentially the same time, or failed with some period of time between the failures. In this report these two slides are together treated as the Point of Initiation, the PI. The area of the PI is in an un-managed area (Figure 3) below a portion of the Gasping Goodwin Aerial timber sale. The PIs are in the mature timber near the base of an approximate 50- to 60-foot high bedrock cliff. The eastern most PI occurred on planner slopes characterized by 70% to 90% inclinations. The area of this PI is underlain by colluvial deposits, no bedrock was observed in the debris slide scar. The crown of the scar is estimated to be about 40-feet wide and the scar about 3-feet deep. No evidence for concentrated water flow following failure was observed. About 70 feet to the west is the other debris slide scar also clearly associated with the January 2009 storm. This scar certainly also contributed to the debris flow and flood. It is estimated to be about 20-feet wide and about 30- to 40-feet long and several feet deep. This scar (as noted earlier in **Section 4.5.**) exhibits a relatively shallow gully suggesting concentrated water flow following failure. Again the slide appears to be confined to colluvium, for no bedrock was observed. The bedrock cliff above this scar is characterized by joints that have created a very steep poorly-developed cleft-like feature that could concentrate surface-water flow; however, evidence for concentrated surface flow from the cliff was not noted.

Just to the south of the PI is the earlier mentioned easterly-trending branch of Jones Creek (Figure 2). During reconnaissance of the PI area a small debris slide related to the January 2009 storm was observed on very steep cliff-like slopes near the head of this branch. The slide scar was estimated to be about 15-feet wide by 15-feet long and about a foot deep. Though sediment from this scar was delivered to the east-branch stream, the amount was relatively small. Observations of sediment in the channel of this branch suggests that by the time this branch joined the main channel of Jones Creek, the amount of sediment delivered to the main channel was small and most likely not a factor in the development of the slides at the PIs and contributed little sediment to the debris flood.

6.2. DEBRIS-FLOW TRACK

The debris-flow track extends about 1,200 feet down slope from the PI to the mouth of Jones Creek (Figure 2). As noted above, the track is characterized by a steep gradient in the narrow confines of the creek, locally bedrock is now exposed at many locations. Scouring of the side-slopes of the channel occurred up to a height of about 5 to 7 feet above the current bottom of the creek. Currently, a couple minor to modest-size log jams were observed during the field reconnaissance; only minor amounts of sediment were present behind the jams. Reconnaissance of the creek revealed vegetated and subdued debris-slide scars here-and-there along the channel, and skid trails and roads locally parallel to or leading away from the banks of the creek. Presumably these trails and roads are related to the past logging activities noted during review of the aerial photographs.

6.3. AREA OF DEPOSITION

The earth materials (sand, gravel, and finer sediment) along with the organic debris that became the debris flood at the mouth of Jones Creek were deposited across areas of the property (Figure 2), predominately portions of the lower areas of the property (Figure 4). The debris apparently filled the artificial ditch constructed to carry the creek to the south, and the creek cut a new course to the northwest down the gravel/dirt driveway (Figures 5 and 6). Locally the depth of the new channel was significant. A “blanket” of gravel was deposited across the driveway and, locally, hillside areas to the north side of the residence (Figure 7); the gravel blanket extended down slope toward the one-lane road that extends eastward from Goodwin Road (Figure 8 and 9). Run off from the newly eroded channel continued along the western margin of the property and into a drainage ditch on the south side of the one-lane road.

Debris was also deposited in areas on the south side of the residence (Figure 10) and sediment accumulated in the narrow walkway area on the eastern side of the residence. Though no mud or debris entered the residence, sediment entered or surrounded small outbuildings to the north or east of the residence. Sediment also accumulated along the east side of the workshop and entered that structure.

7.0. DISCUSSION

The purpose of this reconnaissance was to develop a preliminary opinion with respect to the following questions:

1) Was the PI of the debris slide on DNR managed lands?
2) Was the PI 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?

In this section observations and opinions with respect to these questions are provided. **Section 7.1.** provides observations and conclusions with respect to questions 1 and 2. **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 timber harvesting might have had on the development of debris slides at the PI. **Section 7.4** provides a brief discussion regarding my opinion as to the degree of causal influence the management activities may have had in development of the debris slides and associated flood.

7.1. LOCATION AND MANAGED-LANDS

The two debris slides that make up the PI initiated on DNR-managed lands. Both slides occurred in the unmanaged area adjacent to 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 PI prior to arrival of the rains and accompanying winds and warmer temperatures. The PI is located well below the generally accepted rain-on-snow dominated zone; however, a classic ROS situation developed anyway. As noted earlier, the area above the cliffs and the PI was clear cut about 4 to 5 years earlier. Extrapolation of the modeling of peak flow, as discussed by Beschta (1995) and Beschta and Veldhuisen (1993) in the two aforementioned watersheds to the east, to the conditions in the upper portions of the Site suggest a potential to increase peak flows (channelized flow and overland flow) in the upper areas of the Site due to the harvest activities. 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 studied. 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. The discussion in this report does not try to account for this condition, largely because it is not known if this condition actually existed at the time of the storm, and because it is suspected that such a condition likely did not exist. 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 field reconnaissance of the PI evidence for earlier (particularly 2001 to pre-2009) significant debris slides in the immediate area of the PI was not observed, 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 PI occurred in an unlogged area adjacent to the Gasping Goodwin Aerial timber sale. The area of the PI is characterized by locally steep colluvial slopes that back up against the essentially vertical bedrock cliffs. Based on our field reconnaissance and review of the LiDAR topography, the area of the PI would certainly have been classified as Class IV-Special (potentially unstable) terrain, following guidelines and criteria discussed in the Washington State Forest Practices Rules (WAC 222-16-050) and Board Manual Section 16, and removed from the timber sale, as it was. Class IV-Special terrains area areas judged to particularly susceptible to landsliding. The intent of removing such areas from harvest is to retaining the trees in order 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 such areas.

7.4. SUMMARY DISCUSSION

At the PI there were several possible 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.

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 remembered that the slides in the PI occurred an unmanaged area of mature timber underlain by thick colluvial (surficial) deposits. The relatively high elevation and steep slopes at the PI and locally the steep gradients of the drainage channel provided an environment conducive for rapid down-slope movement once the slides developed.

The two debris slides that are collectively referred to as the PI occurred on steep colluvial slopes at or near the base of relatively high bedrock cliffs. Above the cliffs the hillsides, which underlie a portion of the area of the earlier timber harvest, slope toward the cliffs. This topography would direct runoff toward the cliff and the area of the PI. As discussed in **Section 4.5**. the amount of additional runoff from the timber harvest area could vary from very little to significant. The contributory area above the PI would not be large due to the orientation of the cliff face, the narrow size of the PI, and thus the narrow nature of hillside area above the cliff that shadows the PI. Thus the portion of increased peak-flow water directed into the area of the PI from above would not be great. In addition, except for the one poorly developed rock cleft discussed earlier, bedrock features that would direct runoff from above into the area of the PI were not observed. In the case of the east PI the crown of the debris slide scar is not even located at the base of the cliff, but located down slope from the base of the cliff. Though some groundwater from the harvest area does eventually percolate through the subsurface and into the PI area, it is my opinion that it is not likely that groundwater movement through the soil and bedrock could have occurred quick enough, or in sufficient volume, to have reached the PI in a couple of days and been a factor in the development of the debris slides that caused the debris flood. Likewise there is no evidence that significant peak flows were generated, or that whatever water was present was concentrated into the area of the PI. In my opinion it is more likely that the debris slides occurred in response to very local conditions. The weak colluvial soils standing in steep slopes were likely already potentially close to failure. Review of the climate history suggests the early January storm was comparatively a fairly extreme event. The water introduced by the melting snow and accompanying rainfall on a possibly already weak slope provided the proverbial “straw that broke the camels back” and triggered the slope failures and subsequent debris flood.

8.0. RECONNAISSANCE LIMITATIONS

This reconnaissance report presents a qualitative assessment of the debris slide and associated debris flood that impacted the property located at 6578 Goodwin 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) Was the PI of the debris slide on DNR managed lands?

2) Was the PI in an area of recent management activity?
3) Did the management activity contribute to debris slide initiation and the subsequent debris flood?
4) How much did the management activities contribute the initiation of the debris slide and the debris flood?

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, my 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 an original signature and stamp, or authorized facsimiles of the same.

END

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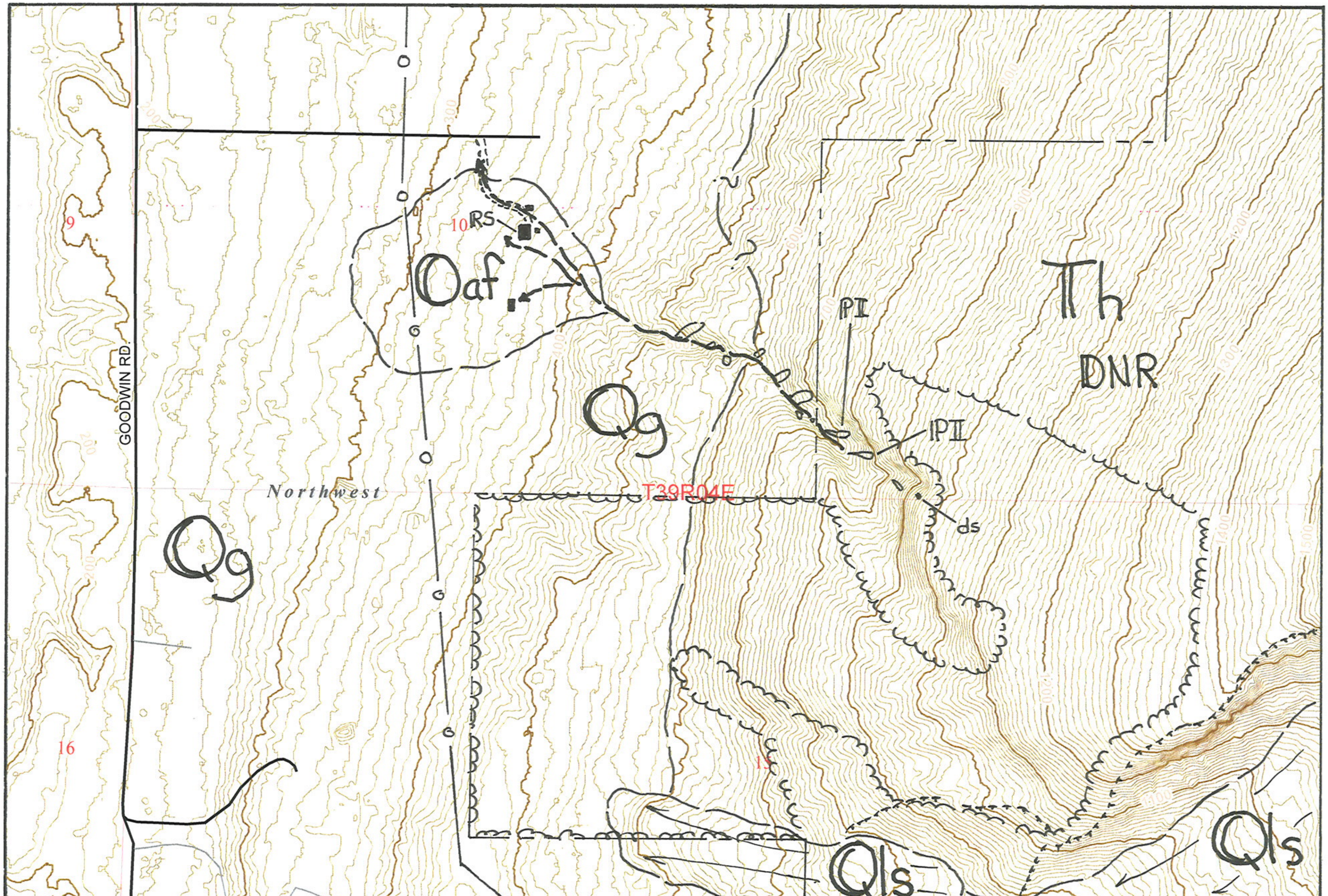
AERIAL PHOTOGRAPHY REVIEWED

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 8-45-65 and -67 to -68	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 73-45-35 to -36	1:12,000	Color



1"= 500'
1:6,000

N
W
E
S

410
Feet

Figure 2. Simplified Geology Map
Engineering Geologic Field Reconnaissance
Debris Slide and Debris Flood Affecting 6578 Goodwin Road
Whatcom County, Washington

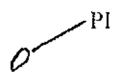
Compiled from Lapen (2000), field reconnaissance, interpretation of aerial photographs, and interpretation of LiDAR topography

EARTH MATERIALS

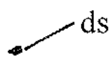
Qaf	Alluvial fan deposits
Qls	Landslide debris
Qg	Glacial outwash and undivided deposits
Th	Huntingdon Formation

MAP SYMBOLS

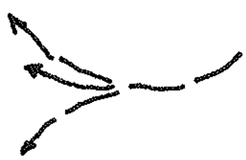

Geologic contact, queried where uncertain



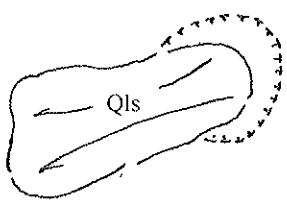
Point of Initiation of debris slide and debris flood



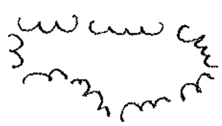
Debris slide discussed in Section 6.1.


Approximate route of debris slide track and general routes of debris-flood lobes on alluvial fan surface

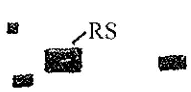

Landslides on slopes of Jones Creek



Landslide, shows crown of scarp of landslide


Approximate boundary of the Gasping Goodwin Aerial timber sale

Property line



Approximate location of residential structure and out buildings on the affected property RS = Residential Structure


Approximate location of the gas pipeline

FIGURE 2A. Explanation for: Figure 2. Simplified Geologic Map
Engineering Geologic Field Reconnaissance
6578 Goodwin Road
Whatcom County, Washington

Figure 3. Upper portion of eastern most debris slide scar of the PI. The other debris slide scar that is part of the PI is about 70 feet to the west (left in the photo). View looking to the north.
(Photograph by D. Hooks)

Figure 4. View of debris deposited on upper area of alluvial fan. Residence with blue-gray roof, other structures are out buildings. View looking northwest.
(Photograph by D. Hooks)

Figure 5. View looking up slope toward apex of alluvial fan that has developed at mouth of Jones Creek. Gully eroded by storm runoff crosses left area of photograph. Sediment and organic debris deposited by debris flood seen to left (south) of gully. View looking southeast.
(Photograph by D. Hooks)

Figure 6. Photograph looking up slope on alluvial fan and gully showing volume of debris deposited and water in gully. View looking southeast.
(Photograph by D. Hooks)

Figure 7.
View of debris deposited on lower area of alluvial fan and covering driveway. Note runoff in shallow channels eroded in debris. View looking southeast.
(Photograph by D. Hooks)

Figure 8.
View of debris spread out across lower areas of Site, including driveway and vegetated areas. View looking to the southeast.
(Photograph by D. Hooks)

Figure 9. Lobe of debris that flowed over vegetated areas on south side of residence (red brown structure in background on right side of photograph). White structure is an out building. View looking west. (Photograph by D. Hooks)

Figure 10. Overview of debris deposited on lower areas of Site and driveway extending to the western edge of the property. View looking northwest. (Photograph by D. Hooks)