Appendix C

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE

DAM BREAK, DEBRIS FLOOD,
AND
AFFECTED PROPERTIES

Marshall Hill Road and Mt. Baker Highway
Whatcom County, Washington

Prepared for:

Jeff May
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Washington Department of Natural Resources
Land Management Division

May 31, 2009

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

Caring for
your natural resources
... now and forever

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

SUBJECT: **ENGINEERING GEOLOGIC FIELD RECONNAISSANCE**
Dam Break, Debris Flood, and Affected Residential Properties
Marshall Hill Road and Mt. Baker Highway
Whatcom County, Washington

DATE: May 31, 2009

The following Engineering Geologic Field Reconnaissance report presents our findings and a discussion regarding the dam and debris flood that affected several residential properties along Marshall Hill Road and Mt. Baker Highway in Whatcom County, Washington. The dam break and flood occurred during the early January 2009 storm. This reconnaissance report addresses the following points: 1) location of the dam break that caused the debris flood, 2) was the dam break in an area of recent forest-management activities, 3) did the management activities contribute to dam break and debris flood initiation, and 4) how much was that contribution.

If you have any questions, please call.

Respectfully submitted,

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Marshall Hill Road & Mt. Baker Highway
Whatcom County, Washington

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

SUBJECT: **ENGINEERING GEOLOGIC FIELD RECONNAISSANCE**
Marshall Hill Debris Flood
Whatcom County, Washington

DATE: May 31, 2009

1.0. INTRODUCTION

At your request we have completed an engineering geologic reconnaissance of the dam break and debris flood, referred to herein as the Marshall Hill Debris Flood, which occurred at the southeast end of Sumas Mountain. The dam break and debris flood occurred in the early morning of January 8th 2009 (Initial Incident Report, 2009). This flood affected 19 properties, two county roads, one state highway, and one other road in the west-central area of Whatcom County (Figure 1). The flood occurred during the early January 2009 storm. The debris flood initiated with a dam break involving an orphaned road in the SW¼ of Section 20, T39N, R5E; and affected roads and properties located in Sections 29, NE¼ 32, and the NW¼ of 33, T39N, R5E (WBL & M) in the US Geological Survey Deming 7½ minute Quadrangle. The debris flood and properties are situated in the Deming Watershed Administrative Unit. To date neither Watershed Analysis nor Landslide Hazard Zonation mapping has been undertaken for this area. The Deming Mountain Road Maintenance and Abandonment Plan (RMAP) covers the area where the debris flood initiated, however it does not identify a road or railroad grade at the dam break location (Department of Natural Resources, 2004). The properties are 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 Department of Natural Resources (DNR) Initial Incident Report (IIR) used the title of Marshall Hill Slide to identify the incident that is the subject of this reconnaissance report. In this report we have chosen to identify the incident in question using the name Marshall Hill Debris Flood.

Shortly after the debris flood, McDonald (2009a) identified the impacted private and public properties. The private properties affected to greater or lesser degrees belonged to: Brester, Cronk, Demeyer, Gerber, Graham, Johnson, Knebel, Monaghan, Seefeld, Raper, Rensink, and Williams. Affected public properties include Mt. Baker School District 507 and Whatcom County Parks and Recreation. The County roads affected were Marshall Hill Road and Truck Road. State Highway 542 (aka, Mt. Baker Highway) was also impacted, as was Deal Road, a road between the two county roads. Please see Figure 2 for the location, at the base of the hill, of the affected properties and roads.

The purpose of our geologic field reconnaissance was to locate the point-of-initiation (PI) of the debris flood (in this case the dam break), observe the site conditions at the PI, observe the conditions along the debris flood track, and note conditions in the area of deposition. In addition, we were asked to provide a professional opinion, based on the office data reviewed and field evidence we observed, as to the natural and, if applicable, the anthropomorphic contributory factors that influenced the development of the dam break, as well as the triggering event that caused the flood. We also provide site specific recommendations intended to help reduce the potential for future debris floods and property damage at the site in question.

2.0. SCOPE OF WORK

Our scope of work included the following tasks:

- Review of pertinent published and unpublished geologic reports and maps in our office files
- Review of 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 Forest Practices Application history in and about the area in question
- Reconnaissance of the debris flood point-of-initiation (the dam break) and flood track
- Reconnaissance of the depositional area of the debris flood
- Photographing pertinent aspects of the debris flood and flood track
- Review of relevant photographs of the depositional areas
- Review of pertinent historical rainfall and snowfall data
- Review of available rainfall and snowfall data related to the January 4 to 8, 2009 storm
- 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 Earth Sciences Program in which the general nature of the proposed reports and estimated schedule of field work and report completion were discussed. No specific site was discussed in any detail.

3.0. LIST OF ILLUSTRATIONS

4.0. PHYSICAL SETTING

The physical setting of the dam break PI, the debris flood track, and the area of deposition (all collectively referred to as the "Site") are characterized by the topography, climate, geology, and landslides. 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: hillside area and valley floor (Figures 1, 2, and 3). In the hillside area the PI is at the southeast end of a graben-like forested wetland area at the head of a very large deep-seated landslide (Figure 3) at an approximate elevation of 2,100 feet. Drainage from the graben-like area is directed to the southeast and quickly descends into an incised drainage cut into moderate to locally precipitous hillside topography. This drainage is informally named the Marshall Hill Drainage (Figure 3). Locally this drainage is characterized by inner-gorge topography, well incised with high steep side-slopes, bedrock cascades, and towering waterfalls; however, several stretches exhibit relatively gentler gradients with more subdued topography. The affected residences are located on gentle slopes at the base of the hillslope and further to the southeast on a terrace-like area of the North Fork Nooksack River valley floor.

At the Site the southwest-facing slope of Sumas Mountain exhibits an average inclination of about 20% along the flood track. However, local bedrock cliffs characterized by essentially vertical inclinations of several tens of feet are present. About 700 feet to the southwest of the Site is another well-incised drainage. Geologic mapping published by Dragovich and others (1997) characterizes the site of the residential structures as collaesing alluvial fans that have built up at the mouths of the Marshall Hill drainage and an unnamed drainage to the southwest (Figures 2 and 3). The depositional area and affected residences are situated on the relatively gentle topography of these alluvial fans, at elevations of approximately 260 to about 370 feet. The alluvial fans extend about 1,800 feet to the southwest from the mouth of the drainage to the North Fork Nooksack River. Levees border both sides of the Marshall Hill Drainage channel at the mouth of the drainage. The local relief between the depositional area and the PI is high, approximately 1,780 feet vertical over a horizontal distance of about 9,000 feet, measured from the base of the slope.

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 Site is about 6½ miles southwest of the Canyon Lake and Kenney Creek watershed and is likely subject to similar general climatic conditions as that watershed. Based on the general climatic description for the Canyon Lake and Kenney Creek watersheds it is reasonable to infer that in the area of the Site the majority of the rainfall occurs between mid-October and late February (Canyon Lake and Kenny Creek Watershed Analysis, 1993). Yearly rainfall in the Canyon Lake and Kenney Creek watershed is estimated to average about 70 inches in the lower elevations to about 100 inches/year at higher elevations. The nearest weather reporting station is located at the Glacier Ranger Station (Western Region Climate Center (WRCC), 2008), about 18½ miles to the northeast of the Site.

The Glacier recording station is some distance away but is at an elevation of approximately 1,000 feet. In our opinion it does not appear to be unreasonable to assume that historical precipitation conditions at the PI are at least somewhat similar to the Glacier station. The area of the PI is in the rain-on-snow dominated zone. The generally accepted zone of rain-on-snow influence in this portion of the Cascades is from 1,600 to 4,000 feet (Canyon Lake and Kenny Creek Watershed Analysis, 1993). 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. The WRCC (2008) reports the annual average rainfall at the Glacier Ranger Station varies between about 68¾ and 71 inches with a yearly standard deviation of about 12 inches. The mean annual for the 1949 to 1983 POR is 66⅔ inches of rain. 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 .15 to .6 inches for both months. However, the maximum one day total in January during the POR is about 3½ inches, for one day in December is about 4⅔ inches. Based on the daily average the highest 4-day average would be about 1¼ to 1½ inches for both months. 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 POR for snowfall – 1948 to 1982. 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, 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 a foot-and-a-half or so 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 10 inches, and the January rainfall equaled or exceeded 10 inches, to try to provide a minimum match to the conditions leading up to the January 2009 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 January’s 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.

4.2.2. January 2009 Storm – The damaging storm in question began on January 4 and continued to January 8, 2009, and followed on the heels of the December 2008 snow storms mentioned above. No recording stations are located at the Site or immediately near it. However, interpretation of a map of radar imaging of the four days of rain (National Weather Service, 2009) suggests that the area near the south end of Sumas Mountain received about 9 to 11 inches of rain during that period. 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 the south end of Sumas Mountain and slopes above the affected residences is also uncertain. However, based on anecdotal discussions with the Unit Forester at the Deming Work Center, it appears that the snowpack was a couple of feet, maybe as much as three feet. Rainfall, 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. In addition, wind speeds between 20 to 30 mph from the SSW 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 bedrock and the surficial deposits that overlie the bedrock. Surficial deposits include glacial sediments, soil and colluvium, landslide debris, alluvial fan deposits, and alluvial deposits. A brief description and general distribution of these earth materials is presented below and shown on Figure 3. Two geologic maps covering the Site were reviewed.

4.3.1. Bedrock – The bedrock geology at the Site is represented by the Eocene age Padden Member of the Chuckanut Formation (Dragovich and others, 1997). The Padden Member is moderate- to well-sorted sandstone and conglomerate alternating with mudstone and minor coal (Dragovich and others, 1997). Several southwest-northeast trending synclines and anticlines are mapped in the vicinity of the Site and consequently mapped bedrock attitudes show a wide range of strikes and dips. At the Site the bedrock exhibits a general northwest strike and dip to the southwest. Locally the bedrock is broken by sets of generally steeply dipping northeasterly and northwesterly striking joints. The bedrock crops out at many locations along the scoured stream channel at the Site and is assumed to underlie the surficial deposits about the Site.

4.3.2. Surficial Deposits – The **glacial sediments** in the area are generally mapped as glacial till with some glacial deposits mapped as drift (Dragovich and others, 1997). Patches of glacial till are mapped at elevations above and below the 2,100-foot elevation of the PI. No glacial deposits are mapped along the flood track; however, field observations indicate local glacial deposits are present. These deposits are composed of bedded to poorly-bedded gravel, sand, silt, and clay.

Soils and colluvium are derived from the mechanical and chemical weathering of the underlying bedrock. These deposits are composed of varying amounts sand, silt, and clay intermixed with blocks of bedrock and organic debris. Soil mapping obtained from the Natural Resources Conservation Service website (2009) classifies the soils underlying the lower gradient portions of the Site as Comar silt loam and those underlying the steeper gradient slopes as Andic Xerochrepts on 60 to 90% slopes. The Comar silt loam is characterized as moderately well drained and has a moderately high water capacity. The Andic Xerochrepts soil is described as a loam intermixed aerially with bedrock outcrops. The loam component is characterized as well drained, moderately permeable, having a high water capacity, moderate runoff, and moderate 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.

Landslide debris is composed of a mixture of sand, silt, clay, and blocks of bedrock. The blocks of rock can be quite variable in size. More recent slides can also contain organic debris.

Alluvial fan deposits are composed of interbedded debris-slide deposits and fluvial sediments. The debris slide deposits consist of generally poorly-stratified, poorly-sorted deposits soil and accumulations of angular bedrock debris. They are mapped to occur at the mouths of Marshall Hill Drainage and the unnamed drainage.

Alluvial deposits are composed of stratified gravel, sand, silt, and clay. They underlie the valley floor areas of the Site, and can be interfingered with the alluvial fan deposits.

4.4. LANDSLIDES

Landslide processes in the area of the Site can be classified into two broad categories: 1) More-or-less intact rotational or translational slides of widely varying size and thickness and 2) debris slides and debris floods. Debris slides are essentially confined to the side slopes of the drainages. As can be seen of Figure 3 a very large deep-seated translational slide underlies large portions of the hillside area just to the west of the debris flood track. Rockfall processes likely also occur at the Site, but are probably very rare and relatively small in scale, though the collapse of the entire hillside, as happened to the south (Devils Slide area), can not go unnoticed (Brunengo, 2001). Very large earth flows have been recognized and mapped on the east side of Sumas Mountain to the north of the Site.

5.0. HISTORICAL SETTING

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

5.1. LANDSLIDE HISTORY

Review of 6 sets of aerial photographs dating from 1976 to 2001 reveled only a couple of small debris slides originating on flood channel side slopes in the Site. The 1976 aerial photographs showed minor debris-slide activity on the north and south slopes of the debris flood channel on the higher gradient slopes near the base of the hill. This slide activity was in a recent clear cut estimated between 5 and 15 years old based on vegetation observed on aerial photos. No run out down the channel was observed on aerial photos and it could not be determined whether the slides were influenced by logging activities such as tree falling and yarding. No other landslide activity was observed along the debris flood track or in the area of the large mapped deep-seated landslide on the photographs reviewed.

Evidence suggesting past debris slide activity is limited in the area of the Site. Our field observations and interpretations of the LiDAR topography suggest that a subtle alluvial fan has developed at the mouth of the Marshall Hill Drainage and the unnamed creek. The alluvial fan deposits are mapped by Dragovich (1997) and illustrated in Figure 3. The gently sloping fan shape along with the small amount of topographic relief from the apex to the distal end of the fan indicate that only minor amounts of material have been deposited in this area. This likely indicates debris flow and/or debris flood events in this channel are infrequent. It is also possible that the alluvial fan has developed almost exclusively from stream erosion and deposition with little or no debris flow/debris flood history at the Site.

5.2. FOREST PRACTICES AND LAND USE HISTORY

The past forest practices history and land use history are briefly discussed below. The forest practices history is discussed first. That discussion is based on review of vertical, stereographic aerial photographs dating back to 1976 and review of information in the forest practices applications database. The land-use history is derived from review of the same aerial photographs and information from the database of the Whatcom County Assessors office.

5.2.1. Forest Practices History – The following discussion is based on review of vertical, stereographic aerial photographs dating back to 1976 and review of the DNR database which had record of several harvest activities adjacent to or in the vicinity of the Marshall Hill Drainage dating back to late 1980s. The 1976 aerial photographs show by that time most of the south end of Sumas Mountain had been logged and based on the appearance of regeneration in the aerial photos the harvesting may date to more than 30-years earlier. We presume that the road grade associated with this debris flood was constructed during this period of historical logging. No new clear cuts are visible in the photo record again until the 1995 photographs when large areas of the south end of Sumas Mountain were starting to be harvested again. The 2001 photos show a DNR State Lands timber harvest named Welcome Mat located mid-slope to the west of the debris flood channel.

As part of the more recent timber harvest activity, two roads were constructed across the Marshall Hill Drainage. The lower road, named the D-6100, was constructed across the Marshall Hill Drainage between 1995 and 2001; the upper road, named the D-6200, shows up on the 1976 photos and so it was constructed prior to that. Both crossings are not in inner gorges and culverts were placed in both stream crossings.

5.2.2. Land-Use History – Review of aerial photos shows the residential structures and, where present, the associated outbuildings on the Cronk, Johnson, Monaghan, and Raper properties were built prior to 1976. On the Knebel property the current residence near the highway was present on the 1976 aerial photographs. We could not locate the Brester residence on the available aerial photography; however review of the Whatcom County Assessor database indicated the Brester house dates from early in the last century. The structure on the Gerber property first appears on the 1978 aerial photographs. On the Knebel property the second structure, located further back from the highway, was built between 1983 and 1995. All the roads are present on the 1976 aerial photography.

6.0. RECONNAISSANCE OBSERVATIONS

Our reconnaissance observations are presented below. In the first subsection our reconnaissance of the debris flood track and PI (dam break site) is presented. The next subsection briefly summarizes the damage to the affected properties. Figure 3 shows the approximate location of the dam break. The length of the debris flood track is reported to be about 1¾ miles long (Initial Incident Report, 2009).

We have classified the mass of soil, rock, and organic debris that came down the Marshall Hill Drainage as a debris flood based on nomenclature advanced by Hungr and others (2001). Debris floods are described as surging flows of water with a high debris content in a steep channel (Hungr and others, 2001). Debris floods move at an extremely rapid rate; greater than approximately 16 feet (5 meters) per second. Debris floods are differentiated from debris flows in part by the morphology of the deposit. In general, debris flood deposits are thin, wide sheets of material as opposed to debris flow deposits which are generally thicker, hummocky, and lobate (Hungr and others, 2001). Debris floods are also differentiated from debris flows by the impact they have on objects and structures in their paths. Structures and objects are typically surrounded by debris and damage to the structures is usually similar to a water flood. Debris floods can occur on slope gradients lower than those generally required to sustain the mobility of debris flows. Our field observations of the deposition area at the Site indicate damage to homes and structures was similar to those observed in a water flood, with the exception of the crushed structure near the base of the slope where the channel gradient makes a relatively sharp transition from high gradient to low gradient channel.

6.1. DEBRIS FLOOD TRACK AND PI (DAM BREAK) SITE

On February 2nd and 3rd, 2009, we traversed the entire debris flood track from the deposition area to the PI. We started at the bottom and worked our way upslope across the D-6100 forest road stream crossing and up to the D-6200 forest road stream crossing on the first day. On the second day we drove in on the D-6200 road and walked up to the PI, the dam-break location.

Along the steeper gradient portions of the stream, the channel is now scoured to bedrock. The depth of scour varied locally from approximately 10 feet to 35 feet. Bedrock exposed in the streambed includes fine- to medium-grained sandstone with probable shale interbeds; and conglomerate. Some of the exposed sandstone is laminated and fossiliferous. Distinct joint sets with varying orientations were observed in the exposed bedrock. Two near vertical waterfalls are present in the lower stream channel near the base of the slope.

Following the initial debris flood event, small slumps have developed in channel side slope colluvium in areas where channel side slopes were over-steepened by erosion from the debris flood. These slumps typically involved between 20 and 30 cubic yards of material and have deposited in the channel bottom.

Evidence for the large volume of water and the high rate of flow was obvious everywhere along the channel. Both the D-6100 and D-6200 roads were washed out during the debris flood event (Figures 4 and 5). From measurements of the deformed culverts left behind in the stream crossings, we estimate the culverts were 48 inches in diameter. A large boulder approximately 6 feet by 6 feet by 10 feet was deposited by the debris flood on the D-6100 road grade (Figure 4); another indicator of the extreme volume of water moving down the channel during the debris flood event. Logs and rocks were abundant on both road surfaces on either side of the washed out D-6100 road grade.

Between the D-6100 and D-6200 forest roads, glacial material including glaciolacustrine deposits with abundant cobbles was observed. Landslide debris was also exposed in inner-gorge slopes. In addition, a shear zone up to about 2-feet thick with slickensides, polished surfaces, and mashed and broken rock was exposed in the inner gorge along this stream reach. This shear zone provides field evidence for the large deep-seated landslide mapped to the west of the debris flood track (Dragovich and others, 1997) of which the stream and debris flood track make up the eastern lateral margin (Figure 3).

The debris flood PI is located at a failed orphaned road-fill prism (Figure 6) at the easterly end of a wetland approximately 1½ acres in size. The depth of the water behind the orphaned road prior to failure was an estimated 8 feet. The 8-foot depth is based on the apparent contact between snow and water prior to the presumed rapid draining of the wetland when the orphaned road prism failed. The snow-water or snow-ice on top of water contact was well preserved at the time of our field visit. The failed road prism appears to have been essentially level prior to failure. At the orphaned road centerline, the washed out gap measured 40-feet wide with an upstream gap of 30 feet and a downstream gap of 43 feet. The depth from the top of the upstream side of the road prism to the creek bottom was 22-feet, post failure. The up-stream side of the orphaned road fill appeared to be 9½ feet high, with respect to the bottom of the wetland, prior to failure. It does not appear that the impounded water overtopped the dam. Instead it appears that the fill prism failed by some other mechanism, most likely saturation of the fill. It was unclear from field observations whether a culvert was present in the fill prism prior to failure. No culvert remnants were observed in this area at the time of the field visit, however it would be expected that evidence of a small culvert would be washed away in an event of this magnitude. The fact that the fill prism had not failed sooner suggests that a culvert was likely present, but was not functioning in order for the water to accumulate to a depth this time to saturate the fill and trigger the failure and flood.

On the west side of the inner gorge of the Marshall Hill Drainage at the east-west section line (Figure 3) between Sections 20 and 29 (about 7,200 feet from Mt. Baker Highway) we observed a system of ground cracks. This system is about 25 to 30 feet back from the top of the inner gorge. The cracks extended for perhaps a hundred feet or so. The cracks were open from 2 to 5 inches and appeared to be associated with a subtle break-in-slope that varied from about 1- to 6-inches high.

6.2. SUMMARY OF DAMAGE TO AFFECTED PROPERTIES

A brief summary of the damage to the affected properties is presented below. Private properties are first discussed and the affected properties are grouped as to whether they are hillside or valley floor and in alphabetical order. Following this, damage to public properties including roads is briefly reviewed. The depositional area is about 23 acres (Initial Incident Report, 2009). Please see Figure 2 for the location of the properties at the base of the slope and the roads.

6.2.1. Hillside Private Properties – Hillside private properties include **Gerber**, **Graham**, **Mt. Baker School District**, **Seefeld**, and **Williams**. Damage to these properties was confined to scour of the channel and associated erosion of side slopes where Marshall Hill Drainage crossed the respective properties. Subsequent side-bank failures occurred locally.

6.2.2. Valley-Floor Private Properties – The valley floor properties experienced greater damage, in some cases much greater damage.

Brester Property – About half the property was inundated with mud and debris. An existing small house was crushed and a small trailer wrecked (Figure 7).

Cronk Property – Debris just grazed the existing house but apparently did little if any damage to the house. Mud and debris was deposited over a good portion of the western areas of the property covering a large area of pasture land (Figure 8).

Demeyer Property – A small portion of pasture land in the northwest corner of the property was inundated with mud and debris.

Johnson Property – The house on the Johnson property was surrounded by mud and debris, including beneath the house (Figure 9). Mud also got into the interior of the house.

Knebel Property – It appears that there are two homes on this property. One located near Highway 542 and the other is near the creek, set back from the highway about 250 feet. At the house near the highway mud and debris was deposited adjacent to the house (Figure 10). At the other house Debris was placed against the house and mud splattered on the sides of the house (Figure 11). At least one window was broken and mud got into the house.

Monaghan Property – Mud and debris was placed against the house and spattered on the exterior walls (Figure 12). Windows were broken and mud got into the interior of the house. It appears that a metal awning on the south side of the house was ripped off the house and incorporated into the debris and carried away toward the North Fork Nooksack River along with a motor vehicle. The property was almost completely covered with flood debris.

Raper Property – Mud and debris was deposited across the eastern portions of the property. Some came to rest next to the existing residence (Figure 13).

Rensink Property – Large portions of pasture area between Truck Road and North Fork Nooksack River were covered with debris.

6.2.3. Public Properties – Public properties include one Whatcom County holding and four roads.

Whatcom County Parks and Recreation – The eastern area of a parcel along the North Fork Nook Sack River was covered with mud and debris (Figure 14).

State Highway 542 (aka Mt Baker Highway) – The highway was covered with mud and debris.

Marshall Hill Road – The road was covered with mud and debris (Figure 15).

Truck Road – The road was covered with mud and debris (Figure 15).

Deal Road – The road was covered with mud and debris (Figure 15).

7.0. DISCUSSION

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

1) Was the PI of the slide on State Lands?
2) Was the PI in an area of harvest activity?
3) Did harvest activity contribute to the failure?
4) How much was the contribution?

In the following discussion we provide our observations and opinions with respect to these questions.

The Marshall Hill Debris Flood PI, the dam break, is located on DNR-managed land. The PI is in an area of historic harvest activity inferred from the presence of the old road grade and associated fill prism and regenerated mature timber that did not appear to be old growth. No recent harvest activity has occurred at the PI site as it is surrounded by mature mixed conifer and hardwood trees.

In our opinion, the Marshall Hill Debris Flood was not a natural event. The field evidence clearly shows that the orphaned road grade created a dam. A large pond developed behind the dam as the result of several days of extreme rain and warming that caused significant snowmelt. Either a culvert existed, and at the time of the storm could not drain the pond fast enough because it was too small or damaged, or there was no culvert and this ROS event was so much greater than any other earlier event that the fill prism was overwhelmed by the water in the pond and failed. The catastrophic failure of the orphaned road-fill prism allowed the pond to drain very rapidly, initiating the debris flood. Without the orphaned road-fill prism damming the wetland outlet and creating a pond, it is our opinion that a debris flood of this magnitude would not have occurred.

Similar smaller-scale debris flood events have likely occurred naturally in the past and will potentially occur naturally in the future as the result of slumps and debris slides from inner-gorge slopes damming the creek and failing catastrophically as natural dam break floods. The crack system near the 20/29 section line mentioned above could potentially develop into a slope failure that could dam the drainage. While this process is a possibility, we did not observe other locations along our traverse that showed evidence of potential for causing a catastrophic dam break flood similar to the magnitude of the Marshall Hill Debris Flood in the foreseeable future. This should not be construed as a guarantee that a similar debris flood event could not happen again.

8.0. RECOMMENDATIONS

Now that the orphaned road-fill at the wetland outlet is gone, the hazard of another event resulting from water ponding behind the fill is no longer present. We recommend that if the D-6100 and D-6200 roads are rebuilt across the debris flood track, additional attention is paid to appropriate culvert sizing. Also, if the orphaned road at the PI is ever proposed for reconstruction, we recommend an oversize culvert be placed in the fill during road use and that the culvert be pulled and the fill removed following road use.

9.0. RECONNAISSANCE LIMITATIONS

This reconnaissance report presents a qualitative assessment of the debris flood that impacted several residential and public properties located on the south end of Sumas Mountain in Whatcom County during the early January 2009 storm. The charge of this reconnaissance was to develop an opinion with respect to the following questions:

1) Were the locations of PIs that caused the debris floods on State-managed lands?
2) Were the PIs in areas of recent management activities?
3) Did the management activities contribute to the slides and debris flood initiation?
4) How much was that contribution?

This reconnaissance report presents observations and opinions, with respect to these questions, based on field reconnaissance and review of office derived data. If new information should become available, the geologic interpretations, and thus, the discussion and subsequently, the recommendations could require modification.

The signature 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 signature and stamp or authorized facsimiles of the same.

END

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AERIAL PHOTOGRAPHY REVIEWED

Date	Flight Line/Frames	Approx. Scale	Medium
7/15/76	NW-C-76 24C-19 to 21	1:24,000	Color
6-3-78	NW-78 62B-1 to 4	1:12,000	B/W
5/23/83	NW-C-83 13-49 387 to 392	1:12,000	Color
5/26/95	NW-95 30-49-2 to 8	1:12,000	B/W
8/26/01	NW-C-01 58-49- 87 to 93	1:12,000	Color

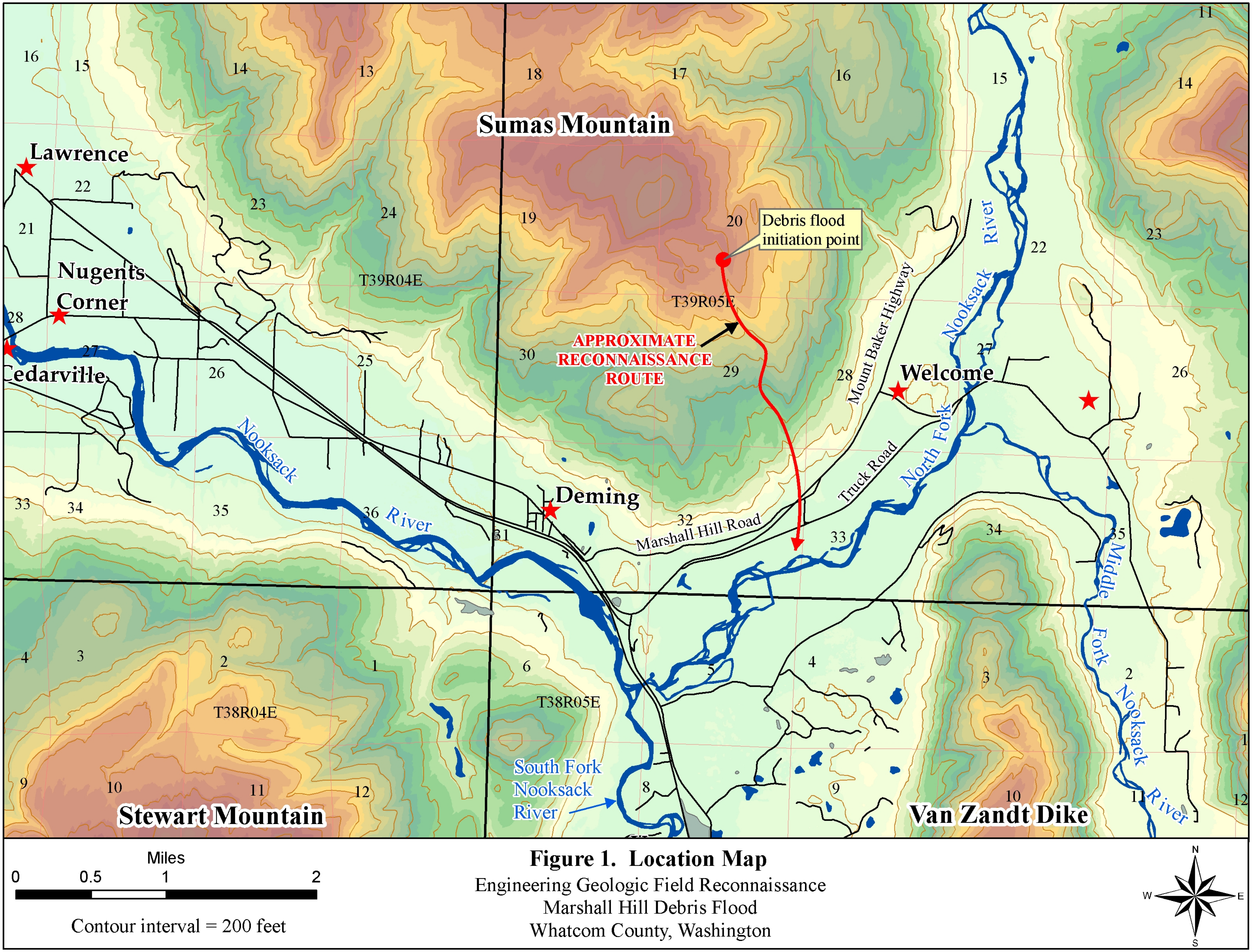

Figure 1. Location Map

Engineering Geologic Field Reconnaissance
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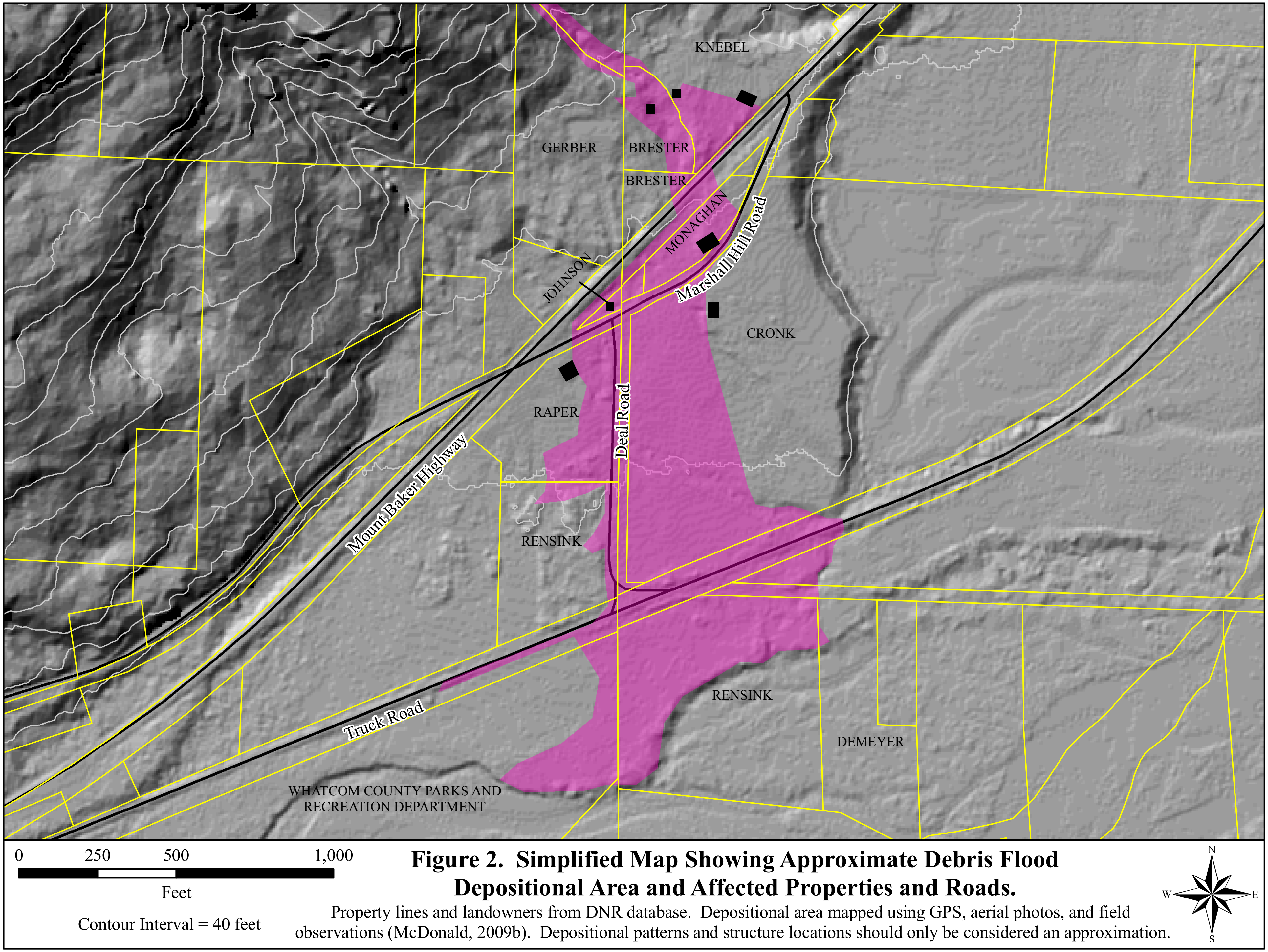


Figure 2. Simplified Map Showing Approximate Debris Flood Depositional Area and Affected Properties and Roads.

Property lines and landowners from DNR database. Depositional area mapped using GPS, aerial photos, and field observations (McDonald, 2009b). Depositional patterns and structure locations should only be considered an approximation.

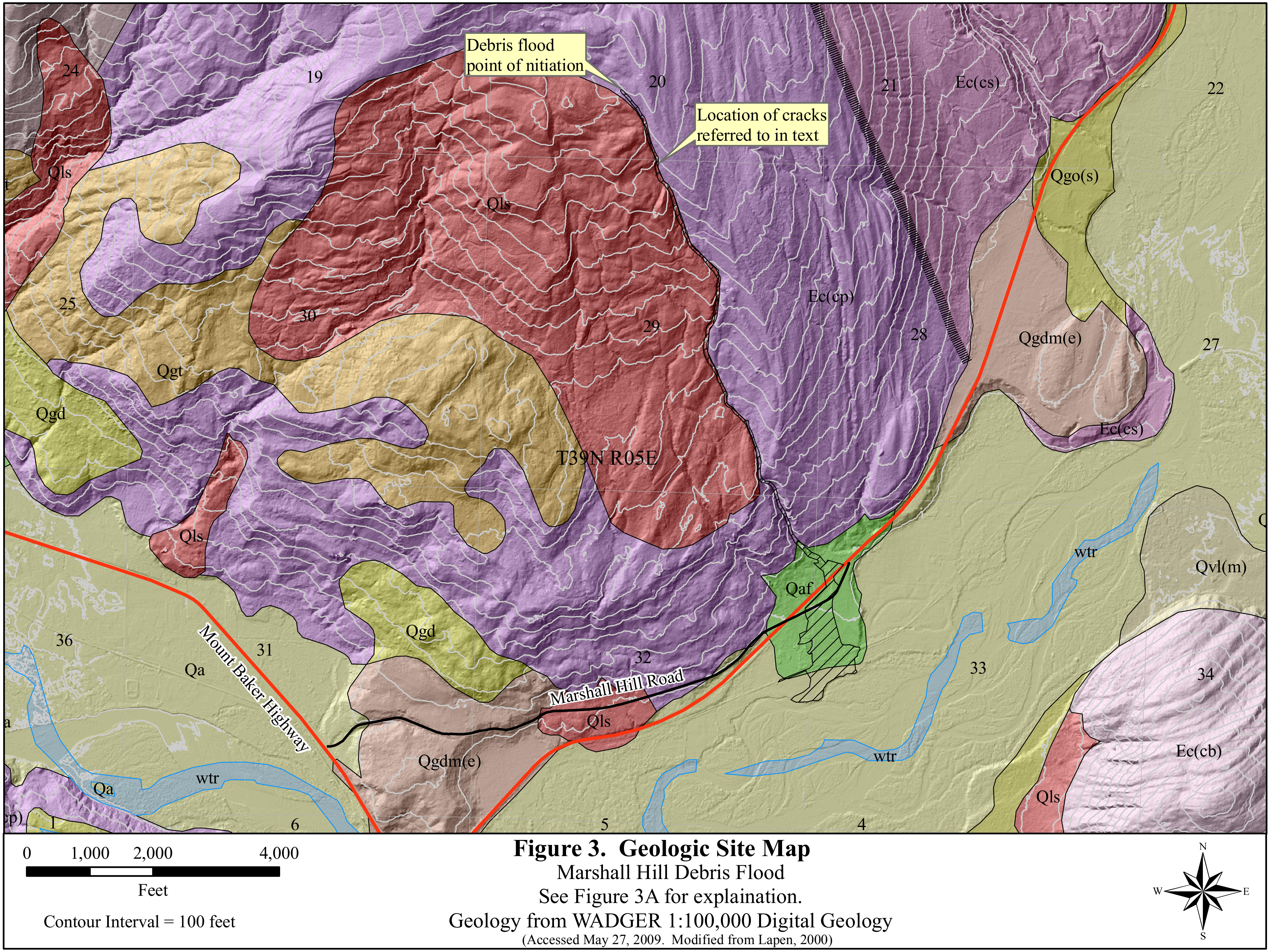


Figure 3. Geologic Site Map

Marshall Hill Debris Flood

See Figure 3A for explaination.

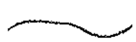
Geology from WADGER 1:100,000 Digital Geology

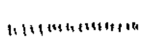
(Accessed May 27, 2009. Modified from Lapen, 2000)

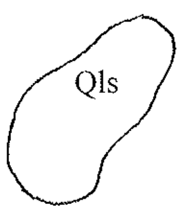
EARTH MATERIALS

Qa	Alluvium
Qaf	Alluvial fan deposits
Qls	Landslide debris
Qvlm	Lahar deposits
Qgd	Glacial deposits undifferentiated
Qgos	Glacial outwash
Qgdme	Glaciomarime drift
Qgt	Glacial till
Ec(cb)	Chuckanut Formation – Bellingham Bay member
Ec(cs)	Chuckanut Formation – Slide member
Ec(cm)	Chuckanut Formation – Maple Falls member
Ec(cp)	Chuckanut Formation – Padden member

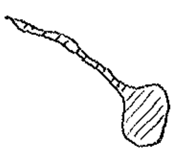
MAP SYMBOLS


Geologic contact


Gradational geologic contact



Landslide


Debris flood track and depositional area, see Figure 2 for greater detail in depositional area

29 Section number

wtr water, course of North Fork Nooksack River

FIGURE 3A. Explanation for Figure 3 Geologic Site Map

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Figure 4. Photograph of Large Boulder Deposited on D-6100 Road. Photograph taken facing west.

Figure 5. Photograph of Washed Out D-6200 Road. Photograph taken facing north.

Figure 6. Photograph of Debris Flood Point-of-Initiation, Dam Break Site. Photograph taken facing southeast.

Figure 7. Photograph of Brester Residence Post Debris Flood. Photograph taken facing west.

Figure 8. Photograph of Cronk Residence Post Debris Flood. Photograph taken facing east.

Figure 9. Photograph of Johnson Residence Post Debris Flood. Photograph taken facing northeast.

Figure 10. Photograph of first Knebel Residence Near Highway 542 Post Debris Flood. Photograph taken facing southeast.

Figure 11. Photograph of second Knebel Residence Approximately 250 Feet Northeast of Highway 542 Post Debris Flood. Photograph taken facing northeast.

Figure 12. Photograph of Monaghan Residence Post Debris Flood. Photograph taken facing southeast.

Figure 13. Photograph of Deal Road and Raper Residence Post Debris Flood. Photograph taken facing north.

Figure 14. Photograph of the South End of the Debris Flood Deposition Area.
Photograph taken from helicopter facing southeast.

Figure 15. Photograph of the North End of the Debris Flood Deposition Area.
Photograph taken from helicopter facing northeast.