Geotechnical Assessment of the December 2007 Debris Flow Complex

in Eilertsen Creek, Woodson, Oregon

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(1) Purpose and Scope

On Tuesday morning, December 11, 2007, a massive road fill failed catastrophically into the upper reaches of Eilertsen Creek in northwestern Oregon (Figure 1), sending a torrential mix of sediment, water, and wood downstream. This debris torrent raced approximately 1.75 miles (i.e., 2.5 stream miles) down the Eilertsen Creek canyon in less than three minutes (approximately 50 miles per hour). Debris inundated the community of Woodson at the mouth of the canyon, covered Highway 30 and the Burlington Northern railway tracks in a sea of mud and logs, and flowed into the Westport Slough on the Columbia River floodplain. Fortunately, no one was injured. The debris torrent, however, damaged considerable property in Woodson, resulted in lengthy highway closures and delays during the clean-up operation, received global media attention, and prompted several technical assessments of the fill failure and flooding in Woodson. Initial reviews of the event identified a number of complicating factors, including the presence of two landslides upstream of the fill in the headwaters of Eilertsen Creek, impoundment of approximately 35,000 yd^3 of water (i.e., about 7 million gallons) on the upstream side of the fill prior to its collapse, additional failures near the fill that also delivered materials to the channel, and remnants of an old railroad trestle buried in the remains of the fill.

This is one of several reports, prepared for or by the Oregon Department of Forestry (ODF), related to the December 2007 storm, the fill failure, and the Woodson debris flood:

(1) "Forest and Debris Recovery Final Report; Winter Storm – December 2007" (ODF staff, 2008a), which includes information regarding landslides and road-related issues in the vicinity of Eilertsen Creek, and elsewhere in northwestern Oregon;
(2) Eilertsen Creek – Kerry Road Embankment Failure Timeline (Seward, 2008);
(3) Forest Practices Administration and Compliance Review, Eilertsen Creek – Kerry Road Embankment Failure (ODF staff, 2008b), which assesses administration of the Oregon Forest Practices Act (FPA) and compliance with the Oregon Forest Practices Act Statutes and Administrative Rules for road maintenance and timber harvest in the vicinity of the fill;
(4) an independent geotechnical review conducted by Gunnar Schlieder (GeoScience, Inc.), at the request of ODF; and,
(5) this report, prepared by ODF geotechnical specialists, which reviews the fill failure and upslope landslides to assess factors related to their initiation and behavior, including the effects of an extremely intense storm during the preceding week that elevated stream flows and flooded many communities in northwestern Oregon and southwestern Washington.

ODF geotechnical assessments of the Woodson event were charged with the following objectives:

(1) identify the causal factors, run-out paths, and delivery areas of the road fill failure and subsequent debris-flow event;
(2) determine the relationship of the fill failure to the two known landslides located in the headwaters of Eilertsen Creek, as well as their causal factors, run-out paths, and delivery areas; and,
(3) identify the causal factors, run-out paths, and delivery areas for other known landslides or road failures in the immediate vicinity of the fill failure, which might

have some bearing on understanding the spatial and temporal associations of the December 2007 events.

This assessment focuses specifically on the geotechnical aspects of the December 2007 events. While there was substantial landslide and debris-flow activity in the larger area (see ODF staff, 2008a), the Eilertsen drainage became the focus of this review due to the degree of damage incurred to Highway 30 and the community of Woodson, and the unique circumstances surrounding the legacy road fill.

(2) Introduction

In its report of the debris-flow impacts in the Clatskanie area, the local newspaper banner reads "Déjà Vu, All Over Again" (Clatskanie Chief, 4/25/96). The pictures of Woodson in the attached article look strikingly similar to those shown in the news media following the December 11, 2007 event (Figure 2). They refer, however, to a debris flow that hit Woodson and damaged homes on April 23, 1996. According to local news reports, similar events have occurred during the last century in Eilertsen Creek and adjacent canyons draining the northern flanks of Clatskanie and Tunnel mountains.

Our assessment indicates that a combination of inherently unstable terrain, wet Pacific Northwest winters, and historic land-use practices can be attributed to these recurring landslides, floods, and property damage. The following discussion summarizes factors related to the initiation and propagation of landslides and debris flows in the Woodson area, including the local geology and geomorphology, chronology of landslides and debris flows in relation to large-scale storm events like that occurring in early December 2007, and history of land-use practices. Of particular note is the construction of a logging railroad grade that traverses Eilertsen Creek and adjacent drainages, to which a number of the larger landslides and debris flows have been linked. When the railroad was abandoned, portions of this grade were converted to truck haul roads and others reverted to forest.

(2a) Geological perspective

<u>Overview</u>

Eilertsen Creek is one of a number of streams that flow north into the Westport Slough, which is located along the southern margin of the lower Columbia River floodplain between the towns of Clatskanie and Westport. The streams drain the north side of Tunnel Mountain and adjacent ridges. These drainages are characterized by gentle to moderately sloping ground incised by a network of steep, confined, v-shaped canyons.

The Columbia River is cutting through the heart of the Coast Range in this geologically active area. Much of the area on the north side of Tunnel Mountain is interpreted to be part of a large, ancient landslide complex (Figure 3). This is evidenced by the following:

- a stair-stepping slope profile with gentle benches and steep scarp slopes
- hummocky terrain
- mid-slope ponds and marshy areas
- a poorly developed drainage network
- observation of ongoing slope movements

The complex is likely a result of down-cutting by the Columbia River at the toe of the slope during periods of lower sea levels in the past. Portions of this complex are more active than others. Reactivation of secondary, deep-seated landslides within the

complex is probably linked to down-cutting by Eilertsen Creek and the other streams draining the slope. The streams act as conveyor belts carrying sediment off the slope down to the floodplain of the Columbia River. As stream erosion undermines support at the toe of a slide, movement is triggered, and the slide moves down and enters the stream channel. The stream starts eroding this new material and the process repeats itself.

When a landslide enters a channel, the result can be catastrophic. If the landslide fails rapidly and enters a channel, all or a portion of the slide may mobilize as a debris flow and continue travelling down the channel. If the landslide completely blocks the channel, it can form a dam and impound water. Landslide dams can last a few minutes or thousands of years. The dam can fail catastrophically, releasing a torrent of debris and water downstream.

Eilertsen Creek Watershed

The Eilertsen Creek watershed encompasses 594 acres, slightly less than one square mile. Elevation in the watershed ranges from ten feet where it empties into the Westport Slough to 1424 feet on Tunnel Mountain. The drainage comprises mostly gentle to moderate slopes. Steep slopes, exceeding 60%, are generally found in the headscarps of deep-seated landslides and along incised stream channels.

The geology of the area is complex. It has been mapped several times (Niem and Niem, 1985; Ketrenos, 1985; Eriksson, 2002), and the model for the area will likely be refined by future mapping efforts. The Eilertsen Creek watershed is composed of weak marine sediments and volcanic deposits, overlain by more competent basalt flows of the Columbia River Basalt Group. The marine sediments are likely basalt conglomerates and tuffaceous silty sandstones of the Scappoose Formation, and tuffaceous, micaceous sandstones and siltstones of the Pittsburg Bluff Formation. Subaerial basalt flows of the Gray River Volcanics might be located low in the watershed. Mapping to the east and west of Eilertsen Creek indicate that rock bedding dips southward into the hill up to 40 degrees. However, strike and dip measurements vary considerably to the south.

(2b) Historical perspective

Local newspaper articles and other historical sources indicate that catastrophic landslides, debris flows, river flooding, and intense wind storms have occurred repeatedly in the Clatskanie area, at least since the early 1880's when such observations first were recorded by early pioneers. A big storm in January 1880 resulted in flooding and debris flows on the Clatskanie River, located about six miles to the east of Woodson (Columbia County Historian, 2002). Debris flows and high stream discharges washed out infrastructure on Fall Creek west of Clatskanie in January 1895, following the highest recorded flood on the Columbia River in 1894. These events pre-dated the onset of extensive upland logging and other development in the area. According to historical accounts, the first logs were brought out of the Clatskanie hills in 1904 (Columbia County Historian, 2002) to feed the construction boom in Portland and along the Columbia River.

According to the Clatskanie Chief newspaper (2/7/08), "the area between Clatskanie and Westport, where numerous creeks cascade out of the Coast Range onto what was the Columbia River flood plain - before it was diked beginning a century ago - has historically been prone to mudslides at the bottom of these steep canyons… geologists

say that the major cause is the combination of the steepness of the slopes and extremely heavy rainfall." Debris flows and flooding have been reported in the area since the 1800's, with catastrophic, property-damaging events occurring in 1914, 1933, 1948, 1996, 1997, 2005, and 2006 on Columbia River tributaries in the vicinity of Eilertsen Creek (Farnell, 1980; Rule and Maser, 2002); see Figure 4. An analysis of historical aerial photographs and orthophotos confirms the high density and frequency of landslides in this area. Figure 5 shows the distribution of landslides and debris flows identified on aerial photos, beginning with the earliest available photo series in 1939. Table 1 identifies each feature by drainage, type, age, and forest-management activity. This analysis indicates that a number of drainages (i.e., Kerry, Olsen, Eilertsen, OK, and Tandy creeks) have experienced multiple events during the last 70 years.

Historical accounts of debris flows in the Clatskanie area suggest that many have been large-magnitude, highly erosive events, similar to the one occurring in Eilertsen Creek in December 2007. A January 1914 edition of the Clatskanie Chief recounts a debris-flow event in Blitz Creek between Eilertsen and Tandy canyons:

> "The slide started several hundred feet up the canyon, sweeping with terrific and relentless force down the side of the mountain, carrying everything before it. Trees were torn up by the roots and borne along in the stream of destruction… About midnight the second slide occurred, being much larger than the first. Four acres of land surrounding the house was buried under from twelve to fifteen feet of debris… The county road which runs between Elliott Bros. place and the mountain is buried for a distance of some 400 feet beneath twelve feet of logs and wreckage and the scene presented is one of desolation and destruction." (Clatskanie Chief, 2/7/08).

Furthermore, on Christmas Day, 1933, the Clatskanie Chief (12/29/33, 12/27/07) reported that water dammed behind a railroad trestle over OK Creek (i.e., next drainage to the east) burst through its impoundment, causing a wall of water and debris to rush downstream, knock a house across Highway 30 and into the slough, and kill several residents. An eye witness to the 1933 event on OK Creek stated that: "a twelve foot wall of water, logs and boulders thundered down… it swept bare the creek bottom destroying everything in its path, and cleared out the canyon to a great height" (Rule and Maser, 2002).

Storms in May-June 1948 and February 1996 produced river floods with calculated 100-year recurrence intervals (i.e., "100-year flood"; Clatskanie Chief, 1/12/06) and property-damaging debris flows in the Clatskanie area. In February 1996, a debris flow emanating from Tandy Creek destroyed one home and seriously damaged others after nine inches of rain fell in Clatskanie in four days (Clatskanie Chief, 2/15/96), while the April 1996 debris flows in Eilertsen and Ross creeks damaged and destroyed homes and flooded Highway 30 at OK Creek during prolonged rainfall (Clatskanie Chief, 2/7/08).

Newspaper editions since 2001 (i.e., Clatskanie Chief archived editions obtained online at http://www.clatskaniechiefnews.com) indicate that flooding and/or debris flows have occurred almost every winter or spring in tributaries adjacent to Eilertsen Creek. These events have alternated between Conyers, Fall, Graham, Tandy, Blitz, OK, Eilertsen, Olsen, and Ross creeks, most triggered by hillslope failures and causing property damage. For example, the January 2006 landslide and debris flow in Graham Creek occurred after 3.8 inches of rain fell in two days, according to the Clatskanie Chief

(1/19/06), resulting in some property damage. This paper edition also remarked that the area surrounding Eilertsen Creek is often the "hardest hit area" in Columbia County.

The lowest reaches of many tributaries in the Clatskanie area were altered by splash damming during harvest of the "old-growth" forests during the late 1800's, although it is not clear whether Eilertsen Creek was splash-dammed. Timber was initially logged along the Columbia River floodplain, and in the mouth end of tributaries that were easily accessible and could be used to drive logs downstream to the Columbia sloughs (Rule and Maser, 2002). Significant upland timber harvest did not begin until the early 1900's. Many of the annual river floods and debris torrents in the late 19th and early 20th centuries apparently were associated with splash damming and log drives to the local mills. By 1883, most streams large enough for log drives in the Clatskanie area had been cleared of obstructions so that logs could be rafted down them to the sloughs during winter rains (Rule and Maser, 2002). These log drives were known to result in debris flows and flooding. For example, "in January 1901 [on the Clatskanie River] the freshet came out with such force, because of a [log] jam on one of the river's tributaries, that the Tichenor Mill Company of Clatskanie was buried in ten to twenty feet of logs and debris …" (Farnell, 1980).

Road fill and sidecast failures have delivered substantial amounts of debris to Eilertsen Creek and surrounding drainages during the past century. A road analysis of the Lower Columbia-Clatskanie sub-basin (Rule and Maser, 2002) indicates that road failures, due to inherently unstable hillslopes, are greatest in watersheds draining to the Westport Slough, which includes Eilertsen Creek. The Eilertsen basin has the highest density of roads (i.e., 1.6 mi/mi^2) of any tributary within the Lower Columbia-Clatskanie sub-basin in which debris flows are known to present a hazard (Rule and Maser, 2002).

One road system in the Eilertsen Creek drainage, in particular, has been associated with a number of sidecast and fill failures since the early 1920's, and it represents a unique piece of logging history in the Pacific Northwest. The Kerry Road (also known as the Starker Mainline or Road 119) currently is used as a haul road by several commercial forestland owners. It contains original and reconstructed sections of the Columbia and Nehalem River Railroad, also known as the Kerry Line railroad grade, which was constructed, beginning in 1913, to log approximately two billion board-feet of standing "old-growth" timber from Columbia and Clatsop county properties owned by Albert Kerry and Wright Blodgett (Columbia County Historian, 2002). The logging railroad extended southward from Kerry on the Westport Slough, through the ridge, and into the Nehalem River valley. The route necessitated construction of 35 trestles, one of the larger ones crossing the headwater channel of Eilertsen Creek, and a 1875 foot-long tunnel through the watershed divide separating Eilertsen Creek from the Nehalem drainage (Figure 6; McCamish, 2007).

Anecdotal information suggests that the original trestle over Eilertsen Creek, estimated to be about 80-90 feet tall, was buried with spoils and construction waste from the tunnel dig, which was located to the west about 0.25 mile from the trestle (Eric Evenson, pers. comm. to J. Hinkle, S. Shaw, 12/11/07). Rail-dump cars probably were used to transport excavated material from the tunnel to the trestle site, where debris was dumped and eventually buried the trestle. A similar process commonly was used during the early 1900's and is described by Sellew (1915; see Figure 7). The tunnel also experienced two partial collapses, one due to natural seepage and the other an act of sabotage by the Wobblies, during the turbulent era when unions aggressively tried to organize

workers in the Northwest. The tunnel was repaired for continued use (McCamish, 2007). Although historical accounts indicate that the rail line was hand-built using carts and mules, the December 2007 collapse of the fill exposed trestle bents of a piling trestle. Figure 8 shows a similar trestle built nearby on the Kerry Grade.

Like most logging railroads of the era, the Kerry line was not built with permanence in mind. It was used between 1915 and 1938, and exchanged ownership several times. As many as 18 different logging companies collectively hauled over three billion board-feet of timber on the lines (McCamish, 2007). The area was mostly logged out by 1936, and rails were pulled over most of the mainline railroad by 1938. The property, on which the December 2007 railroad fill failure occurred, was acquired by Evenson Timberland Agency sometime in the 1920's to 1940's. In 1929, the upstream slopes and headwaters of Eilertsen Creek became part of the 2400-acre Blodgett Tract managed by Oregon State University. As the century progressed, some sections of the line were abandoned, likely due to the failure of railroad through-fills and trestles, and portions of the route (e.g., at OK Creek) were relocated to navigate around wash-outs. The bulk of the upper grade traverse, as it approaches the north tunnel portal, was converted to a truck haul road. New running surfaces have been applied to the grade during active haul periods and additional culverts were placed at some stream crossings (Eric Evenson, pers. comm. to J. Hinkle, S. Shaw, 12/11/07), but it appears that a number of the original crossing structures (e.g., corrugated metal culverts) and through-fills have been retained on the grade north of the tunnel.

It is suspected that a number of the corrugated metal culverts (CMPs) located deep in fills, for example east from the railroad embankment along the Kerry Road, are original culverts laid during railroad construction. CMPs were used by railroads in the earliest parts of the 20th century and were intended as temporary cross-drains. For example, Sewell (1915) states:

> "In the design of [corrugated metal] culverts under the tracks, provision is rarely made for those unusual storms which only occur after long intervals, and in consequence structures which may have stood successfully for forty or fifty years are at times washed out … When structures have been skillfully laid out to stand the ordinary contingencies of 20 or 30 years it is about all that is either practicable or justifiable, and the remarkable storms which come only once or twice in a century are not in fact, and hardly can be, successfully guarded against. This is especially true because the worst effects of even the greatest storms are localized within quite narrow limits. The same is, in substance, true of inundations of railway lines."

In fact, the Kerry Grade has a history of fill and crossing failures, some occurring during active use of the line. For example, water dammed up in the Favorite Creek canyon (tributary to OK Creek) in 1922, upstream of a 75-foot-tall trestle (see Figure 6; trestle number 5); when the impoundment broke, several trestle bents were washed downstream, almost resulting in a train wreck (McCamish, 2007). The trestle subsequently collapsed. The 1933 debris torrent in OK Creek, which resulted in fatalities, emanated from a trestle located up-grade from the previous wash-out. McCamish (2007) states that damaged trestles were "simply jacked up and repaired", so that log transport could continue. After railroad use was discontinued, a number of large failures occurred along the grade, as evidenced from aerial photography (see Figure 5), one of which appears to have been the main source of the debris torrent that traveled down Eilertsen Creek and inundated Woodson on April 23, 1996.

(2c) December 2007 storm

The events leading to the unraveling of the Eilertsen Creek – Kerry Road embankment failure very likely were initiated or accelerated by the storm that pounded northwestern Oregon and southwestern Washington between December 1 and 4, 2007. A post-storm inspection (ODF staff, 2008a) located numerous failures in the vicinity of Eilertsen Creek (Figure 9). Reiter (2008) succinctly summarizes the storm's progress:

> "The wind and rain portion of the storm began as a typical mid-latitude storm in the mid-Pacific. But a major infusion of moisture from two decaying typhoons (Hagibis and Mitag) caused the storm to grow in size and intensity. The first part of the storm brought wind; the second part brought not just hurricane force wind but abundant moisture as well. This storm grew so large that it reached a diameter of several thousand miles. As it grew in size and strength, the storm was able to incorporate abundant moisture from the tropics."

According to Reiter (2008), the storm comprised three "surges" of rainfall, the most significant arriving on December 3 with "near record high temperatures and moist tropical air". Highest-intensity rains fell at higher elevations in the Coast Range, including Nicolai and Tunnel mountains west of Eilertsen Creek. The moisture plume reached from Hawaii to northern Oregon during the height of the storm (i.e., the "pineapple express"; http://www.climate.washington.edu/stormking/December2007.html).

Although the storm was relatively short-lived, with most rain falling within a 48-hour period, rainfall intensities were substantial (Figure 10a). South of Clatskanie, the Miller weather station measured a 24-hour maximum precipitation of 6.40 inches at 1031 ft. elevation (http://www.wrh.noaa.gov/pqr/paststorms/20071203; see Figure 10b) and total rainfall in the December 1-3 period of 8.65 inches. Rain gages in Clatskanie recorded 6.68 inches of rain in the 24-hour period ending December 3 and over ten inches of rain in three days (Clatskanie Chief, 12/27/07). In comparison, the average precipitation for the month of December in Clatskanie is about 9.6 inches (averaged over water years 1935-1999; Rule and Maser, 2002). Eilertsen and adjacent watersheds had little to no accumulated snow at this time. A Washington State Department of Transportation analysis estimates that rainfall intensities were up to 140% of the estimated 100-year, 24-hour storm in northwestern Oregon and southwestern Washington (see Reiter, 2008, for discussion).

What made this storm quite unusual was the rapid response of stream flows to rainfall. River flows in southwestern Washington were "off the charts", with about ten National Weather Service stream gages reporting new, all-time-high peak flows. In addition, 20 of 43 stations surpassed previous flood-stage records (http://wa.water.usgs.gov/news/2007/news.hiflo.dec07.htm). Flow stages rose quickly, with most streams reaching peak-flow stage in a matter of hours. The Chehalis River in southwestern Washington crested, at a peak flow equivalent to a predicted 500-year recurrence-interval flood, in less than 24 hours (http://wa.water.usgs.gov/news/2008/news.chehalis.newpeak.htm). Anecdotal information suggests that the Nehalem River near Vernonia also reached flood stage in a comparable amount of time, cresting in the afternoon on December 3 (http://www.katu.com/news/12124361.html). Although there are no stream gages or stream-flow data for the Clatskanie area, it is assumed, based on precipitation intensities and comparisons with the 1996 "100-year" flood, that the December 2007 storm yielded a similar, or slightly smaller, magnitude flood in the area. The Oregon Climate Service

computed the observed rainfall in the vicinity of Woodson to be about 60% to 80% of the estimated 100-year, 24-hour rainfall (Oregon Climate Service, www.ocs.oregonstate.edu; see also Reiter, 2008). This was the third, or nearly the third, "100-year" flood to occur in the last 60 years.

(2d) Overview of the December 2007 Flood Events

The following synopsis of the physical events leading to the Woodson debris flood is based on conversations with ODF employees and landowners, direct observations, and technical reconstructions of the event. Supporting data and field observations are described in section 4 of this report.

Sometime on December 3, 2007 as the rainstorm intensity peaked and ebbed, several debris flows were triggered in the Eilertsen Creek drainage. Debris, combined with high stream discharges, caused Eilertsen Creek to overflow its banks. Olsen Creek, draining from the west onto the Woodson debris fan, also experienced overbank flows. Water mixed with mud flooded several homes located nearest the canyon mouth (http://www.tdn.com/articles/2007/12/13/top_story/doc4760da427a7d2064763942.txt). Based on field evidence and statements made by employees of Evenson Timberland Agency (ETA; David Evenson, pers. comm. to J. Seward, S. Shaw, 3/3/08), at least four sizable landslides occurred during or shortly after the storm, in the upper reaches of the Eilertsen Creek watershed, two emanating from land managed by the Oregon State University (OSU) Research Forest and two from property owned by ETA. Two deep-seated landslides on OSU property (i.e., Slides 1 and 2; see Figure 1 for location, also see Figures 11 and 12) generated debris flows that travelled downstream to the Kerry Road embankment. Debris piled against the upstream side of the embankment. Each debris flow contained sufficient material to plug the old puncheon culvert(s) draining the base of the 80-ft. high fill. The two landslides on ETA property, which entered Eilertsen Creek, were associated with: (1) a failure in a 12-year-old conifer stand that subsequently caused, or assisted in causing, a portion of the Kerry Road to fail, just to the east of the buried trestle (i.e., Slide 3; Figure 13); and, (2) a deep-seated landslide involving a portion of a spur road between Eilertsen and OK creeks (i.e., Slide 4; see Figure 14).

During the week of December 4 – 11, 2007, water ponded on the upstream side of the railroad embankment. By December 6, when the site was inspected by the local ODF stewardship forester (Mark Reed, pers. comm. to J. Hinkle, S. Shaw, 12/10/07), the water level of the impoundment was nearly coincident with the road surface at the top of the fill (Figure 15). Pond overflow was draining eastward in an inboard ditch, for about 160 ft., and spilling across the headscarp of the road failure to the east (i.e., Slide 3). M. Reed also noted that the fill was intact, although water was seeping from the base of the fill. An excavator had been ordered by ETA for mitigation efforts, to relieve water ponded behind the fill, but equipment was not available until the following week due to demand associated with storm clean-up efforts in the region (Eric Evenson, pers. comm. to J. Hinkle, S. Shaw, 12/11/07).

On Monday, December 10, M. Reed accompanied J. Hinkle and S. Shaw to the site. They observed that the pond level had lowered approximately two feet over the weekend and water from the pond no longer was draining through the ditch-line to Slide 3 (see Figure 1 for location). In addition, the running surface at the top of the fill had developed ½ - to 2- inch wide, discontinuous tension cracks paralleling the grade. At this point,

there was no vertical displacement of the fill along the tension cracks. A cursory inspection of the fill and cross-drainage indicated that the puncheon culvert(s) at the base of the fill were passing only a trickle of water. A corrugated-metal-pipe culvert (CMP), located about 20-30 feet above the downstream base of the fill, exhibited minimal flow, indicating that it was partially blocked, while some gullying associated with pipe outflow had begun to erode the fill face (e.g., observations made 12/10/07). [Eric Evenson has stated that a 36-inch CMP was installed in the mid-eighties by ETA (pers. comm. to Paul Clements, ODF, 2/19/08) to provide overflow relief for the original puncheon culvert.] Our investigation later located pieces of a 24-inch-diameter CMP immediately downstream of the fill site. Substantial seepage was occurring along the fill face, as dispersed and piped flow (i.e., water flowing through macropores in the fill), indicating subsurface flow through the fill. Mitigation measures were discussed, including installing pumps to drain the pond, digging a relief ditch across the road grade, and excavating the existing road-side ditch between the fill and Slide 3 to the east, to relieve water along the 2% down-grade.

On Tuesday, December 11, J. Hinkle arrived early at the site, to find Evenson's crew and equipment in place. He observed that the tension cracks found on the preceding day had become displacement scarps with one to two feet of vertical offset (Figure 16). In addition, portions of the road surface had begun to sag in the downstream direction. The road was unsafe for equipment crossing. ETA and their operator constructed a relief ditch, at a diagonal to the grade on the western margin of the fill, directing outflow water into a swale connected to Eilertsen Creek. The relief ditch was dug approximately four feet deep, enough to allow controlled outflow but not so deep that it would provoke catastrophic fill failure. It became a race against time to drain the pond. J. Hinkle estimated a drop of only one to three inches per hour in the pond level, which indicates that the volume of the pond was extremely large. As the fill surface continued to subside, trees at the base of the embankment cracked and toppled. Over the course of three hours, the displacement scarps in the fill surface roughly doubled their vertical offset. The toe of the through-fill started to bulge downstream at about 11:50 AM, and then the fill failed catastrophically. As the fill collapsed and moved downstream, water and debris from the pond filled in from behind. Debris and ice from the pond surface were laid directly on the pond bottom, indicating that the pond drained from the bottom through the notch created by collapse of the fill, and materials on the surface dropped vertically onto the bed of the pond. A short video clip, shot with a digital camera by J. Hinkle, shows the failure initiation. It can be viewed at http://video.aol.com/video-detail/raw-video-oregon-landslide-as-it-happens/3249614225.

The ensuing debris flood has been described variously, in news and technical summaries, as a debris flow, torrent, dam-burst flood, and hyper-concentrated flood. It contained a slurry of fill materials, debris-flow solids from upslope landslides, impounded water, stream water, and sediment and wood entrained along its path. Within three minutes, the leading front, or bore, emerged in Woodson as a mass of large wood (i.e., some three to five feet in diameter) plucked from the hillsides and/or channel, sandy mud, and a mobile home swept from its foundation near the mouth of Eilertsen Creek Figure 17a). This mobile home previously was damaged by the April 1996 debris flow (see Figure 2). Eyewitnesses indicated that the flow moved between five and ten miles per hour as it exited the canyon and flowed across the existing debris fan towards the slough. Structures on the debris fan were inundated in five to six feet of mud (Figure 17b). Video clips taken from news helicopters circling overhead showed several houses submerged to their eaves by rapidly flowing muddy water and debris, with a jam of large

wood forming on Highway 30 and muddy water flowing into the Westport Slough (http://www.cnn.com/video/?/video/us/2007/12/11/vo.oregon.mudslide.koinkptv). The concrete box culvert passing under Highway 30 became plugged with debris, causing materials to flow over the road surface for several hours until they could be unclogged by Oregon Department of Transportation (ODOT) workers. The debris flood lasted about 10 minutes. A substantial percentage of boulders entrained by the flood were deposited at the canyon mouth, partially buried by fine sediments that settled out of the waning flow. The Eilertsen Creek flood deposit merged with debris-flow deposits delivered from Olsen Creek the preceding week; overlapping deposits were found on the debris-fan apron connecting the mouths of the two creeks on the southwest side of Woodson.

(3) Study Methods

This report relies largely on field observations and data collected before, during, and after the December 11, 2007 debris flood. Anecdotal information from landowners, land managers, agency personnel, and residents also was used to develop an understanding of the history and management practices at the road-embankment site, the sequence of failures and flooding in the upper basin, and flood characteristics as the debris-flood event unfolded in Woodson. The local newspaper, The Clatskanie Chief, proved instrumental in establishing the history of debris flows and flooding in the region. Historical aerial photos were useful in mapping the spatial and temporal relationships between landsliding and debris flows in Eilertsen Creek with recorded flood events in Woodson. This study also relied on live video and still images captured by helicopter media crews and agency personnel, and workers on the ground, to analyze technical aspects of the embankment failure and flood.

A number of days were spent in the field, evaluating and mapping the failure sites, channel, and Woodson debris fan. Field observations of the railroad embankment, upslope landslides, and Woodson debris fan were made by J. Hinkle and S. Shaw on December 10, 2007. J. Hinkle photographed and observed the progression of fill collapse and failure on December 11, as well as the waning stages of debris-fan deposition in Woodson. J. Hinkle and S. Shaw photographed and began initial evaluation of the site following fill collapse on the afternoon of December 11. J. Seward, J. Hinkle, and S. Shaw surveyed the embankment site and upslope landslides on December 17, 2007, and the Woodson debris fan and lower Eilertsen Creek channel segments on January 10, 2008 (with help from L. Farm, ODF). J. Seward and J. Hinkle made periodic inspections of the upper Eilertsen Creek between January 8 and February 25, when the site was covered with snow. A channel survey of the upper watershed and mainstem channel was completed on February 25. The upslope landslides and debris-flow tracks were surveyed on February 26 by J. Seward, J. Hinkle, S. Shaw, and G. Schlieder. The embankment site was re-surveyed on March 3 by J. Seward, S. Shaw, and G. Schlieder, during which the continued erosion of the exposed fill surfaces was noted. J. Hinkle and G. Schlieder revisited the channel between the fill and the Woodson debris fan on March 14. Survey data were obtained using a fiberglass measuring tape, laser rangefinder, clinometer, compass, and GPS unit.

Survey data were used to construct longitudinal and cross-sectional profiles of the failures, embankment site, and channel from the top of the watershed divide to Highway 30 in Woodson. None of these data were available for these sites prior to landslide failures and embankment collapse, including the profile of the original ground surfaces. Therefore, the ground surface was reconstructed on the longitudinal profiles from

evidence gathered in the field (i.e., slope geometries adjacent to the failure site), from DEM-derived and USGS 1:24000-scale topographic maps, and from historic aerial photos.

A number of aerial photo flight series were used during the analysis to evaluate site-specific and watershed-scale features. Some, but not all, of the landslides and debris flows identified in aerial photos (e.g., see Figure 5) were field-verified. Available flight series included those from: 1939, 1948, 1956, 1957, and 1961 (source: U.S. Army Corps of Engineers); 1969, 1977, and 1989 (source: ODF; Campbell Group supplied some photos for 1977); 1994 (source: OSU, upper watershed only); and, 1998, 2001, and 2006 (source: ETA). Stereo pairs and geo-referenced scanned images were utilized in the analysis, as well as orthophoto images from 1995, 2000, and 2005.

(4) Observations and Data

The physical components of the Eilertsen Creek debris-flow complex are:

(a) several **deep-seated and road-related failures** that occurred rapidly, prior to embankment failure, delivering debris and water to Eilertsen Creek during the December 2-4, 2007 storm;
(b) a ***deep-seated landslide (Slide 1) and associated debris flow***, located in a unit harvested in 1992 on OSU research lands, portions of which failed rapidly during the week of the storm and initiated a debris flow that entered Eilertsen Creek and deposited at the base of the Kerry Road embankment;
(c) a ***deep-seated landslide (Slide 2) and associated debris flow***, occurring in a 2004 harvest unit on OSU property, portions of which failed rapidly during the week of the storm and initiated a debris flow that entered Eilertsen Creek and deposited at the base of the Kerry Road embankment;
(d) the Kerry Road ***embankment failure*** on ETA property that occurred on December 11, 2007;
(e) the ***debris flood***, or embankment-burst flood, resulting from the catastrophic failure of the Kerry Road embankment; and
(f) the ***deposition zone*** in Woodson.

This group of components is referred to collectively as a “debris-flow complex” because of the rather unique, complicated, and interconnected nature of the events leading to embankment collapse and flooding. The following discussion describes the physical factors involved in slope failure and debris transport, based on field observations, collected data, and interpretation of available aerial photographs.

(4a) Failures of December 2-4, 2007

Field observations and site evidence indicate that at least two large failures (i.e., Slides 3 and 4; see Figure 1 for location) occurred during, or shortly after, the early December storm. The existence of Slide 3 was known by December 6, 2007 when the railroad fill was inspected (E. Evenson and M. Reed, pers. comm.). This slide involved loss of a 30 ft stretch of the cut-and-fill road prism and fillslope, about 160 ft. to the east of the railroad fill on the Kerry Road, and delivered debris directly to Eilertsen Creek. Slide 4 also initiated a debris flow following collapse of a hillslope that undercut a truck-haul spur road off the Kerry Road. It was discovered in the field by ODF personnel on December 13, 2007. This debris flow travelled down the east fork of Eilertsen Creek (see Figure 1) and deposited material at the mainstem confluence. Aerial video clips of the Eilertsen

drainage, taken during and after the Kerry Road embankment-burst flood on December 11, show the debris-flow track from Slide 4, indicating that this failure pre-dates the embankment failure (ODF, Incident Management Team, 12-11/07).

There are two components to Slide 3: an initial, relatively small, deep-seated failure; and a subsequent failure of a portion of the Kerry Road downstream of Slide 3. The failures appear to have occurred consecutively, with some unknown intervening period of time. The initial slide was triggered several hundred feet uphill from the Kerry Road in the unit that was cooperatively harvested by ETA and OSU in 1992 (i.e., same harvest unit as Slide 1). Field evidence suggests that a portion of the hillslope failed as a result of groundwater seepage along a bedding contact in the Pittsburg Bluff Formation. The failure occurred in a slope concavity, or “bedrock hollow”, at the point of channel initiation (i.e., where groundwater flow naturally reaches the ground surface and establishes a defined channel). An approximately seven-foot-high headscarp shows a distinct seepage plane about four to five feet beneath the ground surface, along which substantial dispersed and piped flow continues to drain out of the soil and onto the headscarp located upslope of the road. Soil pipes were observed to be as large as five inches in diameter. During the storm, it is likely that considerable volumes of subsurface water was flowing downslope, leading to rapidly rising pore-water pressures and piping erosion, which in turn reduced stability of the mass. Portions of the slope surrounding the channel initiation point failed to depths of about two feet below the seepage layer, along the bedrock surface. The resulting debris slide scoured the existing channel downstream, over a distance of about 30 ft, before depositing on the lower-gradient slope created by the road. An approximately 200 ft^2 debris deposit, consisting of woody debris and sediment, is lodged at the estimated location of the road cross-drain intake, although the drainage structure and road prism now are gone. Evidence of impoundment and debris accumulation on the upstream side of the road prism suggests that materials clogged the cross-drain, most likely a CMP, before the road prism failed. Remnants of several 24-inch metal culverts were found downstream in Eilertsen Creek, which might have originated in the fill at Slide 3 or have been flushed into the canyon in earlier years and remobilized by the December 11 flood.

Figure 18 shows a reconstructed longitudinal cross-section of the road-related component of Slide 3 and profile of the tributary channel draining to Eilertsen Creek, based on field-survey data. The road prism at the site is assumed to be 26 ft wide, comparable to widths measured up-grade between Slide 3 and the railroad embankment. Dammed water and debris, resulting in culvert blockage on the upslope side of the road, as well as water flowing down the ditch from the Eilertsen Creek embankment impoundment to the west, likely led to water overtopping the road surface. This overflow caused gullying and destabilization of the road prism and fill slope, with fill and underlying materials downslope being eroded to an average depth of about 10 feet. The debris flow generated from the road failure scoured the lower channel to bedrock. Based on the reconstructed cross-section in Figure 18, a volume of material displaced by the failure was calculated at about 3000 yd^3. At survey point J17, a measured channel cross-section indicates that the debris flow reached a vertical height of about 20 ft in the channel. A near-vertical drop-off at the channel confluence with Eilertsen Creek likely caused the debris flow to accelerate rapidly as it entered the main channel. Given the generated volume of debris and water, and steep channel gradients in upper Eilertsen Creek, it is possible that materials could have been delivered to Woodson on December 3, when some residences initially were flooded with mud and water. The fact

that this flood consisted mainly of muddy water suggests that it bore mostly suspended sediments and was not a debris flow as conventionally defined.

The presence of the initial failure in the plantation upslope of the road, and its likely triggering of the road failure downslope, indicates that water flowing eastward down the roadside ditch, as a result of the impoundment behind the Kerry Road fill, was not the sole contributor to the Slide 3 road failure. Ditch water, however, might have contributed to erosion of the Slide 3 headscarp, because it drained over the lip of the intact road surface and onto the west side of the fill-slope scarp for several days before the pond level subsided enough to prevent water access to the ditchline. The impoundment drainage through the ditch did not appear to be especially erosive, as materials and vegetation in the ditch bottom remained relatively undisturbed (i.e., see right-hand ditch in Figure 13). The road failure scarp continues to experience erosion as the headscarp propagates upslope of the area previously occupied by the road prism, and additional debris from unraveling of the channel deposits and near-vertical banks likely will continue to travel downstream to Eilertsen Creek.

Slide 4 is a large failure that likely initiated by stream undercutting at the toe of the hillslope. The slope collapsed into the creek, causing an upslope progression as successive portions of the slope failed. This failure rapidly propagated upslope to the spur road constructed off the Kerry Road in the 1980's (?) to access timber along the ridge separating the mainstem and east-fork Eilertsen drainages. An approximate 100-foot stretch of the road prism was removed, from the fill-slope inboard to about the road centerline (see Figure 14). Based on field measurements, an estimated 4000 yd^3 of road fill and slope substrate slid into the east-fork channel from the left bank, travelling downstream as a debris flow. A large deposit of sediment and wood remains lodged in the east-fork channel just upstream of its confluence with the mainstem. Judging from its size relative to the volume of material displaced by the landslide, however, it appears that the bulk of this debris flow continued downstream in the mainstem Eilertsen channel. Field observations suggest that the downstream margin of these deposits was truncated and/or overlain by the December 11 flood deposits. The headscarp of Slide 4 continues to unravel and likely will result in the eventual loss of the entire road prism.

It is conceivable that Slides 3 and/or 4, and ensuing debris flows, resulted in flooding of Woodson residences during the December 2-3 time period. They each contained sufficient volume and potential energy (i.e., from moving over steep channel gradients) to travel the length of Eilertsen Creek. Furthermore, aerial photographs from 1998 (see Table 1, landslide no. 16) show that a failure travelled the length of the east fork Eilertsen Creek and lower Eilertsen mainstem. The debris-flow track from this failure can be traced on the photos from its initiation point adjoining the Kerry Road to the debris fan in Woodson. This event most probably is associated with the Woodson flood that occurred on April 23, 1996, and severely damaged several homes (Clatskanie Chief, 5/2/96).

It is possible, therefore, for these catastrophic failures and large debris flows to traverse the mainstem channel from the east fork and upper headwaters of Eilertsen Creek to the Highway 30 corridor. One anecdotal account (Rick Richmond, 3/14/08, pers. comm. to J. Hinkle) suggests that flooding of homes in Woodson during the December 2-3 time frame was associated with a debris slide occurring on a side-slope just up the Eilertsen canyon from Woodson (i.e., within 1000 feet of Highway 30). There also is a possibility that the December 2-3 floods in Woodson might actually have come from the Olsen

Creek drainage to the west, although that might have been less likely than Eilertsen being the source of Woodson floodwaters. Another resident (Misty Roubal, http://www.tdn.com/articles/2007/12/13/top_story/doc4760da427a7d2064763942.txt) noted that, during the storm, flood waters were draining under their home, located on the easternmost margin of the Woodson debris fan, which means that an Olsen Creek discharge would have had to inundate the entire Woodson fan and the Eilertsen Creek mouth. Neither of the residents' statements could be confirmed, however, because no post-storm inspection of the Eilertsen and Olsen upper watershed and channel areas had been performed before the December 11 debris flood. This event likely erased evidence of any floods or debris flows that occurred during the preceding week.

(4b) Slide 1 and subsequent debris flow

Slide 1 occupies a portion of a much older "deep-seated" failure, whose features can be discerned on the ground and in aerial photos post-dating the 1992 OSU timber harvest (see Figure 1 for location). In the 1994 flight series obtained from OSU (photo no. 94-6-13, dated 6/28/94), the recently harvested surface shows subtle evidence of ancient slumping along a scarp that rimmed the upper end of a tributary basin feeding the headwaters of Eilertsen Creek. This feature is not easily distinguished on photos pre-dating the 1992 harvest, when standing timber obscured the ground surface, but it likely pre-dates initial harvest in the area. Slide 1 is about 500 feet long and has an average width of 160 feet. The site in which Slide 1 occurred is stocked with a dense stand of about 12-year-old conifers, and the landslide surface is covered with such a thick pile of downed young trees that it is difficult to see the soil surface.

According to field observations, this slide was triggered before the Kerry Road fill failed (M. Reed, pers. comm. 12/10/07; J. Hinkle, S. Shaw), most likely during the week of December 3, 2007. No one reported seeing the slide occur, so that the exact time of failure could not be established. However, the freshness of the failure scarp and debris-flow track, high water content of the deposit, and continued calving of the displaced materials along the failure plane suggest that Slide 1 occurred days, rather than weeks, prior to the embankment failure. Employees of ETA could not recall having seen Slide 1 or Slide 2 in the months preceding the fill failure (Eric Evenson, pers. comm., 12/11/07; David Evenson, pers. comm., 2/25/08).

Field evidence shows that, like Slide 4 downslope of a Kerry Road spur, this failure resulted from stream undermining of the hillslope toe. The slope initially failed approximately 150 ft downstream of the current channel initiation point, as described below. The ensuing slide involved largely translational movement, with the ground likely sliding in at least three failure blocks, although some shallow rotational movement and lateral extension is suspected in the upper portion. A reconstructed longitudinal cross-section of Slide 1 (Figure 19a) denotes these discrete failure units as Blocks A, B, and C. Block A failed first, followed by B and C, with the last exposing the upper extent of the failure surface and eroding the outer road shoulder of Skull Ridge Road. At present, the road running surface remains intact.

The landslide cross section and downstream channel profile in Figure 19a and 19b are based on ground surveys, field observations, and interpretation of available photos and topographic data (see Appendix (1) for plan-view map of Slide 1 survey). They have been generated as a means for determining the relative volumes and pathways of material delivered to the Eilertsen Creek channel network. The projected plane of the

ground surface prior to early December landsliding has been reconstructed from Digital Elevation Model (DEM) topographic data, aerial-photo interpretation of ground features seen in the 1994 photos, and topographic inference based on adjacent intact portions of the hillslope. The reconstructed ground surface is indicated as a dotted green line on Figure 19a. The topographic slope break shown in the center of Block A defines the lower rim of the bowl-shaped upper basin and might coincide with the toe of the antecedent deep-seated landslide. Figure 19a also shows the surveyed current ground surface (solid line), as well as a projected failure plane underlying deposits of materials displaced by ground movement. This plane is represented by a dashed line, because it is not possible to predict its exact location without more quantitative, labor- and time-intensive methods (e.g., subsurface exploration). However, the exposed failure scarp just below the road and a relative position of the toe of the failure plane (i.e., where the downslope portion of the failure plane intersects the ground surface) provides a general sense of the failure-plane depth (see Figure 19a), which averages 30 vertical feet. For the purposes of reconstruction, the failed mass was divided into three large blocks, based on surface expressions of movement and ground separation along the surveyed landslide surface, including tension cracks and water-filled depressions akin to small grabens that can develop between discretely moving landslide blocks. The body of the failure likely could be more complicated; however, because the surface is obscured by jack-strawed trees, it was not possible during this survey to find all surface expressions of subsurface movement. Furthermore, without subsurface exploration, it is difficult to determine whether the Slide 1 failure plane coincides with the rupture surface of the ancient deep-seated failure, although that could be the case. The failure-surface depth exceeds the typical rooting depth of forest vegetation; therefore, it is unlikely that roots provided any resistance to shear along the failure surface (orange dashed line).

Field data and analyses indicate that the toe of the landslide mass failed first, as rising stream flows in the tributary channel undercut the adjoining slope. Loss of the lower mass likely triggered sliding as upper portions of the slope were no longer supported, causing an upslope progressive failure. It is likely that Block A slid downward along the failure plane (see Figure 19a), and disruption of its surface resulted in shallow, rapid failing of surface deposits. The bulk of displaced materials from Slide 1 were lost from the face of Block A (Figure 20a); sliding of debris into the creek initiated the channelized debris flow that traveled downstream toward the Kerry Road embankment (Figure 20b). *In-situ* stumps (see Figure 20a), partially buried by ravel from the scarp of Block A, pin the surface emergence (i.e., “day-lighting”) of the deep-seated failure plane some distance upslope, likely at or near point X24 on the survey. It is hypothesized, based on rock-outcrop patterns in the upper basin, that the failure plane is controlled structurally and has a relatively planar surface. Hence, movement of failure blocks largely was translational in nature and each slid downward as a discrete mass. As Block A slid downslope, displacement of Blocks B and C likely was activated. Widening of laterally continuous tension cracks and small depressions (i.e., dotted lines in Figure 19a) has been observed in successive field visits to the site, indicating that extensional displacement continues to occur. This observation suggests that these landslide blocks are still moving downslope, and additional failures along the face of Block A are likely, although predicting when and how much is problematic. On March 14, 2008, for example, it was observed (J. Hinkle) that further unraveling of the Block A scarp had occurred, and it is possible that spring rains might trigger additional erosion along margins of the landslide mass.

Field evidence indicates that Block C might have experienced some shallow rotational movement as well. Tipped stumps on the surface and failure along its lateral margins suggest a minor rotational component. The lateral margins of Block B also show some evidence of outward slumping. The stream is actively downcutting and re-establishing a channel along the eastern margin of the landslide, causing additional undercutting of the landslide margins and consequent slumping. Some of this slumping might have contributed to additional debris-flow-like deposits distributed in the channel upstream of survey point X25.

A landslide mass balance was constructed from Figure 19, by comparing the relative volume of displaced landslide materials lying above the projected plane of the original ground surface with the volume of materials removed (i.e., the difference between the surveyed landslide surface and projected ground surface). The volume of landslide sediment evacuated into the channel is estimated at about 16,000 yd^3. This value roughly represents the minimum volume of material incorporated in the debris flow that traversed the tributary channel leading to the road embankment. Assuming that the location of the depicted failure plane is a reasonable estimate, a calculated total volume of materials displaced by movement of failure blocks A, B, and C is about 59,000 yd^3. Approximately 25% of the total landslide volume mobilized as a debris flow that travelled down the channel.

The debris-flow track emanating from the toe of the landslide follows the headwater tributary channel to its confluence with the southwestern Eilertsen headwater channel, where the channel junction now is buried by debris deposits. The debris flow scoured the channel to bedrock through most of its length, roughly 700 feet (see Figure 20b). The total surveyed distance from the upper landslide headscarp to the buried channel confluence is 1290 ft (i.e., 0.24 mile). The average channel gradient is 18%, with an excess of 50% near the landslide toe.

The debris flow was erosive, mobilizing sediment, wood, and any other debris in its path. The average vertical height of debris-flow erosion along the channel walls and on vegetation is 15 feet. An inset to Figure 19b shows a cross section of the channel about half way down to the Kerry Road fill, in which one side of the debris flow scoured higher up the incised channel margins than the other. This cross section was measured in a channel bend, and the elevational difference from side to side indicates that the debris flow travelled rapidly enough to become super-elevated where the channel changed course around a bend.

The zone of debris-flow deposition begins roughly 1080 ft downstream from the edge of Skull Ridge Road and the landslide headscarp. It stretches all the way downstream to the former base of the Kerry Road fill, with deposits increasing in depth towards the fill. Deposits from this debris flow can be traced across approximately 75% of the bottom of the impoundment that formed upstream of the embankment.

Some field evidence tends to suggest that the initial debris flow did not enter a large body of water at the base of the embankment. Remnants of the debris-flow deposits, located on the floor of the drained impoundment, show minimal sorting and grading. A greater degree of sorting and grading would be expected of water-lain deposits. In addition, at the 1080 ft survey point on the channel profile, thin horizontal beds of fine sediment were noted, which likely indicate settle-out of materials during the waning stages of the debris flow. Similar deposits were found, at about the same topographic

elevation, in the channel eroded by the debris flow emanating from Slide 2. One of several hypotheses discussed in the field contends that these deposits might be a possible indicator of debris-flow deposition prior to water impoundment behind the embankment. This argument is based largely on the absence of slip faces (i.e., horizontal beds form downstream ends that build downward and outward as sedimentation progresses). This line of evidence, however, was deemed to be somewhat inconclusive because the downstream margins of these beds are vertically truncated (i.e., missing), as though they were eroded by rising water levels during pond formation or erosion following catastrophic release of water during the fill failure.

Field evidence is indisputable that the debris flow emanating from Slide 1 left a well-defined track and depositional fan that can be traced to the base of the embankment. The role of forest management in causing the failure, however, is less well-defined. It is probable that water draining from ditch lines on the Skull Ridge Road contributed to the water yield of the slope, although it was not the primary cause of slope failure (i.e., see previous discussion of stream undermining). The cumulative road surface area draining onto the slide is approximately 7500 ft^2, which represents a 7% increase in the size of the surface recharge area for the Slide 1 basin. What remains unknown is the relative size difference between the topographic basin containing Slide 1 and the "effective" hydrologic basin, which includes areas outside the topographic basin that deliver subsurface water to the Slide 1 catchment. Given the size of the road-surface area relative to the hydrologic basin area, the contribution of road runoff to the basin hydrology likely is small compared with the subsurface flow draining from upslope contributing areas. In addition, the road-surface area is an order of magnitude smaller than the area of Slide 1 (i.e., about 75,000 ft^2). Consequently, the volume of road runoff likely is proportionately smaller than the subsurface water volume travelling through the landslide, particularly the volume that would have been necessary to initiate a large deep-seated landslide.

Given the 24-hour rainfall amounts recorded during the storm (see report section 2c), stream flows probably elevated rapidly in these headwater drainages, due to a combination of inflow factors, which resulted in slope destabilization. Contributing factors included elevated groundwater tables in the drainage basin, associated with rapid influx of heavy precipitation, and might have included other factors known to affect forest hydrology on commercial timberlands (e.g., changes in forest-canopy through-fall, interception, and evapotranspiration). A number of studies in Pacific Northwest forested watersheds have concluded that changes in forest type, canopy closure, and stand age can alter slope water yields (e.g., Hubbart et al., 2007), which, in turn, can affect the frequency and distribution of landslides. This relationship is better understood for shallow, rapid landslides than deep-seated failures. Kiem and Skaugset (2003), for example, indicate that increased canopy closure generally equates with decreased incidences of failures in shallow soils on steep, topographically convergent hillslopes. Other studies suggest that increases in groundwater recharge following timber harvest can increase deep-seated activity in some but not all cases (e.g., Miller and Sias, 1998). In general, as landslide thickness increases, the roles of increased water yield and decreased root cohesion as trigger mechanisms become less well-known. Given the inconclusive scientific body of knowledge with respect to timber harvest and deep-seated landslides, as well as limited hydrologic information for the upper Eilertsen watershed, it is not possible to state definitively the relative contribution of forest management to failure of Slide 1.

(4c) Slide 2 and subsequent debris flow

Similar to Slide 1, this landslide occurred on the surface of a much larger, ancient deep-seated failure that forms a bowl-shaped slope concavity and occupies the upper basin of the southwestern headwater tributary to Eilertsen Creek (see Figure 1 for location). Slide 2 is observable in a number of aerial-photo series pre-dating and following timber harvest by OSU in 2004. The forest-practices notification to ODF for this harvest unit indicates that areas of old slope instability were observed during timber-sale preparation. In fact, large stumps left from initial harvest of the slopes in the early 20th century largely remain upright and intact, indicating that the late-successional forest grew on top of the ancient slump blocks, or rode down the hill when these blocks moved. The movement exposed a portion of a tree trunk that apparently was buried by past slope movement (Figure 21b). The recent landslide body is about 300 ft long and averages 100 ft in width. Its headscarp is located about 120 vertical feet downslope of a spur road and landing (i.e., the 1692 Road), and there is no visible sign of surface drainage from the road or landing to the headscarp. The unit occupied by Slide 2 contains no standing timber, although it has recently been replanted.

Field evidence indicates that Slide 2 was initiated by groundwater seepage, high pore-water pressures, and possibly channel-undercutting of the toeslope in the vicinity of the channel initiation point, likely in response to elevated stream discharges and subsurface flows during the early December storm. Exposed soil on the east flank exhibits a mottled appearance, which indicates long-term presence and fluctuation of groundwater (see Figure 21a). Substantial seepage continues to occur along a contact exposed near the base of the headscarp (i.e., survey point S29), and likely contributed to slippage along the failure plane that triggered the landslide. Figure 22 (a and b) shows the longitudinal cross section of the slide with the surveyed ground surface as a solid line, the reconstructed plane of the ground surface prior to failure indicated as a dotted green line, and the hypothesized failure surface depicted as an orange dashed line (see Appendix (1) for plan-view map of Slide 2 survey). Depth to the failure surface is on the order of 30 feet. The failure plane intersection with the ground surface is identifiable in the field, and those points have been mapped on the survey. The upper failure surface is at the base of the prominent headscarp formed during the December 2007 landslide, and the lower intersection is defined by a several-foot-high rocky ledge recently exposed by erosion of landslide debris deposits, approximately 15 to 20 feet downslope of survey point S27. It is assumed that rising groundwater tables contributed to increased subsurface flows along this contact, which in turn accelerated erosion at the toe. Failure at the toe propagated upslope along a shallowly concave failure plane, causing the entire mass between the rocky ledge and survey point S30 to slump and flow downslope as a largely translational failure. The native ground surface between this rocky ledge and another one downslope at survey point S22, approximately 190 ft slope distance, is buried in a relatively thin veneer (i.e., less than about five feet) of debris that drifted down the slope from the toe of the landslide. Approximately 300 yd^3 of debris is perched above the 6-ft-high bedrock step at survey S22 (i.e., extending upslope from survey point S23 to S25), and evidence of continued downslope movement includes large tension cracks between S24 and S25. Mass- balance computations indicate that Slide 2 contributed about 4500 yd^3 to the channel network, which is roughly 30% of the volume transported from Slide 1.

The ensuing debris flow probably launched in the vicinity of survey point S25 and split around the slumped mass at survey point S24, rejoining downslope in the established

stream channel at S20 (Figure 22b). A portion of the debris flow entered the established channel along the eastern margin of this mass, while another portion followed a debris-flow track around the west side. A well-defined debris-flow track and deposition zone, extending down-channel from survey point S20 to the railroad fill (i.e., about 800 ft slope distance) indicate that this debris flow delivered materials directly to the base of the embankment. The erosive force of the debris flow scoured sections of the channel to bedrock. Debris-flow deposition began about 300 ft upstream from the puncheon culvert draining the Kerry Road fill, as indicated by horizontally bedded fine sediments, like those described for Slide 1, and a 100-ft section of entrenched channel that incised through about four feet of recent debris-flow and older deposits. This debris-flow deposit contains fewer small fragments of woody debris than that from Debris-flow 1, although it appears to have incorporated considerable slash from a 2006 salvage harvest on ETA land. The mobilized slash formed a debris dam, the remnants of which span the debris-flow track approximately 100 ft upstream of the embankment base. Similar to Slide 1, the exact relationship between recent timber harvest and activation of Slide 2 cannot be stated with certainty.

Debris flows from Slides 1 and 2 coalesced at the channel confluence immediately upstream of the Kerry Road embankment. Materials from the Slide 1 debris flow deposited at least 50 ft upstream in the debris-flow track of Slide 2. This observation might tend to suggest that Slide 1 occurred after Slide 2, with its debris flow overtopping that of Slide 2. Evidence in the field, however, was considered inconclusive for determining the sequence of sliding. The most critical observation from the field is that both debris flows clearly traveled to the culvert intake in the Kerry Road embankment.

(4d) Eilertsen Creek – Kerry Road embankment failure

Figure 23 shows the reconstructed longitudinal cross section of the railroad fill based on survey data and field observations. The original fill geometry was established from noting the position of a puncheon culvert on the downstream end (Figure 24a, b), measuring the roadbed width adjacent to the chasm left by the failed embankment (Figure 25a, b), and projecting remnants of the fill down to the channel deposits on the upstream side. The buried trestle was recreated using pictures of similar trestles built on the Kerry Grade.

At some point during the December 2-4, 2007 storm, the old puncheon culvert(s) located at the base of the fill became plugged. The most likely scenario is that one or both of Slides 1 and 2 clogged the culvert, forcing water to back up behind the embankment (see Figure 15). This event was not witnessed directly. It is suspected, though, that if the culvert had become blocked prior to the storm, partial or complete erosion of the fill would have occurred earlier and been observed during field visits on December 6 and 10. The fill was largely intact less than 24 hours before it failed (J. Hinkle, S. Shaw, 12/10/07 observation). A leading hypothesis is that the debris flows were deposited largely on ground rather than in a large pond of water, as described previously, given the relatively unsorted appearance of the main depositional mass adjacent to the fill base. In addition, ETA employees had not witnessed any appreciable water accumulation behind the fill in the past (David Evenson, pers. comm. to J. Seward and S. Shaw, 2/25/07). D. Evenson also indicated that Kerry Road fills were patrolled relatively frequently to trap and remove beavers, a known source of cross-drain trouble. In fact, a beaver-gnawed chunk of hemlock was found outside of the Slide 1 debris-flow track, evidence of beaver activity in the area. Notwithstanding, the sheer volume of debris-flow

deposition was sufficient to overwhelm the puncheon cross-drain system and bury the existing channel confluence area to an average depth of about 15 ft. In addition, the CMP installed as overflow relief would have been buried by debris, given its position about 10 feet above the stream bottom before debris-flow deposition. The total debris-flow volume is estimated to be close to 20,000 yd^3 from displaced landslide materials (i.e., Slides 1 and 2), not counting the substantial volume of channel materials likely entrained by the passing debris flows

Water impoundment behind the fill could have occurred in a matter of days following culvert plugging. The maximum pond depth, at the point when the water level was less than one foot from the top of the embankment (i.e., on 12/6/07), is estimated to be about 15 to 20 feet, based on water-level marks left on partially submerged trees following fill collapse and impoundment release. Using an average depth based on this measurement, and a reconstruction of the pond area from survey data as shown in Figure 26, the total impounded-water volume is approximately 35,000 yd^3, which was spread over 1.5 acres. Rule and Maser (2002) computed the following flood discharges for Eilertsen Creek, given 25-, 50-, and 100- year recurrence intervals: 127, 145, and 162 cfs (cubic feet per second), respectively, based on drainage area, average annual precipitation, and modeled stream flows. The headwater tributaries of Eilertsen Creek, draining to the fill, occupy about 5% of the overall drainage area, generating a small percentage of the stream discharge. Even a fraction of the 25-year flood magnitude on Eilertsen Creek (e.g., 3% of the flow, or 4 cfs) is sufficient to generate a comparable volume of impounded water in three days or 72 hours (i.e., about 38,000 yd^3). Unfortunately, there are no stream gages in the vicinity that could be used to compute the actual flood recurrence interval corresponding to the December 2007 storm event.

The exact geometry of the original puncheon culvert is problematic. Channel erosion following fill failure exposed a portion of the culvert outlet, in which at least three large-diameter logs were used (i.e., about 3-4 ft. diameter cedars; see Figure 24b). Given the thickness of the fill at its base (see Figure 23), however, it is not clear how the culvert was constructed through the base of the fill. Single logs would have had to span over 200 ft., and the exposed puncheon logs are sloped much too shallowly to have been lain on a channel gradient exceeding 20%. Perhaps a series of puncheon sections were cobbled together or stacked in the upstream direction to achieve the necessary length and slope angle. Observations of 12/10/07 suggest that some upper sections of the puncheon structure might have been exposed farther upstream, signifying that the fill could have begun to erode around the puncheon in the days prior to catastrophic fill collapse.

Based on surveyed profiles in Figure 23, the volume of materials in the embankment, prior to failure, is estimated to be about 34,000 yd^3, assuming an average fill width of 125 ft. and area (i.e., length X depth) as shown in Figure 27. This second figure shows the cross-section of the fill at right angles to the direction of Eilertsen Creek flow, indicating the area of fill removed by fill collapse and subsequent flooding.

Coincidentally, the volume of material removed during construction of the tunnel in the early 1900's is about 35,000 yd^3, lending credence to the legend that tunnel waste was used to bury the railroad trestle at Eilertsen Creek. The tunnel excavation volume was computed using an average height and width of 20 and 25 feet, respectively, based on vintage photos of the north tunnel portal and a recorded length of 1875 ft (McCamish, 2007). The sediment remaining after the failure is sandy and non-cohesive. Soil of this

nature is relatively prone to the formation of soil pipes that tend to enlarge and propagate in the presence of subsurface flow, eventually leading to collapse of the pipes. A mostly non-cohesive soil also exhibits lower shear strengths than a soil that derives part of its strength from cohesion. In addition, it is more likely to lose strength due to soil saturation. There is evidence of long-term soil saturation in a portion of the remaining fill (see Figure 25a), as indicated by the grayish color of the soil.

Not all of the fill materials were sedimentary. A variety of artifacts were found following fill collapse, including pieces of crockery, quantities of candle stubs, dovetailed wooden-box pieces, large amounts of cut lumber scraps, rail sections, a glass liquor bottle, portions of hand tools, and a number of unidentified iron objects looking like they belonged to railroad equipment. The relative volume and random distribution of the lumber in the fill might have provided additional pathways for subsurface flow.

Field observations during and after the catastrophic failure of the fill (J. Hinkle, S. Shaw, 12/11/07) indicate that the base of the fill failed first, causing the middle section of the embankment to collapse downward into the channel. Popping and cracking of trees at the fill base, heard in the hours prior to the failure, suggest outward bulging of the base. It is suspected that partial fill saturation and soil piping, observed in the days prior to fill failure, created large voids in the interior of the fill that subsequently collapsed and undermined the integrity of the fill. Materials on the surface of the pond (i.e., a layer of ice, floating debris) dropped vertically onto the pond bed as impounded water was released, indicating that the pond drained initially from the bottom. In addition to roughly 30,000 yd^3 of fill materials, a minimum of 15,000 yd^3 of debris deposited upstream of the fill were washed downstream (i.e., volume of sediment deposited on top of the surveyed surface and below the elevation of the reconstructed pond bed surface).

Recent observations (J. Hinkle, 3/14/08) indicate that additional materials from the fill and adjoining slopes are continuing to creep into the channel. A 50ft. by 100ft. chunk of ground on the west side of the fill, extending from the road to the Eilertsen channel, has begun to slide downward into the creek. It appears that the embankment site will continue to add debris to the channel network into the foreseeable future. It is not possible, however, to predict the timing or magnitude of any additional debris flows that might be generated from continued slumping of fill materials and subsidence of adjacent slope sections.

(4e) Debris flood and transport down Eilertsen Creek

The debris flows emanating from Slides 1 and 2 at the head of the basin are distinguished from the debris-water slurry formed by the catastrophic failure of the Kerry Road embankment, on the basis of solid-to-fluid ratios. A continuum of ratios is found between stream flows, hyper-concentrated flows, and debris flows, generally indicated by increasing sediment concentrations and particle-size distributions. Hyper-concentrated and dam-burst floods form when a channel obstruction (i.e., log jam, landslide deposit, natural or artificial dam) is breached, releasing impounded water and debris catastrophically, and sending a flood wave down the channel that exceeds the magnitude of floods typical for the stream (Pierson and Costa, 1987; Johnson, 1991). Generally, debris flows move as a single unit, whereas in hyper-concentrated flows, debris tends to drop out, with boulders and larger clasts deposited first, while the water moves on through the remaining mass. Given that the Eilertsen flood exhibited some characteristics of both debris flows and hyper-concentrated flows, it likely falls

somewhere between the two on the sediment-water continuum. Estimates of sediment and water volumes impounded behind the fill indicate that the mixture was roughly 50% water and 50% sediment, suggesting that it probably fell in the hyperconcentrated-flow category (as per Pierson and Costa, 1987). Live videos of the flow exiting Eilertsen canyon show that debris (i.e., rocks, logs, mud) moved as a more plastic mass on the flood bore (i.e., flood front). Initial deposition was followed by a lengthy train of water carrying mostly finer debris that flowed through this mass and into the Westport slough (http://www.cnn.com/video/?/video/us/2007/12/11/vo.oregon.mudslide.koinkptv). The main deposit on the highway appeared to be jumbled and poorly sorted, characteristic of debris flows, whereas deposits on the debris fan and in upstream channel reaches showed more sorting and gradation, somewhat more diagnostic of waning stages of a catastrophic flood. Hence, for lack of an appropriately defined term, the Woodson flood will be referred to as an “embankment-burst flood” or “debris flood”, to indicate that it is a distinct process and related to failure of the Kerry Road embankment.

The Eilertsen channel downstream of the failed embankment can be described as a transport channel; that is, materials carried by the stream flow primarily are moved through the channel network rather than deposited and stored long-term as channel bed, bar, or bank materials. Montgomery and Buffington (1998) classified transport channels as those generally having a channel gradient between 3% and 20%. The Eilertsen channel sustains channel gradients exceeding 3% over its entire length (Figure 28), with the exception of several lower-gradient reaches that store sediment. The channel only maintains a gradient at or below 3% downstream of the channel loss of confinement. The point of confinement loss has been placed, based on channel surveys, within 100 feet upstream of the bridge on the private access road that cuts around the south side of Woodson (Figure 29). Hence, the loss of confinement is within several hundred feet of pre-existing home sites damaged by the debris flood. Consequently, Eilertsen Creek primarily funnels debris flows and floods downstream without substantial long-term accumulation of debris in the channel, although there is temporary deposition of debris in side-channel terraces, and the primary deposition site for these materials is the debris fan on which Woodson has been built.

There is substantial evidence that debris flows have scoured the Eilertsen channel multiple times. Deposits from at least three distinct debris flows have been found outside the active channel margin, on terraces well above the channel bed. At least two can be traced to their source: the December 11 debris flood; and a debris flow emanating from the east-fork Eilertsen Creek that left a recognizable trail of coarse, yellow sandy deposits in some lower-gradient reaches. It is assumed that this deposit is associated with the 1996 debris flow that resulted from a Kerry Road fill failure on what locals refer to as “Sand Hill”. The geometry and stratigraphy of the existing terrace deposits in lower-gradient reaches suggests the following sequence: the channel is buried to some depth by debris-flow deposition; stream flows eventually erode through the deposits to re-establish a channel bed, leaving the margins of the deposit exposed; another debris flow deposits on top of existing terrace and channel deposits; again the channel eventually downcuts through the deposits; and the cycle continues.

With the exception of three distinct reaches, the Eilertsen channel is relatively uniform, with a moderate gradient and minimal sinuosity (i.e., bends; see Figure 30). The atypical reaches are associated with an alder flat, located about 0.5 mile downstream of the Kerry Road embankment (see Figure 28), a moderate-gradient reach just upstream of the lower Kerry Grade crossing (i.e., abandoned grade and crossing about one mile

upstream of Woodson), and a series of tightly confined S-curves that end about 1000 ft upstream of the channel loss of confinement. Aerial photos show an extensive flat area (i.e., about seven acres) outside of the active channel margin, which is dominated by sag ponds and red alder overstory. Historic aerial photo records indicate that this area has been disturbed routinely by debris flows from Eilertsen Creek and channels draining the ridge between the mainstem and east-fork Eilertsen channels. It appears to be part of a large deep-seated failure, the toe of which has been reactivated by recent flooding (Figure 31). Debris and water from the embankment failure overwhelmed the incised-channel margins of Eilertsen Creek, to a vertical height of about 20 ft, overtopping the alder flat and draining back into the channel at its downstream end. Based on surface scour of the native ground, it appears that the bulk of the debris flood was diverted from the channel, which hooks around the south side of the alder flat, and the flood shot straight across the flat. It is likely that the flood bore was accelerating upstream of this flat, as it traveled down channel reaches in excess of 20% and passed over a near-vertical bedrock step just upstream of the flat.

Downstream of the abandoned lower Kerry Grade railroad crossing, the channel enters a lengthy reach characterized by S-curves or corkscrew bends in which the channel bed has deeply incised (i.e., average of ten vertical feet) through old channel deposits dominated by debris-flow materials. This section looks deceptively straight and moderate-gradient on topographic maps when, in reality, many local reaches are much steeper and tightly confined. Upstream of the railroad crossing is a lower-gradient, relatively straight reach. The channel narrows through a constriction at the old trestle site, where channel sidewalls are armored by old trestle stringers and pilings (Figure 32). Based on historical aerial photos, the trestle appears to have been removed prior to 1948. This notch forms a major bottleneck for the channel, forcing debris flows and floods to pool upstream of the crossing or overtop the channel margins. The 1998 aerial photos show that a laterally extensive zone of deposition occurred in the past at the upstream end of the notch. Undoubtedly, this bottleneck impeded the 1996 debris flow as it traveled downstream, forcing it to spread laterally upstream of the old trestle crossing before entering the incised canyon.

An analysis of channel hydraulics indicates that flood flows initially are slowed as they pool upstream of the old trestle crossing. Flows squeezed through the trestle-crossing constriction are then forced to accelerate again, and they continue to pick up speed when they are forced into the narrow canyon dominated by tightly confined S-curves. The net result is that flows become narrower, deeper, and faster in the canyon. S-curve channel segments largely are scoured, whereas some debris deposition has occurred in lower-gradient, less-confined reaches, both upstream and downstream. Lower-gradient channel reaches upstream of Woodson likely cause flows to slow again as they approach the debris fan. Debris-flood scour marks were found well above the channel bed (e.g., over 20 vertical feet, where the flood ramped up out of the channel). Just downstream of the S-curves, debris was found from the December storm, plastered tens of feet high in trees growing on elevated stream terraces. The bottleneck upstream of the old railroad crossing does serve to meter the flow, so that floods do not enter Woodson as one massive, instantaneous flood wave. However, it appears that confinement of flow through the constricted reach downstream accelerates flows and increases their erosive power in the S-curves. Hence, debris flows and floods are able to cover the remaining thousand feet of lower-gradient, widening channel reaches with sufficient velocities and force to rearrange the debris fan in Woodson.

(4f) Debris deposition in Woodson

The deposition zone in Woodson was relatively more documented, during flooding, than upper reaches of Eilertsen Creek, because the media focused more on flooding of homes and the highway and less on what was occurring upstream (Figure 33). Many of the observations described below are taken from watching aerial-video footage. Several news and agency helicopters circled overhead as the flood neared its final stages, and a number of reporters, agency employees, and neighbors took photos of the flood wave as it entered Woodson, crested, and trickled to an end. These photos also were useful in evaluating the distribution of materials across the Woodson debris fan. For example, one observer estimated that the debris flood was moving about five miles per hour as it hit the highway, which is a good guess. An analysis of film footage shot from a helicopter suggests that the flows were travelling 4.2 mph (i.e., about 200 cfs); this value was obtained from watching video shots of logs floating past two known points on the ground.

Videos and photos show that debris entrained in the flood deposited unevenly across the existing Woodson debris fan, with larger piles coming to rest on the highway and upstream of obstructions (e.g., debris piled around homes, vehicles, etc.). The loss of gradient between the canyon mouth and the highway, the positive gradient of the highway berm, and plugging of the box culvert beneath Highway 30 were sufficient to slow the large pulse of logs and debris that arrived on the flood bore. This first pulse of debris was responsible for shoving the well-photographed, single-wide trailer onto the highway. This mass, including the trailer, served to capture or deflect other debris arriving later.

Video footage indicates that, over the course of 10 minutes as the flood crested and waned, the water content of the debris mass increased. In essence, the flood progressed from a coarse debris plug to watery mud to muddy water, with the initial flood pulse of logs and sediment deflecting subsequent flows of muddy water to the east and west. The deflected flows likely are what caused the deposition zone to expand along the highway corridor and merge deposits from Eilertsen Creek with those previously deposited to the west by debris flow(s) emanating from Olsen Creek. The initial debris plug inundated the homes nearest the highway in about 3-4 feet of mud and woody debris; however, it was the discharge of muddy water at the crest of the flood that raised flood stage to the eaves of the houses. When this flood of muddy water ended, the water level receded, leaving the more solid, initial mass of debris in place. Much of the water-mud mixture drained through the debris piles on the highway and into the Westport Slough, where the incoming tides pushed debris upstream until the tide turned and river flow changed direction.

Figure 34 shows a surveyed plan view of the Woodson debris fan and homes, businesses, and the Highway 30 corridor with respect to Eilertsen Creek. There is little doubt that the buildings, highway, and railroad tracks are built on a periodically flooded debris fan. The earliest aerial photos, taken in 1939, show the debris-fan surface as well as a plume of debris (i.e., subaqueous debris fan or delta) beneath the slough waters directly offshore. The geometry of the slough delta has changed over time, in response to pulses of debris entering the channel from upstream flooding events.

Although the elevational difference across the face of the fan (i.e., in a direction paralleling the highway) is minimal, ranging from 0% to 3%, the highest part of the fan

surface coincides with the Eilertsen channel where it drains across the fan toward the slough. Typically, a debris fan is thickest and most frequently disrupted near the main channel, which is the primary pathway for debris transport from a canyon mouth to the fan. As the horizontal angle increases away from the canyon mouth, the magnitude of deposition and surface disruption generally decreases. The importance of angle and distance can be seen in Figure 34, with respect to relative damage. Those residences in the direct path the debris flood received the highest degree of structural damage. The single-wide trailer on the west side of Eilertsen Creek was battered and pushed onto the highway (see Figure 2), and the home on the east side of the channel was severely damaged structurally. Those homes and businesses toward the outer margins of the fan, although substantially flooded, were not hit as hard by the initial flood bore that deposited the largest rocks, logs, and sediment load.

It appears, from the timing and spatial distribution of flood deposits, that the bulk of the largest debris (i.e., logs, boulders) was entrained by the initial passing flood waves as they raced down the canyon. This plug of debris arrived first in Woodson and likely was propelled, or pushed from behind, by the immense flood of water unleashed by the embankment failure. This hypothesis would be consistent with the observations made in Woodson that the large logs arrived in a pulse of thick mud and debris, followed by a more prolonged train of mud and muddy water. Estimates of the volume of material deposited on the Woodson debris fan are based on the numbers of dump-truck loads hauled away by ODOT, the average debris depth (i.e., about five feet), and the fan area. The cumulative debris volume was about 57,700 yd^3 (Stephen Hay, ODOT engineering geologist, pers. comm. to J. Hinkle, 4/4/08). Although much of this volume was removed by ODOT, a significant volume of debris still covers the fan surface and inundates some residences.

(5) Summary and Conclusions

Historical accounts and recent evidence of landsliding and flooding in Columbia River tributaries between Clatskanie and Westport demonstrate that hillslopes in this area are inherently unstable, particularly during the annual heavy rains that fall between November and May. Looking back through recent history, Eilertsen Creek and its neighboring drainages have experienced, alternately or concurrently, debris flows or flooding nearly every wet season, at least since the mid 1990's. In addition, numerous failures have occurred, some with extensive property damage, throughout the last two centuries, with the earliest recorded failures in the 1880's. A combination of factors leads to high frequency of landsliding in these drainages: high-intensity storms blown in from the Pacific Ocean less than 30 miles to the west; relatively incompetent bedrock; and hillslope hydrologic conditions conducive to instability, including the presence of loose sandy soils overlying more consolidated layers that control patterns of groundwater flow and result in abundant slope seepage. These factors are compounded in Eilertsen Creek, and several drainages to the east, by the historic Kerry Railroad Grade, which was built as a temporary route for hauling "old-growth" timber from the forest in the early 1900's. Two of the largest debris flows or floods in the historic record have been associated with the catastrophic failure of railroad embankments and trestles on the Kerry line: the failure of a trestle over OK Creek in 1933, which resulted in fatalities, and the collapse of the Eilertsen Creek railroad embankment on December 11, 2007 that fortunately occurred without loss of lives.

This study was undertaken to determine the causes and downstream consequences of the railroad embankment failure and subsequent debris flood. Conclusions from this analysis are summarized as follows:

(1) Field evidence indicates that there were several components responsible for the flooding of Woodson on December 11, 2007: two ancient, ***deep-seated landslides*** upstream of the railroad embankment, portions of which were re-activated by the early December storms (i.e., Slides 1 and 2); ***debris flows*** emanating from both landslides; catastrophic failure of the ***Kerry Road embankment*** on December 11; and a ***debris flood*** that resulted from the catastrophic failure of the embankment.

(2) In addition, at least two other failures in the basin, one located about 160 ft to the east of the railroad embankment on the Kerry Road (i.e., Slide 3), and another on a truck-haul spur road about 0.25 mile to the east (i.e., Slide 4), might have led to initial flooding of Woodson during the December 2-4 storm event, although the evidence is equivocal. Both occurred on ETA property. Woodson residents still were cleaning up from the first flooding event when the December 11th. debris flood inundated their homes. Both failures delivered debris to the mainstem Eilertsen Creek with sufficient volumes and potential energy (i.e., due to steep channel gradients) to potentially transport water and sediment to Woodson. It is not clear whether one or both of these failures initially flooded Woodson, or whether the source of the December 2-3 debris flooding was more localized to the lower Eilertsen and Olsen creeks. The December 11 debris flood wiped out any evidence of an earlier occurrence in the channel or on the debris-fan surface.

(3) Slide 1 occurred in a unit harvested in 1992 on OSU-managed lands, within a much older, deep-seated landslide. Field evidence shows that the early December 2007 failure was triggered by stream undercutting of the toe, which caused several portions of the hillslope to fail headward toward the ridge as discrete failure blocks. Although road drainage from the adjacent Skull Ridge Road likely contributed water to the failure body, stream undermining is likely the primary trigger. Road runoff is estimated to have provided a minimal percentage of the water necessary to initiate a deep-seated landslide. Elevated stream flows and rain through-fall associated with the high-intensity storm of December 2-4 is suspected as the main driving factor. An estimated 25% of the total landslide volume slid into a tributary channel draining the headwater basin of Eilertsen Creek.

(4) Slide 1 triggered a debris flow that delivered roughly 16,000 yd^3 of landslide debris to the upstream base of the Kerry Road embankment. The debris flow scoured the channel from the landslide toe to its deposition zone at the base of the embankment and, therefore, can be used as clear evidence that the landslide delivered materials directly to the location of the puncheon culvert in the fill. The debris-flow materials are distinguished from those of Slide 2 by their composition and cover roughly 75% of the area submerged by water impounded behind the embankment during and/or following the December 2-4 storm event. This debris flow delivered roughly four times more volume of material than did Slide 2.

(5) Slide 2 occurred in a 2004 harvest unit on OSU-managed lands, within an ancient, deep-seated failure. It is suspected that groundwater seepage, and stream undermining of the toe at the channel initiation point for an Eilertsen Creek tributary, caused the slope to fail at the base of the pre-existing headscarp. A distinct groundwater seepage layer was observed at this point on

the slope. Slide 2 failed as a translational slide that deposited a veneer of sediment downslope. Slide 2 delivered roughly 25% of its volume to the channel.

(6) Slide 2 triggered a debris flow that contributed about 4500 yd^3 of landslide debris to the base of the Kerry Road railroad embankment. Similar to Slide 1, the Slide 2 debris flow scoured its channel and left a deposit that extends to the former location of the puncheon culvert. Debris flows from Slides 1 and 2 entrained additional material in the channel (i.e., sediment, wood) as they passed, augmenting the volume of landslide materials ultimately deposited on the upstream side of the fill.

(7) The toes of both landslides continue to shed materials into the debris-flow tracks, suggesting that landslide debris will be delivered to Eilertsen Creek into the foreseeable future. As indicated above, a large volume of landslide material still is perched above the headwater tributaries to Eilertsen Creek. It is not possible to predict if or when another debris flow might be mobilized by continued landsliding.

(8) The physical characteristics of the deposit, including depositional stratigraphy, suggest that the debris-flow deposits accumulated prior to the formation of the deep pond observed on December 6 and 10, 2007. Although it is not possible to state exactly what clogged the puncheon culverts draining the embankment, and when the obstruction occurred, it can be said with certainty that each of the debris flows contained sufficient volume to overwhelm and block the puncheon culvert and overflow CMP.

(9) The railroad embankment likely was formed when the Kerry Grade tunnel was built, as a convenient waste site for excavation materials and construction waste. The embankment contained a volume of materials roughly equivalent to the estimated amount of waste removed during tunnel construction, that is, about 34,000 yd^3. These materials were dumped over the existing trestle, to form an 80 ft. high by 250 ft. long, by approximately 200 ft. (at its base) wide embankment.

(10) Calculations suggest that the volume of water ultimately impounded behind the fill, roughly 35,000 yd^3, could have amassed during the 3-day storm in early December. Water depths averaged about 15 ft over a surface area of about 1.5 acres, with an additional 15 ft thickness of debris-flow deposits forming the pond bed. These deposits overlay an unknown thickness of sediment deposited prior to the debris flows, based on results of a drive-probe measurement adjacent to the fill base (G. Schlieder, pers. comm.).

(11) Between December 6 and 10, when field observations occurred, some amount of impounded water drained eastward along the inboard ditch to the site of Slide 3 on the Kerry Road. By December 10, the pond level had dropped such that water no longer was being relieved through the ditch-lines. Instead, according to field observations, water was draining through the fill as dispersed and piped flow, indicating that the lower portions of the fill were saturated. Piped flow signifies that portions of the fill interior had been eroded, leaving void spaces through which water was flowing.

(12) Slide 3, located 160 ft. to the east along the Kerry Road, is not related solely to the Kerry Road embankment overflow. It was initiated in a 12-year-old plantation as a relatively shallow failure that travelled downstream in a small tributary to Eilertsen Creek during the week of December 3, 2007, and likely plugged a culvert in the Kerry Road. The culvert was overwhelmed and water overtopped the road surface, resulting in gullying and subsequent road failure. Although

water from the railroad-embankment impoundment was observed flowing down the inboard ditch into the road failure scarp (M. Reed, pers. comm., 12/10/07), it likely was not the only cause of Slide 3.

(13) On December 11, observations made during and after the railroad-embankment failure indicate that the fill collapsed initially at the bottom, as the interior bulged outward and ultimately burst. This rupture likely created a plug of debris that was propelled downstream by the wall of water released from the impoundment. Film clips of the debris-flood arrival in Woodson indicate that the flood bore contained a higher coarse-sediment content than the trailing flows, which largely consisted of a long train of muddy water.

(14) Some percentage of the original fill materials remain at the site, so a volume on the order of about 25,000 – 30,000 yd^3 probably was released into Eilertsen Creek by the embankment collapse. An additional minimum of 15,000 yd^3 of impounded debris-flow materials also were washed downstream during flooding.

(15) The ensuing debris flood traveled at speeds reaching about 50 mph as it traversed the mainstem Eilertsen Creek to Woodson. The debris flood scoured approximately 1.75 miles of channel, in places overtopping the channel inner gorge and eroding slopes at least 20 vertical feet above the active channel. In lower-gradient reaches, some deposition occurred on terraces created by a number of older debris flows, including one traced to the failure along the Kerry Road that likely was the source of the damaging debris flood in April 1996.

(16) It is suspected, based on depositional evidence, that the debris flood became tightly constrained just upstream of the lower Kerry Railroad Grade crossing, so that it was forced to slow down before it entered the narrow, tightly confined, deeply incised canyon upstream of Woodson. This bottleneck prevented the flood from reaching Woodson as one single, huge flood wave, causing the flood to be drawn out over about 10-15 minutes.

(17) The initial flood wave reached Woodson in about three minutes, carrying the bulk of the coarse debris (i.e., logs, boulders, other coarse materials) that largely deposited on the low-gradient fan and Highway 30 corridor. Some materials traveled into the Westport Slough, as did substantial volumes of muddy water trailing the flood bore; these waters flowed through the coarse deposits or were diverted east and west along the highway corridor. Much of the large wood (e.g., 3-4 ft. diameter logs) likely was entrained by the passing flood wave from positions higher on the hillsides (i.e., those that were not mobilized by the 1996 flood) or from the channel bottom where they either rolled or were dropped by the 1996 flood. The latter flood also was so powerful, judging from aerial-photo and field evidence, that it similarly would have sluiced the canyon of large debris and left little large wood to be incorporated in the 2007 flood.

(18) The homes hit hardest structurally from the debris flood were those in the direct path of travel (i.e., nearest the Eilertsen channel). Those homes located distally from the channel received relatively less structural damage directly from impact by large moving debris, although water and mud damage was substantial. Direct impact to homes close to the channel also appeared to be a factor in the April 1996 floods, as evidenced by photos from that event showing significant damage to the same dwellings.

(19) Historical aerial-photo interpretations indicate that the Woodson debris fan formed well before the earliest photos taken in 1939. An offshore delta or fan, built outward from the Eilertsen channel mouth and underwater in the slough, has grown and eroded periodically over the last century but has remained a visible sign of debris deposition in Woodson at least since the 1939 photos were

taken. It is likely, therefore, that sediment deposition from debris-flow events has occurred repeatedly throughout recorded history and pre-dates human settlement of Woodson.

(6) Acknowledgments

The timely, informed, and helpful assistance of Deborah Hazen, chief editor of The Clatskanie Chief, is greatly appreciated. A number of her articles, from which this report was drawn, can be found in the appendices. The authors would like to thank Lin Farm and Mark Reed, ODF, for assistance in the field. Logistical and office support also was supplied by Mike Simek and staff, ODF Columbia City office. Oregon State University, in particular David Lysne, was very helpful in providing access, aerial photos, and information regarding the Blodgett Tract. Finally, Eric Evenson and the employees of Evenson Timberland Agency are gratefully acknowledged for providing property access, historical insights, aerial photos, and answers to many questions posed during the analysis. Readers are strongly encouraged to contact the report authors if they note historical inaccuracies in this report, or can add to the understanding of past landslide events in the vicinity.

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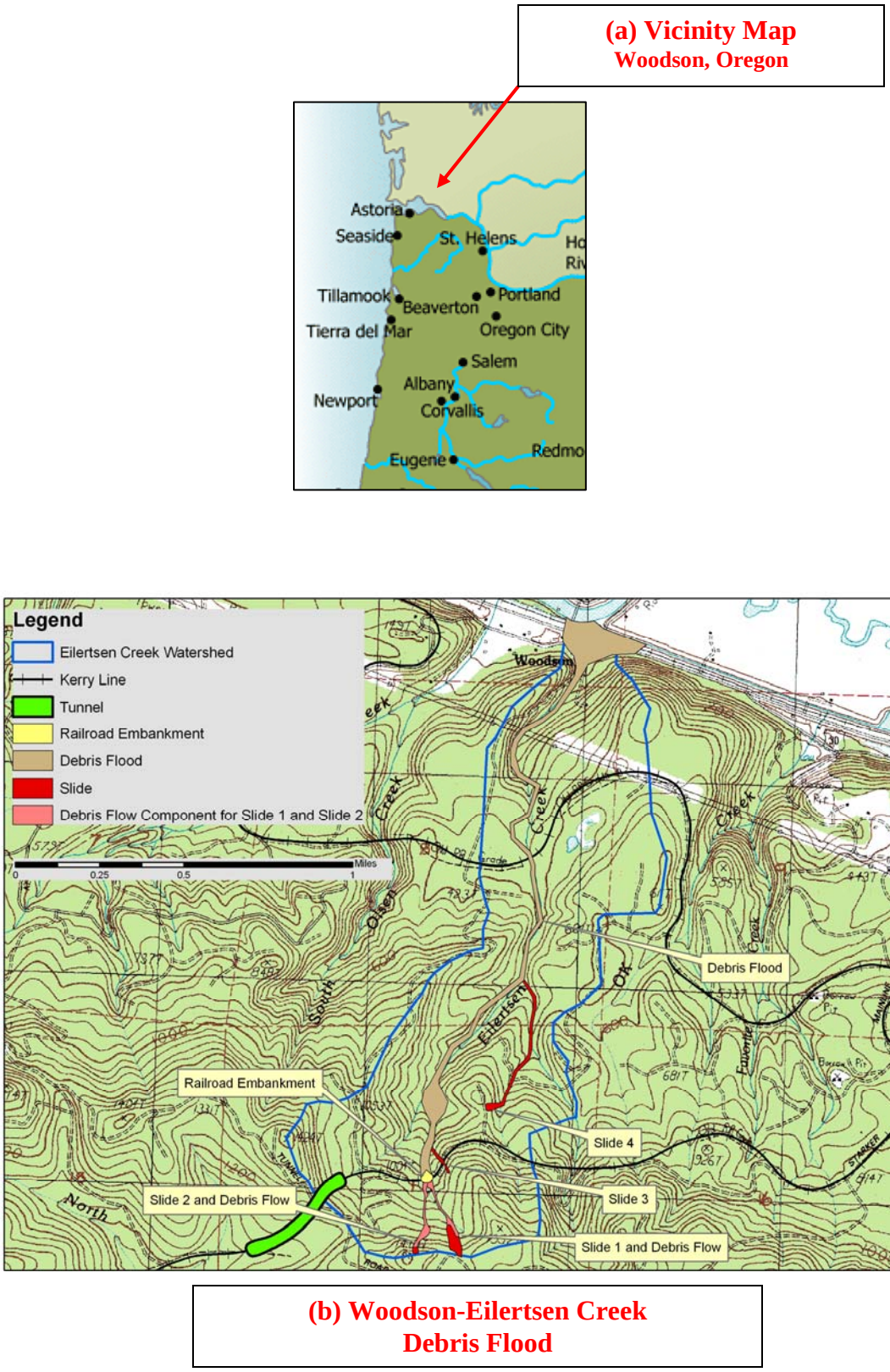


Figure 1. Maps showing: (a) the location of Woodson, Oregon, relative to northwestern Oregon (dark green) and southwestern Washington (light green); and, (b) the path of the debris flood down Eilertsen Creek, from the site of the road/railroad embankment failure to the community of Woodson. Slides 1, 2, 3, and 4 occurred during the December 11, 2007 storm (see text for discussion).

"Déjà Vu All Over Again…."

Caption from The Clatskanie Chief, Thursday, April 25, 1996, referring to a mobile home damaged in April 1996 following the February flood of the same year. The residence shown below sustained relatively minor damage in the April 1996 landslide.

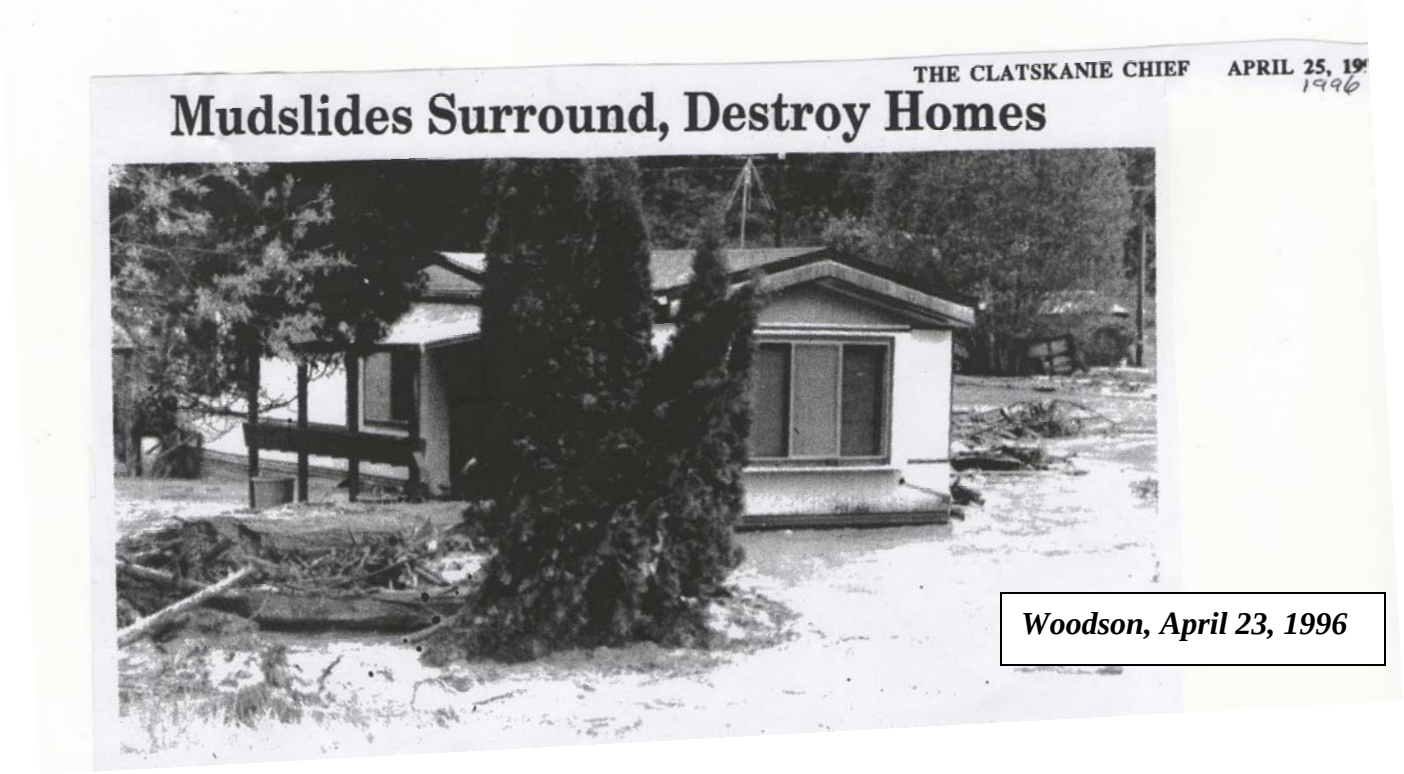


Figure 2. Mobile home damaged by the April 1996 debris flow (upper image). This structure likely is the same residence carried onto Highway 30 by the December 2007 debris flood. (photo: ODOT, 12/11/07).

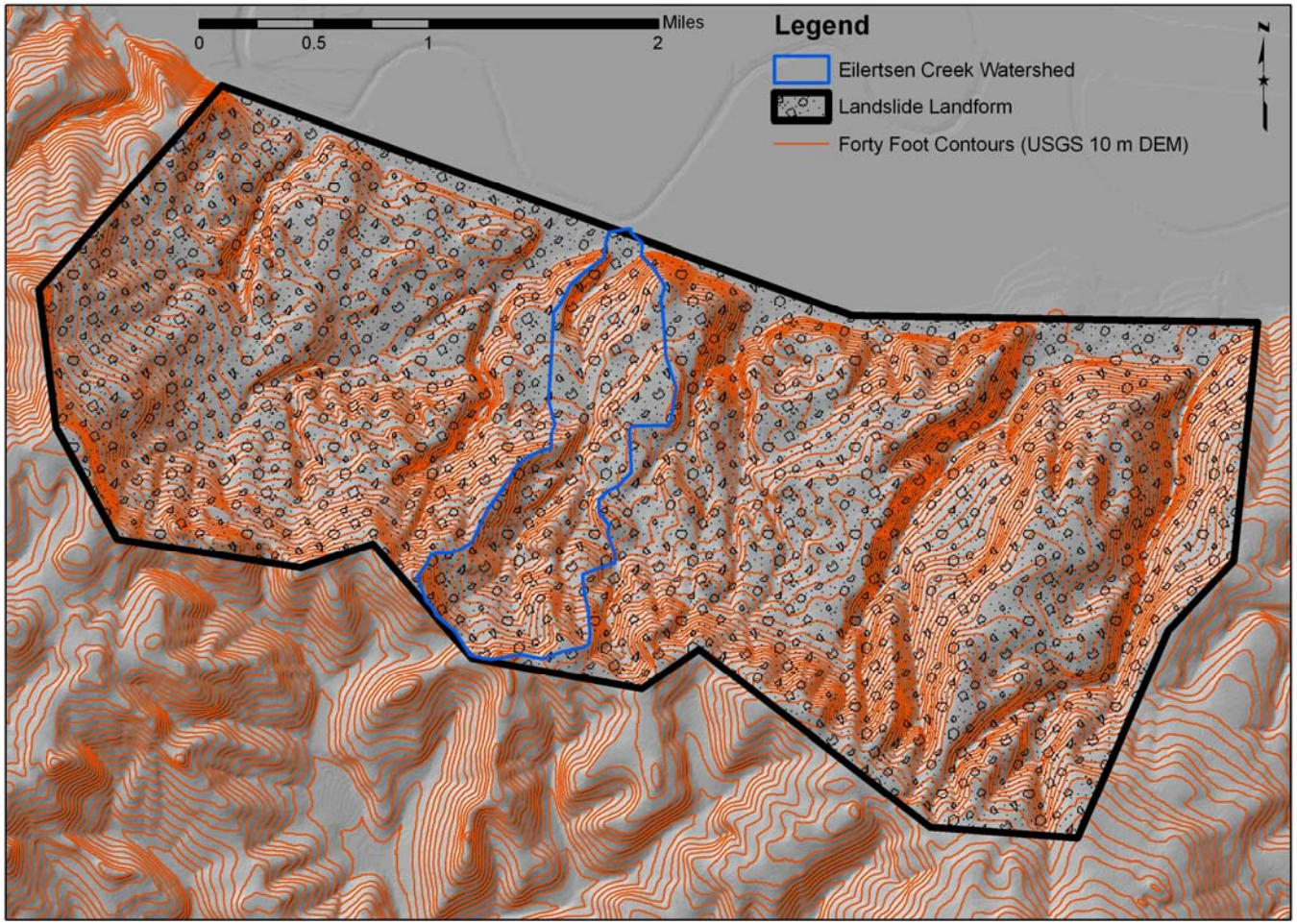
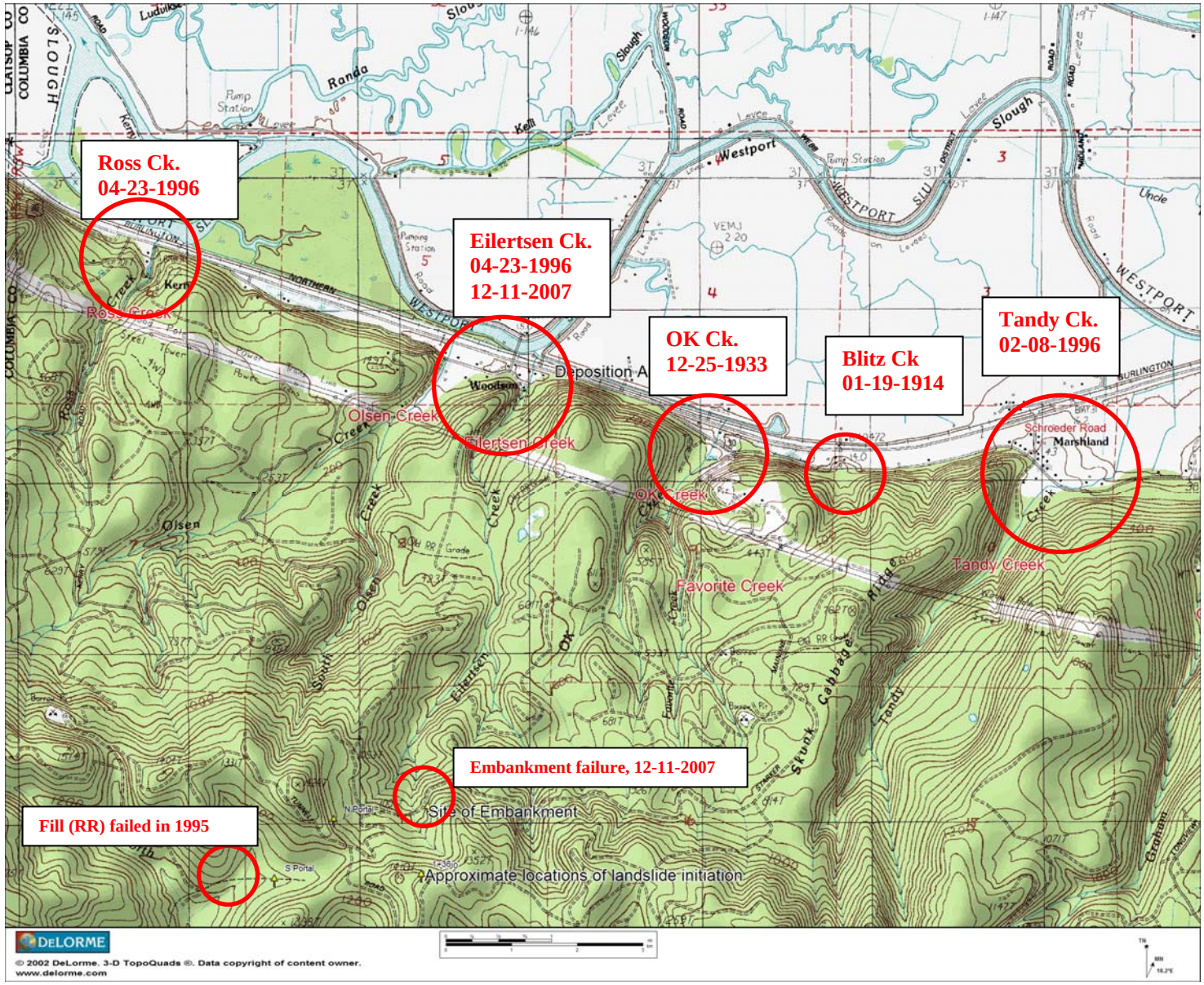


Figure 3. Ancient, deep-seated landslide complex on the north side of Tunnel and Clatskanie mountains. The Eilertsen watershed boundary is shown as a blue polygon.

Figure 4. Residences damaged by debris flows between 1914 and 2007, in Ross, Eilertsen, OK, Blitz, and Tandy Creeks.



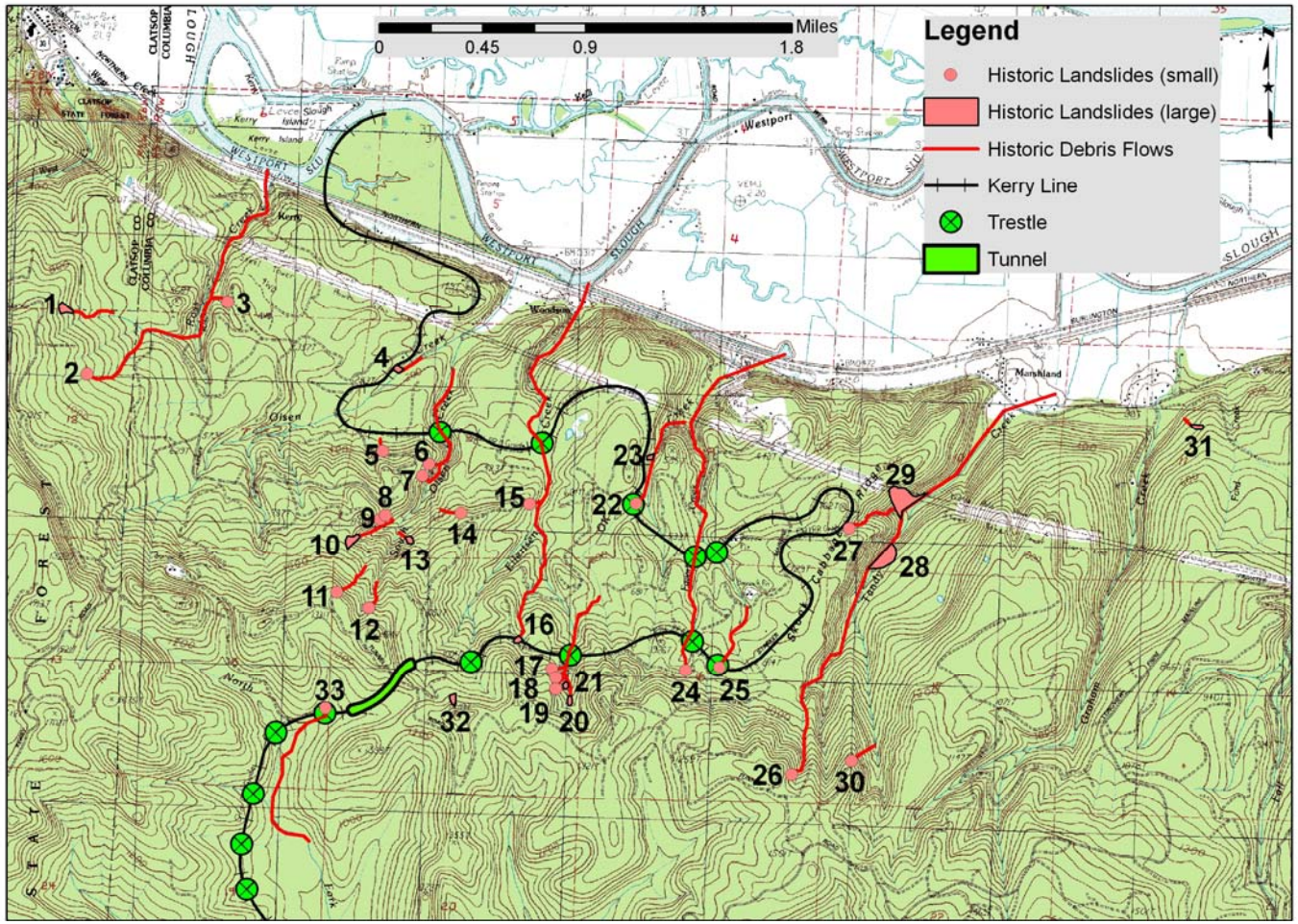


Figure 5. Distribution of landslides and debris flows, based on aerial-photo interpretation, between 1939 and 2007. Mapped failure locations are numbered and shown with the Kerry Railroad grade for reference (see text and Figure 6 for further discussion). Numbered failure sites are referenced by drainage, features, and age in Table 1.

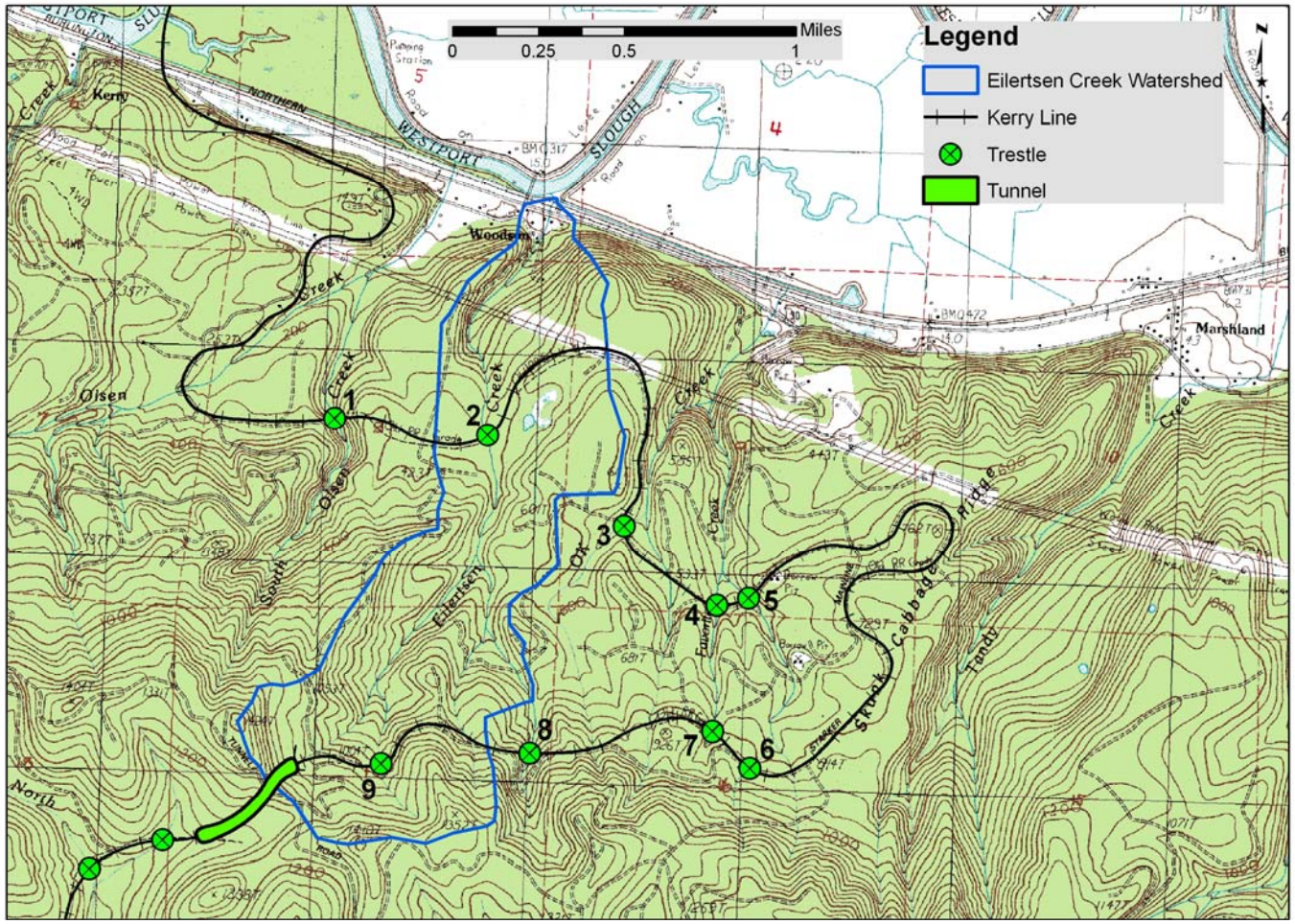


Figure 6. The Kerry Railroad grade, showing the location of the rails from Kerry, on the Columbia River slough, southward through the tunnel located just west of the buried trestle on Eilertsen Creek, which would have been trestle number 9. The Eilertsen Creek watershed boundary is shown as a blue polygon. (modified from McCamish, 2007).

Figure 7. This photo, taken from Sellew (1915; Fig. 34), shows Western Air-dump cars filling a trestle and is envisioned as a process similar to what might have been carried out in burying the Eilertsen Creek trestle.

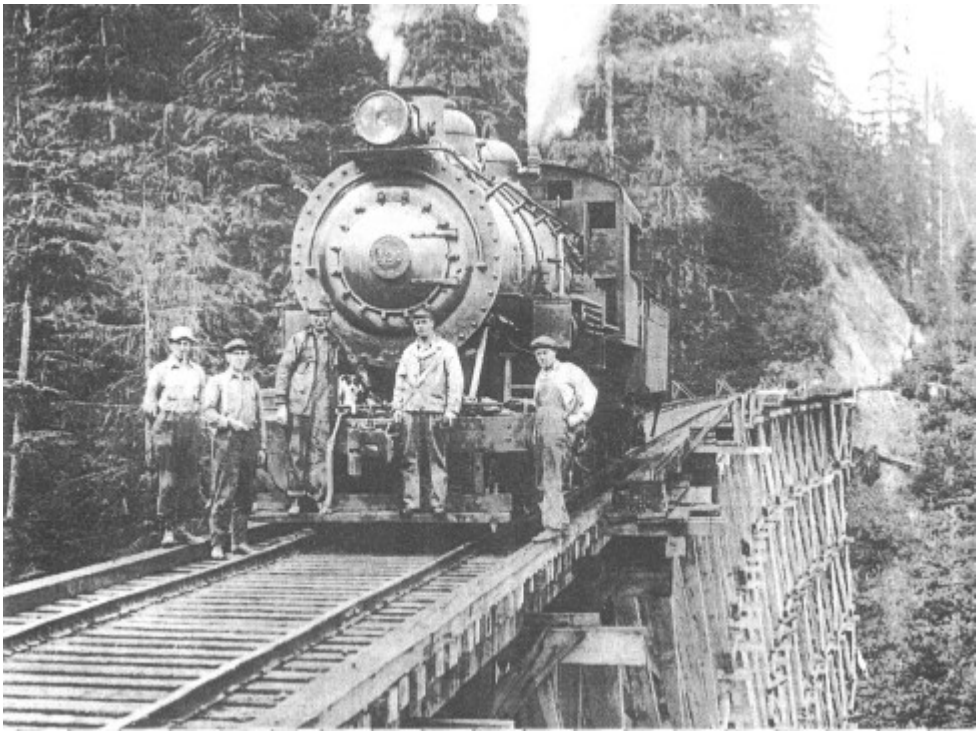


Figure 8. A similar trestle on the Kerry Grade, identified as trestle #8 (McCamish, 2007). This photo likely was taken on the trestle that spanned OK Creek, about 0.5 mile down-grade from the Eilertsen Creek railroad embankment (see Figure 6 for location). This trestle failed in 1933.

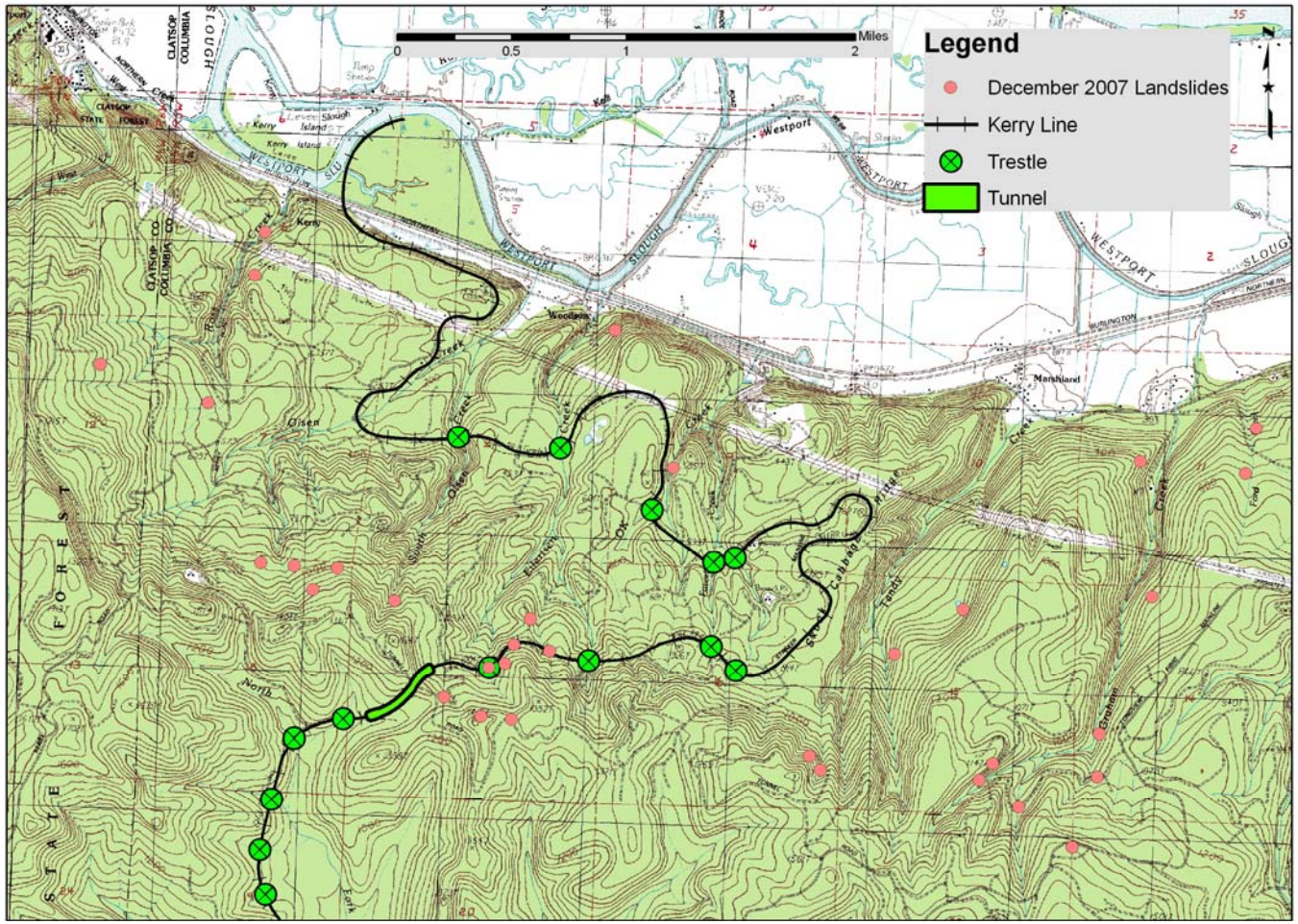


Figure 9. Location of failures associated with the December 2007 storm (pink dots), in the vicinity of Eilertsen Creek (data obtained by ODF, 2008), with the Kerry Railroad grade for reference.

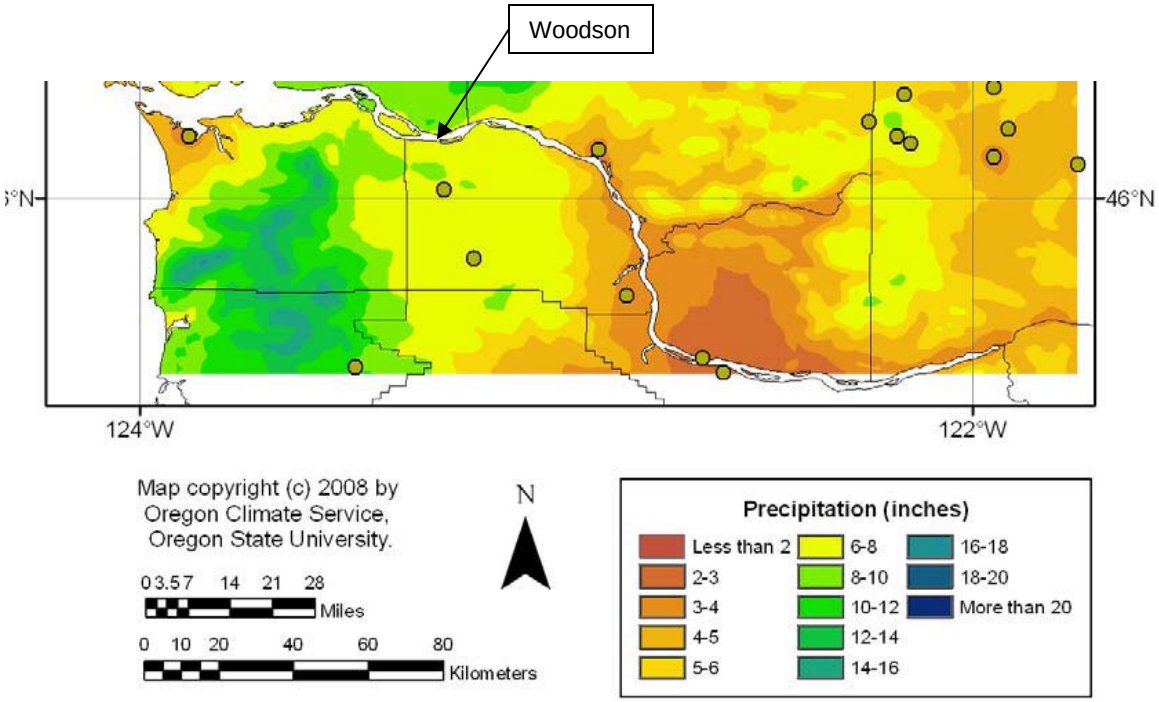


Figure 10a. Isopleths for the maximum 24-hour precipitation that fell during the early December storm. Taken from Reiter (2008).

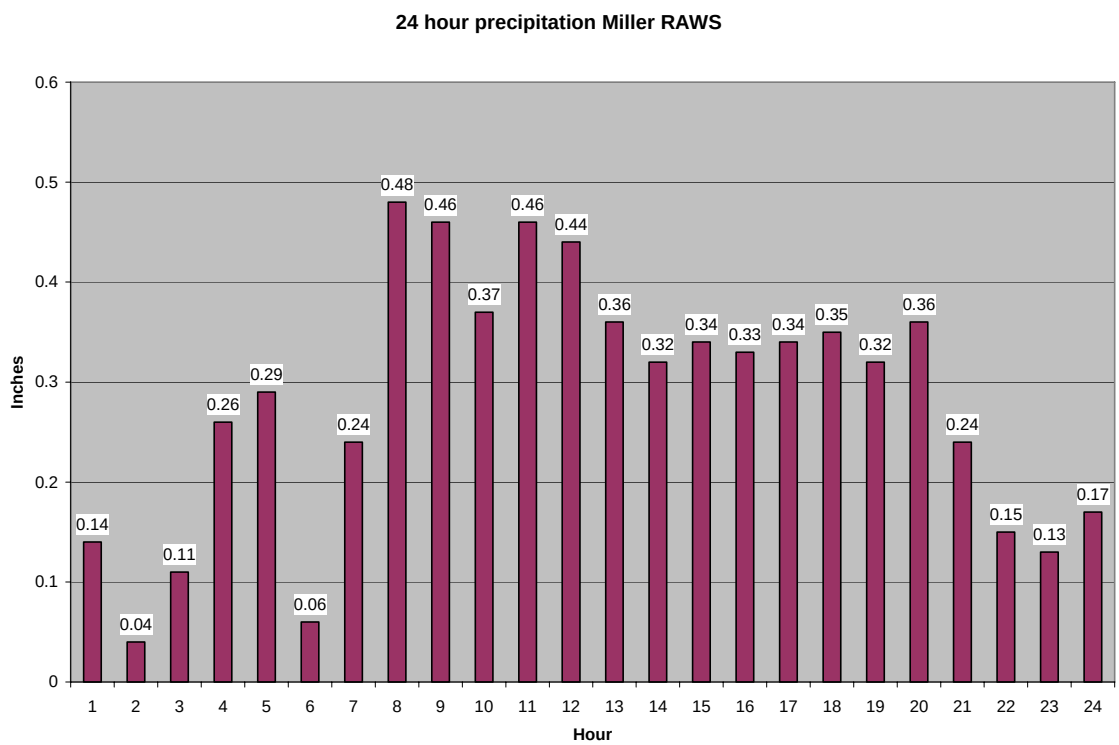


Figure 10b. 24-hour precipitation measured at the Miller RAWS (remote automated weather station), located SE of Woodson, for the period from 2:00 pm, December 2, 2007, to 2:00 pm, December 3, 2007. A total of 6.40 inches fell during this time.

Figure 11. Upper portions of Slide 1, with person for scale (left of stump; see above), showing headscarp and downed trees on landslide body. (photo: J. Seward, 2/26/08).

Figure 12. Aerial photo of Slide 2, that failed in the headwater basin of Eilertsen Creek, about 0.25 mile upstream of the Kerry Road embankment. (photo: ODF, 12/11/07).

Figure 13. Road failure component of Slide 3, occurring about 160 ft. to the east of the Eilertsen Creek embankment on the Kerry Road. (photo: J. Hinkle, 12/10/07).

Figure 14. Slide 4, a hillslope failure resulting in partial loss of the roadbed on a Kerry Road spur. (photo: S. Shaw, 3/3/08)

Figure 15. Water and debris impounded behind the Kerry Road embankment on Eilertsen Creek. The water elevation was one to two feet lower than the road surface in this photo taken 12/10/07. (photo: J. Hinkle).

Figure 16. Tension cracks showed about one to two feet of vertical displacement (see arrows above) in the morning of December 11, 2007, several hours before the embankment failed. (photo: J. Hinkle).

(a)

(b)

Figure 17 (a and b). Debris and mud inundate Woodson, flooding homes and covering Highway 30 and the Burlington-Northern railroad tracks. In (a), a portion of Highway 30 is exposed. The initial flood wave of large logs, rocks, and property (i.e., mobile home, boat) can be seen in the center right of the photo. (photos: S. Shaw, 12/11/07).

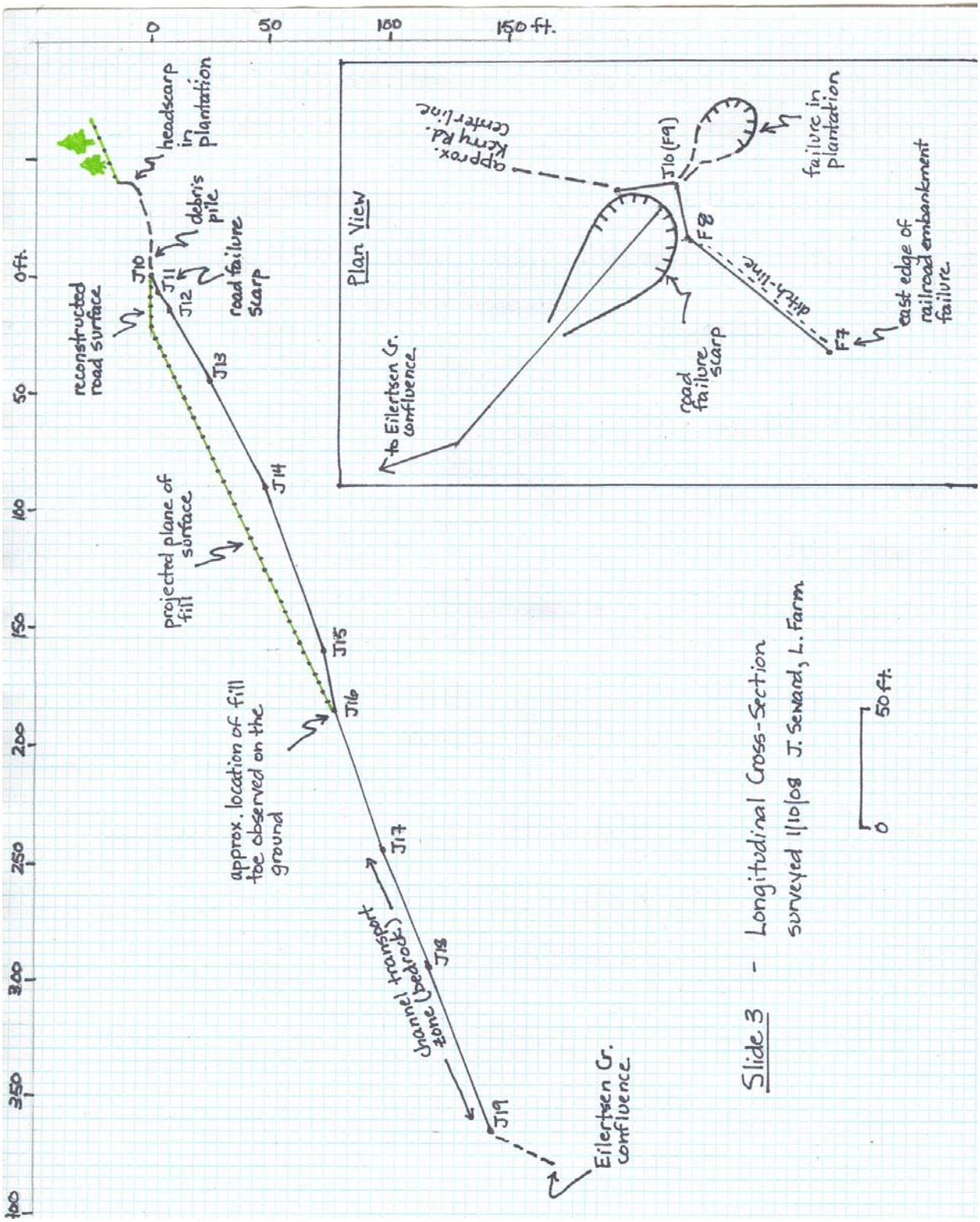


Figure 18. Surveyed profile of Slide 3.

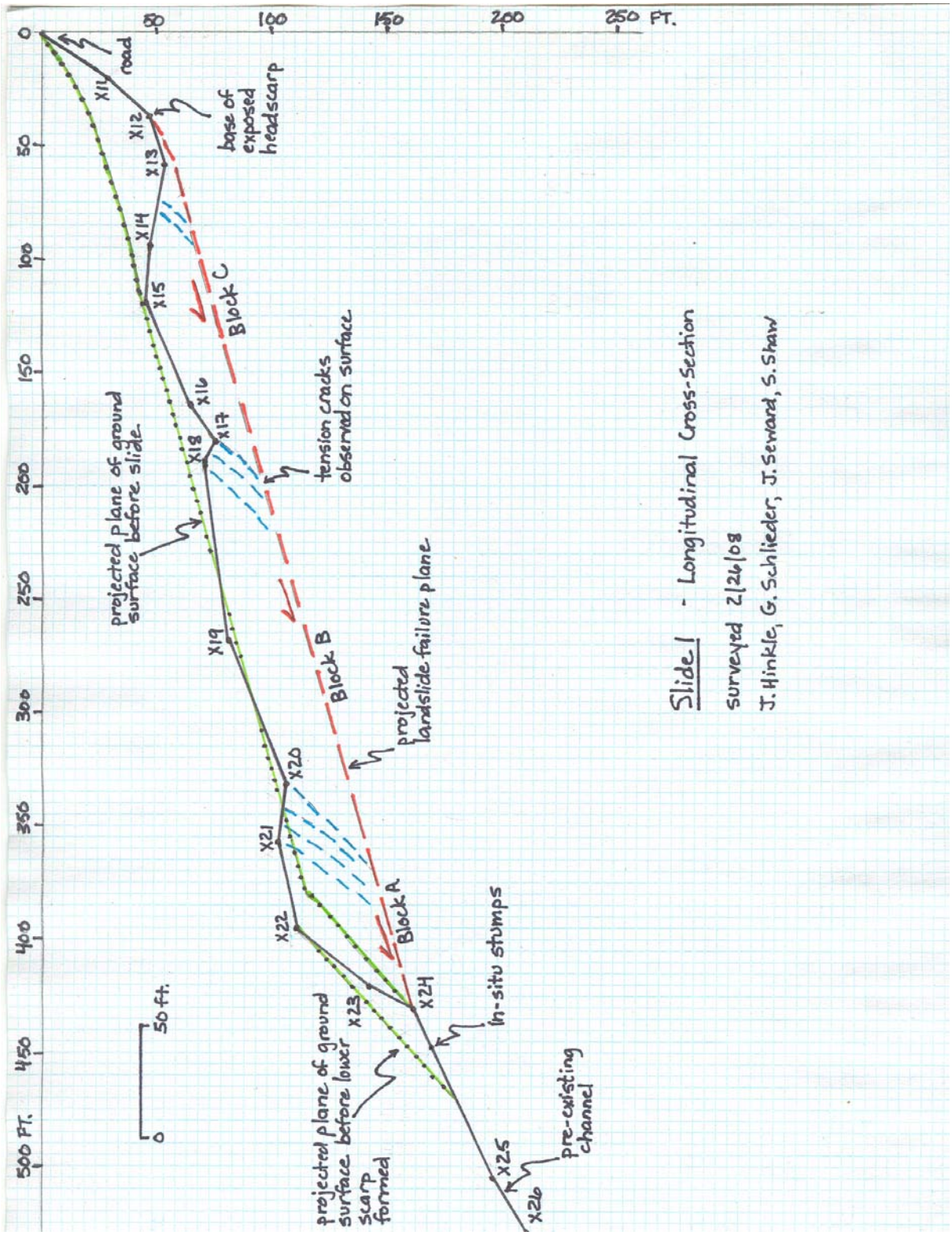


Figure 19a. Surveyed profile of Slide 1.

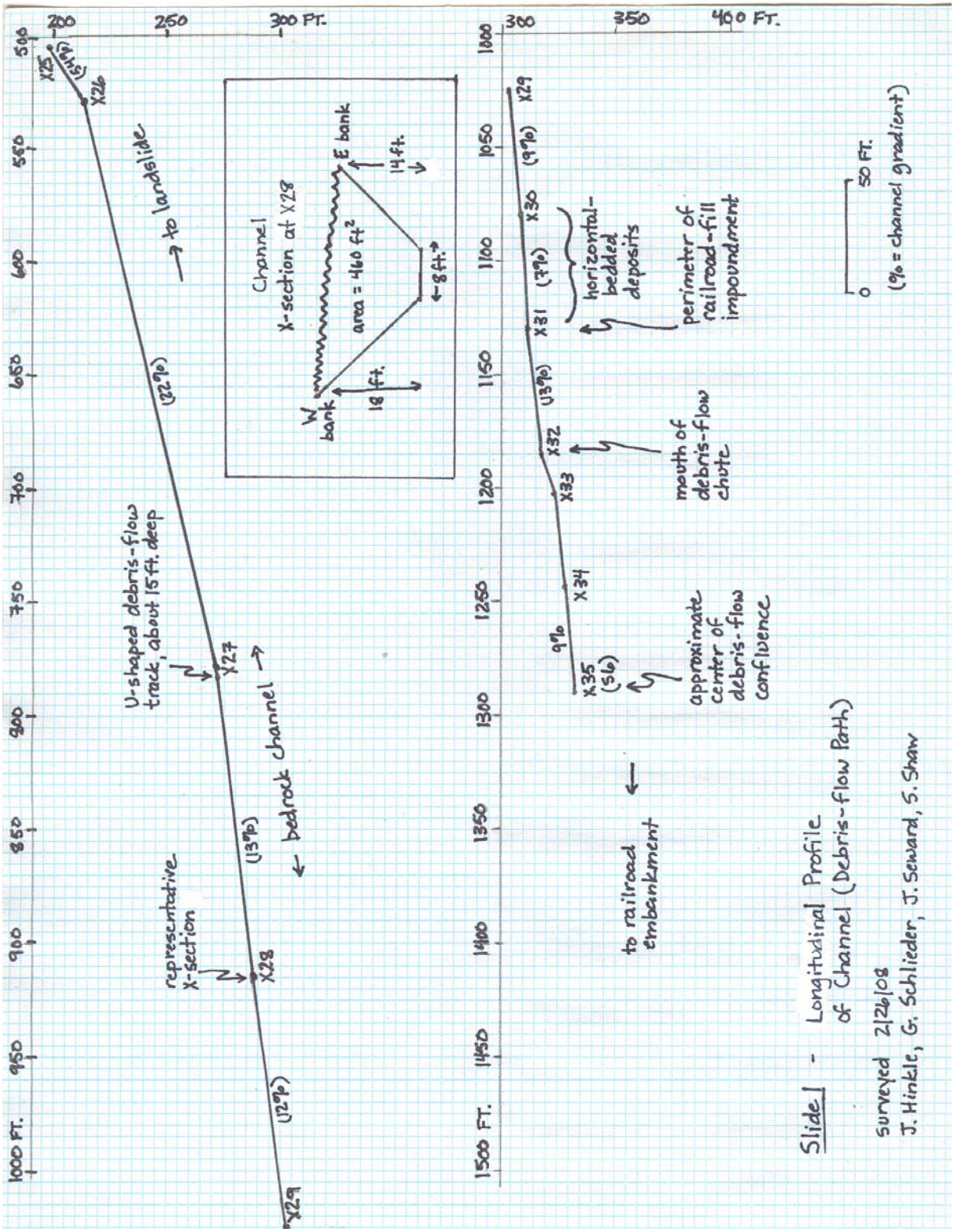


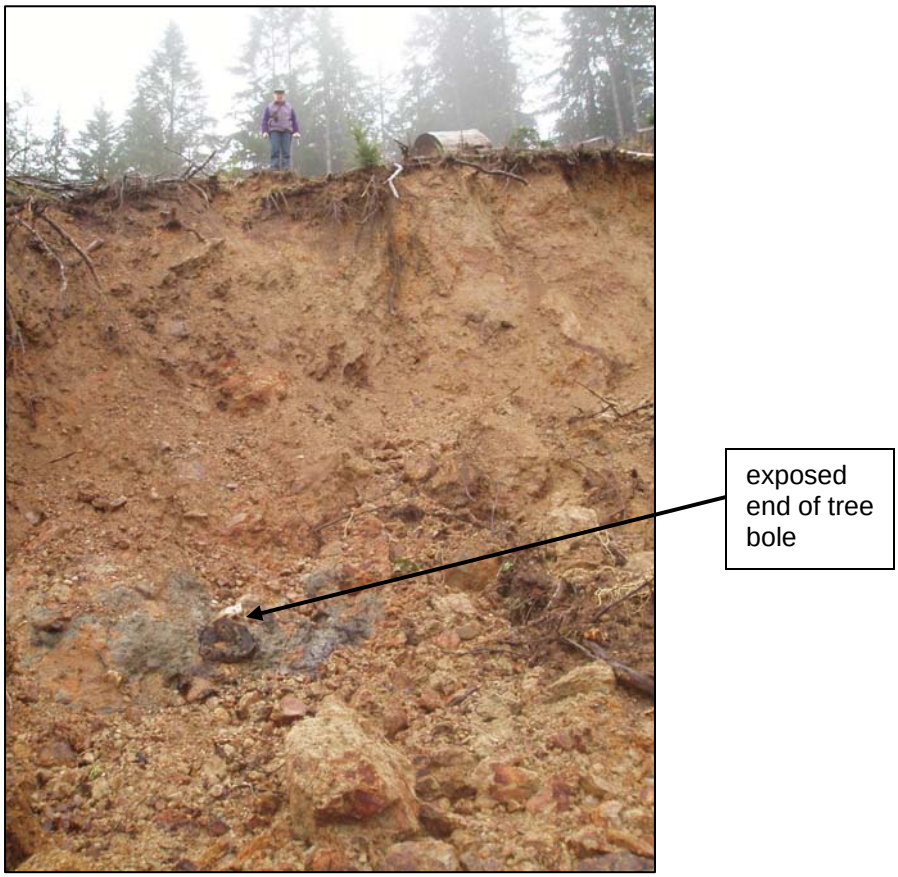
Figure 19b. Surveyed profile of Slide 1 channel/debris-flow track. In the figure inset showing a channel cross-section, the wavy line indicates the top of the debris flow as it travelled downstream.

(a)

(b)

Figure 20 shows the lower scarp (a) and debris-flow track (b) for Slide 1. The buried (*in-situ*) stumps can be seen in (a). In (b), the height of debris-flow erosion in the channel averages about 15 ft. (photos: (a) J. Seward, 2/26/08; (b) S. Shaw, 2/26/08).

(a)



(b)

Figure 21. Exposed woody debris buried by past slope movement at Slide 2. (a) Exposed wood fragments and mottled soils on the east flank of Slide 2. (b) Exposed portion of a tree trunk surrounded by gleyed soil.

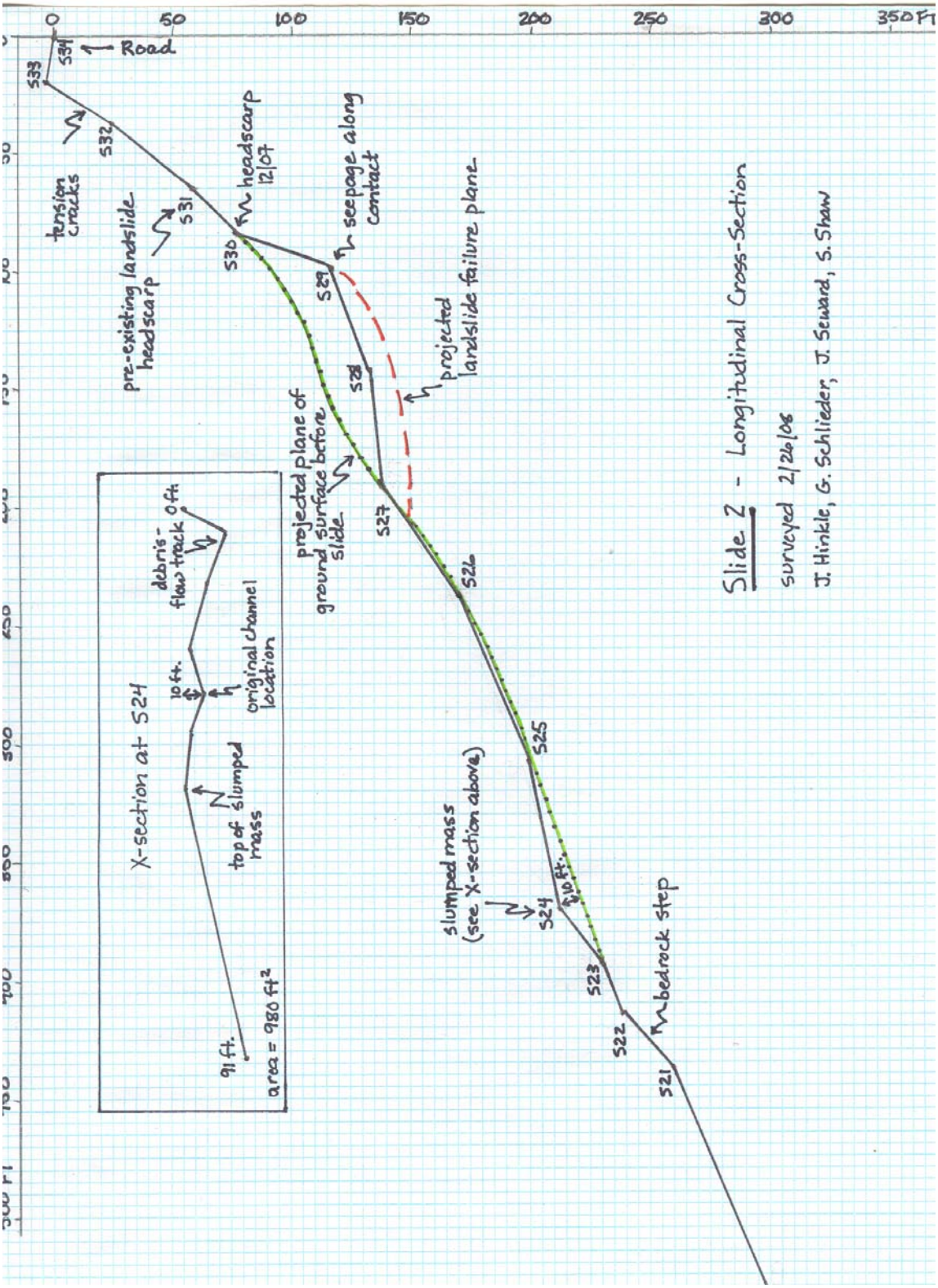


Figure 22a. Surveyed profile of Slide 2.

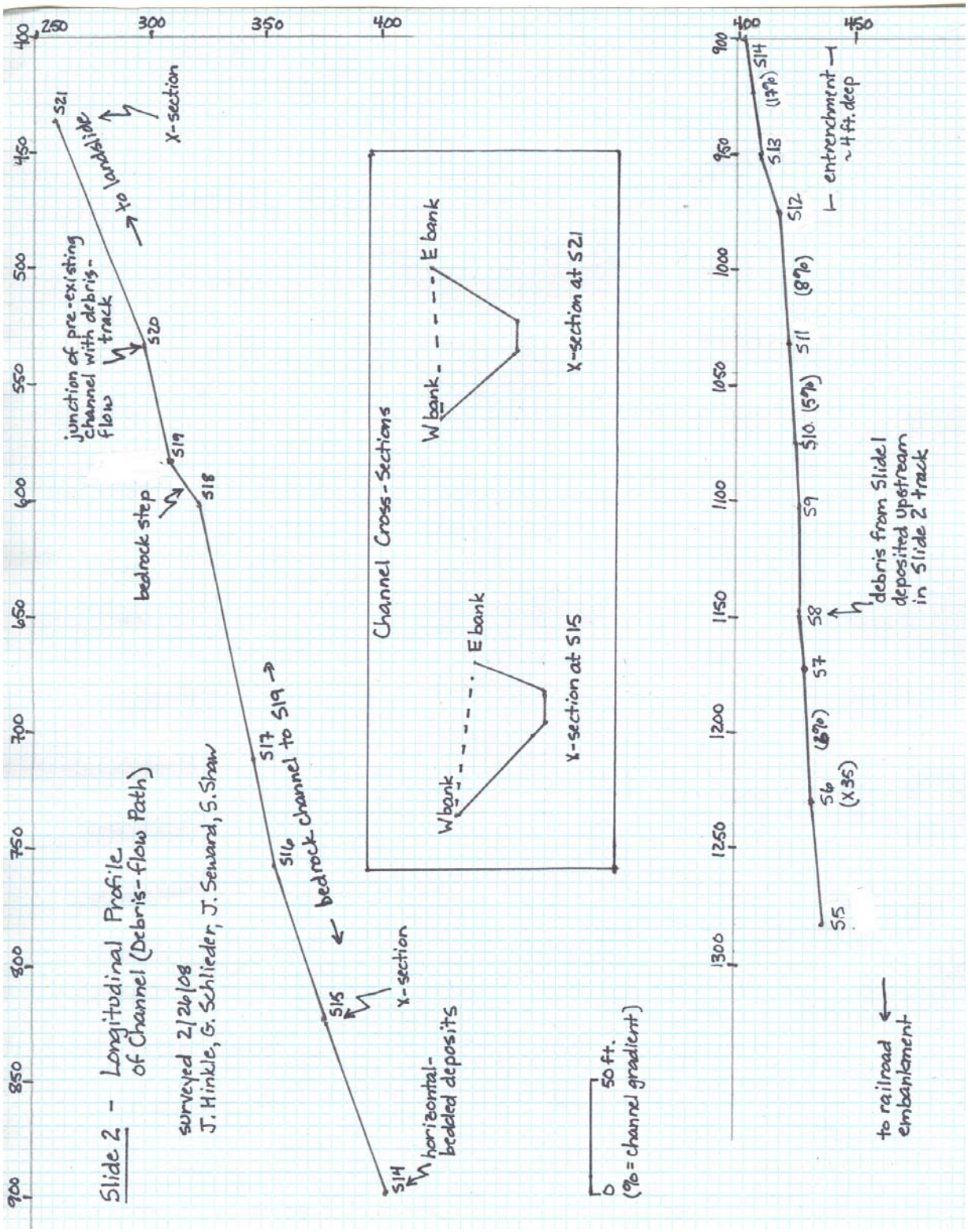


Figure 22b. Surveyed profile of Slide 2 channel/debris-flow track. The dashed lines on the channel cross-sections in the figure inset indicate the top of the debris flow.

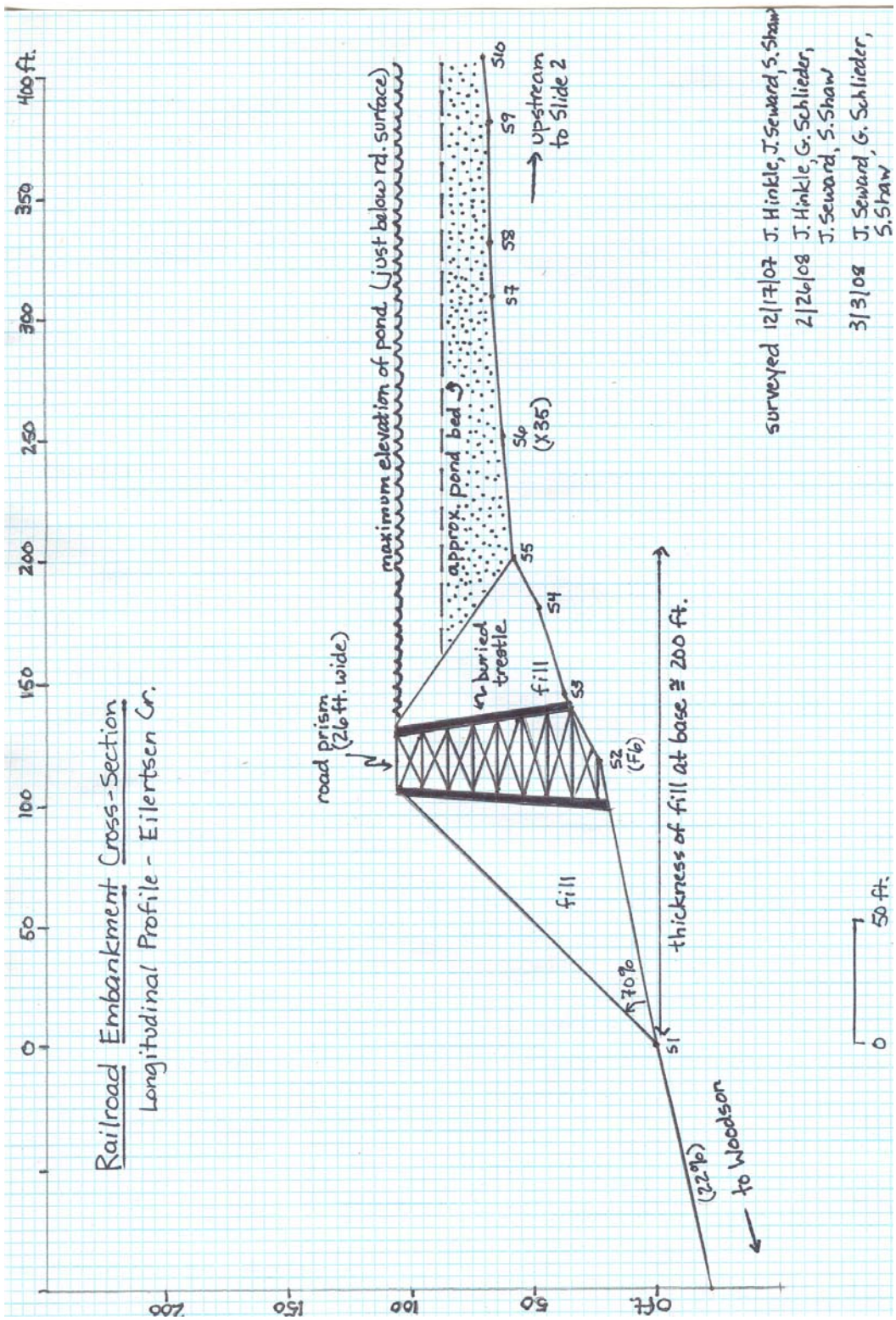
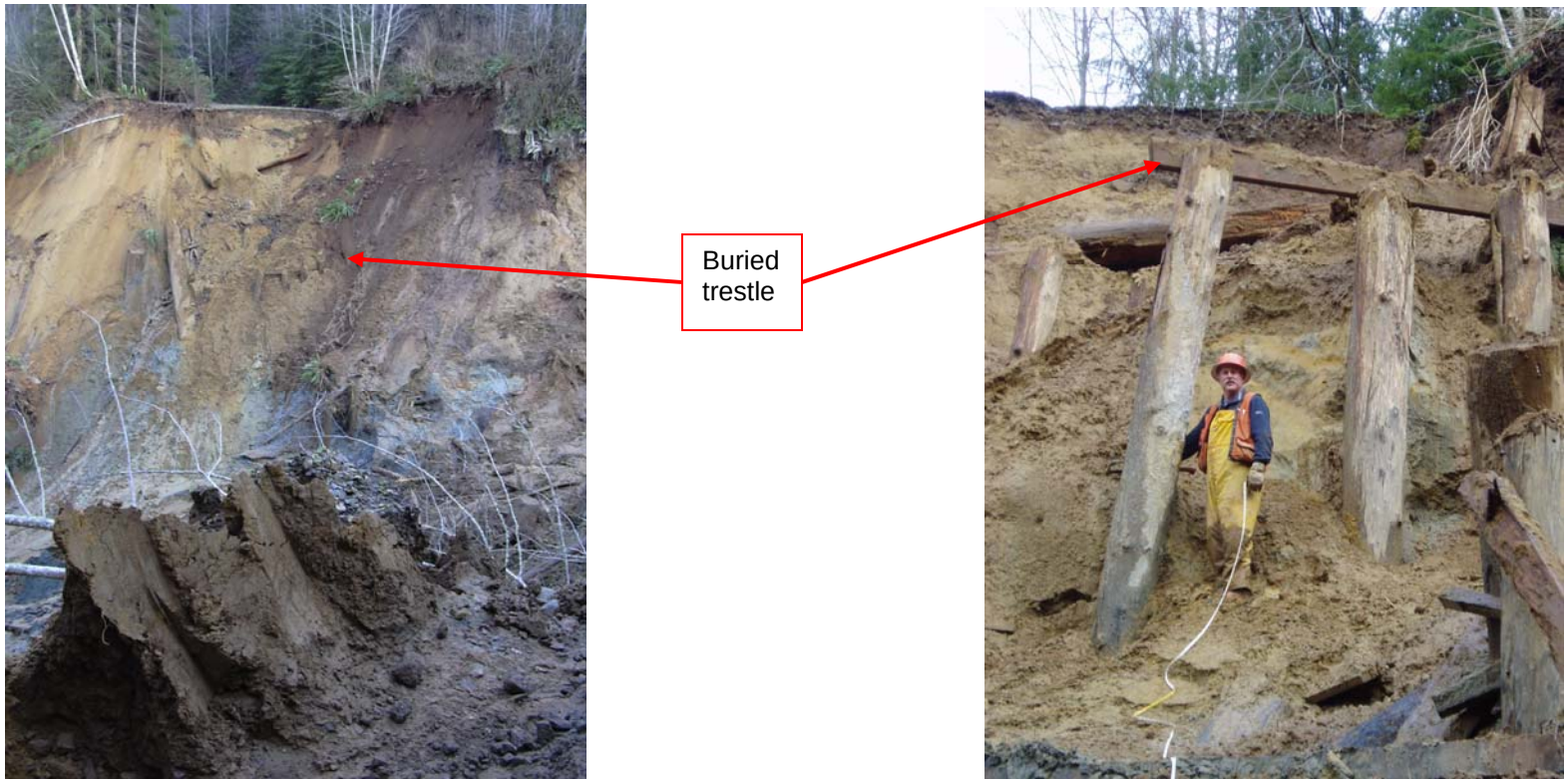


Figure 23. Surveyed profile of Eilertsen Creek and reconstructed cross-section of the Kerry Road Embankment with buried trestle. The vertical distance between S1, at the puncheon culvert outlet, and the top of the embankment is about 110 feet.

Figure 24. Reconstructed elevation of the top of the embankment and road surface, with the puncheon culvert in Eilertsen Creek for scale. (a) canyon left by failed embankment fill. (b) original puncheon culvert that drained the embankment, consisting of three large-diameter logs forming the drainage out-flow for Eilertsen Creek. Hard hat for scale. (photos: J. Seward, 2/25/08).



(a) (b)

Figure 25. Failed portion of the embankment, viewed east along the Kerry Road, showing: (a) the road width (about 26 ft.) and soil characteristics (note bluish gray sediments indicative of perennially saturated soils); and, (b) portions of the buried trestle bent, barely observable in the photo on left (taken 12/11/07; S. Shaw) and more fully exposed in the photo on right (taken 3/3/08; S. Shaw).

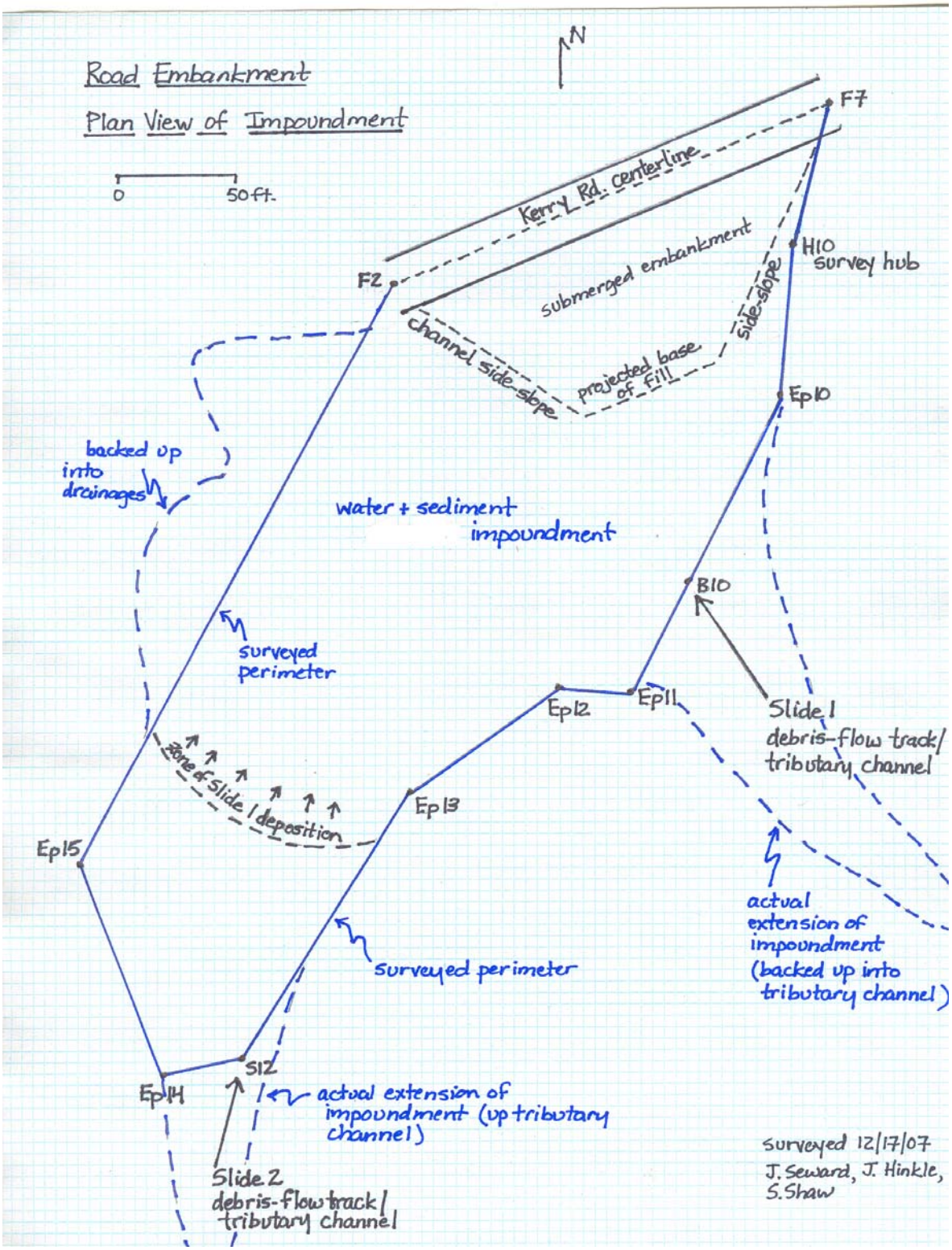


Figure 26. Surveyed perimeter of impoundment that developed behind the Kerry Road embankment.

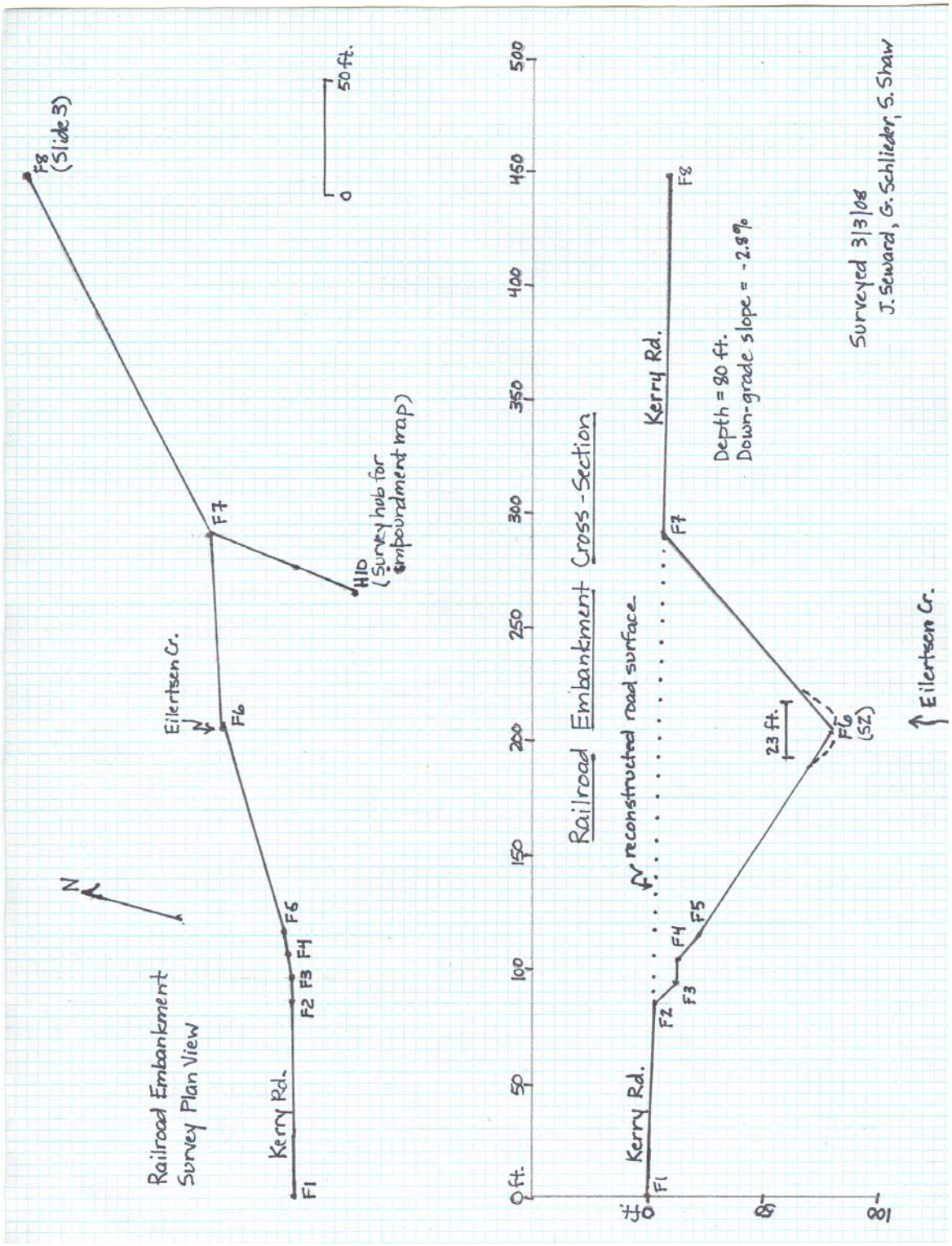


Figure 27. Surveyed cross-section of the embankment, after failure occurred. The Kerry Road continues to the west and east of the surveyed failure site, and Eilertsen Creek flows at a right angle to the cross section. A plan view of the survey line is shown in the top portion of the figure.

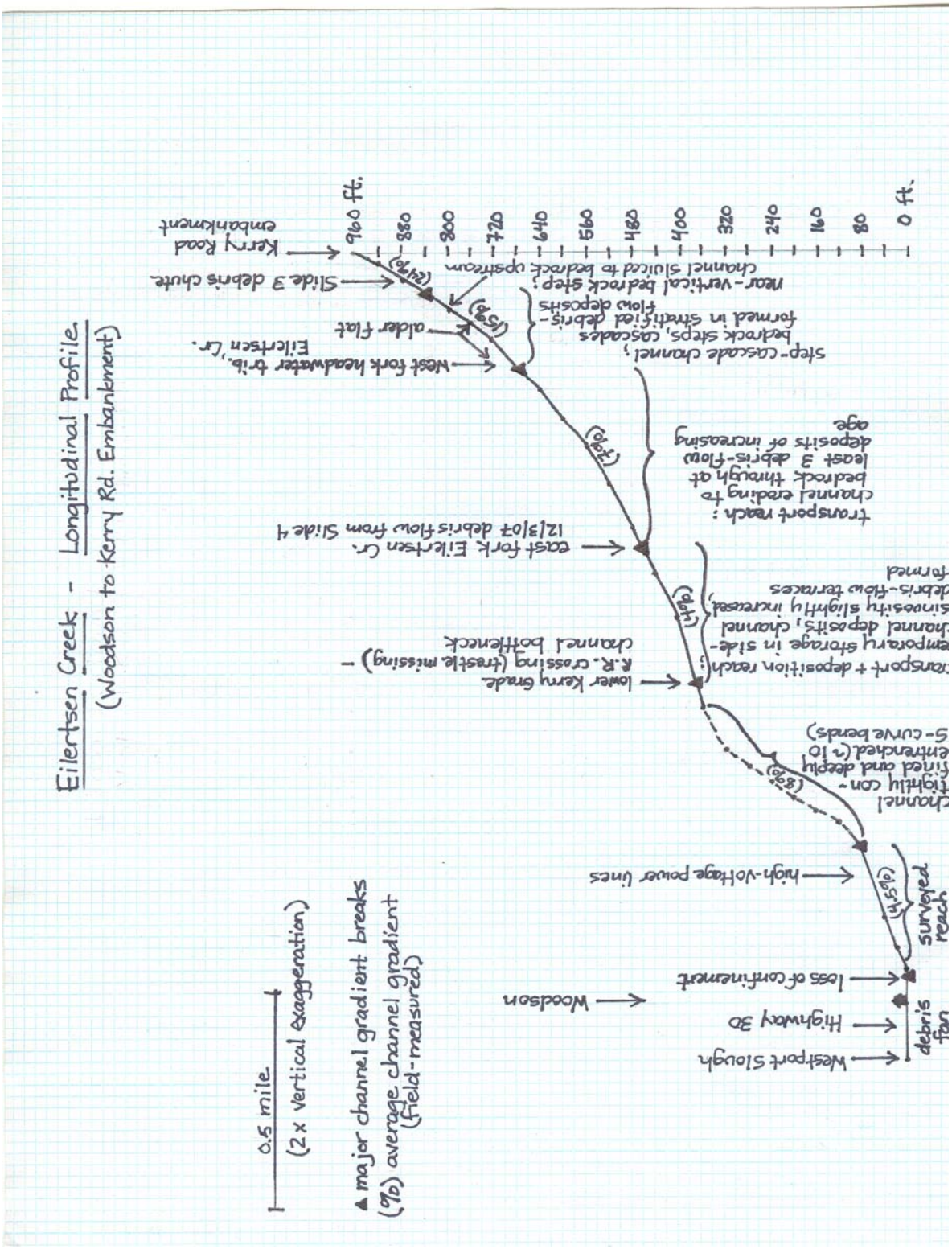


Figure 28. Longitudinal profile of Eilertsen Creek, between the Kerry Road embankment and the Westport Slough on the Columbia River. This profile was compiled from topographic data (2x vertical exaggeration) and from field measurements and observations.

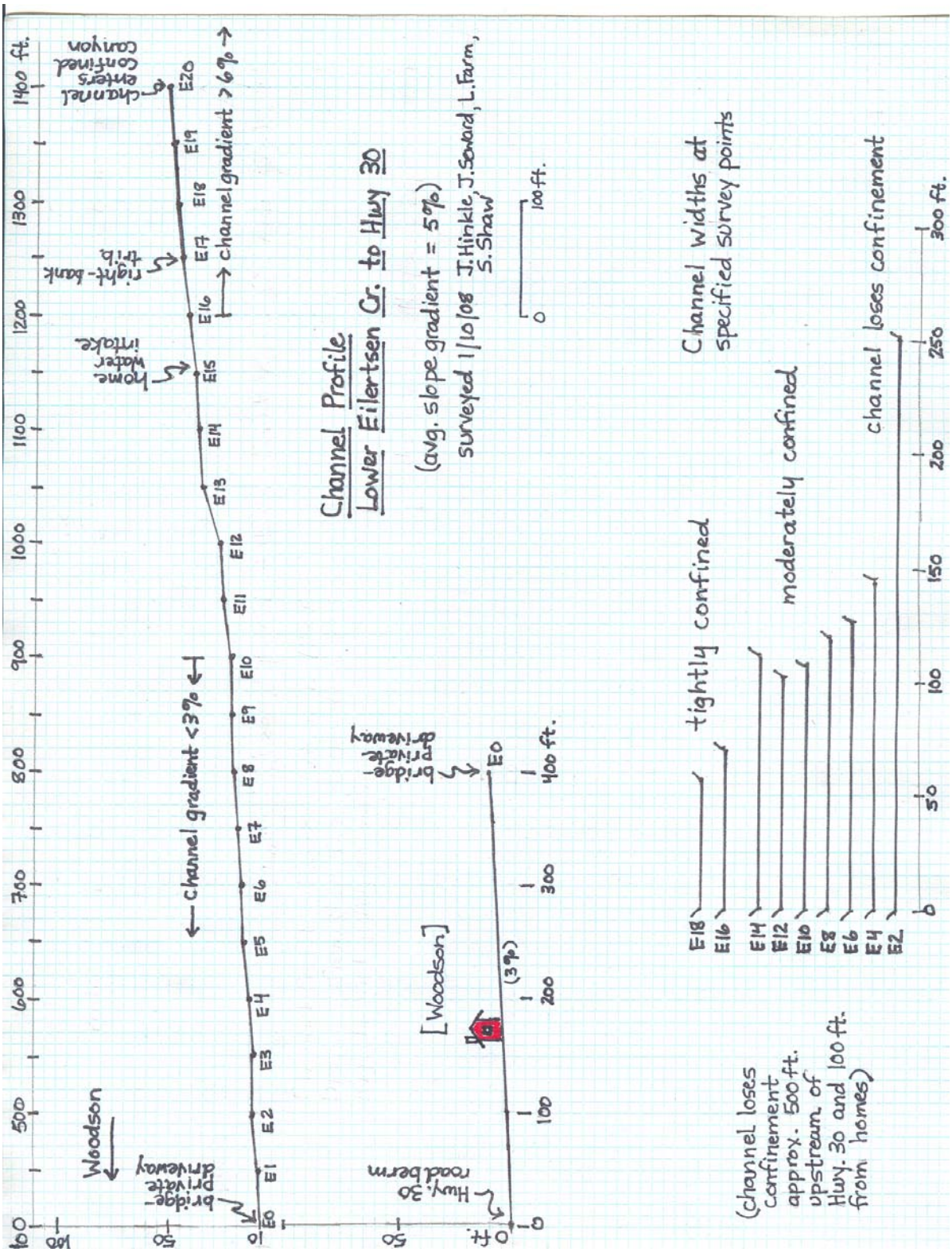


Figure 29a. Surveyed profile of the lower 1400 feet of Eilertsen Creek, south of Highway 30. Channel-width measurements (lower portion of figure) demonstrate the progressive increase in channel confinement with distance upstream of the debris fan.

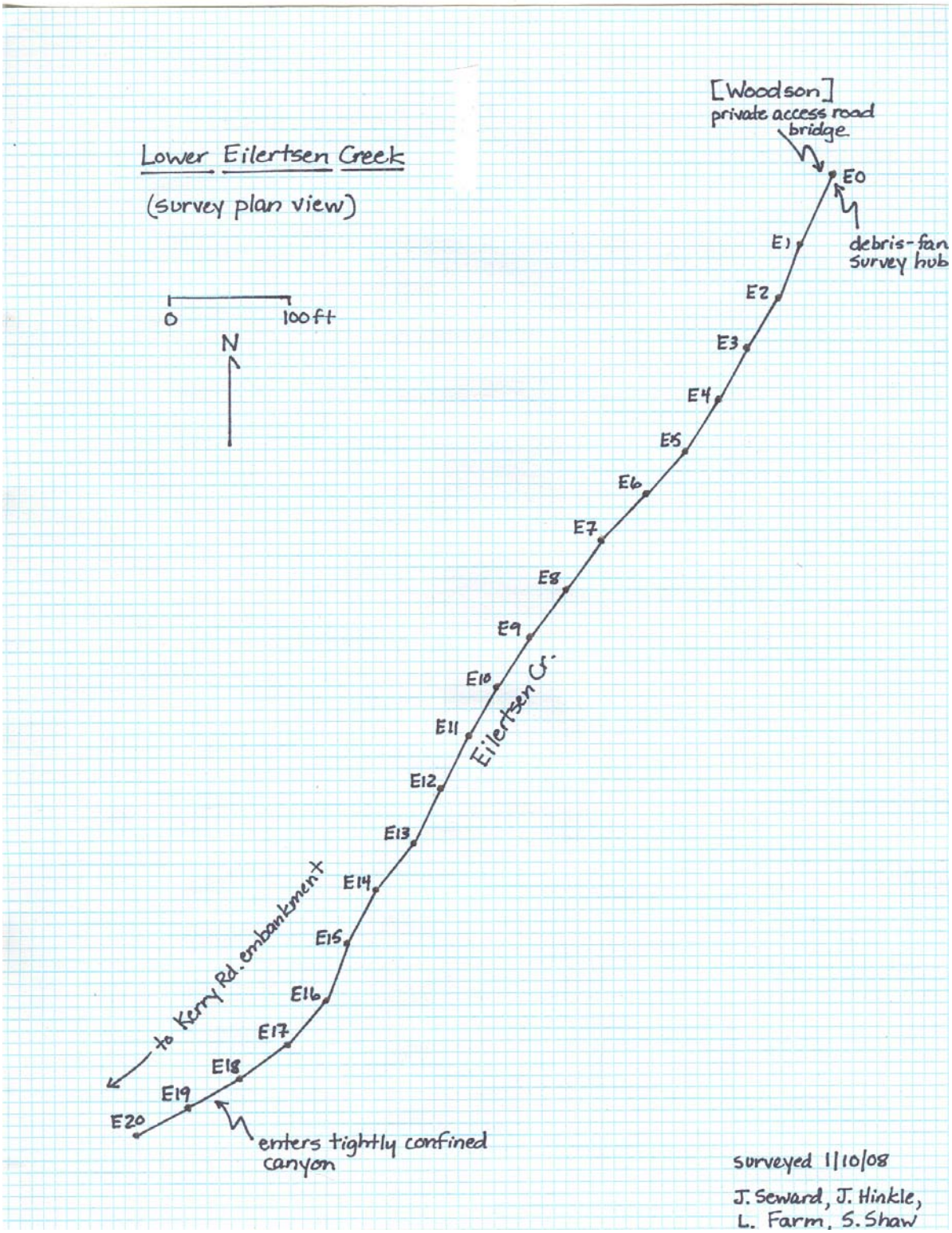


Figure 29b. Plan view of the surveyed lower Eilertsen Creek channel (see Figure 28a).

Figure 30. Upper Eilertsen Creek, showing the debris-flood erosion of the channel. This segment is representative of the channel transport zone through which the debris flood travelled. (photo: J. Hinkle, 2/25/08.)

Figure 31. Toe of a reactivated deep-seated landslide occupying the downstream margin of the large alder flat, located 0.5 mile downstream of the Kerry Road embankment, which received the brunt of the accelerating debris flood as it travelled down a steep portion of Eilertsen Creek. (photo: J. Hinkle, 3/14/08).

Figure 32. Remnants of the lower Kerry Railroad Grade trestle crossing. (photo: J. Seward, 2/25/08).

Figure 33. Aerial view of the lower Eilertsen Creek and Woodson debris fan, taken during the December 2007 debris flood. Note the debris moving upstream in the Westport Slough, due to incoming tides. The Eilertsen Creek debris flood and Olsen Creek debris flow(s) coalesced in the vicinity of the blue-roofed building in the foreground. (photo:ODF files, 12/11/07).

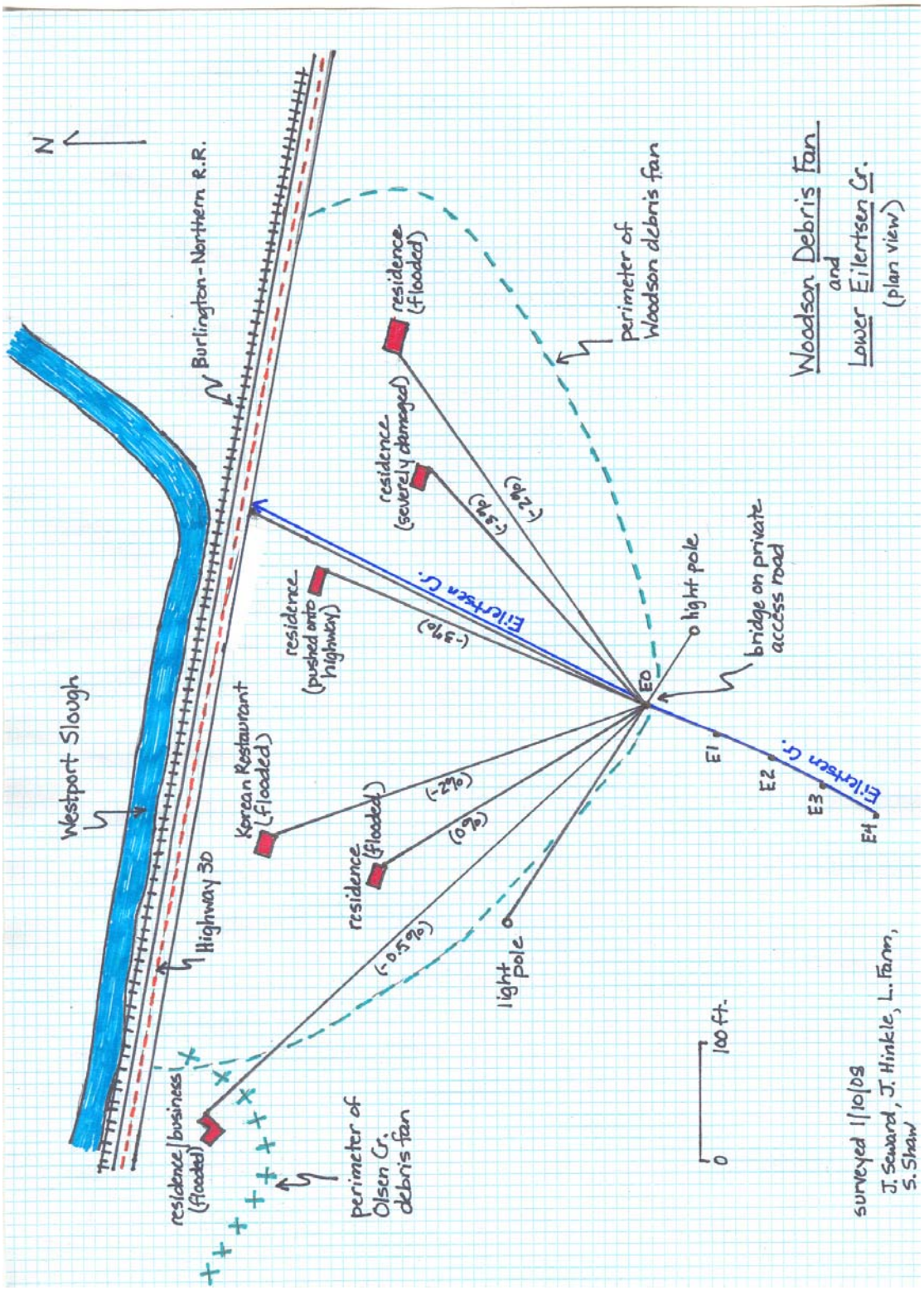


Figure 34. Surveyed plan view of the Woodson debris fan and lower Eilertsen Creek, showing the location and relative elevation of buildings and Highway 30.

Table 1. Landslide and debris-flow inventory, based on aerial-photo interpretation, for the years 1939-2007. See Figure 5 for a distribution map.

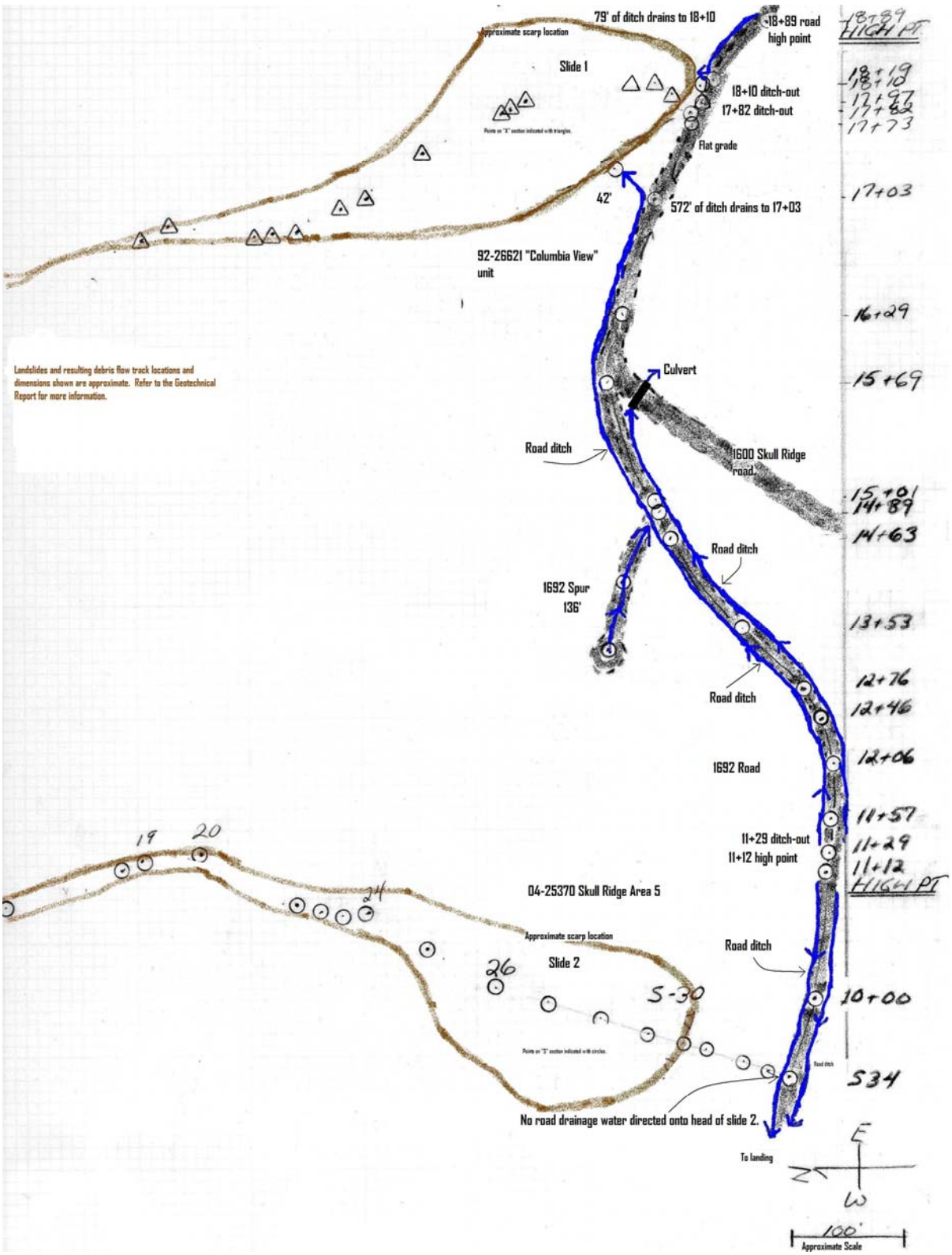
Landslide/Debris-Flow Number	Drainage	Feature	Photo Number	Previous Photo	Age	Notes	Forest Management
1	Kerry Creek	slide and debris flow	1939 j and 1948 y	none	1930's	road just above?	high-graded prior to 1939?
2	Kerry Creek	slide and debris flow	2000 ortho	1995 ortho	1996		harvested prior to 1995
3	Kerry Creek	slide and debris flow	2000 ortho	1995 ortho	1996		harvested prior to 1977
4	Olsen Creek	slide and debris flow	1998 20	1995 ortho	1996	railroad grade failure	high-graded prior to 1939?
5	Olsen Creek	slide and debris flow	2000 ortho	1998	1998 - 2000	road failure	harvested prior to 1977
6	South Olsen Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1977
7	South Olsen Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1977
8	South Olsen Creek	slide and debris flow	2006 15	2005 ortho	2005 - 2006		harvested prior to 1989
9	South Olsen Creek	slide and debris flow	2006 15	2005 ortho	2005 - 2006		harvested prior to 1989
10	South Olsen Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1989
11	South Olsen Creek	slide and debris flow	1995 ortho	1989	early 1990's	landing failure	harvested prior to 1977
12	South Olsen Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1977
13	South Olsen Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1989
14	South Olsen Creek	slide and debris flow	1998 17	1995 ortho	1996	landing failure?	harvested prior to 1989
15	Eilertsen Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1977
16	Eilertsen Creek	slide and debris flow	1998 17	1995 ortho	1996	railroad grade failure	harvested above road prior to 1994

17	OK Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1995
18	OK Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1995
19	OK Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1995
20	OK Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1995
21	OK Creek	slide and debris flow	1998 17	1995 ortho	1996		harvested prior to 1995
22	OK Creek	slide and debris flow	1998 17	1995 ortho	1996	railroad grade failure	harvested prior to 1969
23	OK Creek	slide and debris flow	1998 17	1995 ortho	1996	railroad grade failure	high-graded prior to 1939?
24	OK Creek	slide and debris flow	1939 c/d and 1948 f	none	1933	blew out two crossings	pre-harvest?
25	OK Creek	slide and debris flow	2000 ortho	1995 ortho	1996	railroad grade failure	harvested prior to 1969
26	Tandy Creek	slide and debris flow	2000 ortho	1995 ortho	1996	below road	harvested prior to 1969
27	Tandy Creek	slide and debris flow	2000 ortho	1995 ortho	1996	railroad grade failure	harvested prior to 1969
28	Tandy Creek	slide	2000 ortho	1995 ortho	1996		harvested prior to 1995 or 1977?
29	Tandy Creek	slide	2000 ortho	1995 ortho	1996		harvested prior to 1969
30	Tandy Creek	slide and debris flow	1995 ortho	1977	early 1990's	landing failure?	harvested prior to 1977
31	Graham Creek	slide	1939 b	none	1930's		high-graded prior to 1939?
32	Eilertsen Creek	slide scarp	1948	none	1930's		harvested prior to 1948
33	North Fork Fishhawk Creek	slide and debris flow	2000 ortho	1995 ortho	1996		harvested prior to 1948

(8) Appendix

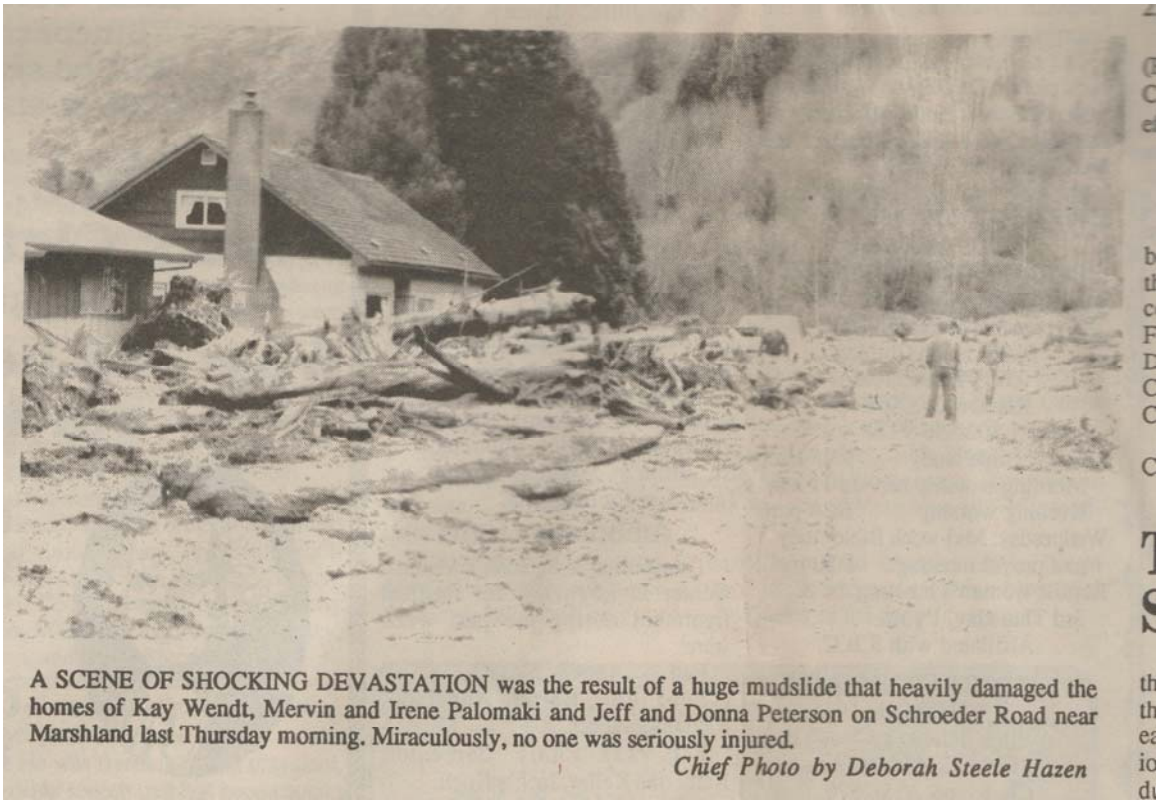
(1) plan view of survey for Slides 1 and 2

(2) Scanned newspaper articles pertaining to landslides and debris flows in the Woodson area



(1) Plan view for survey of Slides 1 and 2.

"The Clatskanie Chief" February 15, 1996



A SCENE OF SHOCKING DEVASTATION was the result of a huge mudslide that heavily damaged the homes of Kay Wendt, Mervin and Irene Palomaki and Jeff and Donna Peterson on Schroeder Road near Marshland last Thursday morning. Miraculously, no one was seriously injured.

Chief Photo by Deborah Steele Hazen

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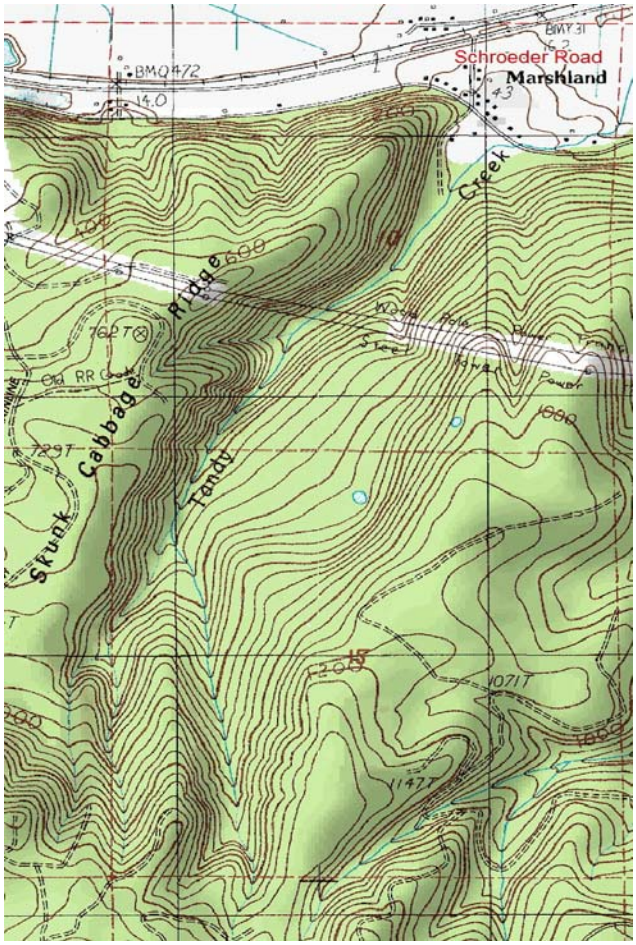


"Out in Marshland…A thundering roar came from above the canyon in back of them. Then the house was surrounded and invaded by tons and tons of mud and logs. The home of Jeff and Donna Peterson and family, just east of the Palomakis, was similarly destroyed, as was the home of Kay Wendt, just to the west.

Several other houses along Marshland's Schroeder road were damaged by an arm of the huge mudslide, which sliced diagonally across a wide meadow, over Highway 30, and onto the railroad tracks across the highway.

Almost incredibly, no one was seriously injured."

"The Clatskanie Chief" February 15, 1996

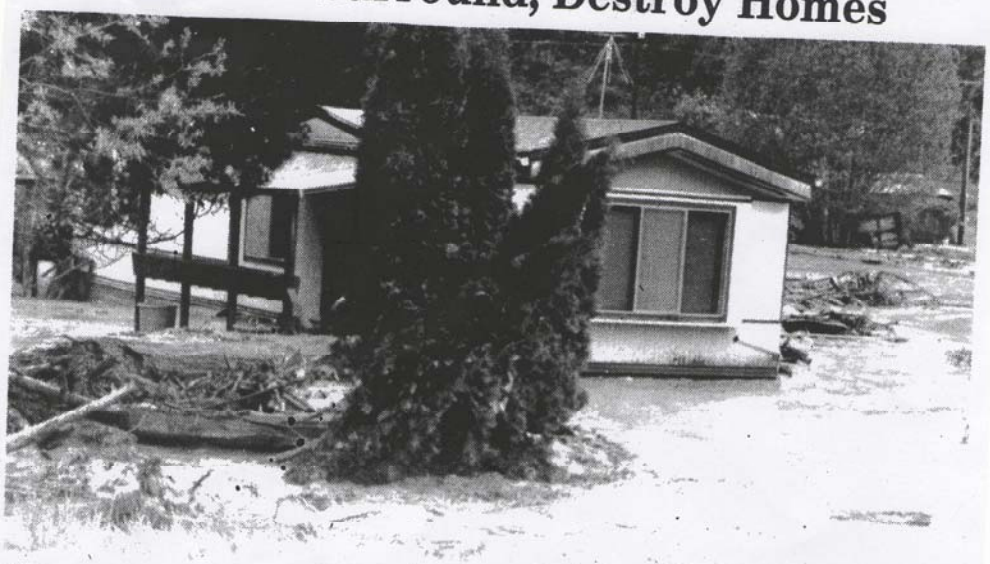
Mudslide Reminiscent of Mt. St. Helens

REMINISCENT OF THE DESTRUCTION left by the eruption of Mt. St. Helens is the mudslide that devastated three houses in the Marshland area and damaged several others. The slide travelled down Tandy Creek Canyon, through the housing development, across a large meadow and over Highway 30 (pictured above), during Thursday morning's torrential downpour. *Chief Photo by Deborah Steele Hazen*

"Mudslides Surround, Destroy Homes", *The Clatskanie Chief, April 25, 1996*

Mudslides Surround, Destroy Homes

THE CLATSKANIE CHIEF APRIL



MUDDY WATERS SWIRLED around the mobile home of Gary and Peggy Kimber (top photo) at Woodson Tuesday afternoon after a raging Eilertsen Creek sent a huge mudslide down the canyon, surrounding and damaging several homes in the neighborhood. At the same time another huge slide roared down the Ross Creek Canyon at Kerry, between Woodson and Westport, and destroyed (at right) the homes of Jack and Ethel Conklin and Bill and Merle Nicholson. Nicholson was the only one at home at the time of the slide and barely escaped it. With the help of volunteers, the Conklins were able to rescue three of their four dogs from the wreckage of their home.

Chief Photos by Deborah Steele Hazen

Chief

MAY 2, 1996 USPS 116-360 NUMBER 51

Geologist Says... 5/2/1996

Mudslides Caused by Water; Group Addresses Problems

by Deborah Steele Hazen

"Mudslides are caused by three things - water, water and water."

Last week's disastrous mudslides, according to a geotechnician specialist with the Oregon Department of Forestry were geologic "design events" caused by heavy rains, following the "antecedent" deluges earlier this season.

David L. Michaels, the ODF geology expert, told a group of county, state and local officials and property owners gathered at a meeting at the Clatskanie Fire Station Tuesday afternoon, that the slide in the Ross Creek canyon above Kerry last Tuesday, April 23, was the most recent in "thousands of years of history."

Michaels, who conducted an on-site inspection of both the Kerry and Woodson slides late last week, told those gathered at the meeting that the Kerry slide started on an "ancient natural slide with its tow in the creek."

Michaels said a 12 year old clear-cut some distance above the slide, showed no signs of erosion and was not involved in last week's slide that destroyed two homes at Kerry and heavily damaged an unoccupied house that was under renovation.

There were no clear-cuts above the Woodson area slide that damaged several other homes during heavy rains last Tuesday.

Rainfall figures recorded at the city water treatment plant in Clatskanie totalled 2.47 in the 24 hour period ending at 8 a.m. April 23 and 1.23 inches in the 24 hour period ending at 8 a.m. on April 24. That totaled 3.7 inches in the 48 hour period in the midst of which the two slides occurred.

Last week's rainfall total compared to the over nine inches of rain that fell in a four day period during the February flood, including 4.2 inches in the 24 hour period ending at 8 a.m. on Feb. 8th the day of the flood and the Marshland mudslide. (See separate weather story elsewhere in this issue of the *Chief*.)

Michaels said his inspection revealed that the Woodson slide down the Eilertsen Creek canyon began on an old railroad fill dating from the 1920s. Maintenance on a logging road up the canyon met all standards and was not a factor in the slide, Michaels said.

Although manmade features or practices can sometimes "trigger" landslides, Michaels emphasized, he did not believe they were a "significant or relevant" factor in the case of last week's slides. He stated he could not give an opinion on the Marshland mudslide, because he had not inspected that site.

The natural features of the landscape - mountainous terrain, numerous streams and canyons combined with heavy rains - makes this area prone to landslides, Michaels explained. Historically, there have been similar slides in most stream beds. The houses that were damaged in this winter's slides were built on "debris fans" from ancient slides, he said.

Unfortunately, Michaels noted, insurance companies and the Federal Emergency Management Agency (FEMA), are "not well-equipped to deal with landslides."

While geologists can make risk assessments about an area's potential for slides on a "case by case, site specific basis," the slide expert explained, there is no accurate way of predicting when a slide will occur. "We can say this could slide, but not that it will slide next week. We might be able to say that we've had enough rain that you might not want to stay where you're at."

The best way to prevent property damage from mudslides is through education and land use planning, Michaels said. "Don't build in the barrel of the gun and recognize how bad the risks are."

Addressing the Problems

Michaels' report came during the meeting called by Columbia County Emergency Management Director John DeFrance for the purpose of addressing problems caused by the mudslides at Kerry, Woodson and Marshland.

(Continued on Page 12)

More on Mudslides

(Continued from Page 1)

By the end of the two and a half hour long meeting, the group of about 30 agency representatives and property owners had outlined seven specific problem areas and identified agencies to take charge of addressing them.

The county will continue to work with the state to have the homes damaged by last week's slides included in the FEMA eligibility. DeFrance explained that because of the time elapsed since the February flood disaster declaration, FEMA's regulations would not include last week's mudslide victims without the state asking that an exception be made.

It was noted that the Red Cross had met with slide victims last week to address their immediate needs. Slide victims needing further information may call DeFrance at 503 397-2100.

The problem of silt deposits and wood debris left by the flood was discussed. The county road department and the Division of State Lands will look for sites to deposit the debris. Although it was suggested that in many cases it would be better to leave the mud and reseed after clearing the rocks and woody debris.

Woody debris can be "scarified" into piles and burned, it was noted. The Clatskanie Rural Fire Protection District and the Oregon Department of Forestry will monitor wood debris burning.

Staff of the Natural Resources Conservation Service is committed to working with the state and private property owners under the Emergency Watershed Protection Program to restore streams to their beds, said Bill Eagle, regional representative of the NRCS. Surveys are underway for work on Tandy Creek at Marshland, Graham Creek, which has heavily damaged the Midland Water System and threatened homes; "No Name" Creek above the Schultz property between Marshland and Woodson, and Ford Creek above the Nusom home east of Marshland.

However, Eagle said, the problems at OK Creek, which has flooded the Lammi Rock Pit and crossed Highway 30 damaging the Burlington Northern railroad lines and contributing to flooding problems on the Marshland Drainage System, plus the problems at Eilertsen Creek at Woodson and Ross Creek at Kerry, have not yet been addressed. He agreed to take the lead in the stream restoration issue with the cooperation of Oregon Department of Fish and Wildlife.

Property owners in the areas of damaged streams may contact Eagle at 503 397-4555 or 503 338-8595.

A Burlington-Northern representative stated the railroad company intends to "come down with a big pile driver crane and clean-out the culverts and get the debris all cleared up."

Jim Brown, adminstrative assistant to the Columbia County Board of Commissioners, will continue to work with the several community water systems in the area between Clatskanie and Westport, that have been damaged by the flood. The county is investigating the eventual merger of the water systems.

Oregon Department of Transportation will work with the local drainage districts to address the problem of flood waters flowing over the highways and into the drainage systems which are not equipped to handle the volumes of water they have been receiving.

"We're prepared to handle the water that falls on our land," Margaret Magruder of the Marshland Drainage District stated. "But when the water comes down from the hills, across the highways and into our system, we're not equipped to handle that. We're draining lots of property that we don't have assessments for."

With the cooperation of ODOT, Magruder said she would investigate the possibility of funding to assist the local drainage improvement companies in dealing with the flood waters.

Another meeting of the group, with reports on the progress of addressing the issues, is set for Tuesday, May 14, at 1 p.m. at the Clatskanie Fire Station. Interested persons are invited to attend.

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