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DEBRIS FLOW ASSESSMENT
EILERTSEN CREEK/WOODSON
December 2007 Storm
T 7N, R 5W, Sections 5, 8, & 17

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Prepared for:

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EXECUTIVE SUMMARY

Since 1914, the area of Woodson, Marshland, and Kerry has been subject to at least 6 different newsworthy debris flows which have caused property damage, injuries, and deaths. Due to timely warning and evacuation of Woodson and the closure of Highway 30, the damage from the December 11, 2007 debris flow event was limited to property.

The debris flow which reached Woodson started at an embankment initially constructed for the Kerry Railroad in 1915/16 and later used for the Kerry Road. An estimated 22,500 tons of silty sand and 20,000 cubic yards of water formed the beginning of the debris which traveled approximately 2 miles down Eilertsen Creek and deposited in Woodson, on Highway 30, and in Westport Slough.

The embankment failure was caused by the impoundment of water behind the embankment after an estimated 9,000 and 3,000 cubic yards of soil (and woody debris) from two separate debris flows was deposited upstream of the embankment. The debris plugged the inlets of both the main puncheon culvert at the base of the embankment and a smaller relief culvert located higher in the embankment. The debris flows occurred on December 3, as part of a multitude of such slope movements (eight in the Eilertsen Drainage alone) during an extraordinary storm event.

Both debris flows upstream of the embankment initiated at the toe of large, deep-seated failures. The larger debris flow occurred at the toe of a 1.75-acre slope movement, which generated scarps up to 60 feet high, involving an estimated 85,000 cubic yards or 140,000 tons. The maximum depth of this slope movement approaches 50 feet. The smaller debris flow originated at the toe of a similar slope movement involving 6,300 cubic yards. Geomorphic evidence of pre-existing, old, deep-seated slope movements can be identified by stereo-graphic interpretation of historic aerial photos. The deep-seated slides at both December '07 debris flow initiation sites have been present since prior to the early 1900s.

Five other debris flows totaling an estimated 6,500 cubic yards can be shown to have initiated in the Eilertsen and East Eilertsen basins on December 3. The timing is less certain of a sixth failure of an embankment 160' east of the main railroad fill, which involved a debris flow estimated at 4,250 cubic yards. This failure occurred either on December 3, shortly after the culvert located there was plugged by a small debris flow, or later, after water overflowed from the main railroad fill impoundment and traveled to this site along the roadside ditch.

Based on an eyewitness account, none of the debris flows originating on December 3 and prior to December 11reached Woodson. The mud deposited in the hamlet on December 3 originated at one or more of 5 failures reported to have occurred along the east side of the lowermost reaches of Eilertsen Creek.

The 8-day delay between the formation of the impoundment and the failure of the large embankment can best be explained by the time for the saturation front to reach the downstream face of the embankment through the silty sand fill. Once the saturation front had reached the base of the downstream face, water seeping from the lower portions of the fill resulted in a positive feedback situation of erosion of the fill and accelerating discharge.

The area of the larger of the two debris flows above the railroad embankment had been clearcut in 1992, and, at the time of the December 2007 event was vegetated with a dense canopy of 25-foot tall trees (mostly Douglas fir and some Alder). Following the 1992 harvest, this area had been through two major storm events (1996 and 2006) without in-unit failures. The area around the second, smaller debris flow failure had been harvested in 2004, and been subject to the November, 2006 storm event, which resulted in the record monthly total precipitation at Clatskanie since record-keeping began in 1948. As a result, it appears that neither the removal of the canopy or root-strength issues can be implicated in the causation of these failures.

It is more likely that the record-setting 24-hour precipitation (6.67" in 24-hours at the Miller RAWS site) remobilized the large deep-seated failures and initiated the debris flows in this vicinity. The three-day total precipitation measured at Miller was 9.19", and the monthly precipitation measured at Clatskanie was 18.48", the third-highest monthly total recorded there since 1948.

INTRODUCTION

This report presents the results of a geologic/geotechnical assessment of the causes and slope movement mechanisms that led to the railroad fill failure which occurred on the morning of December 11, 2007 in the Eilertsen Creek drainage (T 7N, R 5W, Sections 5, 8, and 17, Figure 1). The failure sent a debris flow through the hamlet of Woodson, across Highway 30, and into Westport Slough, destroying several residential structures and covering the highway with mud and large woody debris. Due to warning of the impending failure by ODF personnel prior to the event, the effects were limited to property damage. This report was completed at the request of the Oregon Department of Forestry's Policy Unit. The assessment was completed in its entirety by Gunnar Schlieder, Ph.D., an Oregon Certified Engineering Geologist.

DOCUMENTED DEBRIS FLOW HISTORY, WOODSON AND SURROUNDING AREA

Based on historical information mostly from the *Clastkanie Chief* newspaper, Woodson itself and the surrounding area have been subject to impacts from debris flows for a long time. A summary Table compiled from several articles by Deborah Steele Hazen (*Clatskanie Chief*) and other sources follows:

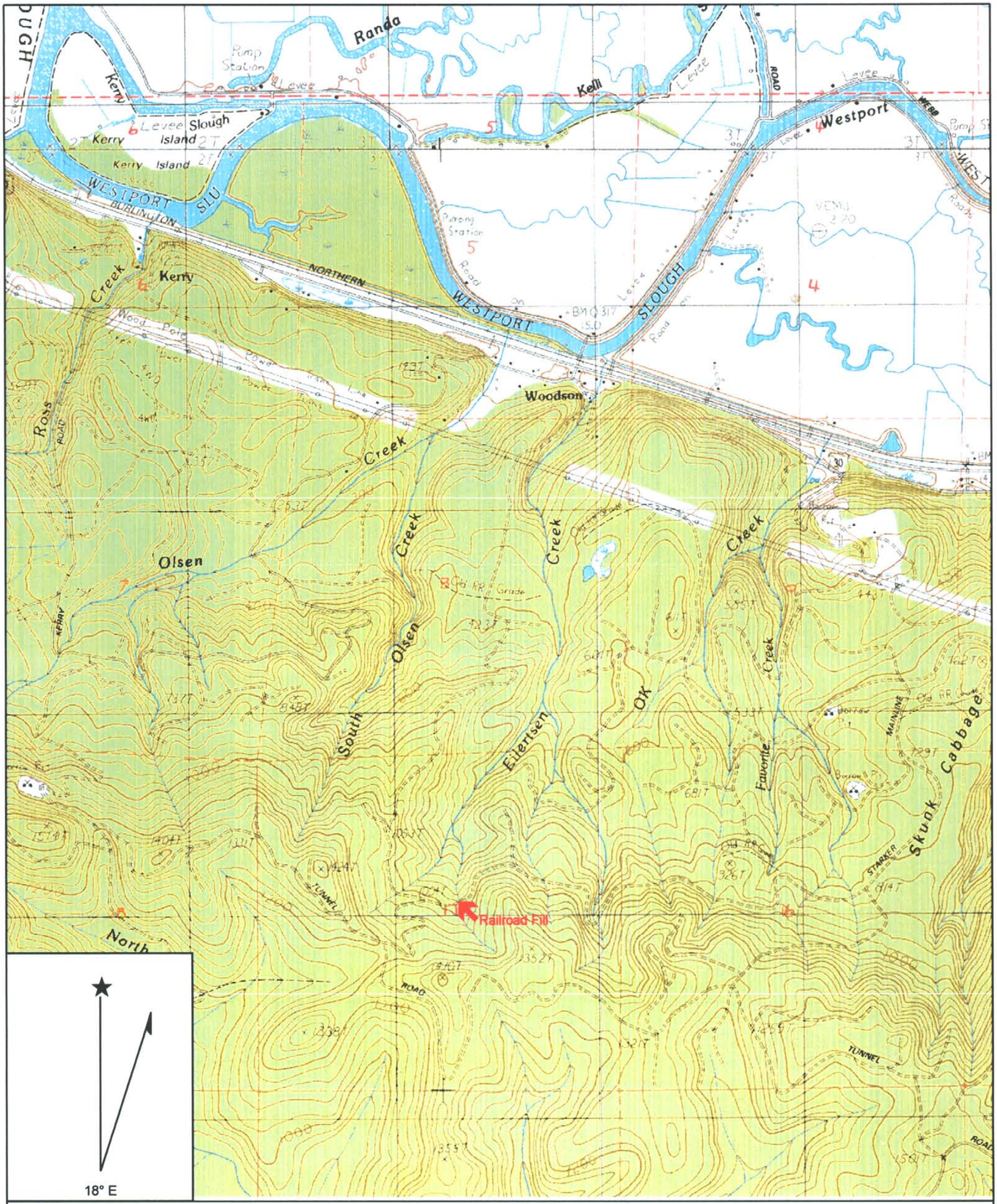
Date	Town	Creek	Structures	Fatalities
January 9, 1914	No Name	Blitz Creek	1 Barn	Farm Animals
December 25, 1933	No Name	OK Creek	1 House	2 People
February 8(?), 1996	Marshland	Tandy Creek	3+ Houses	-
April 23, 1996	Woodson	Eilertsen Creek	3+ Houses	-
"	Kerry	Ross Creek	2+ Houses	-
December 11, 2007	Woodson	Eilertsen Creek	3+ Houses	-

This compilation covers only those debris flows which delivered sufficient material to the communities along Highway 30 to cause damage to structures and result in media attention. The path of the 1996 debris flow which caused the damage at Woodson is shown on Figures 2 and 3.

GEOLOGY AND SOIL (Published Literature)

The *Geologic Map of Oregon* (Walker and McLeod, USGS, 1991) indicates that the Eilertsen Creek Drainage is underlain by *Tmst* and *Tc*. *Tmst* is described as:

> "**Marine sedimentary and tuffaceous rocks (middle Miocene to upper Eocene) -** tuffaceous and arkosic sandstone, locally fossiliferous, tuffaceous siltstone, tuff, glauconitic sandstone, minor conglomerate layers and lenses, and few thin coal beds..."



Name: MARSHLAND
Date: 3/27/2008
Scale: 1 inch equals 2000 feet

Location: 046° 06' 17.5" N 123° 19' 46.9" W
Caption: Figure 1: Location Map

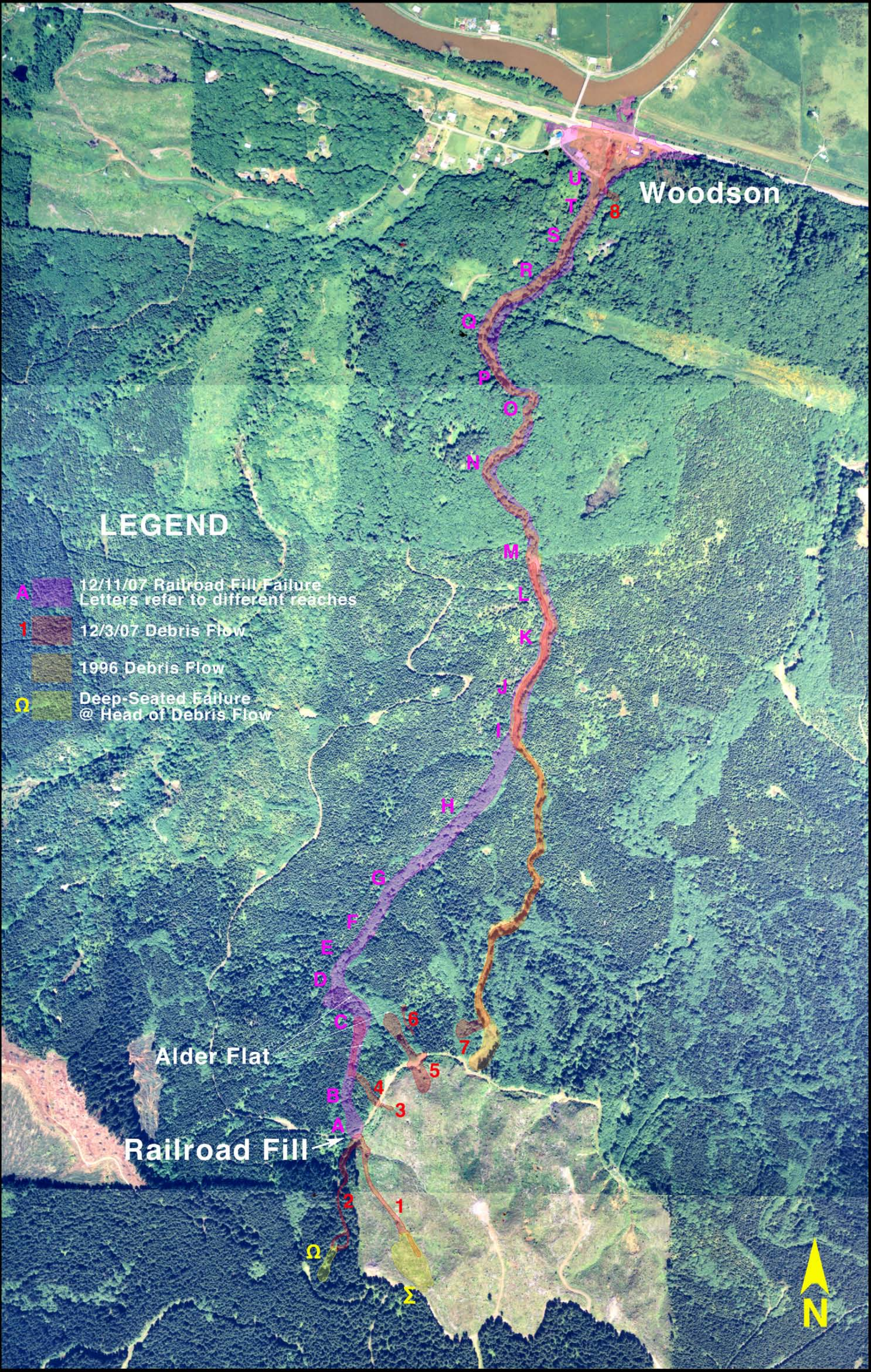


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Figure 2: Overview Map

Base from 1998 ORM Air Photos
Scale Approximate: 1" = 1000'

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Figure 3: 1996 Event

Base from 1998 ORM Air Photos
Scale Approximate: 1" = 1000'

The *Tc* unit is described as:

> "**Columbia River Basalt Group and related flows (Miocene) -** Subaerial basalt and minor andesite lava flows and flow breccia; submarine palagonitic tuff and pillow complexes of the Columbia River Basalt Group....locally includes invasive basalt flows. Flows locally grade laterally into subaqueous pillow-palagonite complexes and bedded palagonitic tuff and breccia. In places includes tuffaceous sedimentary interbeds..."

The *Soil Survey of Columbia County, Oregon* (USDA Soil Conservation Service, 1986) indicates that the upper portions of the Eilertsen Creek basin and the area adjacent to the channel are underlain by *Scaponia-Braun silt loams*. The easternmost portion of the upper study area is underlain by *Anunde silt loam*. The *Scaponia* soil is indicated to have formed in colluvium derived dominantly from siltstone. The typical stratigraphy of the *Scaponia* soil is described as:

> "Typically, the surface is covered with a mat of leaves, twigs, and moss about 2 inches thick. The surface layer is dark brown silt loam about 7 inches thick. The subsoil is dark brown and dark yellowish brown silt loam about 25 inches thick. The substratum is dark brown silt loam about 10 inches thick over fractured, soft siltstone. Depth to the soft rock ranges from 40 to 60 inches. The subsoil is 30 to 55 percent soft siltstone fragments".

The Unified Soil Classification System group symbols for this soil are: 0 - 7": ML; and 7 - 42": ML.

The *Braun* soil is also described as formed in colluvium derived dominantly from siltstone. The typical soil stratigraphy is described as:

> "Typically, the surface is covered with a layer of leaves, twigs, and moss about 2 inches thick. The surface layer is dark brown silt loam about 4 inches thick. The subsoil is dominantly dark yellowish brown silt loam about 26 inches thick over fractured, soft siltstone. Depth to the soft rock ranges from 20 to 40 inches. The subsoil is 25 to 60 percent soft siltstone fragments."

The USCS group symbols for this soil are: 0 - 4": ML; 4 - 18": ML; and 18 - 30": ML.

The *Anunde* soil is described as formed in colluvium derived from siltstone and mixed with volcanic ash. The typical soil stratigraphy is described as:

> "Typically, the surface is covered with a mat of leaves, twigs and moss about 2 inches thick. The surface layer is dark brown and brown silt loam about 17 inches thick. The upper part of the subsoil is dark yellowish brown silt loam about 30 inches thick, and the lower part is dark yellowish brown silty clay loam 13 inches thick."

The USCS group symbols for this soil are: 0 - 17": ML; 17 - 47": ML, CL-ML; and 47 - 60": ML.

AERIAL PHOTO INTERPRETATION

Historic aerial photos of the area were obtained from several sources and reviewed stereographically. Air photos on file at the University of Oregon Aerial Photography Collections included the years 1954, 1963, 1965, 1970, and 1980. Lower-resolution air photo scans were obtained from ODF for the years 1969, 1977 and 1989. High-resolution scans were obtained from ODF and Evenson Timber Association for the years 1994, 1998, 2001, and 2006. Of these, for reasons of completeness of coverage and lack of other people's markings on the photo originals, the 1998 air photos were utilized to generate Figures 2 through 4. On Figure 2, a small portion of the 2006 air photos is inset to provide the location of the 2004 harvest unit.

Geomorphic mapping was performed for the area around the railroad fill on stereo-pairs of the 1994 and 2006 air photos. These photo years were picked due to the absence of trees or brush in the vicinity of Debris Flow 1 and Debris Flow 2, respectively. In particular, this mapping focused on the presence of evidence for deep-seated slope movements, such as mid-slope benches, arcuate scarps, hummocky topography, and disrupted drainage. In addition, these photos were used to prepare more detailed maps of the initiation sites, tracks, and deposition areas for these debris flows.

Numerous larger-scale (several acres in size) slope movements were identified in the two drainage basins (Creek 1 and Creek 2) where the pertinent Debris Flows 1 and 2 occurred on December 3, 2007. These slope movements have been marked with a yellow overlay on Figures 5 and 6. It must be noted that, with the exception of those areas which underwent active movement on December 3, 2007, the other areas are identified as slope movements from geomorphic evidence only and no subsurface exploration was conducted to confirm the extent or depth of these movements.

Based on the presence of natural ponds lower on the slopes in this vicinity and in the Eilertsen Creek basin, very large and very deep-seated (tens to hundreds of feet?) rotational slope movements may be present in this area. However, with the possible exception of disaggregation of the rock mass and permitting more water infiltration and more rapid weathering of the rock, these movements, if indeed present, are inconsequential for purposes of this assessment.

The 1998 air photos clearly show the initiation site and path of the debris flow which impacted several houses at Woodson on April 23, 1996. The debris flow originated immediately below Kerry Road at a small draw which is tributary to a larger fork of Eilertsen Creek . For purposes of this report, this larger creek has been designated "East Fork Eilertsen Creek". It must be noted that the east fork of the "East Fork" which is shown on the USGS topographic map (Figure 1) does not really discharge to the actual "East Fork of Eilertsen Creek, but rather is tributary to OK Creek.

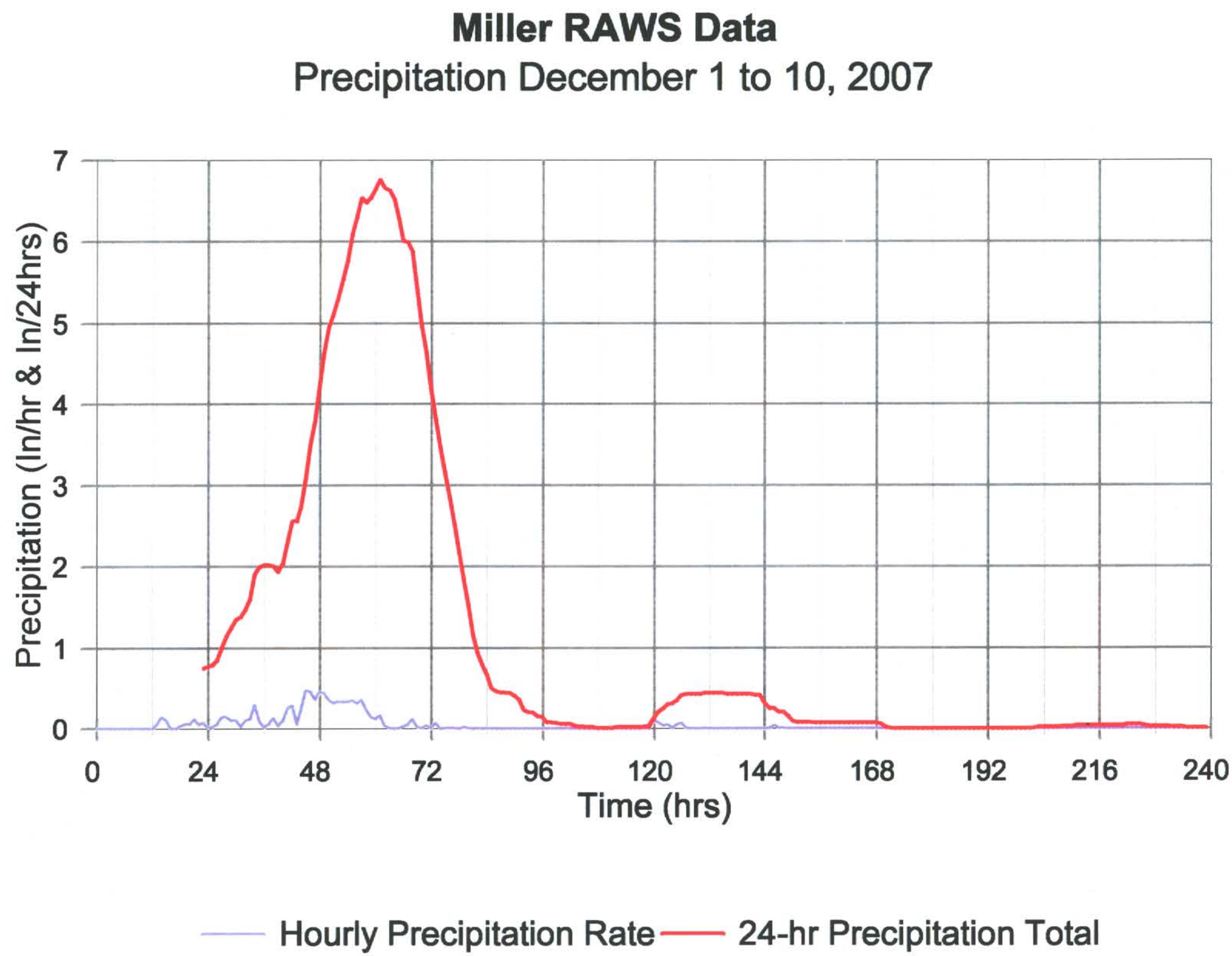
In addition to the geomorphic interpretation, the aerial photos were used to determine approximate drainage basin areas and the approximate area of the pond. The table on the following page presents these results. Please note that these values are approximate only, because the air photos are not corrected for angular distortion or elevation.

TABLE 1
DRAINAGE BASIN AREAS (FROM AIR PHOTOS)

Drainage Basin/Feature	Area (acres)
1a	4.74
1b	2.35
1c	1.80
1d	1.11
1e	3.31
1f	4.13
1g	2.42
1 Other (Combined Channel)	1.32
1 Total	21.20
2a	3.50
2b	3.18
2c	2.83
2d	2.91
2e	0.63
2 Other	3.36
2 Total	16.41
Total Drainage Area above Railroad Fill	37.61
Pond	1.12

PRECIPITATION RECORDS

The closest rain gauge to the Eilertsen Creek/Woodson area is located approximately 5 miles south-southeast and is called Miller RAWS. Precipitation data from this gauge for December 1 through 10 are presented as a chart on the next page. The total precipitation for the preceding 24-hour period is presented in red and hourly values are presented in blue. The December 3 official 24-hour precipitation was 4.65 inches. Historic precipitation records available for Clatskanie since 1948 indicate that December 07 had the third-highest monthly precipitation (18.48 inches) with the highest precipitation recorded November '06 (21.75") and the second highest in January, 1953 (18.56"). The highest official 24-hour total for Clatskanie is 4.1 inches.


Miller RAWS Data
Precipitation December 1 to 10, 2007
Precipitation (In/hr & In/24hrs)
0
1
2
3
4
5
6
7
0
24
48
72
96
120
144
168
192
216
240
Time (hrs)
Hourly Precipitation Rate
24-hr Precipitation Total

Hourly or daily data is not readily available for the Clatskanie Site. However, historical data were available in graph form at http://raws.wrh.noaa.gov/roman/ at the time of this writing. Data should be available in spreadsheet form once the MesoWest server is back on-line. The Miller data for November 2006 indicate that approximately 33 inches of precipitation feel at that station that in November, '06. Approximately 9.4 inches fell there during a 2.13 day period from 11/5/06 through approximately 11/7/06, with the maximum 24-hour precipitation rate at approximately 6 inches.

SITE OBSERVATIONS

The area was visited by GeoScience on four occasions: February 21 and 26, and March 3 and 14, 2008. On the first visit, the focus was on a determination of the sequence of events and extent of the failures above and at the railroad fill which failed catastrophically on December 11, 2007. The second visit was dedicated to measuring field-developed topographic sections along the paths of Debris Flows 1 and 2 and over the associated deep-seated failures. The third visit included installation of a Williamson Relative Density Drive Probe (see below) in the debris flow deposits immediately upslope of the failed railroad embankment and visits to other debris flow sites in the immediate vicinity. The fourth visit focused on the path of the 12/11/07 railroad fill failure from the railroad embankment site to Woodson.

Methods

Topographic sections were measured using a clinometer and 300-ft. fiberglass tape. The slope angle and slope distance was determined for slope or channel segments selected to minimize variation of the slope angle at a scale of 10 to 20 feet per inch.

The Williamson Relative Density Drive Probe utilizes a 12-lb slide hammer to drive nominal ½-inch steel pipe into the ground. Blow counts are obtained for 6-inch intervals and presented as blows per foot per six inches. As used by GeoScience, the pipe is driven with a smooth-walled coupling at the end but without a plug. In this manner, a small sample of the material at the bottom of the drive probe can usually be obtained.

Where appropriate, soils were classified according to the Unified Soil Classification System (USCS) using ASTM Method D-2488 (Visual-Manual Procedure).

Results/Observations

Numerous recent shallow-rapid failures can be observed from Highway 30, which appear to have occurred coevally with the failures above Woodson on December 3, 2007. These include failures in the lower side slopes of Graham Creek and Tandy Creek and deposits from failures in Olsen Creek. These sites were not visited, but significant cleanup operations related to deposits from these failures were in progress along Highway 30 during the two earlier visits to the site. The deposits from Tandy Creek include large woody debris which appears to have been transported to within a couple of hundred feet of Highway 30.

By the time GeoScience visited the site, much of the woody debris had been cleaned up in the Woodson area and the highway had been completely cleared of mud. As a result, observations related to the extent of the 12/11/07 failure are limited to those made on aerial and site photos obtained by ODF and ODOT personnel and the media following the event.

Several debris flows were observed to have originated in the vicinity of the railroad embankment which failed on 12/11/07. Most of these failures are shown on Figures 2, 4, 5, and 6. The failures have been numbered for purposes of this report, but it must be noted that these numbers are not meant to represent a time-line of the events. However, the failures will be discussed following the number scheme in the following section.

Slide/Debris Flow 1

Slide 1 is located immediately north of the ridgeline road and has been designated Σ on Figure 2. The slide portion of this failure is approximately 440 feet long in a SE-NW direction (per measured section B - A, Figure 7) and from 150 to nearly 200 feet wide, resulting in a total area of slope movement deposits of about 1.75 acres. The southwestern, southern, and south-southeastern margin is formed by a scarp which ranges in slope angle from a low of 46 degrees at the south end to vertical along the southwestern margin (see site photos, next few pages). Along Section A - B the scarp is 28 feet long (slope distance), increasing in height to the middle of the southwest margin, where it is estimated to reach 60 feet.

Where the slide scarp touches the road margin, two sections of the northern road-side ditch discharge onto the slope. The eastern portion drains approximately 70 feet of road and the western portion extends approximately 80 feet from where it is cut off by the scarp. At that point, another branch of the ditch extends to the north off the road. A portion of the 80-foot segment appears to drain west into this northern branch which also appears to carry the drainage off the north side of the road from approximately another 400 feet of road. Prior to the presence of the road, approximately half of this area (the width of the road) would have drained to the south. Another approximately 200 feet of the road skirting the south side of the 2004 harvest unit is drained to a discharge point located on the southeast side of the "bowl" in which Slide 2 is located.

The north branch of the ditch extends 42 feet at an overall slope angle of 2 degrees from the roadside to the top of the scarp of Slide 1 . From there, the scarp drops at an angle of 53 degrees for 37 feet and then at 90 degrees for another 5 feet. The base of the scarp is covered by an apron of debris. The total height (vertical measurement) of the scarp from the upper end of vegetation to the top of slope movement deposit is on the order of 40 feet. Based on the air photo interpretation (Figure 5), a scarp was present along the western, southwestern, and southern margin of current Slide 1 prior to the harvest performed in Basin 1 in 1992. However, at that time, the scarp was significantly colluviated and consisted only of a steeper, vegetated slope segment (angle indeterminate).

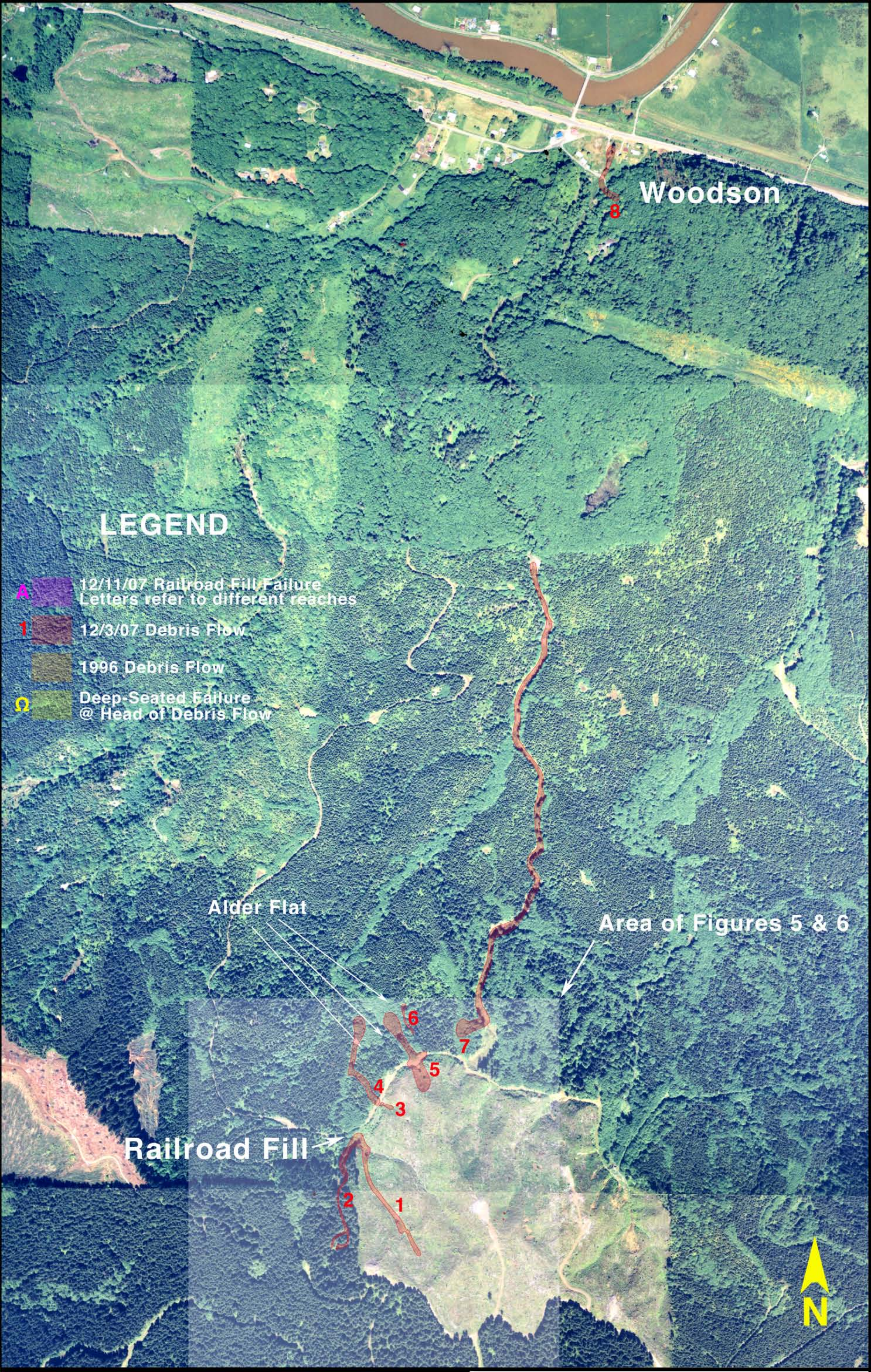


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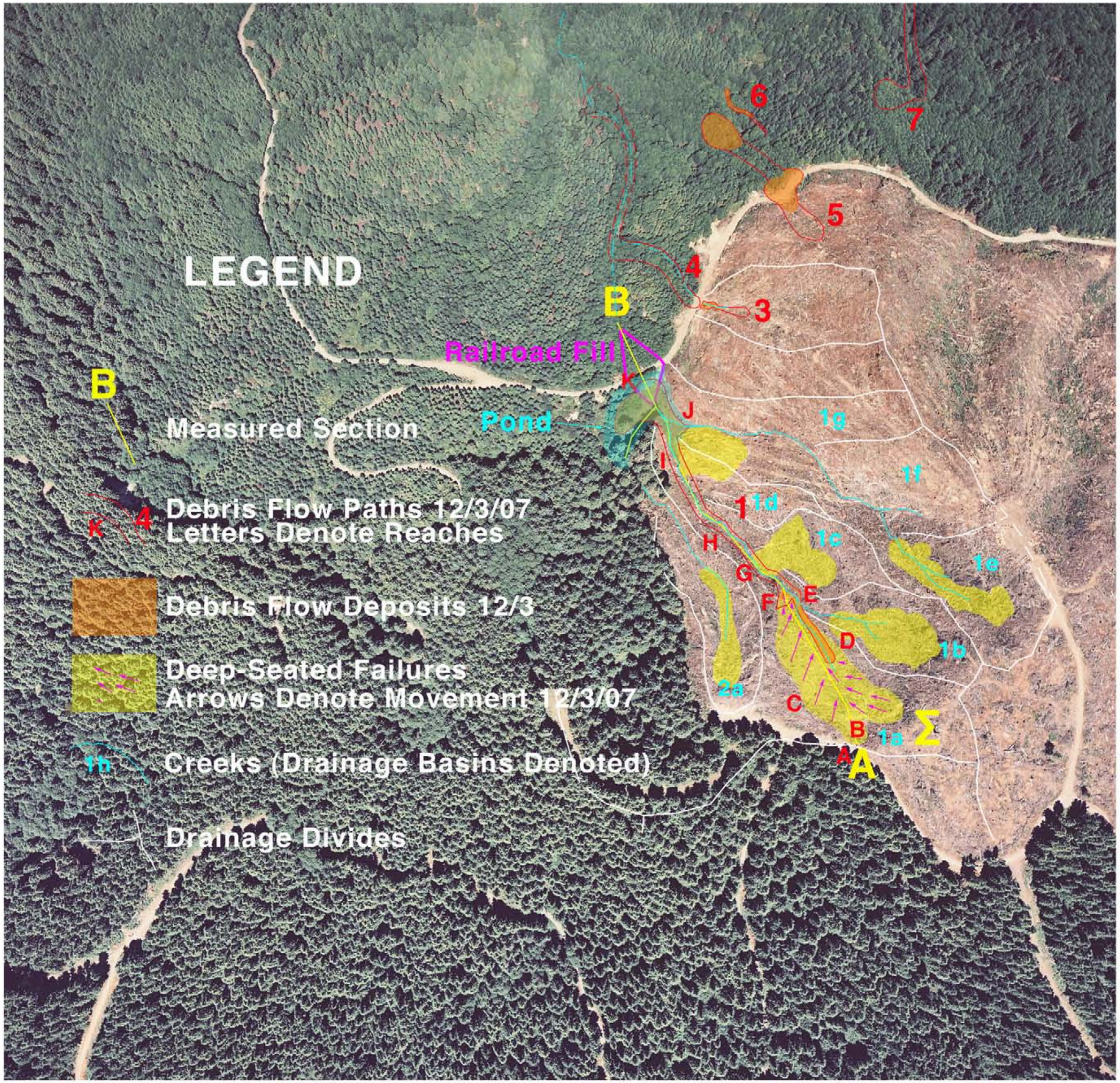
Figure 4: 12/3/07 Debris Flows in Eilertsen Basin

Base from 1998 ORM Air Photos
Scale Approximate: 1" = 1000'



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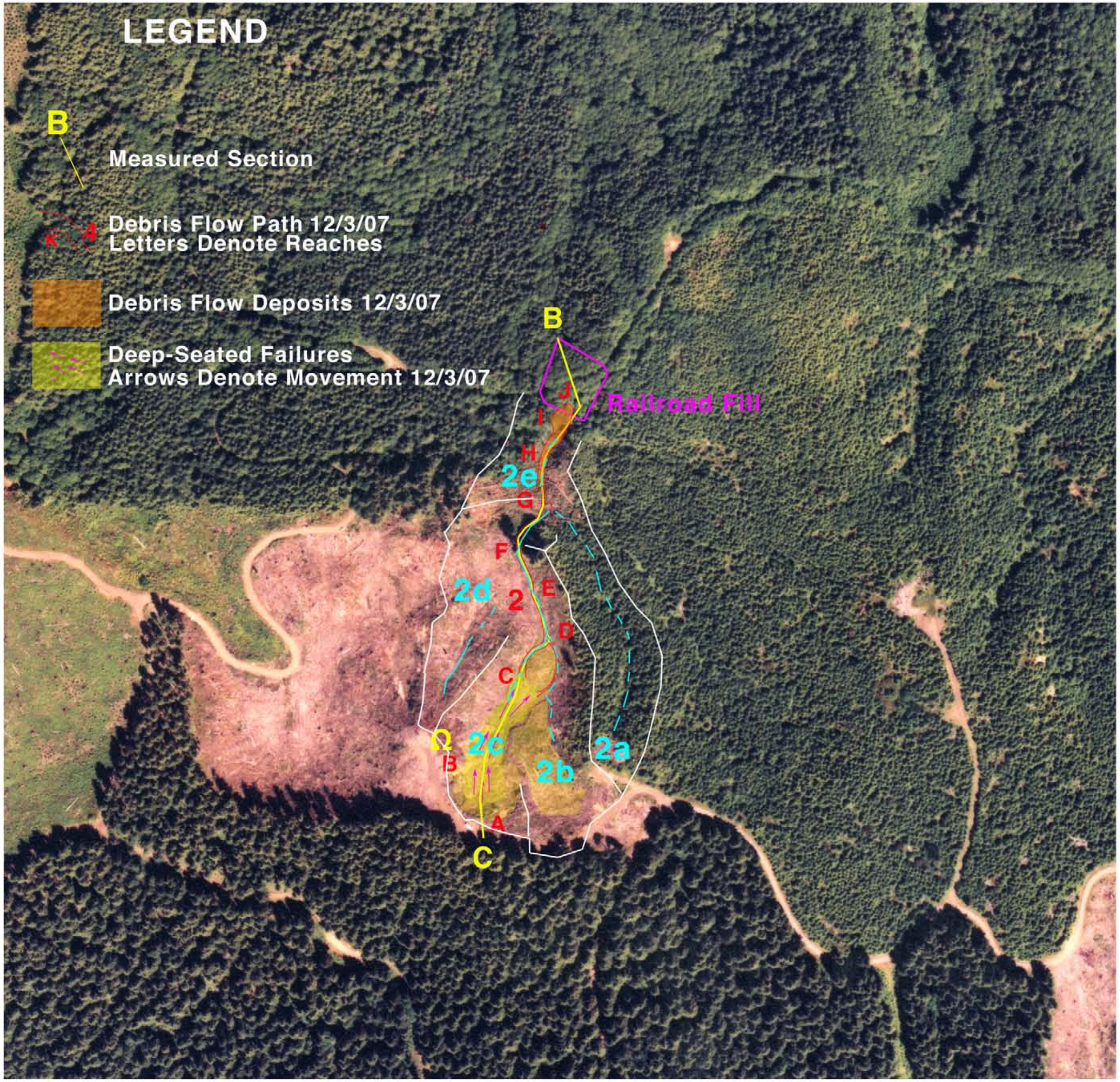
Eilertsen Creek, December 2007, Debris Flow Assessment

Figure 5: Pertinent Features in Vicinity of Basin 1

Base from 1994 Air Photo. Scale Approximate: 1" = 500'



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Eilertsen Creek, December 2007, Debris Flow Assessment

Figure 6: Pertinent Features in Vicinity of Basin 2

Base from 2006 Air Photo. Scale Approximate: 1" = 500'

Note: Section measured with clinometer and fiberglass tape.
Subsurface information inferred except at DP-1

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Eilertsen Creek Dec. '07 Debris Flow Assessment
Figure 7: Cross Section B - A
Scale as Shown

Roadside ditch segment at point “A” on Figure 5. View W.
Head scarp of Slide 1 is a couple of feet to right of lower right corner.

Ditch from road to discharge point above scarp of Slide 1. View S to road.
Note organic debris in channel and lack of scouring.

Discharge point of ditch from road to N. Slide 1 deposit below. View NE.
Note organic debris and lack of scouring in channel.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Location A on Figure 5: Roadside ditches near head scarp of Slide 1
	Photos Taken 3/03/08

In-place, partly decomposed to stained state sedimentary rock is present in the area of the maximum height of the scarp in the northwest-central portion of the southwest margin of Slide 1. At point "B" on Figure 5, the scarp exposes (and is located along) a lithologic contact, where completely decomposed sandstone overlies partly decomposed siltstone. As used in this report, completely decomposed state (CDS) rock can be remolded more than 50 % with finger pressure and partly decomposed state (PDS) rock is remoldable less than 50 %. In this case, the sandstone is completely remoldable and forms a silty Sand (SM) upon remolding. The material is non-plastic, indicating that the percentage of fines (silt) is relatively low (probably less than 10 %). During the site visit on March 14, when significant precipitation was occurring, the ditch discharge, estimated at a total of approximately 3 to 4 gallons per minute, resulted in mobilization of some of the sand on the head-scarp. The siltstone unit is significantly less than 50 % remoldable with finger pressure. On February 26, which was a day without precipitation, water was observed seeping from the upper portions of the siltstone unit at the headscarp.

The surface of Slide 1 is characterized by replanted trees which have been rotated in an upslope direction, with many trees completely toppled. The trees which remain standing are leaning to the SE in the southeastern portion of the slide and to the SSW in the southwestern and north-western portions of the slide. Several closed-contour depressions are present in the central portion of the slide and along the southwestern and western margin. The scarp along the eastern and northeastern margin of Slide 1 is significantly lower than along the western and southwest side of the movement. In the northeastern portion of the slide, the height of the scarp is less than 5 feet. In that area, trees have been knocked down along the margin with the tops of the trees pointing downhill (to the NW) and aligned parallel to the margin. For the lower approximately 150 feet, a secondary margin with a slope toward the northeast is present parallel to the eastern margin, approximately 25 feet to the southwest. Several tension cracks up to a couple of feet wide run parallel to the secondary margin along the main body of the slide. At the lower end of this secondary margin, toppled trees are also aligned in a fashion similar to those along the eastern main margin. Between these two margins, soft soil is present with flow structures on the surface, and a lack of top soil or vegetation.

The toe of Slide 1 is located at the confluence of Creeks 1b and 1c. In-place rock is exposed at the northeastern margin of Slide 1, where Creek 1c enters the swale in which Creek 1b used to the located. Slide 1 has completely obliterated the channel for Creek 1b and its former location can only be inferred from aerial photos.

The toe of slide 1 consists of a steep drop-off toward the northwest, and the tension cracks paralleling the secondary margin farther up the slide curve to a direction sub-parallel to the orientation of the top of the toe of the slide (SW - NE).

With the exception of minor blocks of surficial material which have collapsed down the slope, the toe of Slide 1 is completely devoid of vegetation and exposes a stratigraphy ranging from the top soil at the top to CDS rock to PDS rock, and finally, near the bottom, to blocks of a poorly cemented siltstone. At one location near the top of the toe, a bed with numerous pelecypod (clam) fossils imprints was noted (see site photos).

View SE to S at point "B". Darker borwn transported soil over in-place compltely decomposed sandstone (remolds to sand w/silt (SW).

View from SW (Left) to NW (Right) at "B".
Contact between completely decomposed sandstone (tan) and decomposed siltstone (brown to gray) in left part of panorama.

View of Slide 1 from near Point "B" on Figure 5. SW on Left and NE on right. Note back-rotated trees in central portion of photo. Cliff on left is between 40 and 60 feet high and exposes compltely decomposed to stained-state sedimentary rock. Scarp on right ranges from 15 to 25 feet high and expose completely decomposed rock.

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	Location B on Figure 5: Head of Deep-seated Slide 1
	Photos Taken 3/03/08

Top of N toe of deep-seated Slide 1. Location F

Head of Debris Flow 1, upper deposit.
Location D

Top of N toe of deep-seated Slide 1. Measuring Section A - B

View from central portion of Slide 1. S is to left and N to right. Note back-rotated fir trees in left middle ground and to right.

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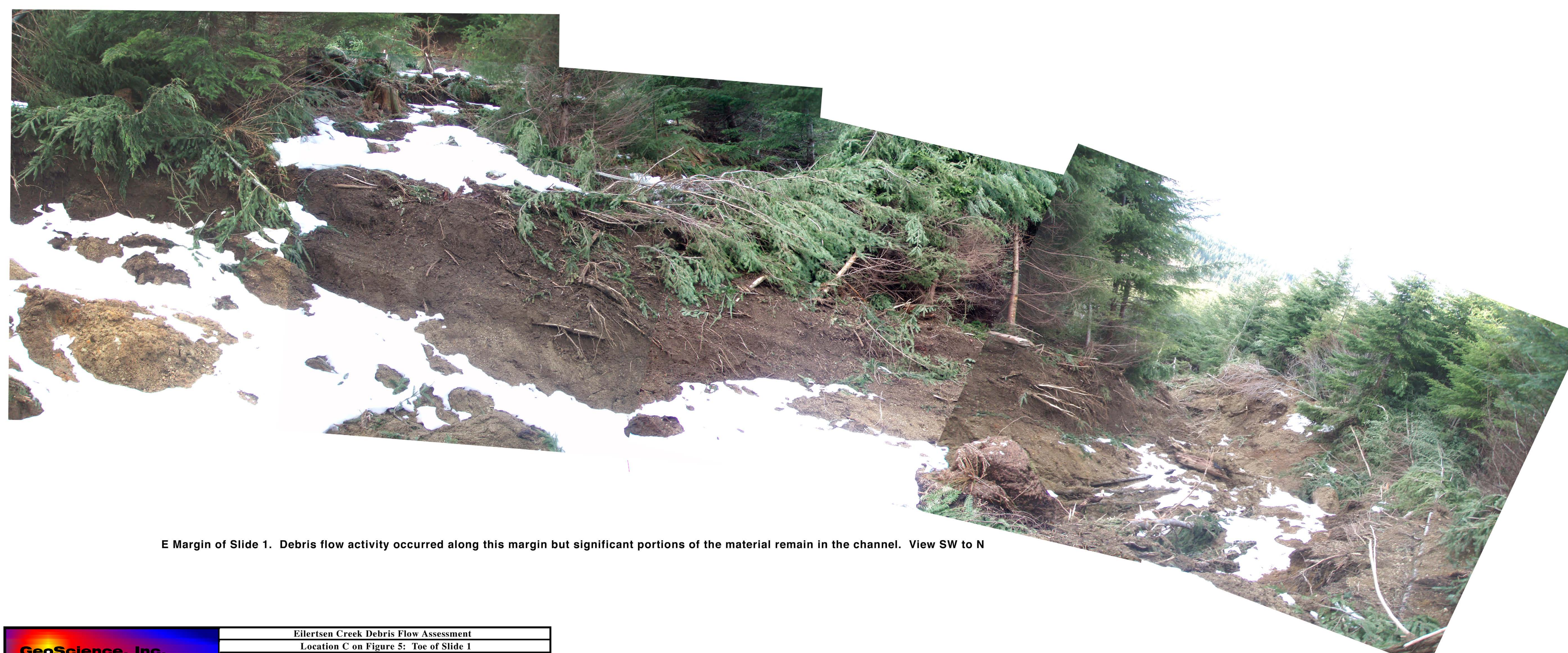
Eilertsen Creek Debris Flow Assessment
Between Locations C, D, E & F on Figure 5: Slide 1
Photos Taken 2/26/08

Toe of deep-seated Slide 1 and head of Debris Flow 1. View NW to NE



E Margin of Slide 1. Debris flow activity occurred along this margin but significant portions of the material remain in the channel. View SW to N

Location E: In-place rock (left lower corner) and trees which have been stripped and arranged parallel to debris flow direction.
View SW to NW in area indicated by lines.

Back-rotated shell bed in partly to completely decomposed
near-shore marine sedimentary rock.

Closer view of pelecypod imprint in completecly decomposed sandstone.
Swiss Army Knife for scale.

Location E to F: Toe of deep-seated Slide 1 with smaller debris flow at left. Confluence of creeks 1b and 1c. Creek 1c enters picture from far left (log across creek). Toe of Slide 1 in central portion of panorama is covering former channel of creek 1b. Head of larger Debris Flow 1 scour area on right.
View SE (left) to W (right)

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Locations E & F on Figure 5: Toe of Slide 1
	Photos Taken 2/21/08 & 3/14/08

Head of Debris Flow 1, at Location "F" on Figure 5. View NW. Note partly decomposed rock rubble lag. Depth of flow on right bank is 17 feet.

Upper reach of Debris Flow 1 near location "G" on Figure 5. View SE. Toe of Slide 1 is visible in background. Note scoured, in-place rock along channel sides.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Locations F & G on Figure 5: Debris Flow 1
	Photos Taken 2/21/08 and 2/26/08

An apron of PDS to stained-state (STS) to visually fresh-state (VFS) siltstone or fine-grained sandstone fragments up to three feet in large diameter is present at the base of the toe of Slide 1, with the downslope edge trailing into the scoured channel of Debris Flow 1 (site photos). If the slope of the debris flow channel downstream from Slide 1 is extended under the slide, the thickness of the slope movement deposit at the toe of Slide 1 is 50 feet. It is possible, although not proven, that a bench is present in the in-place rock which would reduce the thickness of the slide deposit by a few feet. No subsurface exploration was conducted at this location to verify the thickness of the slide deposit. If the slide has a configuration as shown on Figures 5 and 7, the total volume of material involved in this failure is on the order of 85,000 cubic yards, or, at an assumed density of 125 lbs/cubic foot, more than 140,000 tons.

Based on field-developed cross section B - A (Figure 7), Debris Flow 1 traveled a distance of approximately 850 feet from its initiation site at the toe of Slide 1 to the railroad embankment. The elevation change is on the order of 160 feet, resulting in an average gradient of just under 19 %.

The upper 550 feet of the debris flow channel have been scoured to in-place rock along the bottom of the channel, and, in some places, along the sides also (site photos). The relatively soft rock forming the bottom of the channel has been grooved by the passing debris flow. The scouring and/or debris flow deposits extend up the sides of the draw by 15 to 17 feet (not counting secondary failures into the draw) and the cross-sectional area is on the order of 225 to 275 ft^2.

At the confluence of combined Creeks 1b/c with Creek 1d, a deposit containing significant quantities of wood which appears to have been buried for some time, is present in the eastern sidewall of the channel. The wood is black and the soil material around the wood is reduced. The soil in the deposit consists of variably weathered siltstone and fine-grained sandstone fragments in a silty sand matrix which is plastic at natural moisture content. The material appears to be an older slope movement deposit. It is not known whether the deposit is the toe of the deep-seated slope movement noted during the air photo interpretation, or represents a debris flow deposit originating in Draw 1d.

Approximately 550 feet downslope from the base of the toe of Slide 1, a deposit is present in Draw 1b/c/d, which has a relatively low-sloping upper surface with the thickness of the deposit increasing in a downstream direction from a couple of inches near the upstream end to a maximum of approximately 3 feet at the downstream end. The creek has eroded through this deposit exposing crude stratification sub-parallel to the top of the deposit (site photos). The deposit consists mostly of angular siltstone and fine-grained sandstone fragments ranging in size from coarse sand to two to three inches. At the top, a layer of very fine-grained silty sand is present which is approximately half an inch thick. The downstream end of the deposit is sloped relatively steeply down to more typical, unsorted and unstratified debris flow deposits.

The deposits from Debris Flow 1 extend into the confluence area with Debris Flow 2 and to the remnants of the railroad embankment. Debris flow deposits consisting of mud with rock fragments and organic debris extend up the eastern valley side from six to eight feet above the level of the main deposit in the bottom of the draw. In addition, distress to vegetation is observed on trees and brush

Woody debris in previous slide deposit at confluence of Creek 1d with combined 1b/c (Location H). View E. This may be the toe of the deep-seated slide in Draw 1d..

Channel scoured to partly decomposed rock downstream from Location “H” on Figure 5.

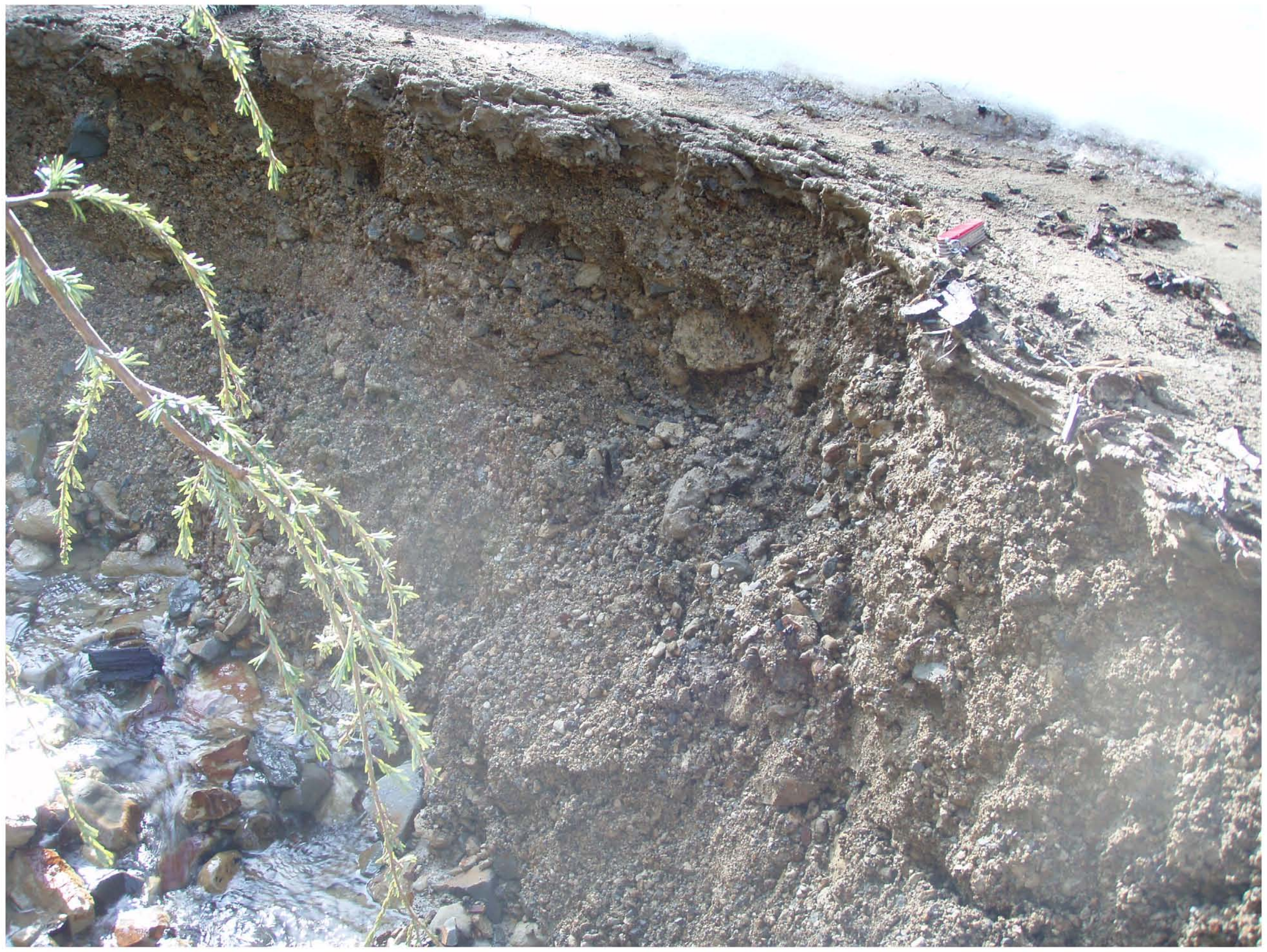
Scour marks on channel floor downstream from Location “H”. View SE.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Location H on Figure 5: Channel of Debris Flow 1.
Photos Taken 2/21/08

Delta deposit formed where creek 1 entered pond impounded by railroad embankment. View NW. Railroad fill failure visible above red hard hat.

Delta deposit in creek 1, view upstream. Deposit located at right. Elevation of deposit indicates high water level of pond.



Closer view of delta deposit at creek 1. Swiss Army Knife for scale. Deposit consists mostly of top-set beds, indicating rising water level during deposition. Uppermost fine-grained deposit formed from settling out of muddy water entering the pond.

Another view of thin fine-grained (silty very fine-grained sand) deposit formed on top of the delta by settling from muddy water entering the pond.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Location I on Figure 5: Delta formed where Creek 1 entered Pond.
	Photos Taken 2/21/08 and 2/26/08

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment

Location J on Figure 5: Debris Flow Deposits S of Railroad Embankment

Photos Taken 2/21/08

to that level. Directional indicators on the distressed vegetation such as broken limbs, organic debris wrapped around tree trunks, etc. show that the debris flow deposits along this slope were emplaced by Debris Flow 1. In addition, mapping of the upper limit of such deposits along the eastern valley side shows an undulating, essentially continuous line extending from the remnants of the embankment to the junction with Draw 1e, and from there rising into Draw 1b/c/d from which Debris Flow 1 issued.

At the easternmost end of the scarp of the railroad fill failure, deposits from Debris Flow 1 were observed to be overlying remnants of the railroad fill (site photos). At this location, the railroad fill consists of angular igneous rock fragments (some vesicular) in a dark brown to dark reddish-brown clayey sand matrix. Similar material is found in the failure scarps on both the west and east sides a short distance below the road. The material appears to have been part of the ballast for the railroad tracks. By contrast, the deposits of Debris Flow 1 consist of yellowish-brown silty sand with numerous yellowish to tan CDS to STS sedimentary rock fragments up to 12 inches in diameter.

The base of the deposits of Debris Flow 1 on Figure 7 is derived by drawing a straight line between the preserved downslope end of the puncheon culvert and the lowest observed presence of in-place rock in the channel floor of Draw 1. This results in a depth of 22 feet. Drive Probe 1 was installed at the location shown and the results are presented graphically on the following page. The drive probe encountered refusal (more than 50 blows for 6 inches) at a depth of 21.5 feet.

Slide/Debris Flow 2

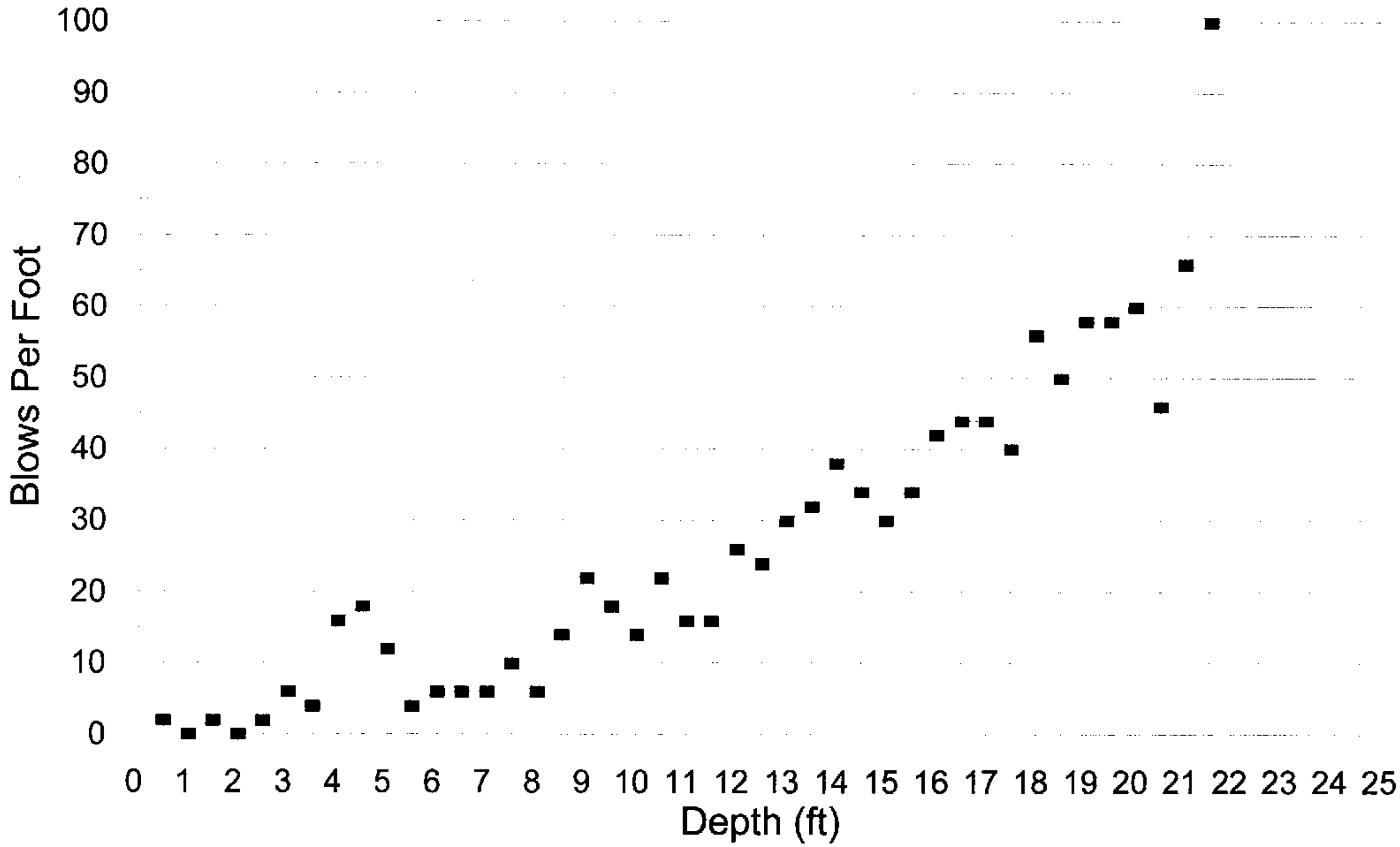
The top of the headscarp for Slide 2 (designated Ω on Figure 2) is located 110 feet slope distance below the top of the slope in this basin. Two additional minor scarps are present in the slope which do not appear to have been active on December 3, 2007, but appear to have been active in the last few years. Each of these scarps is approximately 12 to 18 inches high. From the air photo interpretation, it appears that much of the concave headwaters of this basin is occupied by a deep-seated failure. Counting the December '07 scarp, the upper portion of Slide 2 is 120 feet long and approximately 140 feet wide. Not counting the scarp, the upper slope movement deposit itself is approximately 100 feet long and similarly wide (Figure 8).

Approximately 100 feet north of the base of the headscarp, Slide 2 drops over a lip of in-place rock, consisting of PDS to STS siltstone. From there, the slope movement appears to have occurred more by viscous flow than by sliding at the base of the movement. The upper surface of the slope movement deposit in this vicinity is convex and minor ridges and valleys on the deposit are roughly aligned in chevron form with the "Vs" pointing downslope. This portion of the slope movement is 200 feet long and approximately 80 to 100 feet wide. As a result, the total area of the deposit from Slide 2 is approximately 0.6 acres.

The depth of Slide 2 was not measured but the lip of in-place rock located approximately 100 feet north of the base of the scarp is 10.5 feet below the top of the deposit at the center of the slide. It is probable that this is close to the maximum depth of the failure. The toe of Slide 2 has partially

Eilertsen Creek Debris Flow

Drive Probe in Deposit Upslope of Fill



Note: Section measured with clinometer and fiberglass tape.
Subsurface information inferred except at DP-1

GeoScience, Inc.

Eilertsen Creek Dec. '07 Debris Flow Assessment

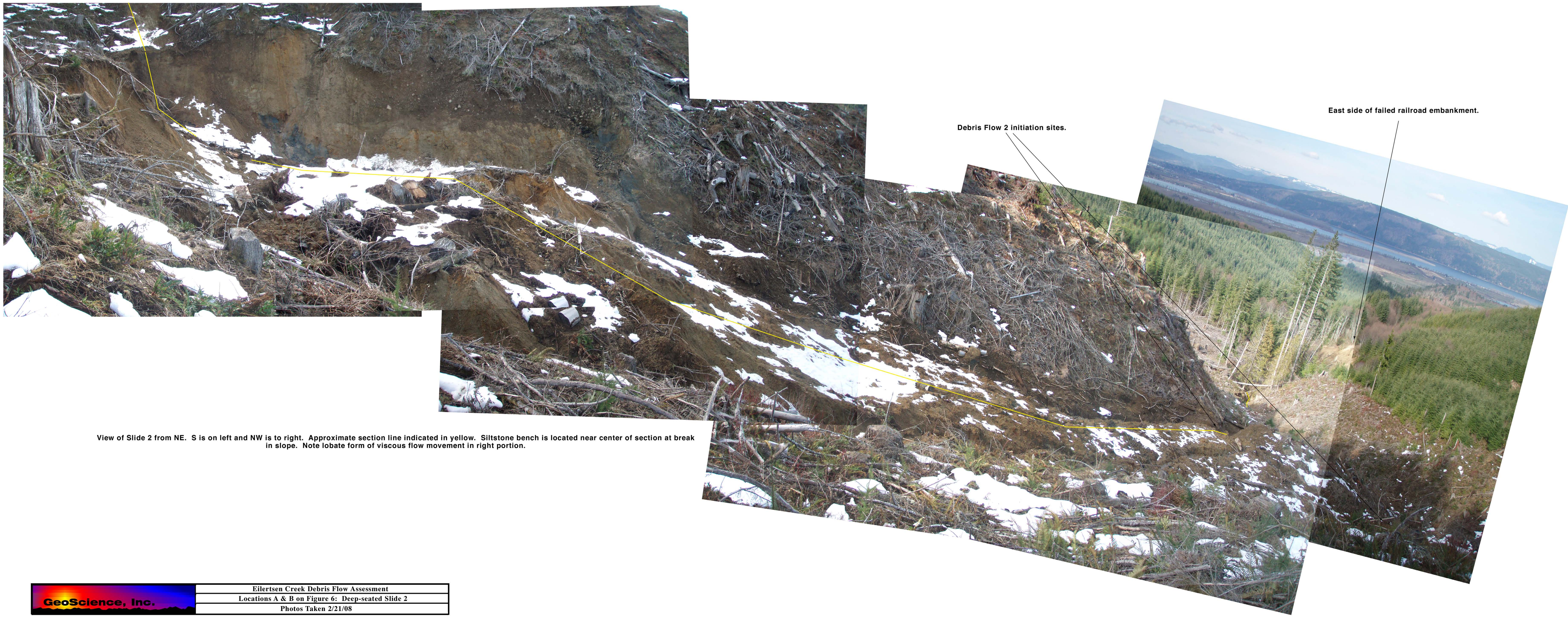
Figure 8: Cross Section B - C'

Scale as Shown

Piece of wood exposed under 15 feet of old slope movement deposit in E scarp.

Contact flowing water between CRB (?) unit above and
completely decomposed sandy marine sedimentary rock below

View of Slide 2 from NW. NNE is to left and SW is to right. Note in-place rock (siltstone?) in bench in right foreground. Deep-seated rotational sliding slope movement spills over this bench and turns into viscous flow type failure. Section B - C indicated in yellow.



View of Slide 2 from NE. S is on left and NW is to right. Approximate section line indicated in yellow. Siltstone bench is located near center of section at break in slope. Note lobate form of viscous flow movement in right portion.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Locations A & B on Figure 6: Deep-seated Slide 2
	Photos Taken 2/21/08

covered and flowed around the upslope side of a small knob of in-place material (or old slope movement deposit). If the margins of the slope movement deposit there are considered to be close to the elevation of the bottom of the center of the movement, the depth in the lower reaches of Slide 2 is also on the order of ten feet (Figure 8). Because this portion of the deposit is convex, the actual average cross section area is probably on the order of 500 feet. Using a similar cross sectional area in the upper portion, the total volume of slope movement deposit which moved at Slide 2 on December 3, 2007 is estimated at 6,300 cubic yards and the total weight of the material is on the order of 10,600 tons.

Debris Flow 2 originated at the toe of Slide 2 as two branches of a debris flow which went around the small knob of in-place material on the west and east and combined to form Debris Flow 2 approximately 160 feet down the channel. In the upper reaches, the cross-sectional area of the disturbed channel section is on the order of 160 ft^2. In the middle reaches of the debris flow, this parameter decreases to approximately 115 ft^2, and in the lower reaches of the confined channel the cross-sectional area is 95 ft^2.

Similar to Debris Flow 1, Debris Flow 2 scoured its channel for most of the confined portion. Debris Flow 2 traveled a distance of approximately 900 feet with an elevation change of approximately 240 feet, resulting in an average gradient of 26.7 %. The confined portion of the channel is around 600 feet long (Figure 8).

At the confluence with Draw 1, Debris Flow 2 deposited a significant amount of large woody debris, consisting of tree trunks and stumps. Much of this debris is concentrated in a line running essentially north-south, located approximately 100 feet from the headscarp of the railroad fill failure (see also Figure 8). On the downstream side of this concentration of large woody debris, the deposit from Debris Flow 2 appears to be relatively thin (a few feet), thinning towards the northeast. The edge of the Debris Flow 2 deposit is located just upstream of the upper edge of the headscarp of the railroad fill failure (see also interpretative photo mosaic of railroad fill failure, first photo mosaic following page 9). At the edge, the deposit from Debris Flow 2 can be shown to be overlying Debris Flow 1 material. The two debris flow deposits have a distinct composition, with Debris Flow 1 material containing numerous rock fragments in the 6 to 12-inch range whereas Debris Flow 2 material contains hardly any rock fragments larger than 3 inches. However, whereas Debris Flow 1 material does not appear to contain appreciable amounts of large woody debris (large logs and large stumps), Debris Flow 2 material is characterized by significant amounts of logs in excess of 2 feet in diameter and large stumps and root wads.

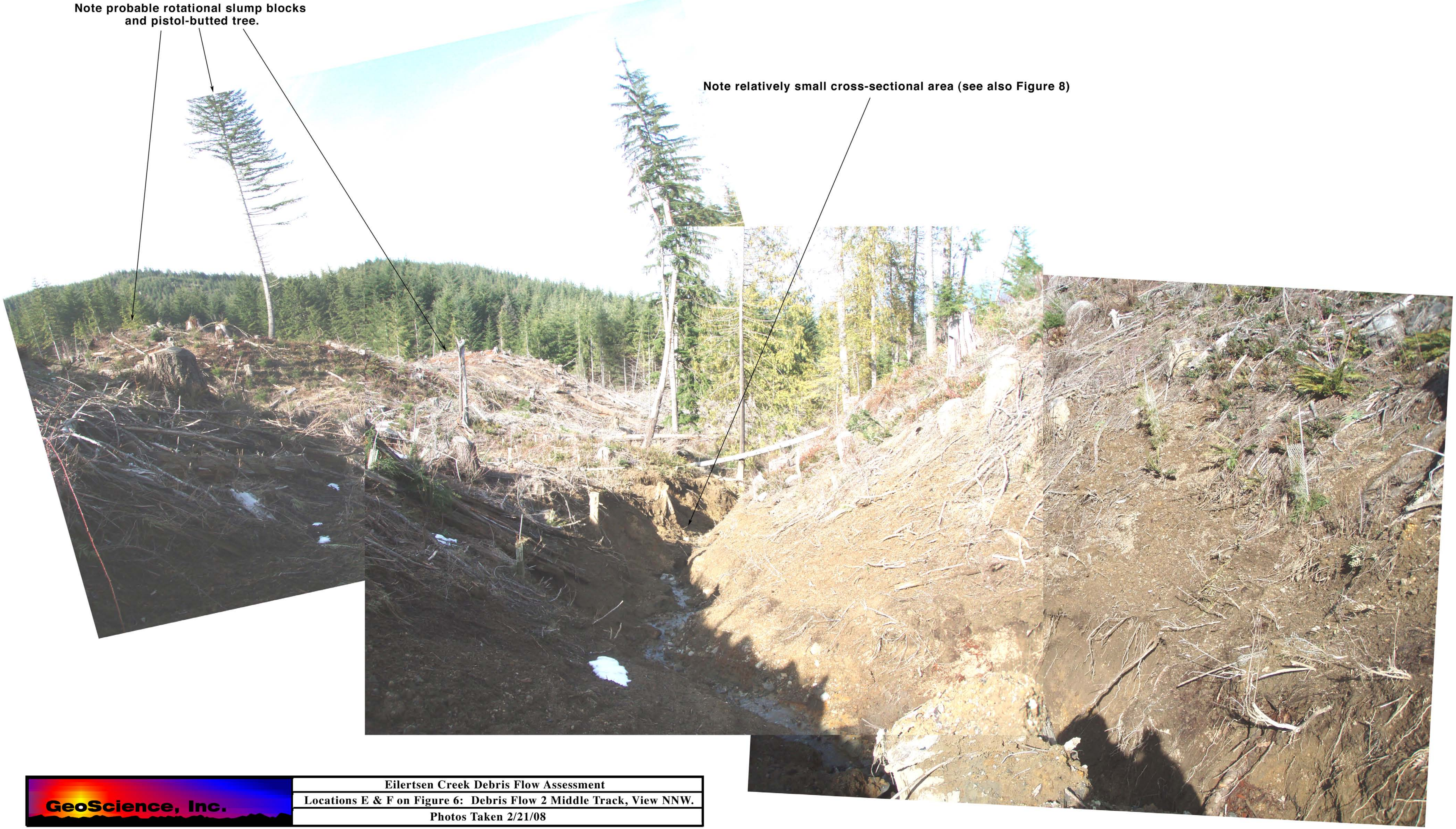
Debris Flow 3

Debris Flow 3 (Figures 2, 4, and 5) is located in a small drainage basin with an indistinct swale to the east of the location of the railroad fill. The initiation site of this debris flow involves an area less than 25 feet wide and less than 30 feet long, with the maximum scarp approximately 6 to 8 feet high. The slope in this area is estimated at 50 percent. Most of the material traveled less than 50 feet from the initiation site. However, the lower edge of the debris flow moved sufficiently far downslope to

Eilertsen Creek Debris Flow Assessment

Locations C & D on Figure 6: Debris Flow 2 Inititation Site

Photos Taken 2/21/08



GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment

Locations E & F on Figure 6: Debris Flow 2 Middle Track, View NNW.

Photos Taken 2/21/08

Debris Flow 2 path between "F" and "G" on Figure 6. Note small cross-sectional area.

Upstream end of depositional area of Debris Flow 2 (Location "G"). View SSW.

Delta at Location "G" on Figure 6 and main depositional area of Debris Flow 2 ("H" on right side).
Flat upper delta surface is at or near maximum pond level. View WNW to NE.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Locations G & H on Figure 6: Debris Flow 2 Lower Path.
	Photos Taken 2/21/08

360-Degree view of central deposition area of Debris Flow 2. Right and left edges are viewing toward SE. Other directions shown above Panorama.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment

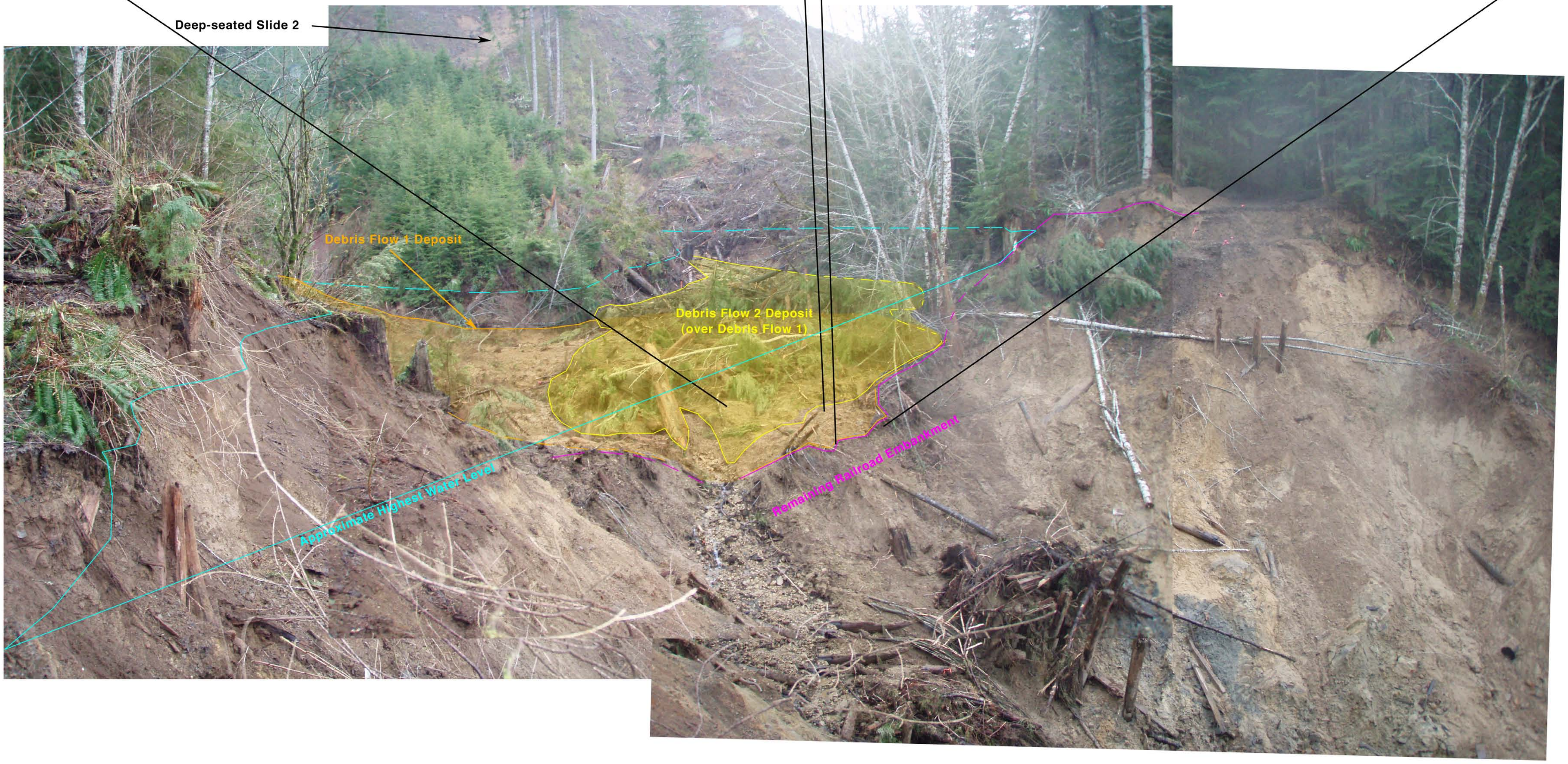
Locations H & I on Figure 6: Debris Flow 2 Deposition Area.

Photos Taken 2/21/08

Contact between Debris Flow 1 deposit (rockier in lower right corner) and overlying Debris Flow 2 deposit (darker, finer grained in central right and lower left corner)

Contact between Debris Flow 1 deposit (lighter yellowish-brown above pointing finger) and railroad embankment fill material (below pointing finger, darker brown).

Deep-seated Slide 2



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Eilertsen Creek Debris Flow Assessment
Location A on Figure 2: View to SW from Former Railroad Fill
Photos Taken February 21, March 3 and 14, 2008

plug the culvert located where the draw crosses the Kerry Road (the old railroad grade). Well-stratified alluvial sediments were deposited in the resulting pond upslope of the road, to a level matching the elevation of the road crown at this point. These deposits are located at the mouth of the draw and do not extend to the road. Therefore, the deposits clearly originated from erosion occurring at the toe of Debris Flow 3.

Debris Flow 4

Debris Flow 4 initiated at the Kerry Road (old railroad grade) 159 feet east of the east edge of the main railroad fill failure. The initiation site is directly downslope of the Draw in which Debris Flow 3 occurred. Between the main railroad fill failure and the Debris Flow 4 initiation site, the southern road ditch has an eastward slope of 3 %.

Debris Flow 4 removed the entire width of the road section, leaving a roughly horseshoe-shaped scarp along its southeastern edge. Based on measurements conducted by ODF personnel, the failure area is approximately 90 to 95 feet wide near the center line of the road (NE - SW) and more than 30 feet deep. A rough estimate of the volume of material which was involved in this failure is 4,250 cubic yards. Northwest-facing slopes adjacent to the draw in which the failure is located are essentially parallel to the slope of the bottom of the channel which, per measurements by ODF personnel, downslope of the toe of the former fill, ranges from 18 to 36 %. The failed material moved approximately 300 feet to the northwest down a draw which meets Eilertsen Creek approximately 300 feet downstream of the former road location at the main railroad fill failure.

From the point where Debris Flow 4 entered Eilertsen Creek, the evidence delineating its path and deposition area has been obliterated or at least made unrecognizable by the 12/11/07 railroad fill failure.

Debris Flow 5

This debris flow originated on the slope above Kerry Road approximately 650 feet northeast of the east edge of the main railroad fill failure. Based on the 1994 air photos, the slope had indications of previous failure, with an arcuate scarp outlining the recent failure area. The pre-failure slope angle in the initiation area above the road is estimated at 70 to 100 percent with the steeper portions located in the area of the pre-existing scarp. The failure area ranges from 50 to 75 feet wide and 150 feet long (upslope direction). The thickness of the recent slide appears to be around 15 feet maximum, although based on aerial photos, the pre-failure slope was already concave, potentially decreasing this value. A significant portion of the debris flow was deposited on the road. The remainder dropped off the road and was deposited in a low-sloping area forested with Alder trees located about 200 feet NW of and below the road. The deposit in the Alder trees consists of a relatively thin layer of silty sand spread over an area estimated at approximately 100 by 150 feet.

Debris Flow 5 did not reach the main Eilertsen channel.

Debris Flow Failure 4. Results from Plugged Culvert due to Debris Flow 3 and Roadside Ditch Carrying Discharge from Plugged Culverts at Railroad Embankment.

Debris Flow Deposit 3 and Delta resulting from Deposition in Small Pond due to Culvert Plugging

GeoScience, Inc.	Ellertsen Creek Debris Flow Assessment
	Location 3/4 on Figure 2: Debris Flows 3 and 4 Panorama
	Photos Taken 3/03/08

Initiation Area. View SE from Road.
Deposit in Foreground.

Deposit on Road, View NE.

Debris Flow Path Downslope from Road. View N.

Debris Flow 6 Path and Deposits

Lower Portion of Path and Depositional Area of Debris Flow 5.
Debris did not reach main stem of Eilertsen Creek (bare area visible through trees in R background.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Location 5/6 on Figure 2: Debris Flows 5 and 6 Panoramas
Photos Taken 3/03/08

Debris Flow 6

Debris Flow 6 is very minor feature which initiated approximately 150 feet below Kerry Road less than 100 feet northeast of the path of Debris Flow 5. The total volume involved in this failure was only a few tens of yards at most. From the initiation site, a path of mud approximately 5 feet wide, with natural levees on either side extends for a couple of hundred feet to the northwest onto the same gently sloping area forested with Alders where Debris Flow 5 was deposited. Debris Flow 6 deposited into a near-closed contour depression approximately 200 feet northeast of the deposition area for Debris Flow 5. None of the material from Debris Flow 6 appears to have reached the channel of Eilertsen Creek.

Debris Flow 7

Debris Flow 7 originated below a spur road 1000 feet northeast of the main railroad fill failure. The failure left an arcuate scarp approximately 100 feet wide at the spur road. The width of the failure area decreases in a downslope (northeast) direction and is estimated at less than 50 feet wide where it enters the channel of the creek below. For purposes of this report, this creek has been designated "East Fork Eilertsen Creek". Debris Flow 7 originated a few hundred feet west of the initiation site of the 1996 debris flow which impacted Woodson. The channel had been re-vegetated with small Alder Trees. Alder trees of this age remain on either side of the channel below the area where Debris Flow 7 entered the creek.

Debris Flow 7 traveled approximately 2,700 feet down the East Fork of Eilertsen to its confluence with Eilertsen Creek. From there, much of the path and depositional area of Debris Flow 7 has been obliterated. However, from the distribution of debris flow deposits on the west bank of Eilertsen Creek, opposite of the point where the East Fork enters the main channel, it appears that Debris Flow 7 arrived at the main channel with some velocity. Debris flow deposits on the west bank are "mounded" at this point, and the deposits located higher on the bank are more organic rich and darker than the deposits of the main railroad fill failure along other parts of the channel. As a result, it appears that Debris Flow 7 ran up onto west bank of Eilertsen Creek higher than the later railroad fill failure material. Downstream from the confluence of the East Fork Eilertsen Creek and Eilertsen Creek, evidence regarding the extent and deposition area of Debris Flow 7 has been obliterated or rendered unrecognizable by the 12/11/07 main railroad fill failure. Based on reports of residents of Woodson, Debris Flow 7 did not reach the mouth of Eilertsen Creek on December 3, 2007.

Debris Flow 8

Debris Flow 8 is located at the base of the slope at the east side of the mouth of Eilertsen Creek at Woodson. According to Rick Richmond, the owner of the property on the east side of Eilertsen Creek below the power lines, this was one of five smaller debris flows originating on his property. One or more of these debris flows contributed to the deposits which surrounded several of the lower-lying homes in Woodson. These deposits were in the process of being cleaned up when the main railroad fill failure occurred on December 11, 2007.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Location 7 on Figure 2: Debris Flow 7 Panorama
Photos Taken 3/03/08

Main Railroad Fill Failure

The main railroad fill failure occurred on the morning of December 11, 2007, eight days after the precipitation event that resulted in the initiation of Debris Flows 1 through 8. Portions of the railroad fill and the wooden trestle it covers remain at their original locations. These portions consist of:

- Embankment soil on the east and west sides, with more remaining on the west than east side (an in-place cedar stump originally covered by the embankment fill is exposed approximately two thirds of the way up the eastern slope).
- Trestle bents and/or wooden trestle uprights are preserved on both the east and west sides.
- The puncheon culvert (built of walls of stacked large logs and a heavy sawn board ceiling) outlet is exposed at the downstream end of the fill and is covered beneath remaining fill and debris in the central and upstream portions of the fill. The culvert remains largely intact, but is apparently mostly plugged.

The fill soil consists mostly of silty sand (SM), sand with silt (SW), and well- to poorly-graded Sand (SW to SP). These materials are non-cohesive. Minor cohesive fill portions are present lower in the embankment on the upstream side, consisting of igneous rock fragments in a clayey sand matrix. It is not known whether the latter fill was placed on the upslope side to provide some barrier to water flow through the embankment in the event that the puncheon culvert was plugged.

The sandy fill material also contains large logs, numerous short pieces of sawn lumber, and other debris apparently generated during construction of the tunnel approximately 1/4 mile to the west. Most of the lumber is in good condition and the logs do not appear to have undergone significant degradation during the nearly 100 years they have been buried in the fill. In areas where higher concentrations of woody debris are present, the sandy fill material color is bluish-gray. In other areas, the fill is tan to light yellowish brown to light brown.

The remnants of a relief ditch were also noted, which had been excavated on the west side of the embankment on the morning of December 11, 2007 in an attempt to provide emergency drainage for the pond. The bottom of the ditch shows no evidence of erosion which might have resulted from the flowing water. This is consistent with the photos of the ditch taken that morning, which show a flow of water through this ditch estimated at a maximum of 2 to 3 inches deep.

Based on cross sections measured parallel and transverse (Figure 9) to Eilertsen Creek, the volume of the railroad fill failure was approximately 22,500 cu. yds. The pond volume (water) at the time of failure, when the pond level was a couple of feet lower than at the maximum, is estimated at 20,000 cubic yards for a total initial volume of the Main Eilertsen failure of 42,500 cu.yds.

The track of the railroad fill failure down Eilertsen Creek has been divided into several reaches which have been labeled "B" though "U" on Figure 2. These will be discussed in the following section, and photos taken at each of these locations are also included.

Railroad Fill View E, 12/07/07. Photo Jason Hinkle ODF

Railroad Fill Shortly Prior to Failure, 12/11/07; Photo Jason Hinkle, ODF

Pond 12/10/07. Photo Jason Hinkle, ODF

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Location A on Figure 2: View of E Side of Former Railroad Fill
	Photos Taken 2/21/08

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Location A on Figure 2: View of W Side of Former Railroad Fill
	Photos Taken 3/14/08

Note: Section measured with clinometer and fiberglass tape.
Subsurface information inferred.

GeoScience, Inc.

Eilertsen Creek Dec. '07 Debris Flow Assessment
Figure 9: Railroad Fill Section, View Upstream
Scale as Shown

Reach "B"

This reach is located directly downslope from the source area of the failure (the old railroad fill). In this reach, which includes the confluence with the draw through which Debris Flow 4 entered the channel, no deposition occurred. The lower to middle side slopes of the draw and the channel floor have been scoured to PDS or STS in-place sedimentary rock. The original cross section of the channel is unknown, and, therefore, it is not known how much material was removed from this stretch of the channel and added to the original mass of the debris flow.

The average gradient in this reach is estimated at 24 %, with a lower gradient in the central portion and a steep drop-off approximately 2/3 of the way down. This geometry is related to a bench of in-place rock which has a steep northern edge. It is possible that this feature represents the scarp of a large-scale deep-seated slope movement which extends through the in-place rock.

Reach "C"

This reach includes the upper and central portions of the "Alder Flat", a very gently sloping area several hundred feet wide at the base of a much steeper slope. It is possible that the "Alder Flat" represents the top of a large rotational slope movement block. The channel of Eilertsen Creek is located along the western margin of the wide flat area. The channel is incised into the flat by 10 to 15 feet. However, for an event of the magnitude of the December 11, 2007 railroad fill failure, this area represents a significant loss of confinement. As a result, the debris flow spread out to a width of 200 to 300 feet or more, depositing a natural levee of trees and mud along the low-sloping eastern margin. In at least one area, below Debris Flow 5, this linear mound of debris has resulted in a shallow (less than 2' deep) impoundment of water.

The passing of the frontal and central portions of the debris flow appears to have stripped essentially all vegetation (leaving one fir tree) and some, or all, of the topsoil from the substrate, leaving tree roots which have been aligned parallel to the flow direction. As a result, the amount of soil removed from this area is probably only on the order of 8 to 12 inches. On the other hand, the later portions of the debris flow left deposits, which range from 0 to an estimated 4 to 5 feet deep, with depth apparently generally increasing in a downslope direction. As a result, it appears that the "Alder Flat represents a net deposition area. If it is assumed that the average depth of the deposit is 2 feet and an average of 0.67 feet of soil was removed, the net debris flow budget resulting from passage through Reach "C" would have been a loss of approximately 5,000 cubic yards, or nearly 25 % of the initial soil volume.

Reach "D"

This area is located at and immediately downstream of the confluence with the "West Fork of Eilertsen Creek. The channel of the creek itself is scoured to a dark bluish-gray material which consists of decomposed rock fragments in a silty sand matrix. The material may represent an older slope movement deposit, or an intra-clastic bed in the siltstone.

View upstream in Reach “B”. Lower end of puncheon culvert.


View downstream in Reach “B”. Note scouring on left bank.


Closer view of scoured in-place rock in Reach “B”. View upstream


Near “knick-point” in Reach “B”. View downstream.


At knick-point (waterfall) in Reach “B”. View downward onto “Alder Flat” (Location “C).


Reach “B”, view downstream, with ODF personnel for scale.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “B” on Figure 2: Upper Portion of Railroad Fill Failure Path.
	Photos Taken 2/25/08, Courtesy John Seward, ODF

View upstream (SW) from "C" into reach "B". Waterfall is visible in middle ground. Note transition from scouring on both sides to deposition on W side (right).

Deposition of "natural levee" along E side in upper portion of "Alder Flat " (Location "C" on Figure 2). View NW. Levee has resulted in formation of pond. Area is directly below Debris Flow 5.

Upstream portion of "Alder Flat". View N. Debris lost confinement at this location, resulting in partial deposition, likely from the rear portions of the flow. However, the front of the debris flow removed vegetation and most of the top soil during its passage through this area. Transion from scour only to partial deposition near people in right part of picture.

Central W portion of "Alder Flat". Note scoured original ground with roots aligned with flow direction and lone fir tree let standing. Original ground is mostly covered to depths of several feet with debris from 12/11/07 event.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach "C" on Figure 2: "Alder Flat"
	Photos Taken 2/25/08, Courtesy John Seward, ODF, and GeoScience 3/14/08

View of Eilertsen Creek at Reach “D” and “E”, at the lower end of and below the “Alder Flat”, downstream of the confluence with the western branch of the creek. The toe of the recent debris flow deposits was slowly failing into the channel at the time of the site visit (3/14/08.

Failures occurring at the toe of the 12/11/07 debris flow deposit at the downstream end of “Alder Flat”. Failures were moving slowly on 3/14/08. In-place (?) rock exposed in the channel.

Two views of in-place (?) rock in the channel. Bedding is dipping 60 degrees to the SW, striking approximately NW. It is not known whether this attitude is structural or is the result of large-scale rotational slope movement.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “D” & “E” on Fig. 2: Lower End of Alder Flat and Channel Below
	Photos Taken 3/14/08

At the time of the GeoScience visit to this area on March 14, the lower portion of the deposits on the Alder Flat was undergoing viscous flow failure into the creek below. Tension cracks had formed for several tens of feet around the upper perimeter of the failure. The failures were probably related to precipitation which had occurred on that day. The toe of the failures was being removed by the creek as rapidly as the material was delivered, creating turbidity in the creek water.

Reach "E"

In this reach, the channel is relatively straight and the floor is scoured to in-place rock. The rock consists mostly of siltstone, with isolated interbeds of fine-grained sandstone. Based on the attitude of the sandstone beds, the bedding of the entire sedimentary rock package is dipping approximately 60 degrees to the southwest, or into the hill. It is not known whether this attitude is related to rotational slope movement.

This reach is also the first place where a terrace of older debris flow deposits remains, consisting of angular rock fragments to several feet in diameter in a sandy or silty sand matrix. These deposits had been vegetated prior to the December 11 event and the root mat remains in place beneath thin deposits of the railroad fill failure.

Based on the USGS topographic map, which is consistent with field measurements conducted by ODF personnel using handheld GPS units, the average channel gradient through this stretch is on the order of 7 to 8 %. Much of the reach "E" has been mostly scoured, with only very minor deposits from the 12/11/07 event, even at the upper limit of the flow along the sides of the channel.

Reach "F"

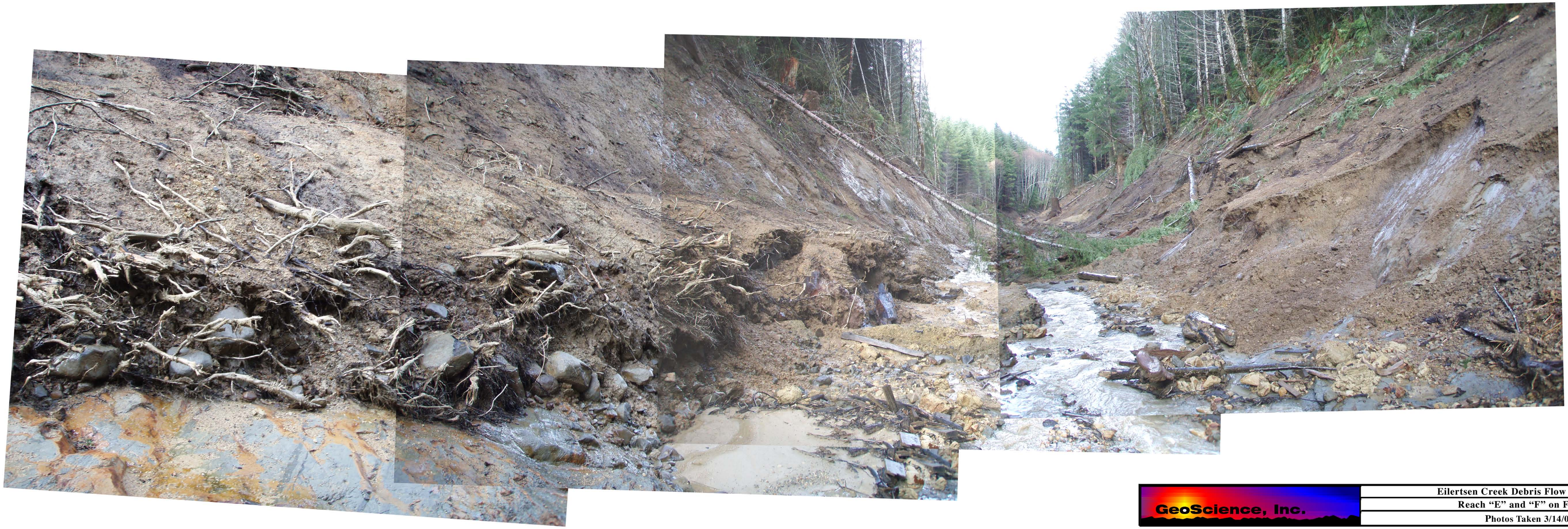
This reach is characterized by increasing frequency and thickness of deposits from the 12/11/07 event. The channel side slopes are lower in this reach than in "E", with some loss of confinement. Deposits are present along much of the upper flow margins on both sides of the channel and in places, deposits of sandy railroad fill material are also present lower on the channel slopes. Older debris flow deposits are exposed in some of the scoured areas and below the recent deposits.

Reach "G"

This reach is similar to "F", with lower side slopes, significant recent deposits of mud and large woody debris over older rocky debris flow deposits. The average gradient remains at 7 to 8 %.

Reach "H"

In this reach, decomposition of the in-place rock forming the sidewalls of the channel appears to have progressed farther than in the preceding reaches. As a result, scouring and removal of the toe of the banks has been more prevalent, resulting in localized side-slope failure after passage of the main portion of the debris flow.



GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “E” and “F” on Figure 2
	Photos Taken 3/14/08

Downstream view of Reach “E” (Fig. 2). Note older debris flow deposit on west bank (left), with mature tree roots preserved (trees removed by recent event). Only a thin veneer of sandy 12/11/07 deposits is on top of the older deposit, which contains larger angular rock fragments.

View downstream of Reach “F” (Fig. 2). Greater thickness of sandy, (recent ?) deposits over older woody debris flow deposit (lower left). Age of more rocky deposit on right is indeterminate. Stump on east bank (right) is in place.

View from NW to SW at point “G” (Fig. 2). Reach “F” on right and “H” on left. Note in-place rock at base of channel bank in center, overlain by older, rocky debris flow deposit, overlain by more sandy 12/11/07 deposit with woody debris.

Channel in Reach “H”, view NNE. Note slump (with small fir) along right bank as a result of 12/11/07 event.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Reach “F”, “G”, and “H” (Figure 2)
Photos Taken 3/14/08

View upstream into Reach "H". 12/11/07 debris flow deposit on left bank off ridge spur forming divide between Eilertsen Creek and draw containing debris flow 7.

Debris flow deposits on far bank are "mounded" at top of disturbed zone, with the color darker than typical sandy 12/11/07 deposits. This may indicate deposition from Debris Flow 7.

View downstream towards "J"

Deposit at confluence of draw containing Debris Flow 7. Scour line in that draw is too low to show over the young alders in middle ground..

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach "H", "I", and "J" (Figure 2)
	Photos Taken 3/14/08

Reach "I"

This point is located at the confluence of Eilertsen Creek with the East Fork of Eilertsen Creek. The latter tributary had delivered a debris flow to this point on December 3. Based on the distribution and characteristics of the debris flow deposits on the west side of Eilertsen Creek, opposite from the confluence, the debris flow from the East Fork impacted the west bank and sent debris flowing upstream into the main channel for several tens of feet. Based on color and composition alone, it is possible that portions of the deposit on the east bank, upstream of the confluence are also part of the Debris Flow 7 deposits. These deposits are darker brown and contain more fines than much of the deposits of the December 11 failure. As a result, it is possible that a significant portion of Debris Flow 7 (from the East Fork) was deposited at this location and only a smaller portion traveled farther north down Eilertsen Creek. However, if this is so, most of the 12/3/07 deposit from Debris Flow 7 was subsequently removed and incorporated into the 12/11/07 debris flow.

Reach "J"

In this reach, evidence of three different debris flow events can be discerned in the stratigraphy exposed in the channel. The surface is covered with deposits related to the 12/11/07 failure. None of the deposits of the 12/3/07 Debris Flow 7, if originally present, can be identified. The recent deposits cover a section of material consisting of angular rock fragments in a silty sand matrix, which is consistent with debris flow deposition. This material is located over a sand deposit which indicates normal alluvial processes. This sand, in turn, overlies another deposit with debris flow characteristics (angular rock fragments in a silty sand matrix). The ages of the two older debris flow deposits are not known. It is possible that the upper of the two older deposits represents the April 1996 debris flow event which issued from the East Fork of Eilertsen Creek and impacted Woodson.

Reach "K"

This reach is characterized by an increase in confinement. Nonetheless, much of the older debris flow deposits was not removed by the recent event.

Reach "L"

In Reach "L", portions of an old road bed formed of roughly hewn planks remain on the west side of the channel. The old road has been covered by a couple of feet of the recent debris flow deposit and possibly, by the 1996 event also. Based on the good preservation of the wood forming the road, it is likely that the road bed had been covered by soil and remained wet most of the time. It is also probable that this system of road bed was placed there due to the presence of soft, muddy or boggy soils. This reach is located at the upslope end of another very flat area which, to the northeast includes a sizeable pond. It has not been determined whether this shallow impoundment is the result of the old railroad grade or if the pond is a natural sag pond resulting from slope movement. If the old road predates the railroad grade (constructed in the early 1900s), then it is probable that the flat, poorly draining area is the result of slope movement.

View to SE.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Debris Flow Stratigraphy at Point "J" (Fig. 2)
Photos Taken 3/14/08

Reach “K”, view NNE. An increase in gradient has resulted in more scouring by the 12/11/07 debris flow. In-place rock exposed at base of left bank and older debris flow deposits in right bank.

Reach “L”. View from SW (left) to NW (right). Along this stretch an old road bed made of hewn planks is exposed in the left bank. Arrows point at boards identifiable on the photos.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reaches “K” and “L” from Figure 2
	Photos Taken 3/14/08

Reach "M"

The average gradient through reaches "J", "K", "L", and "M" is 4 to 5 %. Reach "M"is characterized by the presence of another old railroad grade crossing, which is located at the downstream end of the reach. This old crossing appears to have been constructed in a manner similar to that of the embankment which failed 12/11/07. The crossing is constructed as a buried trestle. However, the height of the embankment at "M" is significantly less, estimated at 20 to 25 feet total (over the downstream channel elevation). An interesting feature, unrelated to the 12/11/07 event, is the presence of well-bedded, mostly tan sandy deposits on the upstream side of the railroad crossing. An approximately 15- to 20-foot deep section of these deposits is exposed on either side of the channel. The sandy material is similar in composition to that of the railroad fill which failed on 12/11/07. However, this deposit is vegetated with timber which is several tens of years old. Older, large stumps are buried by this deposit. It is possible that the deposit formed during construction of the fill which failed last December. During the construction, unvegetated sand would have been exposed for some time on the flanks of the growing embankment upstream. Some erosion of this material would have been inevitable. It is possible that the culvert at the downstream crossing had been plugged. This would then have resulted in deposition of the sand arriving from upstream in the resulting pond. No deltaic foreset beds were noted in the deposit, indicating that the pond level was always close to the depositional surface. For some time, Eilertsen Creek has incised into these deposits again, possibly since the 1996 debris flow event and recent debris flow deposits are present at the toe of the deeper sand deposit.

Reach "N"

This reach is characterized by relatively low gradient, low banks, and a sweeping right turn of the channel. As a result, the 12/11/07 debris flow spilled onto the left bank in the lower portion of the reach. However, this spill-over was limited because the channel gradient and incision increase at the lower end of the right turn, which allowed most of the debris flow mass to remain in the channel. In the upper portion of Reach "N" little scouring appears to have occurred, probably as a result of the narrow passage through the old railroad crossing located immediately upstream, which appears to have limited the cross-sectional area of the debris flow in the stretch downstream from there.

Reach "O"

Reach "O" is characterized by a relatively steep gradient, deep channel incision (estimated at 40 to 50 feet or more in the lower portion), and several near-right-angle turns. The channel floor and sides in this reach are underlain by a discontinuous mass of what appears to be Columbia River Group flow breccia. This material appears to be significantly more erosion-resistant than the marine sediments located along other parts of the channel. As a result, Eilertsen Creek has formed a "knick point" (locally sharply increased channel gradient) through this stretch. The exact gradient was not measured, but according to USGS topo map, the gradient through this portion of the draw is more than 24 % for 500 feet, contrasting with a gradient of 4 % upstream of the lower railroad crossing and an average gradient of 6 % for the next 1,000 feet or more downstream of Reach "O".

Upstream side of old railroad crossing at point “M”. View S (left) to N (right). Light-colored, thinly bedded deposits are sandy, and appear to have formed behind the old railroad crossing, possibly during construction of embankment at crossing that failed 12/11/07. Woody debris and darker mud is from 12/11/07 event.

Remainder of old railroad trestle at point “M” which may have been buried in similar fashion as the crossing that failed 12/11/07. View S.

Buried trestle bents or piles on downstream side of point “M”.

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Reach “M” from Figure 2
Photos Taken 3/14/08

Upstream of right channel curve at “N” (Fig.2). View NW. Note relatively low height of flow through this section downstream from narrows at old railroad crossing (”M”).

Right channel curve at “N”. View N. Note deposits on left bank of curve. Also note increase in channel gradient at curve.
At and immediately below this curve, channel is cut through CRB, which forms a knick point.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “N” from Figure 2
	Photos Taken 3/14/08

Channel incision and increase in gradient downstream of “N”. View NE. Note CRB in place.

Contact between CRB and underlying sedimentary rock at upstream end of “O”

Significant incision of channel at “O”.
Note grooving of softer sedimentary rock
above person.

Failure of W bank into channel at “O” as a result of downcutting during the 12/11/07 event.

Older debris flow deposit below “O”. Note presence of roots.

Older debris flow “terrace” deposit extending from “O” to “P”. Note stripped, in-place vegetation.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “O” and “P” from Figure 2
	Photos Taken 3/14/08

Practically no deposition occurred through this reach of Eilertsen Creek, and significant scouring seems to have dominated the active processes. At the lower end of Reach "O", a significant side slope failure has occurred as a result of the scouring at the toe of the slope (site photos).

Reach "P"

A significant terrace of older debris flow deposits remains along this reach. The deposits are characterized by large angular fragments of the Columbia Basalt flow breccia which must have been scoured by previous debris flows from Reach "O"(?). The terrace had been vegetated with brush and trees (probably Alders) for its entire length, although the age of the trees cannot be established. The roots remain at the top of the debris flow terrace deposit. Also, remnants of brushy vegetation were observed along this stretch which had been stripped of bark and leaves by the debris flow.

Deposition by the 12/11/07 event is very limited along this reach and the next downstream Reach "Q". This may be related to the slight increase in gradient which appears to be occurring between the uppermost portion of Reach "P" and the lowermost Stretch of "Q".

Reach "Q"

This reach is similar to Reach "P", containing a long segment of previous debris flow terrace deposit along its western margin. The lower portion consists of a sweeping right turn of the channel where no deposits of either the recent or previous debris flows are present. The channel in this portion is underlain by siltstone.

Reach "R"

This reach begins with a left turn of the channel and a significant decrease in channel gradient. As a result, this reach represents the upstream end of the main deposition area for the 12/11/07 debris flow event. Large woody debris has been thrown onto the outside (E) bank of the left turn, several tens of feet below the residence of Rick and Jeanine Richmond. This residence has a good view of the lower portion of Reach "Q" of Eilertsen Creek.

It appears that one of the smaller December 3, 2007 side-slope failures occurred at the downstream end of the turn in Reach "R". This was not recognized in the field, but rather, noted only after review of the site photos of that area, and was not subsequently field-verified.

From Reach "R" to Highway 30, both the confinement and gradient of the channel and surrounding area decrease significantly. Confinement is essentially completely lost at Point "U" and the debris flow margins are located along the valley sides extending to the NE and NW from there. Several structures which are located in this triangular area were either inundated or surrounded by debris from the failure.

Older debris flow “terraces” on both sides of channel between “P” and “Q”. View upstream (S).

Slight right curve at “Q”. Terrace deposits terminate upstream from the curve.

View from “Q” to “R”. House is visible in the trees above center of photo.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “Q” from Figure 2
	Photos Taken 3/14/08

Channel near “R”, view N. Confinement decreasing as valley widens.

12/11/07 debris piled at outside of curve at “R”. A small side-draw failure is visible on L.

View downstream at approximately “S” on Figure 2.

View downstream at approximately “T” on Figure 2.

GeoScience, Inc.	Eilertsen Creek Debris Flow Assessment
	Reach “R”, “S”, and “T” from Figure 2
	Photos Taken 3/14/08

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment
Reach "U" from Figure 2
Photos Taken 3/14/08

GeoScience, Inc.

Eilertsen Creek Debris Flow Assessment

Figure 10: 12/11/07 Deposits at Woodson

Photos Taken 12/11/07 by ODF Helicopter Crew

DISCUSSION

Per the contract, this assessment was designed to answer, as well as possible, the following questions:

1. Identify:
   - The path and delivery areas of the December 11, 2007 railroad fill failure and subsequent dam burst flood.
   - The landslide run-out paths and delivery areas for the two known landslides in the drainage above the railroad fill.
   - The path and delivery area of the December 3, 2007 failure from the old railroad grade.

2. Identify the causal factors for each of these events. Include an evaluation of the mechanisms and relative contribution of each to the dam-burst flood.

Based on the site observations, precipitation records, and reports from eyewitnesses, the following time-line summary can be established for events in the Eilertsen drainage in early December 2007:

December 3: After a maximum 24-hour precipitation (at Miller RAWS station, 5 miles S of site), of 6.76 inches with maximum hourly rates of 0.48 inches, Debris flows 1, 2, 3, 5, 6, 7, and 8 occurred, in addition to numerous debris flows in other nearby drainage basins. Because Debris Flow 1 deposits are covered by Debris Flow 2 deposits, it is known that Debris Flow 1 preceded Debris Flow 2. The relative time frame for the other debris flows cannot be established. It is also not known whether Debris Flow 4 occurred on December 3 or during the following days. The road failure located 160 feet east of the railroad fill was first observed on December 6, when the pond was still overflowing to the eastern road-side ditch.

December 7: First site visit by Oregon Department of Forestry personnel (Stewardship Forester). Assistance from ODF Geotechnical Specialists is requested.

December 10: 2-inch tension cracks without vertical off-set are observed by ODF geotechnical specialists in the road near the central portion of the railroad fill. The pool level had dropped a couple of feet from maximum and was no longer overflowing to the ditch.

December 11: ODF geotechnical specialist arrived on site at 7:40 am. The tension cracks had widened and vertical off-set had formed in the road. Excavator was present and excavated a shallow (5 feet deep) relief ditch along the west margin of the railroad fill to attempt to drain the pond. The ditch was completed within an hour. Due to the deteriorating situation, ODF recommended evacuation of Woodson and closure of Highway 30. ODOT representatives attempted to procure high-volume pumps to drain the impoundment. After acceleration of the movement, ODOT closed Hwy 30 at 10:30 am. Railroad fill failed catastrophically at 11:50, releasing approximately 22,500 cubic yards of soil and 20,000 cubic yards of water down Eilertsen Creek. The resulting debris flow arrived at Woodson a few minutes later, impacting and destroying several structures and inundating several others.

The following section addresses, as well as possible the issues surrounding each of the pertinent slope movements.

Debris Flow 1

Debris Flow 1 initiated at the toe of a 1.75-acre deep-seated slope movement. Movement directions of the deep-seated failure can be determined from the rotation of trees. In the upper SE portion of the failure, trees are rotated toward the SE, indicating that the movement there was toward the northwest, parallel with the long axis of the movement. However, in the central and northwestern portion of the deep-seated failure deposit, trees are rotated to the south, indicating a significant movement vector component transverse to the long axis of the slope movement. The scarp along the southwestern margin of the slope movement ranges from approximately 40 to 60 feet high. Some of this steeper slope segment may have been the result of previous movement. However, it appears that more than half the movement is recent. There is no indication that the deep-seated movement over-rode any of its margins. If it is assumed that the failure moved 30 feet in a northerly direction, a significant amount of soil had to be removed from the northwestern toe and the lower northeastern margin in order to provide the void into which the deep-seated failure slid. The lack of overriding of deep-seated slide 1 indicates that the recent movement on the slide is secondary to the debris flow mechanism at its northwestern and northeastern toe. However, based on the presence of several steep slope segments outlining the current location of the scarp on the 1994 air photos, the deep-seated slope movement predates the recent debris flow activity. In addition, based on the presence of large logs in the area of the scarp and the colluviated appearance of the scarp on these air photos, the initiation of the slide predates the first (early 1900s?) and any subsequent logging activity in the area.

Based on the presence of the debris flow channel below the northwestern toe and the partially filled debris flow channel along the lower northeastern margin, it appears that the void was created by removal of the soil in the vicinity of the confluence of Creeks 1a and 1b. Assuming that the failure moved approximately 25 feet to the northwest (entire failure area) and 30 feet to the northeast (lower half of failure), and if the average depth of the toe of the deep-seated failure is 30 feet, the total volume of soil removed in order to allow for the movement would be approximately 7,900 cubic yards. Some additional material was obtained from the channel downstream of the deep-seated failure, so that the total volume of soil which was deposited upstream of the railroad fill embankment from Debris Flow 1 was probably on the order of 9,000 cubic yards or more.

Based on the field-developed cross section shown in Figure 7, the maximum depth of the deposits from Debris Flow 1 upslope of the railroad embankment is probably close to 20 feet deep (allowing for 1.5 feet of pre-failure soil and deposits on in-place rock). Given the maximum depth, the average depth was probably on the order of 10 feet. Therefore, the volume from Debris Flow 1 (9,000 cubic yards) would cover an area of 0.46 acres. Based on the distribution of Debris Flow 1 deposits observed at the surface, it is likely that the deposit also extends some distance westward into Draw 2, and under the deposits from Debris Flow 2.

From a geologic perspective, it appears that deep-seated Slide 1 is related to the presence of the contact between the siltstone and the overlying deeply decomposed sandstone. It is probable that the permeability of the sandstone is significantly higher than that of the siltstone. As a result, a significant portion of the precipitation infiltrating into the decomposed sandstone would be diverted along the contact and would re-surface above where the contact intersects the topography. Assuming that the contact is not perfectly planar, this groundwater flow could or would be concentrated along "valleys" in this contact. This would result in localized increase in pore pressure in those portions of the decomposed sandstone filling the "valleys". In turn, this inhomogeneity in pore pressures would result in localized reductions in shear strength and rapid discharge from the "valleys" might result in piping and mobilization of sand grains from the completely decomposed sandstone. This process could explain the initiation of debris flow activity at this site.

Alternatively, it is possible that the deep-seated slide was initiated simply by removal of lateral support at the toe of the slope by creek erosion. In that scenario, the debris flows originating at the toe of the deep-seated movement would be explained as resulting both from the disaggregation of the rock mass by the sliding movement and the discharge of shallow groundwater percolating through the decomposed sandstone. However, there is no evidence on the 1994 air photos that either Creek 1a or 1b had eroded the toe of the slope movement. Both creek "channels" appear colluviated on these air photos.

The distribution of deposits from Debris Flow 1 along the east bank in the vicinity of the railroad fill indicates that this flow arrived at the railroad embankment with some velocity. The deposits left on the valley side and the damage to vegetation there indicate that the debris flow rode onto the east valley side by 6 to 8 feet, although the left curve is relatively gentle. As a result, it is probable that the debris flow also moved a significant distance up the railroad embankment before flowing southward back off the middle portions of the embankment slope. The northernmost extent of this debris flow can no longer be established, because this portion of the embankment was submerged when initially observed and was subsequently removed by the 12/11/07 failure of the embankment.

It is apparent that the deposits from this debris flow still cover the puncheon culvert inlet. Based on a lack of discharge from the relief culvert located higher in the embankment section, it is probable that the deposits also covered and plugged the inlet for that culvert. As a result, the cause for the railroad embankment failure can be ascribed entirely to Debris Flow 1.

In the context of this assessment, the role of forest operations with regards to the initiation of Debris Flow 1 is of interest. As indicated above, the slope movement activity at Slide 1 clearly predates logging in this area, and probably predates the arrival of white settlers. As a result, forest operations (logging and road building) cannot be implicated in the initiation of the slope movement.

The area around Slide 1 was reportedly clearcut in 1992 and a dense cover of replanted trees approximately 25 feet tall was present at the time of the December 2007 failure. Although, based on the 1998 air photos, several debris flow type failures occurred within and adjacent to the clearcut in 1996, no effects of that storm event are apparent at the site of Slide 1 on the 1998 air photos. As a result, it does not appear that the loss of canopy cover or root strength due to the clearcut can be implicated in the recent failure. In addition, the deep-seated slope movement is occurring at depths of up to 50 feet, which exceeds the rooting depth of fir trees by a factor of 30 to 50 times.

This leaves the issue of the influence of road construction and drainage. The main access road was present in 1996 and 2006, and no evidence of slope movement activity from either of these storm events can be discerned on the 1998 air photos or was reported after the 2006 event. Therefore, the presence of the main road cannot be implicated in the recent failure. A spur road was constructed along the southern perimeter of Draw 2 in order to access the landing used during the 2004 clearcut in the Draw 2 area . The northern ditch of an approximately 200-foot segment of road drains to the northern branch of the main road ditch located above the southwestern margin of Slide 1. The southern ditch of this road drains to the south of the divide. As a result, the total additional drainage area added to the basin of Draw 1a is on the order of 0.05 acres. The total area of Basin 1a is 4.74 acres and the additional would represent approximately 1 percent. It is difficult to envision how such a minor change could have a very large effect.

If neither logging not road-building activity can be implicated in either the initiation or timing of the recent failure, the answer to these questions must be found somewhere else. The question of initiation of slope movement has been addressed above and it appears that the slope movement is mostly the result of the characteristics and distribution of the geologic units at this particular site. The timing of the December 3 failure can probably be best explained using precipitation records.

December 2007 was the month with the third-highest monthly precipitation total in Clatskanie since record-keeping began in 1948. A total of 18.48 inches of rain were recorded there during that month. Based on the data recorded at the Miller RAWS station, 9.19 inches (or nearly half the monthly total measured at Clatskanie) fell there in 3 days (December 1 to 3). In addition, the highest recorded daily precipitation at Clatskanie was 4.1 inches. The highest reported daily precipitation at Miller during the December 2007 event was 4.65 inches and the highest actual 24-hour precipitation recorded there during that time was 6.76 inches. By contrast, the highest recorded 24-hour precipitation at the Miller site during the November 06 event, which produced the record monthly rainfall at Clatskanie (21.75") was just under 6 inches. Therefore, the December 3, 2007 reported daily precipitation exceeded the previously highest reported daily precipitation for Clatskanie by 13.4 % and the highest 24-hour precipitation from Miller exceeds the highest reported Clatskanie precipitation by nearly 65 % and probably the highest recorded Miller 24-hour precipitation rate by 14.6%.

Therefore, it appears that the timing of the slope movement activity in the Eilertsen basin and in neighboring drainage basins can be attributed to the record-setting precipitation event of December 1 through 3, 2007.

One additional item must be noted in regards to the initiation of Debris Flow 1. Prior to the recent failure, it appears that the overall slope angle in the vicinity of the debris flow initiation site (near the northern or northwestern toe of deep-seated Slide 1) was on the order of 30 % or less. This value is significantly below the slope thresholds typically thought required for initiation of "shallow-rapid landslides". Whereas slopes with angles significantly steeper than the threshold angles (i.e. 75 and 80 %) are present in the immediate vicinity of the site (e.g. Basin 2) and other basins adjacent to the west), these slopes did not fail and cause debris flows of the size of Debris Flow 1. Minor debris flow type failures occurred on some of those slopes also, but none of those came close to the magnitude of Debris Flow 1. Therefore, it appears that it may be necessary to re-evaluate the debris flow initiation slope thresholds in the case of the presence of large deep-seated failures comprised of materials of a certain composition (i.e. silty sand). However, as appears to be demonstrated in this case, limitations placed on forest operations would not necessarily result in increased protection for the downslope population if similar geologic conditions are identified at other sites. The latter point is underscored by the history of the vicinity of Woodson, Kerry, and Marshland, where, according to the local newspaper, debris flows appear to have wreaked havoc with houses and lives since the early 1900s and before, not necessarily as the result of human activity in the source areas.

Slide/Debris Flow 2

Similar to Debris Flow 1, Debris Flow 2 originated at the toe of a deep-seated failure. The main difference between the two events appears to be the volume of soil mobilized both as the deep-seated slide and in debris flow mode. Deep-seated Slide 2 involves a rotational failure area, where the slope movement deposit is approximately 100 by 100 feet and estimated at a maximum of 15 feet deep. Using an estimated average depth of 7.5 feet for this portion, the volume of the slope movement in this area would be 2,750 cubic yards. The viscous flow portion of the movement is about 200 feet long and 80 feet wide, with an average depth estimated at 6 feet for a volume of 3,550 cubic yards. As a result the total volume of the remaining deep-seated Slide 2 is on the order of 6,300 cubic yards. The height (slope distance) of the recent scarp at the upslope end of the deep-seated failure is 43 feet. If it is conservatively (erring on the large side) assumed that a mass of soil 100 feet wide and an average of 7.5 feet deep moved 43 feet, and an equivalent amount of soil from toe of the failure was converted to Debris Flow 2, the volume of debris flow 2 would have been close to 1,200 cubic yards, or roughly 15 % of the initial volume of Debris Flow 1.

Debris Flow 2 also gained volume from scouring the channel downstream of the initiation site. In addition, this debris flow picked up significant amounts of large woody debris (logs and root wads). It is likely that the final volume was about 3,000 cubic yards, or one third of that of Debris Flow 1. This difference in volume is reflected in the cross-sectional area of the channel. The transverse cross sections measured along the path of Debris Flow 1 were on the order of 225 to 275 ft^2, whereas those along Debris Flow 2 were 95 to 160 ft^2.

The geologic characteristics of the Slide 2 area appear similar to those at Slide 1, although pre-failure slopes appear to have been steeper in Basin 2 than in Basin 1a. As at Slide 1, the mass of Slide 2 consists of disaggregated, completely decomposed sandstone (now silty sand). Partly decomposed to stained-state siltstone is exposed below and adjacent to the northern edge of the rotational failure portion. One difference between the two slide areas is that a Columbia River Group flow breccia unit is exposed along portions of the western margins of Slide 2. Significant amounts of water were noted discharging from this contact after the failure (site photos). It is probable that this contact and the water which is conducted to the toe of the rotational failure area contributed to the initiation of the deep-seated failure. It is not known whether the angular fragments of igneous rock found in the discontinuous older debris flow terraces along the Main Eilertsen Creek (Reaches E and downstream) were derived from this exposure.

The lower viscous flow portion of the slide has overridden an unknown length of the slope. Therefore, not all of the movement in the rotational failure area above was converted to debris flow volume at the toe of the failure, as assumed in the calculations in the previous paragraphs. Therefore, these calculations must be assumed to be maximum volume estimates.

The area around Slide 2 and along the upper and central path of Debris Flow 2 was clearcut in 2004 and the area around the lowermost path of this flow was salvage-logged in the summer of 2006. As a result, the entire area surrounding Debris Flow 2 had been clearcut at the time of the November 2006 storm event. Nonetheless, there are no reports of significant failures in this area from that storm, which caused numerous other destructive slope movements in northwest Oregon and around Mt. Rainier in Washington. As a result, the remobilization of Slide 1 and initiation of Debris Flow 2 cannot be associated with the canopy removal, or destruction of the fine root system during and following 2004. At the time of the 2006 air photos, the 2004 clearcut area is devoid of vegetation, probably as a result of herbicide application to aid in the establishment of young trees. Therefore, based on the forest management cycle, it is probable that Basin 2a/b was at its most vulnerable point during the November '06 storm event. Because there is no documented response of the slope from that time, forest operations do not appear to have been the most important cause for initiation of Slide/Debris Flow 2. It is more likely that the heavy precipitation which occurred on December 3, with a maximum 24-hour precipitation rate approximately 14.5 % higher than the likely previous record for the Miller RAWS site is the causative factor.

Of course, from a geomorphic approach, numerous deep-seated slope movements are present within Basin 2, all of which appear to predate the arrival of white settlers in this area. Therefore, it is probable that slides and debris flows similar to the 12/3/07 event have occurred in Basin 2 and its vicinity in the recent geologic past such as the last few thousand or tens of thousands of years. The older debris flow terraces found along the Eilertsen Creek channel represent the geologic record of these events.

Debris Flow 2 appears to have barely reached the western and central portions of the railroad embankment remaining exposed after material from Debris Flow 1 had arrived. The linear concentration of woody debris a little west of the confluence of Draws 1 and 2 is interpreted as material that originated in Draw 2 and was deposited when Debris Flow 2 rode up on the deposit of Debris Flow 1 material which had flowed into the lower portions of Draw 2.

Therefore, due to the timing of the two events, Debris Flow 2 does not appear to have contributed significantly to the plugging of the culverts at the railroad embankment. However, in the hypothetical event that Debris Flow 1 had not occurred, Debris Flow 2 would have likely reached and plugged the puncheon culvert inlet. However, due to the smaller volume and angle of impact, it is likely that this debris flow alone would not have also plugged the relief culvert inlet located higher on the embankment slope. This might have resulted in a longer time interval available for mitigation and easier access to the puncheon culvert through shallower water and thinner debris flow deposits. Therefore, it is possible that the 12/11/07 failure of the embankment could have been averted if Debris Flow 2 had been the only event that occurred on December 3.

Debris Flow 3

Compared to Debris Flows 1 and 2, Debris Flow 3 was an unremarkable event. It probably involved between 50 and 100 cubic yards of material, and moved only a few tens of feet. However, the movement resulted in plugging of the first culvert located east of the main railroad fill. The stratified sediments which were deposited between the toe of the debris flow deposit and the south edge of the road are typical of fluvial deposition where flowing water enters a standing body of water, in other words, a delta. The elevation of the top of the delta is equal to the elevation at the center-line of the road, indicating that road was the factor limiting the height of the pond. The sediments clearly originated at the toe of Debris Flow 3 and do not extend to the roadside ditch along Kerry Road.

The slope angle at the initiation site is estimated at 50 % which is low for an open-slope type debris flow initiation site. Moreover the initiation site is in an area densely vegetated with 25-foot tall replanted fir trees which are approximately 12 to 14 years old. Therefore, this site does not meet currently applicable thresholds for probability of initiation of debris flows from either slope or stand age criteria. This indicates that other factors (such as deeply decomposed sandstone and record precipitation) are most likely causative.

Debris Flow 4

The timing for this debris flow is poorly constrained. It is not known whether the failure initiated as a result of the initial plugging of the culvert at this location by Debris Flow 3, or was initiated some time later when the impoundment at the main railroad fill overflowed into the southern roadside ditch. At that time, the volume of water arriving at the site of Debris Flow 4 would have increased significantly, and the water would have been forced across the road by the culvert previously plugged by Debris Flow 3. From there, the water flow would have proceeded down the embankment, probably causing significant erosion. Prior to the plugging of the culverts at the main railroad fill across Eilertsen Creek, the culvert and draw below this location would have drained approximately 5.3 acres. Once the main railroad fill culverts were mostly plugged, and the pond forming there overflowed into the south ditch to the east, the effective drainage basin increased to nearly 43 acres. The resulting increase in discharge over the embankment at the Debris Flow 4 site is the most likely cause of the initiation of this debris flow.

The total volume of Debris Flow 4 is estimated at 4,250 cubic yards, or roughly 25 % of the main railroad fill failure soil volume. Assuming that Debris Flow 4 occurred after Debris Flow 1, it would have encountered relatively little water at the point where it joined Eilertsen Creek. Due to the steep angle at which the Draw enters Eilertsen Creek, it is probable that much of the momentum of Debris Flow 4 was dissipated at the confluence. However, the mass involved makes it likely that the material reached the steep portion of Reach "B" in the Eilertsen channel, and regained velocity at that point. In addition, due to the dense Alder stand previously present in this reach of Eilertsen creek it is probable that it picked up a significant amount of woody debris

The track and deposition area of Debris Flow 4 along Eilertsen Creek has been obliterated by the later main railroad fill failure. Therefore, it is not known whether Debris Flow 4 deposited on the Alder Flat or reached low-gradient portions of Eilertsen Creek between the Alder Flat and the lower old railroad grade crossing. Remnants of a 24-inch culvert are present at the lower end of the Alder Flat. These may be from the culvert at the initiation site of Debris Flow 4 or may be from the relief culvert at the main railroad fill. If it could be established that the remnant originated with Debris Flow 4, it would be almost certain that this event deposited on the Alder Flat and did not affect lower portions of the Eilertsen channel.

Based on the observations of Rick Richmond, one of the property owners in Woodson, whose house has an excellent view of Reach "Q" and "R" of Eilertsen Creek, significant contribution of Debris Flow 4 to the mud which arrived at Woodson on December 3 can be ruled out. Mr. Richmond stated categorically that all the mud which reached Woodson on that date originated from several smaller failures on his property. Therefore, the main effect of Debris Flow 4 on the December 11, 2007 event was a contribution of approximately 4,250 cubic yards of mud which had been placed in the path of the later, larger railroad fill failure. Especially if the material was deposited on the upper end of the Alder Flat, it would have been available for incorporation into the December 11 flow, potentially adding 25 % to the overall soil volume.

Debris Flow 5

This slope movement has little bearing on the events of December 11. The slope movement originated above the Kerry road and a large portion of the slide appears to have been deposited on the road prism. A smaller portion continued down the draw and was deposited as a relatively thin deposit over a portion of the Alder Flat. No significant portions of this flow entered the main Eilertsen channel, or the area disturbed during the December 11 event. However, in combination with the number of other failures in the Eilertsen and adjacent creek basins, this Debris Flow 5 points to the fact that the early December storm event was extraordinary in its intensity.

Debris Flow 6

This was the smallest of the events noted on Figure 2. It originated at the base of a steep slope segment downslope from Kerry Road in an area adjacent to more competent in-place rock exposed by a probable very large-scale slope movement. It is possible that the presence of the more impermeable rock forced groundwater out of the slope in this vicinity, causing the debris flow to initiate. The flow did not reach the main Eilertsen channel or the area disturbed by the December 11, 2007 event.

Debris Flow 7

This debris flow occurred in the East Fork Eilertsen basin, which had been subject to a debris flow in 1996. At that time, the debris flow initiated on the slope below Kerry Road in one of the smaller draws tributary to the East Fork. The 1996 debris flow cut a relatively wide swath through the Alders vegetating the bottoms of both the East Fork and the main valley of Eilertsen Creek to the lower old railroad crossing (Figure 3). From there, the width of the destruction caused by the 1996 debris flow decreased through the higher-gradient portions of the Eilertsen channel. The 1996 event moved and destroyed several unoccupied structures at Woodson and surrounded several others with mud and logs. Highway 30 at Woodson was partially covered by large woody debris in a manner similar to the December 11, 2007 event.

The volumes involved in the 1996 event are unknown, as is the erosion/deposition regime along that path. From the air photos, it appears that the East Fork channel was scoured along the entire path of the debris flow. Partial deposition may have occurred in the low-gradient portion between the confluence of the East Fork with the main creek and the lower old railroad grade crossing (Reaches J, K, L, and M). However, based on newspaper photos of Woodson after the 1996 event, a significant percentage of the mass of the1996 debris flow arrived at Woodson.

This is in contrast to the more recent December 3, 2007 event in the East Fork basin. The initiation area is estimated at 75 feet wide (N - S average) by 150 feet long. It appears that a depth of at least 10 feet was removed on average, which would indicate that a volume of approximately 4,150 cubic yards entered the East Fork channel. No deposits were noted in the upper reaches of the channel and there are no significant deposits visible in the channel upstream from the confluence with Eilertsen Creek. The East Fork channel has again been scoured and the young Alders which had started to grow there since 1996 have been removed to approximately ½ to 2/3 of the previous scour height.

The influence of the road system on the area of Debris 7 is unknown. Because the upper portion of the failure area is significantly wider than the lower portion, it appears that the initiation site must have been in the lower portion of the failure. As the failure progressed headward the sides also caved in and the width increased. Therefore, the initiation of the failure cannot be directly ascribed to the presence of the road. It is possible that the presence of a road ditch diverting water from the Kerry Road to the SW ditch of the spur road above the failure area contributed to the initiation of this failure. However, no direct correlation can be established with the information available.

Debris Flow 7 appears to have impacted the west bank of Eilertsen Creek at the confluence, mounding the debris and sending a portion a short distance upstream in the Eilertsen channel. It is probable that some, if not most of the debris volume continued north down the Eilertsen channel, although a significant deposit may have been left at the confluence.

Based on the lack of impact to the lower reaches of the Eilertsen Channel above Woodson on December 3, 2007, Debris Flow 7 did not extend past the lower old railroad grade crossing. The material must have deposited in the low-gradient reaches above this crossing. This is in contrast to the 1996 event which passed these low-gradient portions. Whereas particulars of the 1996 event are unknown, one significant difference between the two events that can be easily discerned on the air photos preceding and following 1996 is that the earlier flow passed through long stretches of mature Alder stands in the bottom of both the East Fork and main stem of Eilertsen Creek. Based on observations at other long-run-out debris flows which either occurred during the last several years (Tyee Mountain, North Myrtle Creek area, 2005), or are historically documented (Mapleton, 1964), it is possible that the presence of numerous mid-sized trees in close proximity to the channel contributes to the run-out distance of debris flows. The mechanism is not currently well understood but may be related to localized increases in gradient and shear stress formed by a woody debris dam at the front of the debris flow. No such trees were available to Debris Flow 7 either in the East Fork or the main Eilertsen channel because they had been removed by the 1996 event. It is possible that this led to deposition of Debris Flow 7 (presumably above the old railroad crossing) whereas the 1996 event continued through the low-gradient portions of the channel. Further study of this issue is recommended due to the potential implications for debris flow run-out distances in low-gradient (5 % or less) channels where conventional debris flow models indicate that deposition should occur.

Debris Flow 8

Little is known about this event, which may actually consist of several smaller debris flow failures which occurred along the lowermost east bank of Eilertsen Creek immediately above Woodson. However, Mr. Rick Richmond indicated that five smaller failures occurred on his property on December 3, 2007 which delivered mud into the central parts of Woodson, partially covering some of the yards there. One of the failures is visible in the forest on the east side of Eilertsen Creek directly above where the driveway to his residence starts climbing up the east bank. Another failure was later noted on one of the photos taken in Reach "R" of the Eilertsen channel (Figure 2). The latter failure is located directly west-southwest of the SW corner of the Richmond residence.

Initially it had been assumed that the mud deposited in Woodson on December 3, 2007 had been the result of debris flow activity in the upper reaches of the basin. However, based on Mr. Richmond's statements, this assumption appears to have been false.

Main Railroad Fill Failure

The main railroad fill failure occurred on December 11, 2007 at approximately 11:50 am. Due to the multitude of slope-, flood-, and road-related problems in the Northwest Oregon and Southwest Washington area resulting from the December 3, 2007 storm event, the ponding of water behind the embankment had not been noticed until December 6, when personnel of the Evenson Timber Association finally reached this area. At that time, the pond was still at its maximum level, and overflowing to the ditch along the south side of the road east of the embankment. Debris Flow 4 had occurred. The private forest land owner reported the problem to ODF and to the residents at

Woodson. The ODF Stewardship Forester was at the site on Friday, December 7 and asked for assistance from the geotechnical staff at ODF. The geotechnical specialists arrived on Monday, December 10, and noted formation of arcuate tension cracks in the road in the vicinity of the center of the embankment. At that time, the pond level had reportedly already dropped by a couple of feet, and the pond was no longer overflowing to the ditch. However, only small of amounts of water were discharging from the downslope side of the fill. It was not determined whether discharge was occurring from either the puncheon culvert, the relief culvert, due to seepage from the face of the fill, or due to a combination of these, as is most likely.

During the time from December 3rd until the 11th, total precipitation was 0.73 inches at the Miller RAWS station. As a result it is likely that the pond reached its highest level on or shortly after December 3. Based on a maximum estimated pond area of 1.12 acres and a maximum depth of 26.8 feet, the approximate volume of the impoundment is 653,750 ft^3 (24,200 cu.yds or 4.89 million gallons). Based on a total drainage area above the railroad embankment of 37.61 acres, the amount of precipitation needed to fill the pond to its maximum level is approximately 4.75 inches. At the Miller RAWS, the storm event total from December 1 through 3, 2007 was 9.19 inches. Therefore, approximately one half of the precipitation recorded near the site from this single storm would have been required to fill the pond. Due to attenuation by infiltration into the ground, it is probable that a significant portion of the precipitation generated by the storm was delayed from entering Eilertsen Creek by at least several hours, if not days. As a result, following the debris flow(s) which plugged the culverts through the railroad embankment on December 3rd, sufficient water remained in the drainage basin to fill the pond to capacity and overflowing.

The delay between the filling of the pond (prior to the 6th) and the failure of the embankment is significant for the determination of the mechanism of failure. In this context, it is important to note that the embankment was not designed as a dam. The design of earth-fill dams relies on two material characteristics to be effective: The weight of the dam material and shear resistance along the bottom keep the dam in place and a low-permeability layer in the dam fill prevents the impounded water from seeping through the dam.

In the case of the Eilertsen railroad embankment, the weight of the dam and the shear-resistance developed along the bottom and "abutments" (side slopes) was clearly sufficient to hold the weight of the low-strength debris flow deposits and water. The embankment stood at or near maximum pool level for five days or more. However, the embankment lacked the second component of earthfill dams, the impervious layer. The railroad embankment was reportedly originally constructed as a wooden railroad trestle which was subsequently buried by the spoils generated by excavation of the tunnel located approximately 1/4 mile to the west of the embankment site. Based on the characteristics of remaining portions of the embankment this does indeed appear to be the case. The embankment consists of soil with numerous pieces of sawn lumber of different sizes and lengths. There are hundreds or thousands of pieces of boards which are from 6 to 18 inches long. These may well have been scraps generated from the lagging which must have been installed behind timber supports to line the tunnel. The embankment also contained numerous candle stumps which were probably the waste of the candles used to light the tunnel during construction.

Based on the cross sections measured at the embankment site both parallel and transverse to the direction of flow of Eilertsen Creek, the total embankment volume was approximately 32,500 cubic yards, of which an estimated 10,000 cubic yards remain at the site after the failure. About three quarters of the remaining volume are located on the west side and one quarter is on the eastern slope. The material excavated from the tunnel appears to have been completely decomposed sandstone, similar to that found in Slide 1 and Slide 2. The material consists of a fine- to medium-grained sand with varying amounts of silt. Some portions contain barely sufficient silt to be cohesive and plastic when moist but large portions are non-plastic and essentially cohesionless at any moisture content. This is consistent with the reports of the reason for the construction of the tunnel. Based on the information regarding the "Kerry Railroad" available online at www.brian894x4.com/Kerryrailroadhistory.html , the reason for the construction of the 1875-foot long tunnel was that "quicksand" was encountered farther up the hill along the originally planned alignment of the railroad. The tunnel was seen as a more cost-effective alternative to the problem of dealing with the "quicksand". However, once the tunnel had reached 400 feet into the hill, the same material and associated problems were encountered. Initially it was contemplated to freeze the soil permanently, permanently operating a freeze plant at one of the entrances to the tunnel. However, it was finally decided to install a complex drainage system to address the problem. It is likely that the sand was not in fact "quicksand" but rather "heaving sand" or, in more appropriate terms, by discharge of groundwater which was occurring at velocities sufficient to mobilize the sand from the face or ceiling of the tunnel.

Based on the reported length of the tunnel (1875'), the 32,500 cubic yards calculated for the embankment would indicate an overall cross-sectional area of 468 ft^2, or a circle a little over 24 feet in diameter. This is probably larger than the actual tunnel size. However this discrepancy can be explained by the fact that the initial tunnel excavation probably encountered flowing sand and generated more excavation spoils than just the tunnel volume. In addition, 400 feet of the tunnel collapsed a few years later and had to be re-established and one of the portals collapsed later on, requiring additional excavation. If it is assumed that the total excavation was the equivalent of 2,475 feet of tunnel, the effective diameter would be reduced to around 20 feet which is more plausible given the probable size of the trains (locomotive on track approximately 18 feet high and 12 feet wide, requiring additional clearance for smoke and track bed).

The hydraulic conductivity of silty sand ranges from approximately 0.1 to 50 feet per day (EPA Seminar Publication EPA 625/4-85/016 *Protection of Public Water Supplies from Groundwater Contamination*, p. 11). Assuming that the Eilertsen embankment was in a mostly unsaturated condition, containing relatively little free water at the time of the formation of the pond, the seepage velocity can be calculated by using the maximum hydraulic gradient and a hydraulic conductivity in the range from 0.1 to 50 feet per day. The maximum hydraulic gradient which could be developed at this site is approximately 29' per foot, assuming a near-instantaneous filling and exposure of 29 feet of embankment over the more impermeable debris flows. Given the range of hydraulic conductivity, the flow velocity at that time could range from 2.9 to 1459' feet per day. Once the migrating saturation front reached the downstream base of the embankment, the hydraulic gradient would be on the order of 0.66. As a result, the expected flow velocity would range from 0.066 to

33 feet per day. The water front would have had to travel approximately 120 feet to reach the downstream base of the embankment and it probably had from five to seven days to travel that distance. Based on the width of the embankment, this would require an average velocity of 17 to 24 feet per day. Initial velocities of the saturation front through the southern portions of the embankment were probably higher and then decreased with decreasing gradient as the front progressed northward. The average velocities developed from the time-line of the failure values are well within the range expected for the gradient and hydraulic conductivities for silty sand.

Once the saturation front reached the downstream base of the embankment, the discharge from seepage at the toe of the embankment would have been related to the area of saturation exposed. Assuming a movement velocity of 10 feet per day (at the lower hydraulic gradient) and a triangular exposed saturated area 20 feet high and 70 feet wide at the top, the daily discharge would be 7,000 cubic feet per day or 0.08 cubic feet per second or 36 gallons per minute. This would probably be enough to result in localized erosion of the base of the embankment. Once this process starts, a steep lower face would be expected to develop in the lower-most portions of the embankment which, in turn results in a localized increase in gradient and higher flow velocities. As a result, the process turns into a positive feedback loop with ever-increasing flow velocity at the interface and increasing erosion of the base of the embankment.

The foregoing discussion provides a possible explanation for the apparent good initial performance of the embankment and the later rapid deterioration of the situation shortly prior to the catastrophic failure. However, other scenarios could be envisioned that might produce similar results.

Once the catastrophic failure occurred, significant amounts of soil and trees were incorporated on the debris flow's passage down Eilertsen Creek. Portions of this material were deposited along the way, with significant amounts of soil first deposited on the Alder Flat and then in increasing amounts along the wider relatively low-gradient stretches of the channel. Based on a travel time of 3 minutes, the debris flow would have been traveling at an average velocity of 35 miles per hour, which appears intuitively plausible based on the difference in elevation between the scour line on the inside and outside of curves.

Based on the composition of the embankment, the debris flow would have initially contained very few rock fragments. Once it was deposited at Woodson, it contained numerous igneous rock fragments of sizes up to 2 feet or more in diameter. It is probable that these were obtained by scouring of the outcrops of the Columbia River Group flow breccia exposed in Reach "O" and from the older debris flow terraces located in reaches "E", "P", and "Q".

The presence of older debris flow deposits in the channel of Eilertsen Creek starting with reach "E" or "F" is significant. Some of these deposits clearly predate the construction of the railroad and, therefore, the initial harvest of timber in this area, for which the railroad was reportedly built. In addition, it is important to note that at least one of the older debris flows may have passed through Reach "O" with sufficient erosive power to mobilize a significant quantity of large igneous rock fragments. Alternatively, it is possible that some of these rock fragments were derived from the outcrop of flow breccia located in the sidewall of Slide 2. In that case, a debris flow of some competence would be required to move the fragments to Reaches "P" and "Q".

In either case, these deposits indicate that debris flows of sufficient magnitude to destroy homes and inflict injuries and/or death have been a part of the depositional history at Woodson for a long time. The fact that such events are likely to occur again some time in the future cannot be changed by policy or regulations of forest practices. As a result, it appears that a focus on education of the existing downslope population and the entities regulating building permits represents an especially important factor in limiting future risk in this area.

CONCLUSIONS

Since 1914, the area of Woodson, Marshland, and Kerry has been subject to at least 6 different news-worthy debris flows which have caused property damage, injuries, and deaths. It is probable that additional debris flows have affected the area which have not been sufficiently newsworthy to be included in the summaries prepared by the local press.

Precipitation records from the Clatskanie weather station and Miller RAWS site indicate that the storm of December 1, 2, and 3, 2007 was an extraordinary event. At Clatskanie, December 07 had the third-highest monthly rainfall total (18.48 inches) since measurements began in 1948 and the maximum 24-hour total during this event at Miller RAWS (6.76 inches) was probably the highest since records have been kept at that site. It exceeded the maximum 24-hour total recorded during the 2006 event by 15 %. The rainfall recorded at Miller for the 3-day storm event in early December, '07 was 9.19 inches. The greatest monthly rainfall total at Clatskanie (21.75") occurred in November, 2006 and the maximum 24-hour precipitation for that month at Miller was just under 6".

Numerous debris flows occurred both in the Eilertsen drainage above Woodson and in nearby drainage basins on December 3, 2007. These include failures in Graham Creek, Tandy Creek, OK Creek and Olsen Creek. In the course of this assessment, 8 significant debris flow failures (other than the railroad embankment failure) were identified in the Eilertsen Creek basin alone. These are numbered 1 through 8 on Figure 2 of this report. The following table presents estimated or known pertinent parameters of all debris flow events including the main railroad fill embankment failure.

Summary of December 3 through 11 Eilertsen Creek Debris Flows

Failure #	Initial Vol. (yds^3)	Deposited Vol. (yds^3)	Path Length (ft)	Gradient (%) Max/Avg/Min	Initiation Mechanism
1	7,900 (E)	9,000 (E)	850 (M)	21/19/12 (M)	At toe of deep-seated slope movement.
2	1,200 (E)	3,000 (E)	900 (M)	10/27/72(M)	At toe of deep-seated slope movement
3	75 (E)	75 (E)	50 (E)	20/40/50 (E)	At toe of near-uniform slope.
4	4,250 (E)	5,000 (E)	1,000 - 5,400	36/unkn./4% ?	Embankment failure due to plugged culverts.
5	2,200 (E)	2,200 (E)	600 (E)	100/70/0 (E)	Deep-seated slide.
6	<40	<40	300 (E)	100/50/10 (E)	Rapid groundwater discharge.
7	4,150 (E)	4,500 (E)	2,800 -4,500	100/?/4	Steep slope above scoured 1996 debris flow channel? Road ditch?
8	Unknown	Unknown	400 - 1000?	70/10/3?	Cut bank/Fill slope failures?
Main	22,500 (M)	Unknown	10,300 (M)	24/10/3 (M)	Piping/Collapse due to plugged culvert & water impoundment.

Based on an eyewitness report from Rick and Jeanine Richmond, who own the house higher on the east slope above the lowermost stretch of Eilertsen Creek, none of the original December 3 debris flows reached the town of Woodson, except the failure(s) at or near Debris Flow 8, located in Woodson itself. The mud which was being cleaned up in Woodson between December 3 and 11, 2007 was deposited by one or more of these events, which occurred very low in the drainage.

Where a former railroad grade crosses Eilertsen Creek at approximate elevation 980 feet, a large embankment had been constructed in the earliest 1900s. Initially, the railroad constructed a wooden trestle at this site and then buried the trestle with the material excavated from an approximately 1,875-foot long tunnel located approximately a quarter mile to the west. The embankment material consisted of approximately 32,500 cubic yards of mostly cohesionless slightly silty sand derived from complete decomposition of marine sandstone. Minor portions of the lower upslope side of the embankment were apparently constructed of railroad ballast material consisting of angular igneous rock fragments to 6 inches in diameter in a reddish-brown clayey sand matrix.

During the December 3, 2007 storm event, Debris Flows 1 and 2 reached the upslope side of the railroad embankment. Based on superposition of the deposits, Debris Flow 1 entered the area of the confluence of Draws 1 and 2, immediately upstream of the embankment, first. Debris Flow 1 arrived with sufficient velocity to run up onto the railroad (now road) embankment and plug a relief culvert located an estimated 20 feet below the top of the embankment. Debris Flow 1 deposited approximately 21 feet of mud and variably weathered siltstone/sandstone fragments over the inlet of the original wooden puncheon culvert at the base of the embankment. The total volume of deposits from Debris Flow 1 is estimated at 9,000 cubic yards. It is impossible to determine how far Debris Flow 1 would have traveled if the railroad embankment had not been in place. It is possible that the volume would have been sufficient to reach Woodson, in which case it would have probably caused significant damage there.

Debris Flow 1 originated at the northwest and northeast toe of an approximately 1.75-acre deep-seated slope movement in the upper reaches of Basin 1a, approximately 850 feet slope distance from the railroad embankment. Slide 1 is identifiable as a pre-existing geomorphic feature on 1994 air photos, after the area had been clearcut in 1992. Based on the colluviation of the scarp and creek channels, it appears that the last significant previous movement of this feature occurred hundreds of years ago. At the time of failure, the entire area involved in both deep-seated Slide 1 and Debris Flow 1 was densely vegetated with Fir and some Alder trees approximately 25 feet tall or taller.

Based on scarp heights and the direction of back-rotation of trees in different parts of the movement, Slide 1 is estimated to have moved approximately 25 to 30 feet in a northwest direction, with the northwestern half of the slide body also moving approximately 30 feet to the northeast. The total mass in motion on December 3, 2007 is estimated at 85,000 cubic yards or 140,000 tons. None of the slide mass over-rode the surrounding terrain. Therefore, a significant amount of material had to be evacuated from the northwestern and northeastern toe of the slide during or prior to the movement. It is estimated that 7,900 cubic yards of material were removed from the vicinity of the confluence of creeks 1a and 1b in order to create the void for Slide 1 to move into.

Debris Flow 1 initiated in an area with overall slope angles on the order of 30 % or shallower. It is possible that the toe of Slide 1 was locally over-steepened by movement at the time of initiation of Debris Flow 1, but this cannot be verified at this time.

There is no evidence of extraordinary flow in any of the road-side ditches that drain to the slide area. Organic debris, including fir needles which had collected in the ditches was still present after the event when GeoScience first visited the site on February 26, 2008. A total of approximately 550 feet of road length drains to two points above the southeastern and southwestern scarp of Slide 1. 350 feet of this length was previously located within the basin, and does not add to the natural drainage area. The total drainage basin of Creek 1a is 4.74 acres. Road construction prior to 2004 for access to the landing above Basin 2 is estimated to have added 0.05 acres or, roughly 1 % to the total drainage area of Basin 1a. The debris flow initiation area is located at the confluence of Creeks 1a and 1b, which is located 400 and 480 feet from the two ditch discharge points. The total drainage area above the initiation point of Debris Flow 1 is 7.09 acres.

Based on the long-term presence of most of the road and the presence of the entire road system and both clearcuts (1992 and 2004) through the record-setting storm event of November 2006, without documented response of Slide 1, these anthropogenic factors can be all but ruled out as major contributing factors of the initiation. The more likely factor affecting the timing of the failure is the magnitude of the early December 2007 storm event during which the maximum 24-hour precipitation recorded at Miller RAWS during 2006 was exceeded by nearly 15 %.

The same arguments hold true for Debris Flow 2 and deep-seated Slide 2, which occurred in Basin 2c. The volumes involved are smaller for both the deep-seated movement (estimated at 6,300 cubic yards) and the initial debris flow volume (estimated at 1,200 cubic yards). Deep-seated Slide 2 appears to have occurred at a contact of completely decomposed sandstone overlying partly decomposed to stained state siltstone, with additional water contributed to the lower edge of the failure area by a Columbia River Group flow breccia unit exposed in portions of the lower northwest portion of the slide scarp. The lower portions of Slide 2 moved as a viscous flow, overriding an unknown length of the slope below before splitting into two branches above a knob of in-place rock or older, consolidated slide deposits, immediately above the two initiation sites of Debris Flow 2.

Large portions of Basin 2 were clearcut in 2004 and a 2-acre portion of the lowermost basin was salvage-logged in 2006. Debris Flow 2 picked up significant amounts of slash, large logs ,and root wads along the 900-foot length of travel from the initiation site to the railroad embankment site. It is probable that the total volume upon deposition had increased to approximately 3,000 cubic yards. Much of this volume is located upstream from the main deposit of Debris Flow 1 material, and only a thin layer of Debris Flow 2 material reached the base of the exposure of the railroad embankment, remaining after emplacement of 20 feet of Debris Flow 1 material.

Based on these observations, it is certain that the main railroad fill failure would have occurred as a result of the Slide/Debris Flow 1 event only, which resulted in plugging of both the main puncheon culvert and the relief culvert, impounding the pond behind the embankment. It is possible that the main railroad fill would not have occurred if Slide/Debris Flow 2 had been the only event above the railroad embankment. Whereas Debris Flow 2 would have reached the puncheon culvert inlet with sufficient material to plug that culvert, it is unlikely that Debris Flow 2 could have also plugged the higher relief culvert inlet. As a result, the pond depth would have probably been on the order of 20 feet lower and the travel time for the saturation front to the downstream base of the embankment would have been much longer. This, combined with the much shallow depth of the deposits at the main culvert inlet might have allowed for removal of the debris pugging that culvert prior to catastrophic failure of the embankment.

The December 3 storm event also caused initiation of other debris flows in the Eilertsen basin, including a small debris flow (Debris Flow 3) at the lower end of a small drainage basin discharging to a culvert (size unknown) located at the base of a smaller embankment along Kerry Road approximately 160 feet east of the eastern margin of the main railroad embankment. The plugged culvert resulted in formation of a small pond into which a small delta was deposited from the toe of Debris Flow 3. The elevation of the top of the deltaic deposits coincides with the elevation of the crown of the road at this location, indicating that this pond discharged across the road. It is not known whether this caused initial erosion and/or failure of the Debris Flow 4 area, prior to the arrival of water along the southern roadside ditch from the overflowing impoundment at the railroad embankment crossing Eilertsen Creek.

Debris Flow 4 may have been initiated by water flowing over the road embankment below Debris Flow 3 due to the plugged culvert there. However, it is probable that the failure was either initiated or at least significantly enlarged when the impoundment at the main Eilertsen Creek embankment overflowed to the southern ditch along the road which has a 3 % slope to the area below Debris Flow 3. This would have increased the size of the area draining above the road at Debris Flow 4 from approximately 5.3 acres to 43 acres, which represents an eight-fold increase.

The initial volume of Debris Flow 4 is estimated at 4,250 cubic yards. Debris Flow 4 clearly entered the main Eilertsen channel, where it would have picked up at least some additional woody debris from the Alder trees lining the channel. The depositional area of this debris flow is indeterminate. A section from an apparent 24-inch culvert was found at the lower end of the Alder Flat, approximately 1,000 feet from the Kerry Road. If this is part of the culvert at the initiation site of Debris Flow 4, it is probable that this debris flow deposited in the Alder Flat which represents a very low-gradient section with a loss of confinement for the Eilertsen channel. Alternatively, Debris Flow 4 could have continued along the Eilertsen channel and deposited in the low-gradient reach upstream from the lower old railroad crossing. Based on the reports of Mr. Richmond, none of the debris flows which initiated between December 2 and December 11, 2007 reached Woodson.

Debris Flow 5 originated on a slope above Kerry Road which is estimated to be at angles ranging from 70 to 100 %. Air photo interpretation indicates that the slope exhibited evidence of previous failure, with an arcuate steeper slope segment (colluviated scarp) in the area near the top of the recent failure. A large portion of the estimated 2,200 cubic yards of the failure was deposited on the road and a smaller portion continued over the steep slope downslope from the road and was finally deposited on the "Alder Flat". None of the material reached the main Eilertsen channel or the margin of the area disturbed by the 12/11/07 event.

Debris Flow 6 is a minor feature, the initiation site of which is at the base of a natural steep slope segment located below Kerry Road. The initiation site is located where in-place competent rock crops out on the hill-side, possibly exposed in the scarp of a very large-scale, deep-seated slope movement which also forms the Alder Flat. It appears that water was forced out of the slope by the presence of the low-permeability competent rock, causing localized mobilization of the overlying soil/weathered rock section. The debris formed a narrow channel with natural levees and deposited in a low area along the southeast margin of the Alder Flat. None of the material from Debris Flow 6 reached the main Eilertsen Channel.

Debris Flow 7 occurred below a spur road of the Kerry Road approximately 1,000 feet northeast of the main railroad embankment. The east-facing slope of the Eilertsen East Fork failed in debris flow mode, with the failure area approximately 50 feet wide at the toe of the slope and increasing to an arcuate slope segment approximately 100 feet wide at the spur road. The total initial volume of this failure is estimated at 4,150 cubic yards. Because the East Fork channel had been scoured by a 1996 debris flow which initiated a few hundred feet upstream of Debris Flow 7, it is likely that the more recent flow did not gain significant volume on its way down the channel. Debris Flow 7 impacted the west bank of Eilertsen Creek at the confluence with the East Fork with sufficient velocity to mound the debris and portions flowed upstream in Eilertsen a few tens of feet. It is not known whether a significant deposit was left in the main channel at the confluence, or if most of Debris Flow 7 continued downstream. However, based on the lack of debris flow activity observed in the lowermost reach of Eilertsen Creek above Woodson, it can be determined that Debris Flow 7 did not pass the lower old railroad grade crossing.

The fact that Debris Flow 7, which did not deliver to Woodson, followed a portion of the path of the 1996 event which did deliver to Woodson may be significant. It is possible that the lack of Alder trees of any significant size along the path of the recent debris flow resulted in deposition of the recent event along the extended length of low-gradient (4 % or less) channel between the confluence of the East Fork and main stem of Eilertsen Creek and the old railroad grade crossing. The 1996 debris flow from the same area had larger Alder trees available to form log jams or "migrating organic dams".

Debris Flows 8 consists of a reported 5 smaller failures along the east side of the lowermost Eilertsen valley, essentially in the Woodson area. According to Rick Richmond, who owns the house higher on the east slope of the valley, these failures occurred on December 3, depositing the mud in Woodson which, on December 11, was in the process of being cleaned up when the main railroad embankment occurred.

The main railroad embankment failure occurred on the morning of December 11, 2007, eight days after the storm event which resulted in the plugging of the culverts installed through the base and higher portions of the embankment. The pond which formed as a result of the plugged culverts covered an area of approximately 1.12 acres and contained an estimated 5 million gallons of water. The maximum water depth was between 28 and 29 feet above the debris flow deposits behind the embankment. The water depth was controlled by the elevation of the southern roadside ditch on the east side of the embankment. In that stretch of the road, the old railroad grade has an approximate gradient of 3 % up toward the tunnel to the west. The impoundment behind the embankment was first noted on December 6 and ODF personnel were at the site on the following day.

The railroad embankment, which had been constructed by filling soil over a wooden trestle, contained an estimated 32,500 cubic yards of soil of which 22,500 cubic yards were involved in the catastrophic failure. The soil had been derived from excavation and repairs of the tunnel located approximately one quarter mile to the west. The soil consisted of completely decomposed sandstone which had been disaggregated into silty sand. Most of the material is non-cohesive and non-plastic, which is consistent with the reported reason for constructing the tunnel (presence of "quicksand"). Flowing or heaving sand was also encountered during tunnel construction and was addressed by a complex drainage system.

On December 6 or 7, neither the landowner nor the ODF Stewardship Forester noted distress in the embankment. By December 10, when geotechnical specialists from ODF were on-site for the first time, arcuate tension cracks approximately 2 inches wide but lacking vertical offset were noted in the road bed in the central portion of the embankment. By the early morning of December 11, these cracks had widened and portions of the road had dropped by between one and two feet. An emergency ditch was excavated along the western margin of the embankment in an attempt to provide discharge for the impoundment. In order to limit erosion of the ditch floor and downstream channel, the elevation of the ditch bottom was adjusted to provide for a flow only a couple of inches deep. As a result, only a tiny fraction of the water contained in the impoundment at that time was discharged prior to the catastrophic failure. ODOT personnel were in the process of mobilizing large-volume pumps to the site when the catastrophic failure occurred. The town of Woodson had been evacuated and Highway 30 had been closed a little over an hour prior to the failure.

The initial adequate performance of the embankment and later catastrophic failure can be plausibly explained by the time required for the saturation front to migrate from the pond on the upstream side through the silty sand fill to the downstream base of the embankment. The average velocity of the migrating saturation front can be calculated as ranging from 17 to 24 feet per day depending on the initial time of filling of the pond, which is uncertain. Once the saturation reached the downstream side of the embankment, the discharge from the lower face would have been sufficient to initiate erosion of the lower-most portions of the embankment. The resulting steep face would have increased the gradient and discharge locally, causing a positive feed-back situation, accelerating erosion, and ultimately, catastrophic collapse of the embankment.

The resulting failure consisted of approximately 22,500 cubic yards of sandy soil with some woody debris, and close to 20,000 cubic yards of water from the pond. The debris flow traveled close to 2 miles in approximately 3 minutes, at an estimated average speed of 35 miles per hour. Partial deposition of the debris started on the Alder Flat less than 1,000 feet from the embankment site and intermittent scouring and deposition was mostly controlled by the channel gradient from that point downstream, with deposition outweighing scouring in the lower-gradient portions and erosion exceeding deposition in the channel sections with steeper gradients. The final volume which arrived at Woodson and Highway 30 is not known, and will probably never be known, because the debris flow discharged significant amounts of soil and woody debris into Westport Slough. The debris flow destroyed two houses, several outbuildings and vehicles, and surrounded and damaged four other structures to varying degrees.

The presence and size of the upper railroad embankment clearly exacerbated the severity of the event that impacted Woodson on December 11, 2007. However, it is unclear whether the presence of the embankment did not also provide mitigating circumstances on December 3, by providing a dam for Debris Flows 1 and 2. Of these, Debris Flow 1 was clearly the larger event, involving an estimated 9,000 cubic yards by the time it reached the embankment. Had the railroad embankment not been in place, it is possible that Debris Flow 1 would have gained additional volume in the stretch through the embankment site and at least to the Alder Flat, potentially reaching a volume of 10,000 to 15,000 cubic yards. It is not known whether this would then have been sufficient volume to allow passage all the way to Woodson, where the debris flow would have arrived without warning, potentially resulting in injuries or deaths in the residences located most proximal to the channel.

RECOMMENDATIONS

With the exception of the magnification of the December 11, 2007 event by the presence of the railroad embankment, it is difficult to identify causal factors for the December 3 through 11 events in the Eilertsen Creek basin which could be effectively addressed by regulations concerning management of timber lands. The Kerry Railroad was initially constructed to provide access to timber lands and the Kerry Road along portions of the old grade continues to do so.

Assessment of Other Potential Embankment Failure Sites in Oregon

In light of the December 11 Woodson event, it appears to appropriate to review other, similar embankments. This reassessment should not be limited to embankments on timber lands, but should also apply to other embankments found along many county and state highways. The latter may present less of a risk than those on timber lands, mainly due to the fact that public highways are traveled more and plugged culverts are more likely to be noticed prior to formation of a large impoundment. Nonetheless, it must be noted that, historically, large road embankments for public highways have also failed as debris flows without warning (i.e. Hwy 101 at Cape Foulweather in 1964 and 1999). Therefore, an assessment of all embankments with regard to risk to downslope population appears justified in light of the Woodson event. In the case of Woodson, following the December 2007 event, ODF personnel required significant modifications to another large former railroad embankment located downslope and to the east of the failure. In order to be able to prioritize these assessments, the focus should initially be on identification of potential downslope population at risk. For those embankments where no people are at risk downslope, an assessment of the likelihood of failure appears to be moot.

Identification of Deep-seated Slope Movements (Possibly by LIDAR)

Another recommendation which appears appropriate for overall reduction of risk to the downslope population, although not necessarily in the realm of timber management, is an overall assessment of the risk of debris flow generation from the toe of deep-seated slope movements in Western Oregon. These debris flow initiation sites are not necessarily captured within the slope thresholds used in the forest practices rules as a result of Senate Bill 12 and/or many such sites are probably located in areas which are not under the auspices of ODF. In the case of Debris Flow 1, the initiation site is located in an area with overall slopes around 30 % or less. Whereas this may be an exceptionally low slope for generation of a debris flow, the toe areas of large deep-seated failures have been implicated in several recent debris flow failures in Western Oregon.

The main problem to date has been the identification of large-scale deep-seated slope movements which may have been inactive for some time. These features can only be effectively identified by geomorphic means and subsequent on-the ground verification. The advent of LIDAR provides one of the best tools for this process yet, although care must be taken not to overrate the possibilities this technology provides. For one, and most importantly, the quality of the interpretation of the LIDAR is not related to the technology itself but rather to the competence and experience of the person performing the interpretation. Secondly, whereas LIDAR presents the state of the art for developing accurate topographic information in an area where the ground is covered by tree canopy, it must be noted that a LIDAR ground image represents not the landscape or ground surface itself, but rather a large number of points which have been assigned to the "ground-surface" category by a computer algorithm. As a result, the assignment may be erroneous or important detail information may be lost by "smoothing" of the ground surface between adjacent points. This could, for instance, result in loss of such features as small-scale scarps which could be noted by experienced personnel on the ground but would be lost on the LIDAR image.

In addition, once features presenting a potential risk are identified on LIDAR, the presence of the inferred "landslide" must be verified on the ground before planning decisions are made or restrictions are applied. The application of the "multiple working hypotheses approach" is paramount in minimizing the ultimate costs to society of this application of technology. It is conceivable that publication of maps containing unverified LIDAR interpretation could force many entities to spend large sums of money to mitigate perceived "hazards" which are, in reality, non-existent.

Reduction of "Downslope Risk" by Planning Restrictions, Mitigation, or Relocation

Along these same lines, it must again be pointed out that the risk to the population is comprised of two components. The "upslope component" consists of the likelihood of initiation of debris flows and the likelihood of transport to areas where people are likely to be present. The "downslope component" consists of the likelihood that people are present in areas where there is risk from the "upslope component". The importance of both components was recognized in Senate Bill 12, but the due to difficulties in developing adequate definition of the actual risk, implementation of the portions of the legislation applicable to the "downslope component" has not occurred. To date, the focus of the planning has been on the "upslope component" (i.e. restrictions on forest operations) mainly as a result of an apparently widespread (mis-)perception that the "upslope" risk can always be addressed by land management practices or cessation of land management. In many cases, it is more appropriate and sometimes the only option, to manage the overall risk to the population by a reduction or elimination of the "downslope" risk component. This can be achieved either at the planning stage, by preventing placing structures in harm's way, by implementing mitigation at existing or planned structures, or by relocating existing population to areas which are not at risk from debris flow impacts. In the case of Woodson, several structures were located in the impact area of the 1996 debris flow and at least one of them (the single-wide mobile home pushed onto Highway 30 on December 11, 2007) had been damaged by the earlier event. It appears that the current regulatory environment has lacked provisions to prevent continued occupation of some of these structures without restrictions after the 1996 event(s) at Woodson and in the vicinity. Apparently, several of the structures are rentals. Therefore, the people occupying the structures may not have had the advantage of the knowledge of the 1996 impacts to Woodson. In addition, it appears that, under certain circumstances in property transactions, there is no obligation on the side of the seller to disclose such information to potential buyers (e.g. For Sale "As Is").

Given these shortcomings it appears that there is significant room for a reduction of the risk to the general population by addressing the "downslope" risk component. It is quite clear that such efforts could be very unpopular as they would probably result in restrictions of the rights of owners to utilize their property. However, restrictions on land use are regularly being applied for reasons which could be considered significantly more controversial than public safety.

Further Assessment of the Role of Vegetation in Long Run-out Debris Flow Transport

The recent Woodson events have provided additional evidence that the presence of medium-sized trees in close proximity to debris flow channels may contribute to long debris flow run-out distances in systems with relatively low gradients. Such instances have been noted before at other locations in Western Oregon. In the case of the debris flow history in Woodson, the 1996 debris flow, which originated in the East Fork of Eilertsen Creek delivered to Woodson despite passing through approximately 2,000 feet of relatively low-gradient channel. At that time, the area adjacent to the channel was vegetated with mature Alder trees. On December 3, 2007, another failure of similar magnitude occurred in the same drainage, a few hundred feet from the 1996 initiation site. However, this time, the debris flow did not deliver to Woodson, but rather deposited in the low-gradient section of the channel. Because it is likely that the rainfall event on December 3 was actually more severe than in 1996, the apparent main difference is the age of the vegetation which was present along the channel, and, possibly, the amount of "soil" along the East Fork channel. Because long run-out debris flows impact the effectiveness of the "Further Review Area" concept, a more detailed understanding of the factors influencing the run-out of debris flows is desirable. It appears that the understanding of the run-out distances of debris flows consisting mostly of mud and rock fragments is better developed than the interaction of such debris flows with vegetation and the effects of incorporation of the vegetation into the moving mass.

LIMITATIONS

This report was prepared for the use of the Oregon Department of Forestry, and their authorized agents for planning and design purposes. Our professional services were performed, and our conclusions and recommendations provided in accordance with generally accepted principles and practices. This assessment was subject to the limitations of a "Not-to-Exceed" budget. The analyses, conclusions, and recommendations in this report are based on site conditions as they presently exist and on surficial observations and extremely limited subsurface exploration only. The report is not a warranty of subsurface conditions. If, in the future, conditions are found which differ significantly from those presented here, GeoScience must be advised at once so that these conditions and our recommendations can be reviewed and revised, if necessary. Should a substantial lapse of time occur between this investigation and future site activity, or if conditions have changed due to nearby construction or natural causes, the data contained in this report should be reviewed to determine its continued applicability. This report is not intended to provide a seismic risk evaluation of the subject property. GeoScience cannot be responsible for construction activity on the subject property or other sites which neighbor or abut the subject property referenced in this report.

If you have any questions about this report, please do not hesitate to contact me at (541) 607-5700.

Respectfully submitted,
GeoScience, Inc.

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