Chapter 6. Erosion and Sediment

BACKGROUND

In this chapter, natural and management-influenced processes that affect hillslope-channel interactions are investigated. Management activities evaluated include road construction and maintenance, timber harvest and site preparation. In combination with natural processes, management activities may accelerate natural sedimentation processes and adversely impact stream aquatic systems.

Natural Climate and Precipitation Drivers

The Forest's topography reflects the major influences of climate and precipitation on landform. Climate determines available moisture, which largely governs vegetation types, cover, and plant growth rates. Climate also influences fire weather and fire behavior. The timing and magnitude of sediment pulses through the watershed reflects a strong relationship with climate. Intense rainfall can overcome the surface resistance to erosive forces, generating surface erosion as well as possibly triggering landslides that can contribute sediment to Forest streams.

Cycles of sparse and dense precipitation, stream flow, wildfire intensity, erosion, sedimentation, and salmonid spawning runs are intrinsically linked to these variations in climactic processes (Taylor and Hannan 1999). The North Pacific Interdecadal Oscillation appears to be the significant weather cycle affecting surficial processes on the Forest landscape (Mantua et al. 1997). This climate phenomenon affects precipitation, which in turn affects stream flow regimes and subsequently influences salmonid runs in the Pacific Northwest. It also dictates fire weather and fuel moisture levels, influencing fire periodicity and magnitude. Fire, in turn, affects sediment erosion rates through removal of vegetation that reduces raindrop interception and decreases roots that reinforce shallow soils.

There are several weather cycles that can affect management, none of which management can affect. The most well known is the "El Nino/La Nina" cycle that can cause a particular year to be wetter than normal or drier than normal. The Decadal Oscillation Index shows a cycle of wet and dry trends with a recurrence period of about 20 years. Taylor and Hannan (1999) predict an overall trend of wetter and cooler climate in Oregon until about 2019.

Tectonic Setting

In the Forest, faults and the Mill Creek syncline (or fold) create a large, contiguous block that is topographically isolated from surrounding areas (see Map 2.3). The tectonic history and geology of the Forest also influence its propensity for landslides. In particular, an area at the edge of the Forest northwest of Loon Lake shows evidence of deep-seated slides (see Map 2.4). Loon Lake was created as a result of a deep-seated landslide blocking Mill Creek.

SOURCES OF NATURAL SEDIMENT

Soil is continually produced as under-laying bedrock weathers through bio-geological processes. This action produces rock fragments and soil that may eventually be transported downslope by gravity ("colluvial" processes) and/or by moving surface water ("fluvial" processes). Either of these two transport processes creates sediment. Boulders, gravel, and wood from eroding hillslopes also are transported to channel networks, and then subsequently deposited downstream.

Soil Mantle Production and Transport

The rate of soil production from bedrock weathering is important as a starting point to trace sediment routes through the watershed. Sediment available for transport is fundamentally limited by the rate of soil development. In the Forest, as in most of the Coast Range, soil development is considered limited by the rate of bedrock exfoliation, the "peeling" off of the rock surface (Reneau and Dietrich 1991). The pace of exfoliation and soil production is largely controlled by the spalling and chemical weathering of bedrock. Spalling and weathering create boulders, cobbles, and gravels, as well as smaller soil-sized particles, collectively called the soil mantle. Formation of the soil mantle is a fairly constant process. In contrast, the pace at which the soil mantle is then transported downslope by other processes, such as landslides, is more rapid by many orders of magnitude.

Natural processes that deliver sediment into streams can be placed in one of seven general categories:

1. Biogenic sediment transport occurs as the result of burrowing, hoof action, tree throw, root expansion, and similar events. However, biogenic processes may contribute to downstream movement of soils.
2. Soil creep is the slow downslope transport of soil. Where slopes are low to moderate, soil creep redistributes stored sediment to hollows and channels at lower but pervasive rates as compared to landslides that occur on steeper slopes. Creep processes drive dry ravel and hollow-filling sediment transport.
3. Shallow, rapidly moving landslides include any detached mass of soil, rock or debris that becomes larger as it moves down a slope or stream channel. These slides typically result from the concentration of water through subsurface flow in soils overlaying bedrock on steep slopes. Under semi-saturated or saturating soil conditions, these slides may be triggered on steep (~70% or more) slopes. Under increasingly saturated conditions, they slides become more frequent, often accumulating additional volume, mass, and momentum, and sometimes scour channels into bedrock while moving downslope.
4. Debris flows are small landslides initiated and then sustained by water and debris mass inertia. They may accumulate additional mass and volume as they travel downslope. These flows are capable of abrasive scour into bedrock. They also are capable of dislodging and transporting large boulders and wood down steep slopes.
5. Debris flows become debris torrents when a landslide enters and continues down a channel. Debris torrents significantly affect channel structures and riparian vegetation.

This natural process redistributes both soil and wood sediments downslope between hillslopes and channel systems.

6. Bank erosion occurs on slopes directly adjacent to stream channels or within the channel itself. This is a result of the stream making room for high flows by removing accumulated soil, rock and wood.
7. Deep-seated landslides are slides with deep failure zones.

Fluvial Processes that Detach and Transport Particles

The amount (and rate) of rock and soil moved by gravity and water is determined by their resistance to being detached. The amount of force needed to detach a particle from its resting position is known as its critical shear stress. Different soil types and rock sizes have different shear strengths. Soils on the Forest are generally low in cohesion due to their sandstone-rich parent material and low clay content (see Map 2.5).

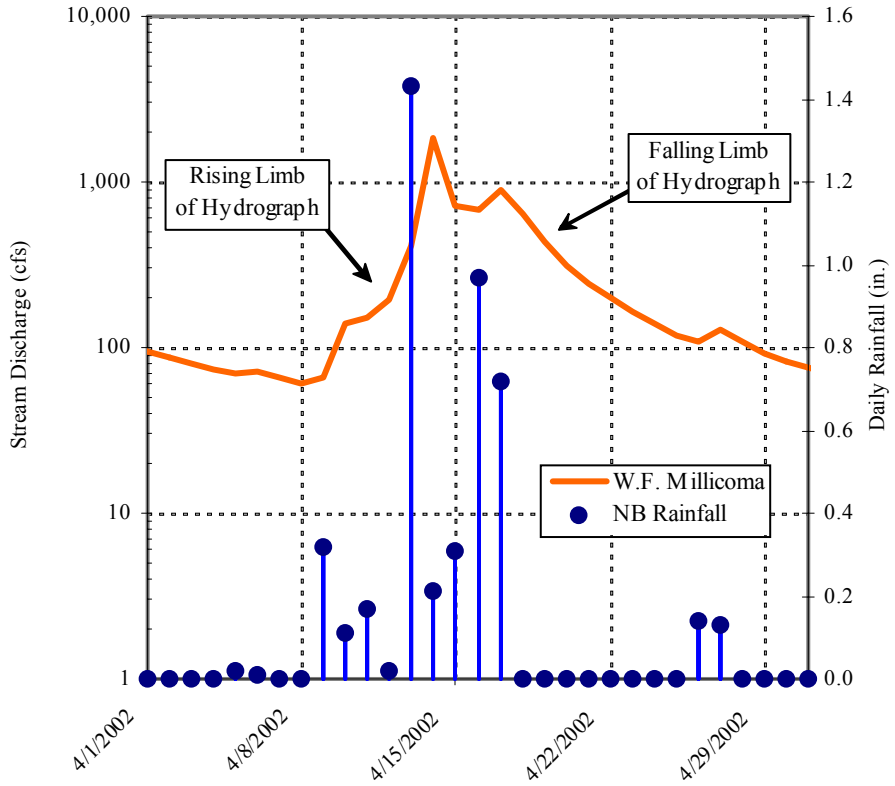
Soils on the Forest also are very transmissive (i.e., permeable) due to their sandy nature. This ability to transmit water limits overland flow that contributes to surface erosion. Water is allowed to travel downslope below the soil surface, sometimes through root pathways or casts. When this water reaches bedrock, the soils above become saturated and increased water pressure induces flows through the soil. This process, on steep slopes, causes a rapid response of streamflow after precipitation.

Figure 6-1 illustrates this streamflow response on the West Fork of the Millicoma River after rains in December 2002. The steep slope of the "rising limb" of the response to rainfall is where most sediment entrainment occurs; sediment deposition is usually associated with receding flows (the "falling limb") following the peak. After about 3 inches of rainfall fell over a 6-day period in December 2002, streamflow sharply increased from about 100 cfs to a peak at 1,100 cfs. This was of sufficient intensity to cause changes in channel location immediately south of the Forest in Hendrickson Creek.

Surfaces with low cohesion can erode especially in channels and slopes with high water concentration or flow. The erosional force from concentrated water flows is expressed as the "stream power" at a specific point. Stream power is a measure of the energy available for moving rock, sediment particles, and woody debris in the stream channel. It is determined by the amount of water above the point and the water surface slope. Resistance to erosional forces is based on a combination of the shear strength of the soil and rock, and the shear and tensile strength of any vegetation cover. Also, vegetation cover acts to reduce the effects of rainfall on soils through canopy interception and evapotranspiration. As a result, places with vegetative cover and intact roots are more resistant to erosion (Roering et al. 2003).

Periods of high surface erosion and mass movement are most closely associated at times when surface critical shear stress is reduced. For example, according to Roering and others (2003), erosion is often accelerated following wildfires when the, "…apparent cohesion due to root re-enforcement" is reduced (Lancaster et al. 2001, Istanbulluoglu et al. 2003). Catastrophic stand-replacing wildfires, while relatively infrequent, may account for the largest portion of the sediment discharged from watersheds over longer time periods (hundreds to thousands of years).

Figure 6-1. Rainfall-runoff relationships in the West Fork Millicoma River.



* NB rainfall is the daily rainfall in North Bend, Oregon, measured at the airport.

GRAVITY-DRIVEN PROCESSES

Soil Creep

Soil creep is a slow, gravity-driven process of downslope movement that is not associated with fluvial (or flowing) water entrainment or suspension. In laboratory settings, soil creep demonstrates a non-linear relationship with landslides (Roering et al. 2003) and can be thought of as a continual downslope micro-adjustment of soil particles. Soil creep rates are difficult to directly measure and have not been extensively investigated (Washington Forest Practices Board 1993). The factors known to influence soil creep rates include soil and rock material, hillslope hydrology, and slope angle. Of factors relevant to creep-driven processes, slope is easiest to estimate, and a simple estimate of soil creep contributions to stream channels can be made.

Methods

Soil creep contributions to streams may be estimated based upon stream lengths adjacent to hillslopes. Assigning creep rates to slope classes allows for this information to be estimated in a GIS using a digital elevation model (DEM). Slope classes were assigned based upon values used in Reneau and Deitrich (1991) and the *South Fork Coos River Watershed Analysis* (Weyerhaeuser 1998). The stream network was overlain on the slope class map and intersected to derive stream length per slope class. A uniform soil depth of 3.280833 feet (1 meter) at the stream bank contact zone was assumed.

The Weyerhaeuser (1993) creep estimates were used to distribute soil creep rates between two slope classes. Slopes less than 30% were assigned an estimated creep rate of 0.0003281 feet per year (0.0001 meters per year). Slopes 30% or greater were assigned a creep rate of 0.0006562 feet per year (0.0002 meters per year). Conservative creep rate estimates were intentionally used because of the lack of field-collected measurements for this extremely slow process.

Results and Discussion

The results of the analysis show that average soil creep sediment yields for the Forest are 4.5 cubic yards per stream mile per year (range 4.4 to 4.9 cu. yd./stream mile/year). On an area basis, soil creep averages about 13.5 cubic yards per square mile per year (range 6.0 to 14.5 cu. yd./sq. mi./year). For the entire Forest, soil creep is estimated to be slightly less than 2,000 cubic yards per year. If this amount is spread evenly across the Forest, it would be less than a sheet of paper in thickness.

This analysis was conducted for the Forest to produce a general estimate of background soil creep sediment contributions into stream channels. As a part of total yield, soil creep represents about 10% of measured sediment in three small, forested Coast Range Basins with similar characteristics (Larson and Sidle 1980). Therefore, it appears that sediment yield attributable to soil creep is relatively small as compared to other sediment-delivery processes such as landslides.

Mass Movement

Landslides are major episodic processes influencing Coast Range topography. This section characterizes the landslide activity in the Forest and similar nearby areas. The spatial pattern of landslides and their influence on fish-bearing streams are examined. Also, human activities that may influence the rate at which landslides occur are discussed. For this discussion, landslides are divided into two types: deep-seated and shallow, rapidly moving. Although deep-seated landslides are less common, their massive, deep-seated flows and slides can contribute large amounts sediments to stream channels. Shallow landslides are common throughout the central Coast Range and are a product of steep slopes, shallow soils, and high-intensity rainfall. Landslides have sculpted the Forest for thousands of years, leaving behind debris fans at the mouths of steep tributaries and V- and U-shaped draws chiseled by successive torrents of soil and rock. The role of vegetation as a control on

landslides through surface strength and soil mantle reinforcement is a subject receiving increasing attention (Roering et al. 2003). Also, how fire affects landslide processes through interactions with vegetation and large woody debris was the subject of computerized terrain modeling by Istanbulluoglu and others (2003) and Lancaster and others (2001). The effects of fire will be discussed later in this chapter.

Deep-seated Landslides

Deep-seated landslides have occurred in what is now the Forest. Some of the more massive slides were identified during field geologic mapping efforts (Baldwin and Beaulieu 1973, Niem and Niem 1990) and are shown in Map 2.4. Deep-seated landslides are typically very large and slower moving as compared to more shallow slides, and occur infrequently. Perhaps the last massive deep-seated slide in the Forest region was the slide that blocked Mill Creek and formed Loon Lake.

While usually naturally triggered, these slides may be activated or exacerbated by road and construction activities, especially where traversing steep slopes or cutting through the base of unstable hillslopes and removing buttress supports. Large-scale alteration of stabilizing forest vegetation, such as through extensive wildfire, may alter evapotranspiration and rainfall infiltration rates and trigger earth slumps, flows, or deep-seated mass movements (ODF/DEQ 2002).

Methods

Features associated with deep-seated landslides were identified through combining slope and saturation models in the GIS. Slope and saturation grids were derived from the 10-meter DEM developed for this analysis. This new DEM, using the SINMAP extension to ArcView GIS (Tarboton 1997, Pack et al. 1999) on the original ODF ground control network, provided greater resolution, especially in mid-slope areas. The slope and saturation maps were used as backdrops and overlaid with digitized geologic data on faults, synclines and anticlines (Baldwin and Beaulieu 1973, Beaulieu and Hughes 1975).

Mapped slides by the Department of Geology and Mineral Industries (DOGAMI) and the Loon Lake slide (inferred) were examined for their shape, saturation and slope ranges. Based on this examination, potential areas of deep-seated landslides were identified through a sequence of filters:

1. Regions of low slope not associated with fluvial terraces or floodplains;
2. Regions of features identified in the first criteria that exhibit higher than normal (modeled) saturation levels compared to the surrounding terrain;
3. Those features satisfying the first two criteria that are spatially associated with tectonic features, major mapped faults and folds of the terrain overlays; and
4. In some cases, those areas meeting the previous criteria that are crescent-shaped in plan view provided a crucial factor to screen geomorphic features to detect potential deep-seated landslide deposits.

Results

Map 6.1 shows that the spatial distribution of potential massive deep-seated slides follows a distinct pattern associated with the Mill and Glenn Creek synclines. In all but two areas, the dip angle of bedding planes for the Mill and Glenn Creek areas of interest were greater than 7 degrees (equivalent to 12.3% slope) In this area of the Forest, the eastern and southeastern escarpments of the central highland terrain are populated with the low-slope, crescent-shaped deposits containing adjacent high slope scarps. These are the locations that are highlighted and labeled in Map 6.1 as mass movements.

The DOGAMI data (Baldwin and Beaulieu 1973, Beaulieu and Hughes 1975) also indicates the presence of deep-seated slides not clearly associated with the synclines along the east and southeastern margins of the Forest. These mass movements (Maps 2.4 and 6.1) have occurred in steep terrain elsewhere in the Forest. These slides are found interior to the synclinal margins of the Forest in the West Fork Millicoma River corridor and along the westward Forest boundary with the Coastal and Tenmile Basins. These locations were all steep with high terrain relief.

Discussion

The DOGAMI mapped slides, including the Loon Lake slide, appear to be but a small subset of the potential sites. Because of the limited timeframe, this analysis identifies potential deep-seated landslide deposits through interpretation of GIS data using the criteria and filters described above. To adequately confirm their presence will require field verification. This will likely be more of a theoretical research interest, rather than of management interest, because of the limited ability to either affect the extent or frequency of deep-seated landslides. However, the same processes that generated the deep-seated landslides identified on the maps are still likely to be present.

The low (temporal) frequency of deep-seated slides is implied by the lack of historic record for these large magnitude events. Since the scope and scale of such disturbances would not have gone unnoticed in historical records, these slides are regarded as prehistoric or paleoevents. Baldwin and Beaulieu (1973) estimate the slides near the Mill Creek and Umpqua confluence to be Tertiary in age. Therefore, while these massive slides are significant terrain shaping processes, they are infrequent and not particularly affected by human activities. However, large-scale earth disturbances such as road construction that cuts across the toes of these slide deposits may reactivate slide movement by removing buttressing support along the base of the slide. In addition, earthquakes and canopy removal may play a role in initiating these mass movements.

Shallow, Rapidly Moving Landslides

Shallow, rapidly moving landslides are a dominant natural process in the Tyee geologic basin, and occur on both forested slopes and on slopes where timber harvest has occurred. However, they also can be triggered by road fill failures or the diversion of road runoff water onto unstable areas, especially steep slopes. Shallow, rapid landslides, debris flows,

and debris torrents are major contributors to sediment transport between hillslope and channel systems in steep terrain (Benda 1990).

Shallow landslides have been the subject of investigations for over a decade. The Forest has an abundance of geomorphic studies and surveys associated with shallow, rapidly moving landslides. There is an extensive body of literature on shallow landslide processes in the Coast Range that includes geomorphic analysis at Mettmann Ridge near the Forest (Reneau and Dietrich 1991) and investigations specific to the 1996 storm impacts on private, state, and federal forestland (Robison et al. 1999). The study by Robison and others (1999) represents an unprecedented field data collection and analysis effort. Their results support other field-based studies (such as Montgomery and Deitrich 1994) that allow numerical simulation and analyses of landslide initiation triggers, flow behavior, and stream impacts. Additional data exists for a Tenmile Lakes watershed that supplements the Robison results.

The first of the following three sections applies slope stability models by Montgomery and Deitrich (1994) and Tarboton (1997) in the form of ArcView GIS extensions (Deitrich and Montgomery 1998, Pack et al. 1999) to a DEM of the Forest. The second section evaluates a dataset provided by the Tenmile Lakes Basin Partnership (TLBP) of shallow landslides in the Noble Creek watershed. Finally, the third section reviews the findings of the field-based investigations by Robison and others (1999) that include information about landslides in the Elk Creek watershed. Combined, these three approaches represent the full range of investigations of landslides in the Forest.

This analysis should be considered a conceptual model designed to provide an understanding of the relative distribution of unstable terrain across the Forest. Therefore, this general ranking effort will aid in the delineation of subregions of interest for more intensive field survey and analysis.

Methods

An ArcView GIS extension computer model called SINMAP (Pack et al. 1999) was used to evaluate shallow landslide hazards based upon topography. This model relies on terrain slope as a major controlling factor, using a three-dimensional method to determine slopes. A new 10-meter DEM was created by using a statistical interpolation procedure called “kriging” in conjunction with an improved slope algorithm on the point elevation dataset provided by the ODF. The DEM produced through this process is superior to the existing one because it overcomes many of the limitations of evaluating landslides with computer models identified in the Robison and others (1999) study.

As a first approximation, the landslide model assumes a uniform distribution of soil cohesion so that the variable influence of root reinforcement is not included. Even though it is just based on topography, the results provide a useful starting point to evaluate slopes and terrain in the Forest.

Results

The computer model output (Map 6.1) shows regions of the Forest that may have a higher probability of slide initiation. At the larger Forest-wide scale, two areas show a higher likelihood of unstable slopes: the northerly draining watersheds along the Umpqua River and the Tenmile Lakes headwaters. Map 6.1 shows topographically dependant landslide hazards in the northerly draining watersheds along the Umpqua River below the Mill Creek confluence. The excessively steep terrain is unstable when compared to the lower slope interior regions of the Forest. Terrain that is predisposed to rapidly moving shallow landslides also is found along the Mill Creek Basin, interspersed and sometimes superimposed over massive, deep-seated slide deposits. Tributaries with names such as "Slide-out Creek" characterize the southeast margin of the Forest.

The Tenmile Lakes headwaters also are exceptionally steep, second only to the Umpqua tributary watersheds. The landslide scars in the Tenmile Lakes area (TLBP 2003) discussed in the next section provide an indication of this area's propensity to landslide. The interior West Fork Millicoma Basin has less severe slope when compared to the Umpqua or Tenmile regions. Nevertheless, field survey efforts (Robison et al. 1999, Roering et al. 2003) indicate numerous landslides in this area resulting from 1996 precipitation events. The methods and survey intensity in these surveys provides the greatest level of detail in field mapping and description of landslides in the Forest.

The computer model results do not include the influence of soil stability from the presence of roots. While root strength is known to be important an influence on landscape geomorphology (Schmidt et al. 2001, Istanbulluoglu et al. 2003, Roering et al. 2003), it varies at finer scales than are detectable in available Forest datasets. However, more complex landslide models often incorporate stand age as an indicator of root strength contributions to slope stability. Field-mapped landslide initiation point data have been collected for the Elk Creek (Robison et al. 1999) and Tenmile Lakes Basins (TLBP 2003). In combination with stand ages, this data provides an initial point for discussing the effects of overstory vegetation, particularly stand age, on landslide hazard.

Noble Creek Landslide Study (TLBP 2003)

In addition to the computer models, field inventories of landslides in the Forest have occurred in the Elk Creek watershed, in some Mill Creek tributaries (Double Barrel and three small streams draining directly into the Umpqua River above Mill Creek), and in the Tenmile Lakes watershed (Big, Noble, Benson and Johnson Creeks). The Elk Creek and Mill Creek tributary studies were conducted by the ODF (Robison et al. 1999), while the Tenmile Lakes watershed surveys were done by the TLBP as part of their assessment process (TLBP 2003). Road-related landslide information also was compiled during ODF's 1997-1998 Forest-wide road inventory (see Map 6.2).

Methods

Field protocols for the Elk Creek (Robison et al. 1999) and Noble Creek (TLBP 2003) landslide surveys were fairly similar. Most importantly for each of the basins, draws were walked from bottom to top and any slides noted. Although the Noble Creek survey collected fewer specific items than the Elk Creek survey, it did include aspect, slope (%), source of the slide, vegetation type at point of initiation, slide dimensions, and whether sediment from the slide entered a waterway. In addition, field observations for the route of the slide were made, photographs taken, and the path of the slide mapped onto USGS quadrangle sheets.

Results

Landslide density for the Noble Creek Watershed following the 1996 storm events was 0.017 landslides per acre. Landslide run-out paths averaged 802 feet and ranged from 130-5,020 feet in distance traveled. The distribution of average landslide path lengths (in % of total slide length) between differing vegetation environments are presented in Table 6-1.

Table 6-1. Average landslide volumes in Noble Creek based on vegetation class at origin.

Parameter	Noble Creek
Study Area (sq. mi.)	3.9
Landslide Density (#/sq. mi.)	10.88
Landslide Density; entered fish-bearing stream (#/sq. mi.)	7.95
Density of fish-bearing streams (mi./sq. mi.)	1.09
Number of landslides that occurred throughout the study area	42
Number of landslides that entered fish-bearing streams	31
Percentage of landslides that entered fish-bearing streams	73.8%
Average volume of landslide that entered fish-bearing streams (cu. yd.).	2,280

Landslides reaching a channel (31) comprised 74% of the 42 total landslides. Of the landslides reaching the channel, 47.1% originated in a recent clearcut, an additional 10.2% in an old clearcut, and 6.8 % originated in mature vegetation. Overall, landslides traveled a cumulative 6.38 channel miles and impacted 0.55 miles (12.9%) of fish-bearing streams in the Noble Creek watershed. One landslide in Noble Creek is an anomaly due to its extreme length (nearly 1 mile) and may be the result of the combined, near-simultaneous failures in the tributary channel feeding this slide.

Discussion

Landslides that occurred in the Noble Creek watershed during the 1996 floods were surveyed using a structured method that included both air photo interpretation and field-based identification and measurement. This survey produced landslide data that may prove valuable given additional processing and analysis. A cursory examination of the TLBP data indicates that landslides in this basin were not unusually dense, although they were large in average volume. Examination of the field data and digitized maps shows that a large

percentage (74%) of the total landslides in the Noble Creek watershed entered fish–bearing streams. These slides averaged over 800 feet in run-out distance, and deposited material along 13% of fish-bearing stream length in the watershed.

No slides that originated in "reprods" (reforested units) reached a stream channel. However, since there was only one sample point for the reprod class, no inference can be made from this statistic concerning significance. The same is true for the "mature" class; due to the low relative proportion of samples in this class, no inference can be made stating the significance of mature vegetation environment and run-out length. Therefore, without additional processing steps and ancillary data, the TLBP dataset is of limited utility and cannot be evaluated on the same basis as the Robison and others (1999) data. These limitations can be overcome by:

1. Compiling and expanding stand age data (circa 1996) from the non-Forest portions of the Tenmile Lakes Basin (a patchwork of ownership) from harvest records and additional air photo analysis.
2. Fully capturing and digitizing the entirety of the TLBP data available in existing field forms into a GIS-compatible format to include survey data and all other attributes (stand volume, valley forms, hillslopes, etc.) from all watersheds in the Tenmile Lakes Basin.

These steps should increase the slide sample numbers and improve the ability to make inferences concerning vegetation effects on slope failure points and landslide run-out distances. This information could then be reliably integrated into a larger dataset of slides for the Forest.

ODF Landslide Study (Robison et al. 1999)

A study was conducted by the ODF in 1997 on landslides following intense rainfall in November and December 1996 (Robison et al. 1999). All landslides were identified and characterized in the field. Results from three study areas that were in steep, sandstone geology in the central Coast Range that were particularly hard-hit by the 1996 storms are reported below. One area was Elk Creek in the upper West Fork Millicoma River on the Forest. Another area, Scottsburg, was along the northeast boundary of the Forest overlooking the Umpqua River and Mill Creek. A third area, Mapleton, was 35 miles to the north in similar terrain and geology. Partial results also were included for a fourth area (Vida). Unlike the other areas, the Vida area is the western Cascade Mountains and is underlain by highly variable volcanic rock and slopes are long with little dissection.

Landslides not related to roads, or in-unit landslides, averaged 11-23 per square mile following the 1996 storms and was highest for the Elk Creek area and lowest for the Mapleton area (Table 6-2). Nearly 70% of the in-unit landslides occurred on hillslopes with the remainder occurring next to or in the channel. The upslope landslides had considerably more volume, on average, than the channel landslides (Table 6-2).

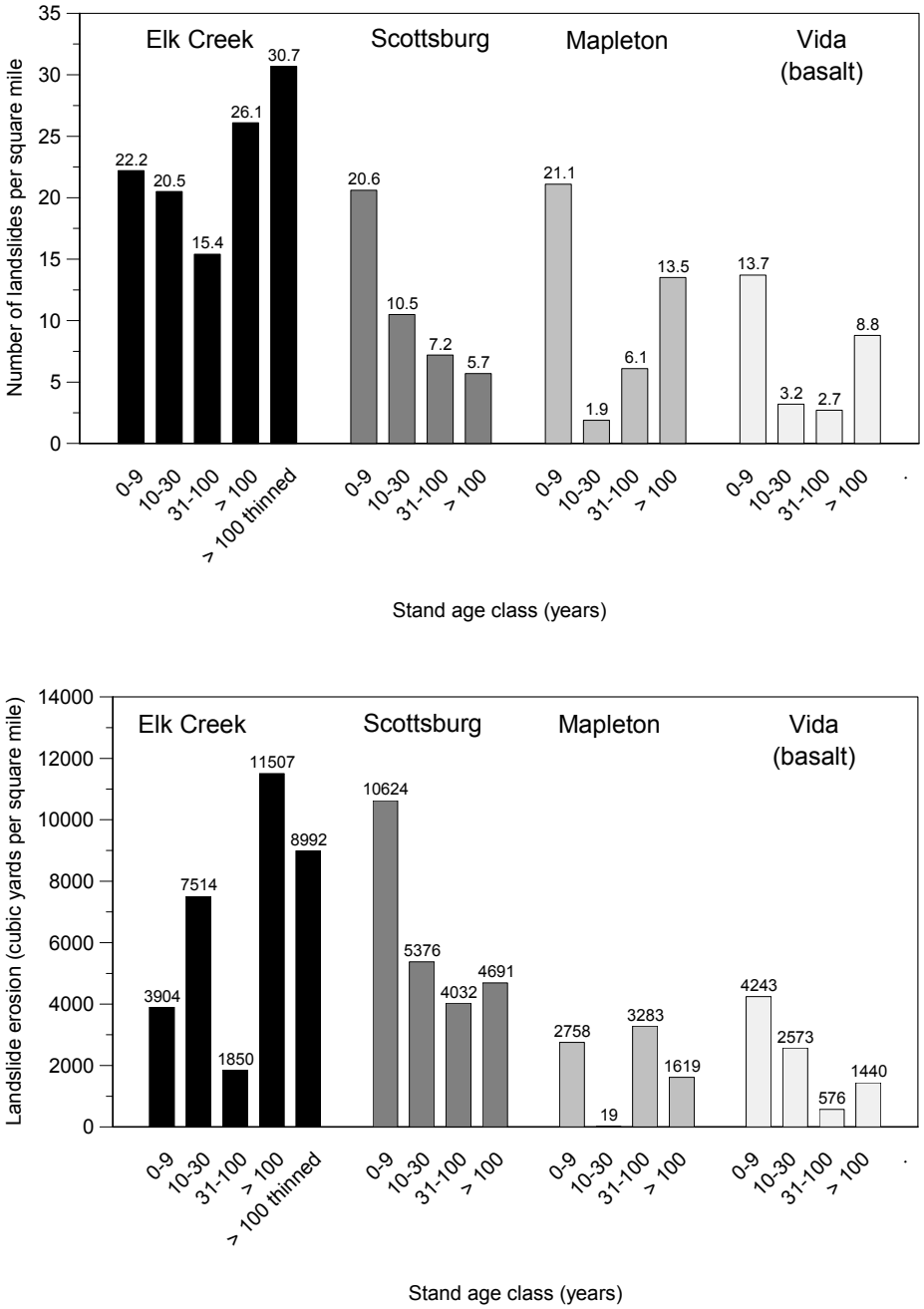
Table 6-2. Landslide characteristics for three study areas in steep sandstone terrain of the central Coast Range following the 1996 storms.

Parameter	Elk Creek	Scottsburg	Mapleton
Storm during which most landslides occurred	Nov. 1996	Nov. 1996	Feb. 1996
Study area (sq. mi.)	6.53	7.10	8.29
Landslide density; all (#/sq. mi.)			
Upslope	15.6	10.8	7.1
Channel	7.5	2.5	4.3
Road	1.2	1.4	1.6
Combined	**24.3**	**14.8**	**13.0**
Landslide density; entered fish-bearing streams (#/sq. mi.)			
Upslope	6.9	7.0	2.4
Channel	2.3	1.8	0.6
Road	0.2	0.6	0.2
Combined	**9.3**	**9.4**	**3.3**
Density of fish-bearing streams (mi./sq. mi.)			
Road along stream	1.5	0.7	0.4
No road along stream	0.2	0.9	1.1
Combined	**1.7**	**1.6**	**1.7**
Number of landslides that occurred throughout the study area	159	105	108
Number of landslides that entered fish-bearing streams	61	67	27
Percentage of landslides that entered fish-bearing streams			
Upslope	44	65	34
Channel	31	72	14
Road	38	40	15
Average volume of landslide material that entered fish-bearing streams (cu. yd.)			
Upslope	521	412	773
Channel	40	27	259
Road	691	181	3492

Landslide density decreased with increasing age of trees growing on the slope for the Scottsburg area, with the density for the 100-year age class only about one-quarter of that for recent clearcuts (0-9 years). The erosion associated with landslides in the 0-9 year age class was about twice that of the other age classes (Figure 6-2).

The Elk Creek area showed opposite results; areas supporting trees older than 100 years had higher landslide density and erosion. The landslide density within intact 100-year-old stands was greater than the density in newer clearcuts (26 versus 22 landslides per sq. mi.) and the erosion rate was over two times higher for the older stands. The higher landslide density in older timber for the Elk Creek area cannot be explained by the terrain being steeper where these stands exist. For both the younger clearcuts and the stands older than 100 years, the percent of land with a slope of 60% gradient or greater was slightly more than 50%. Also, the higher landslide density in older timber cannot be explained by an unusually unstable area within part of the basin. Landslides in this stand age class occurred somewhat uniformly throughout the basin.

Figure 6-2. Landslide density (top) and erosion (bottom), not related to roads, for three areas of sandstone geology in the central Coast Range and one area of basalt geology in the Cascade Mountains following intense rainfall in December and February 1996.



Source: Robison et al. 1999.

Both landslide density and erosion volume in the Mapleton area was 1.6 times higher in newer clearcuts as compared to stands older than 100 years. The landslide density in the basalt Vida area also was 1.6 times higher in newer clearcuts than in areas with stands older than 100 years. In the Vida area, erosion volumes were nearly three times higher for the clearcuts (Figure 6-2).

Three out of four areas showed that landslide density was higher in newer clearcuts than in areas with stands older than 100 years. However, there was not a significant statistical difference in the means between the newer clearcuts and the mature stands when the four study areas were compared using a paired t-test ($P = 0.2$). Similarly, there was not a significant statistical difference for erosion volumes ($P = 0.9$). Consequently, when viewed as a replicated experiment, the data from Robison and others (1999) does not support a conclusion that landslides are denser or cause more erosion in clearcuts than in mature stands. When viewed as a case study, the pooled results for the four study areas indicate that landslide density was 1.5 times greater in the newer clearcuts (0-9 years old) than in mature stands.

In their report, Robison and others (1999) made an adjustment to the landslide density because slope steepness was somewhat less in the newer clearcuts than in the mature stands. With this adjustment, they concluded that the landslide density was two times greater in the newer clearcuts than in mature stands. In contrast to the landslide density, pooled results for erosion volume indicate that erosion was 1.4 times greater in mature stands than in the newer clearcuts. The pooled results for erosion are skewed by the relatively high values for mature stands in the Elk Creek area.

At three of the four areas, landslide density in 31-100-year-old stands was less than either the slopes with new clearcuts or mature stands (Figure 6-2). This 70-year relative lull in landslide activity may be a result of vulnerable areas having already failed during the first 30 years after clearcut logging, followed by a period of high tree density across the slopes and the refilling of hollows with soil and gravel through creep and ravel processes.

The majority of upslope landslides did not directly affect fish-bearing streams, except in the Scottsburg area. About one-third of upslope landslides in the Mapleton area reached fish-bearing streams, while this value was 44% for the Elk Creek area. In contrast, a majority of upslope landslides in the Scottsburg area (65%) reached fish-bearing streams. Most upslope landslides occurred in a western subbasin (Double Barrel Creek) of the Scottsburg area, where nearly every channel experienced a debris torrent and then funneled into Mill Creek, a fish-bearing stream. It is possible that this subbasin received an inordinate amount of rainfall during the November 1996 storm.

The material transported downstream by landslides to fish-bearing streams rarely set up jams of wood, rock, and sediment in the streams (Table 6-3). Only 8% of landslides (all types) could be associated with a debris jam at its junction within a fish-bearing stream or a short distance downstream of the junction. The volume of material in the debris jams averaged 1,277 cubic yards. Overall, the material in debris jams in fish-bearing streams averaged only 216 cubic feet per 100 feet of stream.

Table 6-3. Jams of wood, rock, and sediment transported by landslides into fish-bearing streams.

Parameter	Elk	Mapleton	Scottsburg	Combined
No. of landslides entering fish-bearing streams	64	27	53	144
No. of associated with a nearby debris jam	3	3	6	12
Percent with debris jam	5	11	11	8
Average volume of debris jams (cu. yd.)	830	280	2,000	1,280

Most debris jams were relatively small (less than 200 cu. yd.) but averages were highly influenced by several large debris jams (up to 9450 cu. yd.). At each of the three sites, some landslides ended up in large streams or rivers that were capable of transporting large wood and rock far downstream during high flows. Because the field survey was not conducted during the storm, much of the coarse material could have been washed far downstream by the time observations were made. Only 1 of the 144 landslides that entered fish-bearing streams continued downstream upon encountering a fish-bearing stream. For the single exception, the debris torrent traveled 500 feet down the fish-bearing stream.

The distance upslope from fish-bearing streams where landslides originated averaged from 350-500 feet among the three sandstone study areas (Table 6-4). However, the distribution of distances was spread uniformly from 50-1,000 feet and exhibited no central tendency (Figure 6-3). Slope gradients (measured in the field) at landslide initiation points also varied widely (Table 6-4, Figure 6-3). Nevertheless, for about 90% of the landslides, the slope gradient was 70% or more at the initiation point.

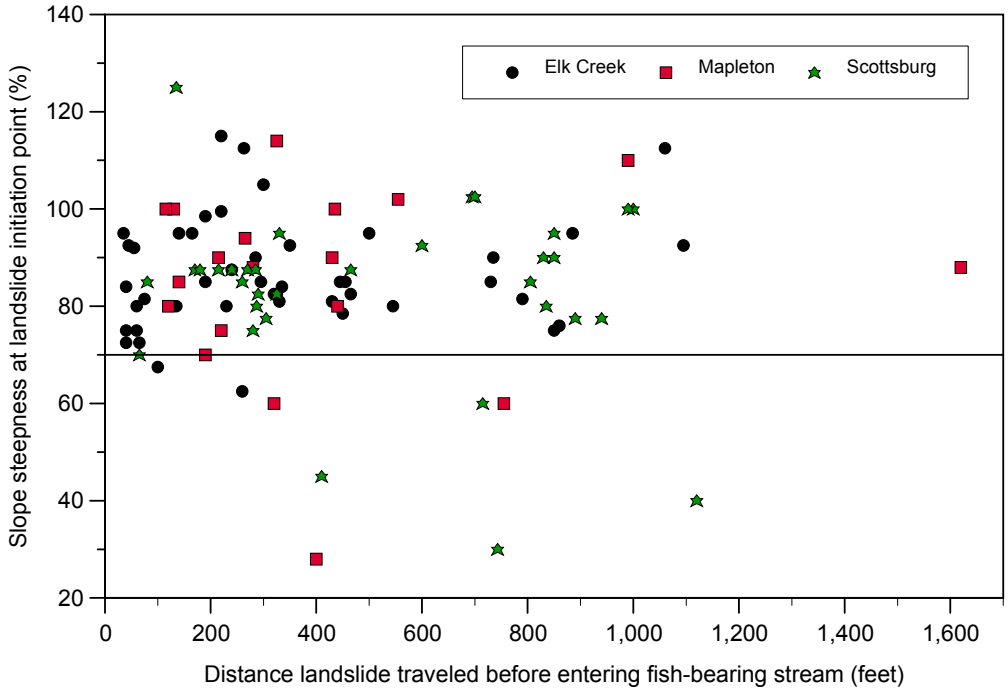
Table 6-4. Distance from initiation point to fish-bearing stream and slope steepness at initiation points for landslides that ended up in a fish-bearing stream.

Parameter	Elk	Mapleton	Scottsburg
Distance from landslide initiation point to fish-bearing stream	350 feet	390 feet	500 feet
Average and range	40-1,100 feet	110-1,620 feet	60-1,120 feet
Slope steepness at initiation point	87%	86%	83%
Average and range	62%-115%	28%-114%	30%-102%

Discussion

Shallow, rapidly moving landslides are common throughout the Forest when triggered by unusually intense rainfall, such as during the November 1996 (Robison et al. 1999) and 1982 storms (Schroeder and Brown 1984). Landslide frequency during normal winters is much lower. Factors commonly hypothesized to influence the rate and density of shallow landslides include rainfall distribution, duration and intensity, slope, subsurface flow concentration, soil properties and depths, vegetation cover, biomass weight, root strength, root density, and influence of fires.

Figure 6-3. Distribution of slope steepness at landslide initiation point and distance traveled to fish-bearing stream for upslope landslides inventoried after the 1996 storms.



Terrain slope is the most critical factor in the evaluating shallow, rapidly moving landslides. Surface shape also affects the slide initiation, largely due to its influence on directing runoff accumulation and soil saturation. In the Forest and in other coastal State Forest units, the ODF study (Robison et al. 1999) confirmed the findings by Montgomery and Deitrich (1994) concerning the primary control that slope plays on slide and flow processes.

The role that vegetation plays in landslide processes is both controversial and in dispute. An overview of perspectives on the effects of vegetation on landslide processes is discussed below.

Point 1. Vegetation intercepts rainfall, thus reducing infiltration rates. Interception of high-intensity rainfall by the tree canopy and the consequent moderation of the rate at which precipitation hits the ground may be another mechanism by which forest areas generally generate fewer landslides than new clearcuts (Keim and Skaugset 2003). Through modeling of high-intensity precipitation and water infiltration through soils with and without a forest canopy, Keim and Skaugset (2003) noted a distinct moderating influence on peak soil pore pressures when a forest canopy was present.

Point 2. Vegetation roots bind soil and increase resistance to shear forces. Tree roots may play an important role in the timing of landslides in this region (Burroughs and Thomas

1977, Gresswell et al. 1979, Sidle 1987). Surface vegetation mechanically binds soils and augments soil cohesion. Vegetation age, stem distribution and spacing are the primary variables controlling this effect due to their influence on the root tensile strength, rooting depth, and interlocking among roots from different plants. The decay of tree roots following clearcut harvesting could open up a window of landslide vulnerability that persists until roots from the next rotation of trees reoccupy the soil mass.

Results in the Elk Creek and the Mapleton area show renewed susceptibility to slides as stand cohorts reached late maturity. It has been suggested that this occurs in part due to increasing space between trees (and roots) due to progressive tree mortality and other factors affecting the spatial distribution of tree, shrub and groundcover and their root structure and extent (Roering et al. 2003). Robison and others (1999) data suggest that slide susceptible periods peak in the first decade after root death due to fires or harvest activities and then rise again after about one century.

Point 3. There is often little vegetation, especially conifers, at slide locations. Many landslide initiation areas are too wet or unstable to grow conifers, and instead support brush and hardwoods (Robison et al. 1999). Field examinations in steep, sandstone geology north of the Forest by Bransom (1990) indicate that conifer roots rarely penetrated into predicted zones of slope instability or hollows. Instead, root masses within these hollows were mostly of brush and hardwood species, which have lower root strength than do conifers (Skaugset 1997). Roering and others (2003) provide a discussion of this effect in their analysis of the Forest and Mapleton landslide study areas used in the ODF study.

Point 4. Landslides can deposit material in fish-bearing streams. The ODF study (Robison et al. 1999) indicates that almost half (44%) of upslope landslides in Elk Creek, and almost two-thirds (65%) of upslope landslides in the Scottsburg area end up in fish-bearing streams (Table 6-2). The results from the TLBP (2003) survey of Noble Creek showed that 74% of slides there ended up in fish-bearing streams (Table 6-1).

Point 5. There is little field data to support the role that vegetation plays in landsliding. The ODF study (Robison et al. 1999) allows for a comparison of landslide density and related erosion for stands of various ages for terrain similar to that found on the Forest. A field-based study on similar geology conducted further north on the Siuslaw National Forest found that landslide rates were 1.3 times higher in recent clearcuts than in intact older forest (Table 6-5); for the steepest and most unstable soil type, landslides rates density was 3.4 times more frequent in recent clearcuts (Ketcheson and Froehlich 1978).

A similar field-based study also conducted in the 1970s on the Siuslaw National Forest, found that landslide density was actually lower in recent clearcuts than in mature timber over the study area (Table 6-5; Swanson et al. 1981). However, for the steepest and most unstable soil type, landslide frequency density was 1.3 times greater for clearcuts. Erosion volume associated with these landslides was 2-12 times higher in clearcuts than in mature timber for the two studies, depending on soil type.

Table 6-5. Density of shallow, rapidly moving landslides (not related to roads) and associated erosion.

Study	Landslide Density (#/sq. mi.)		Landslide Density; Ratio of Clearcut to Mature Timber	Landslide Erosion; Ratio of Clearcut to Mature timber
	Recent Clearcut	Mature Timber		
Ketcheson and Froehlich (1978)				
All soil types	30	23	1.3	4
Steepest and most unstable soil type	58	17	3.4	12
Swanson et al. (1981)				
All soil types	15	21	0.7	2
Steepest and most unstable soil type	27	21	1.3	4
Robison et al. (1999); all soil types				
Elk Creek area	22	26	0.8	0.3
Scottsburg area	21	6	3.5	2.3
Mapleton area	21	13	1.6	1.7
Vida area	14	9	1.6	3.0
Combined	**19**	**13**	**1.5**	**0.7**

WATERSHED SEDIMENTATION FROM FIRES

Natural Fire Regimes

While not frequent in occurrence, large magnitude, catastrophic fires have preceded periods of accelerated erosion and stream sedimentation. These natural disasters no doubt decimated local aquatic systems, but also played a key part in the cycling of nutrients and stream substrates and channel structure. Aquatic systems, which have co-evolved with the dynamic landform processes and climate, have the ability to recover from these disturbances over longer time frames:

> "…under a natural fire regime … streams in the upper drainage experience large sediment deposits (>1 m thick) infrequently (once every hundreds of years) because sources of mass failure are few and sediment bedload transport rates are low" (Reeves et al. 1995).

Large post-fire sediment pulses occur during accelerated erosion periods following infrequent large fires (Istanbulluoglu et al. 2003). Over time, these fire-weather driven events (including both human- and lightening-caused) may account for a large proportion of sediment discharged from the upper basins to storage in low order fluvial channel environments.

Anthropogenic Fire Regimes

Prescribed fires associated with site preparation are of smaller scale in terms of sediment production due to their low fuel loading, fire weather, and scale. Also, riparian buffers remain intact as filter strips and trap fines generated in prescribed burns. The Forest often

exceeds the best management practices for riparian buffer widths. Therefore, the relative contribution of sediment from in-unit burns is expected to be minimal in volume, but perhaps more frequently occurring when compared to the rare but severe stand-replacing wildfire. Broadcast burning associated with in-unit activities is discussed below.

Human-ignition Wildfire

Human-ignition wildfire presents a significant potential hazard for Oregon forests, including the Elliott, and conceivably could increase immediate short term yields of sediment of several magnitudes greater than expected in prescription environments. The presence of fire weather conditions greatly exacerbates risk and is not within human control as are thinning and suppression readiness factors.

Broadcast Burning and Yarding

The baring and displacement of soil during log yarding or skidding has the potential of accelerating sediment loads into streams. The risk is higher on steeper slopes and especially if ground-based logging requires the excavation of skid trails. Intense broadcast burning also can accelerate sedimentation by consuming logs and other organic material; on steep slopes, soil and rock that has built up behind the wood is released (Bennett 1982), and a portion of this buildup may end up in stream channels. This phenomenon is likely of minor consequence for fires of lesser intensity since they leave many larger pieces of wood intact.

Accelerated sedimentation in streams following yarding or skidding of logs and broadcast burning has been evaluated for only a few small watersheds in the Pacific Northwest and some of these studies occurred decades ago, a time when the treatment of soils and streams during logging was occasionally severe. Current practices usually involve much less soil disturbance and less intense burning than what occurred decades ago. In Table 6-6, sediment loads from forested and logged (and some burned) small drainages are presented. These examples are limited this in selection to studies where road-caused landslides were not a major contributor to the overall suspended sediment load.

An extreme case of logging and site preparation intensity occurred in the Needle Branch drainage, located in steep, sandstone terrain of the central Coast Range. The entire basin was clearcut logged using a high lead cable system, intensely burned following harvest, and the stream channels were cleared of most wood. In the lower reaches, stream cleaning was done with the blade of a crawler tractor. These activities produced a three-fold increase in suspended sediment yield that persisted for a number of years and likely represent some of the highest increases in sediment yield possible using practices that have since been replaced with gentler approaches to keeping soil on site.

An equally intensive broadcast burn following logging occurred within Basin #1 of the H.J. Andrews Experimental Forest in the Cascade Mountains. The suspended sediment yield jumped 23 times higher than it was prior to these activities. Sediment yields were significantly less in nearby Basin #6 that had been 100% clearcut and burned, but not intensively. When compared to the sediment yields of two other basins, one forested (#8) and one with half its area partially cut, the sediment differences were small.

Table 6-6. Comparison of the annual suspended sediment yield for forested basins and basins logged and broadcast burned in Oregon.

Study	Average Slope for Basin	Condition	Mean Annual Suspended Sediment Yield (lbs./ac./yr.)
Alsea, Coast Range			
Needle Branch	37%	Forested	473
Needle Branch	37%	Roaded, 100% clearcut, intensely burned, channel clearing	1393
H.J. Andrews, Cascade Mts.			
Basin #1	63%	Forested	71
Basin #1	63%	100% clearcut, intensely burned	1634
H.J. Andrews, Cascade Mts.			
Basin #8	30%	Forested	98
Basin #7	31%	50% partial cut	22
Basin #6	28%	Roaded, 100% clearcut, burned	116
Fox Creek, Cascade Mts.			
Watershed #2	8%	Forested, roaded	18
Watershed #3	8%	Roaded, 25% clearcut	24
Watershed #1	8%	Roaded, 25% clearcut, lightly burned	26

Source: after Larson and Sidle 1980.

Three small watersheds with gentle terrain in the Fox Creek watershed had nearly identical suspended sediment yields even though one was forested, another 25% clearcut, and the other 25% clearcut and lightly burned.

The limited information provided by these studies suggests that intense broadcast burning is a major cause of accelerated soil erosion following clearcut logging on steep terrain, while lighter burns have relatively little influence on suspended sediment loads in streams. Also, there is little to suggest that log yarding alone contributes much sediment to streams.

Current yarding, burning, and riparian buffer practices on the Forest seem well suited for keeping sediment out of streams. Buffers of intact vegetation are retained along all perennial streams and brush is retained (and not sprayed) along intermittent channels. Skyline cable logging systems with carriages are used to provide at least one end suspension of log loads. Ground-based yarding occurs only on the few areas in the Forest where slopes are gentle. There is no use of excavated skid trails on steeper slopes. Broadcast burning is limited to about 15% of the clearcut acreage (about 70 acres per year). Selected areas are burned lightly (only material less than 2 inches in diameter is consumed by the fire) and then planted with forage crops to improve elk forage.

OTHER ANTHROPOGENIC SEDIMENT SOURCES

While the erosion and sediment processes described above are natural and play a major role in forming stream habitat, additional sediment inputs above natural levels may have deleterious effects on a wide range of aquatic species. There are two primary sources for these added sediment inputs: (1) episodic road-related landslides and wash-outs, and (2) the

chronic sediment generated from erosion from unvegetated cut banks, ditches, fill slopes (at stream crossings) and the surface of hydrologically connected Forest roads.

Roads

There is a substantial body of knowledge documenting the influence of roads on sediment production and fill failure in steep terrain (Beschta 1978, Reid and Dunne 1984, Bilby 1985, Duncan et al. 1987, Bilby et al. 1989). These studies identified the following key factors for determining sediment production from roads: topographic position; slope/ground slope; age; side-cast extent/fill slides; surface type/levels of use; and drainage feature failure/road wash.

This discussion starts with road-related landslides, since they have been most evident over the years due to their size and extent. However, sediment generated from road surfaces, ditches, crossing fill and cut banks can have even greater effect because it is chronic (generated almost continuously with road use and delivered during wet periods), and the smaller particle sizes from this source have more potential to damage fish, gills of invertebrates, and spawning beds. Surveys of roads on the Forest were used to identify road-related landslides. These include road drainage surveys conducted in 1997-1998 and the study by Robison and others (1999) that focused on landslides in the Elk Creek Basin resulting from the exceptional storm events of 1996. Also, an updated survey of roads in the Elk Creek Basin was conducted as part of this analysis.

Road Position

As mentioned previously, the Forest road system is of sufficient age that many of the potential hazards discussed above have already occurred. Past road failures were repaired using best practices at the time, or in some cases the roads were relocated or decommissioned. Maintenance levels reflect high standards for the road system. Nevertheless, Forest roads traverse steep terrain, cross large numbers of streams, and run adjacent to fish-bearing streams. Continued high levels of investment in the road system will be necessary to avoid adverse impacts during activities for which the Forest was established.

New ODF forest practices guidelines (ODF 2003) identify six critical locations where roads are especially hazardous or sensitive: stream channels; riparian management areas; wetlands; areas conducive to cut-bank failures; toes of past landslide deposits; and steep, dissected slopes not conducive to full bench and end haul construction methods. The analysis in this section focuses on road location as a broad tool to identify and evaluate the relative magnitude of these road position hazards. The analysis is a broad landscape-level look at the roads and highlights areas for additional detailed investigations.

Methods

A GIS was used to determine road segments on the ridgeline, mid-slope, and streamside landscape positions. Information from the slope map (Map 2.4) was combined with road attribute information to create a map of Forest road types and surfaces. Road types were classified into one of four types: ridgeline, mid-slope, streamside, and valley. Streamside roads are those within 100 feet of streams, while valley roads are those located in broad, flat

plains outside the 100-foot riparian zone. The ridgeline type includes road segments with less than 1/20th of an acre of upslope drainage. Through a process of elimination, roads were classified as mid-slope if they did not fulfill any of the previous three criteria. Using attribute information in the Forest road layer, roads were further differentiated by surface type: gravel, dirt, or unclassified. The results of this analysis are displayed in Map 6.3. Table 6-7 summarizes the number of miles in each road surface type and landscape location by 5th field HUC.

Table 6-7. Miles of various road types and their landscape location in the Forest by watershed and 5th field HUC.

Basin and 5th field HUC	Road Surface	Road Landscape Position				Totals	Percent
		Riparian	Valley	Mid-slope	Ridge		
Umpqua Region							
Lower Umpqua	Dirt	0.6	0.0	7.0	11.8	19.5	24.8%
	Gravel	2.1	0.8	16.4	39.4	58.7	74.8%
	Unclassified	---	---	0.3	---	0.3	0.3%
	Total	*2.7*	*0.8*	*23.7*	*51.2*	*78.4*	---
	Percent	*3.5%*	*1.0%*	*30.2%*	*65.3%*	---	---
Mill Creek*	Dirt	0.1	2.7	5.4	8.6	16.7	30.4%
	Gravel	2.5	1.6	15.2	18.7	38.1	69.0%
	Paved	---	0.1	---	---	0.1	0.2%
	Unclassified	---	---	0.2	---	0.2	0.3%
	Total	*2.6*	*4.4*	*20.8*	*27.8*	*55.1*	---
	Percent	*4.6%*	*8.0%*	*37.8%*	*50.5%*	---	---
	Region Total	**5.3**	**5.3**	**44.5**	**79.0**	**133.6**	---
	Region Percent	**4.0%**	**3.9%**	**33.3%**	**59.2%**	---	---
Tenmile Lakes Region							
Tenmile Lakes	Dirt	---	1.9	4.3	15.3	21.6	21.8%
	Gravel	---	0.1	24.9	50.8	75.7	76.4%
	Unclassified	---	---	1.0	0.8	1.9	1.9%
	Region Total	**---**	**1.9**	**30.2**	**67.0**	**99.1**	---
	Region Percent	**---**	**2.0%**	**30.5%**	**67.5%**	**---**	---
Coos Bay Region							
Coos Bay	Dirt	---	---	0.6	1.6	2.2	6.5%
	Gravel	1.2	0.3	9.8	21.0	32.2	93.3%
	Unclassified	---	---	---	0.1	0.1	0.3%
	Total	*1.2*	*0.3*	*10.3*	*22.7*	*34.5*	---
	Percent	*3.3%*	*0.8%*	*30.0%*	*65.9%*	---	---
Millicoma River	Bridge	---	---	0.2	---	0.2	0.1%
	Dirt	0.5	2.2	21.8	34.8	59.4	22.1%
	Gravel	16.2	19.2	65.8	97.9	199.1	74.0%
	Unclassified	0.1	0.2	4.5	5.5	10.4	3.8%
	Total	*16.9*	*21.6*	*92.4*	*138.2*	*269.0*	---
	Percent	*6.3%*	*8.0%*	*34.3%*	*51.4%*	---	---
	Region Total	**18.0**	**21.8**	**102.7**	**160.9**	**303.5**	---
	Region Percent	**5.9%**	**7.2%**	**33.8%%**	**53.0%**	---	---
	Grand Total	**23.3**	**29.0**	**177.5**	**306.4**	**536.2**	---
	Grand Total Percent	**4.4%**	**5.4%**	**33.1%**	**57.1%**	---	---

* Includes roads in 211 acres of the Middle Umpqua 5th field HUC.

Results

Map 6.3 illustrates the predominance of ridgeline roads in the Forest. There are no consistent criteria for discriminating between ridgeline and mid-slope road locations. Theoretically, a ridgeline road would have no drainage onto the road surface from adjacent slopes and therefore, no ditches. However, while ridgeline roads on the Forest do follow divides, they also traverse the side slopes of peaks along the ridgeline in order to maintain reasonable grades. Based on discussions with the Forest staff, a small threshold was set for contributing drainage area (1/20th acre) to account for these areas. The resulting ridgeline roads seem to conform well to the ones commonly considered to be in this class.

Based on these criteria, over half of the roads (57%) in the Forest are situated on ridgelines. Close inspection of Map 6.3 and Table 6-7 indicates that mid-slope roads represent about one third of the overall road network. Roads located within 100 feet of stream channels comprise 4.4% of the overall Forest road mileage, with the remainder (5.4%) in valleys.

In the Forest, ridge density in the eastern and northern portions is higher than for other portions. Therefore, it is not surprising that these ridges are heavily utilized as routes because they are the preferred road location. Half of the mid-slope roads (92 miles) are found in the Millicoma portion of the Forest, where landforms are less severe than in the steeper Umpqua and Tenmile regions. Almost three-quarters of the streamside roads in the Forest are located within the basins of the West and East Forks Millicoma River watershed.

Discussion

Road position varies between physiographic regions of the Forest and partially reflects the suitability of terrain to roadway location. Ridgeline and riparian road locations are prevalent in the steeper Tenmile and Umpqua regions, while moderately sloping terrain in the interior of the Forest has a higher proportion of roads in mid-slope position.

Table 6-8 illustrates the influence of the landscape position of the road (ridgeline and mid-slope roads) on the risk of episodic sediment delivery to streams. While the frequency of slides, especially smaller ones, does not vary greatly between ridgeline and mid-slope roads, the volume of landslide debris transported downslope does.

Ridgeline roads are generally good road locations to minimize fill failure hazards and hydrologic connectivity between road drainage the stream channel network. Forest roads located along ridgelines contribute little sediment directly to streams unless drainage feature failures trigger slides by concentrating flow on road fill or onto unstable headwalls and hollows (Montgomery 1994). However, even these ridgeline road segments need to be evaluated for drainage ditch needs where runoff from small hillslopes above the road combines with that from the road surface and is routed into steep, concave valley headwalls. Detailed examination of the GIS results, in concert with input from Forest staff and field review, can identify specific problem locations.

Table 6-8. Percentage of slides by slide volume interval and mean slide volume for ridgeline and mid-slope roads.

Slide Volume Interval (cu. yd.)	Percentage of Slides		Mean Slide Volume	
	Ridgeline	Mid-slope	Ridgeline	Mid-slope
0 - 99	55	53	33	35
100 - 199	18	14	103	135
200 - 399	27	11	271	249
400 - 999	0	16	0	610
1000 - 1999	0	5	0	1,249
> 2000	0	1	0	3,134

Adapted from Sessions et al. 1987.

Mid-slope roads are of management concern because of hazardous road prism fill failures that result in subsequent downslope delivery of sediments to stream channels. Many of these roads have high side slopes and some have a legacy of side-cast construction. Plugged drainage culverts and excessive spacing between culverts on mid-slope roads can erode the roadbed, fill, and ditches (Mills 1997). While mid-slope roads are needed to move traffic from streamside to ridgeline positions, a high level of maintenance is needed to adequately maintain them. Features that reduce potential hazards include increasing the frequency of vertical/linear spacing of drainage features, efficient sizing of ditches and relief culverts, and maintenance (Rashin et al. 1999).

Where roads and drainage features are stacked (positioned above other roadways and crossing identical slopes and channels), there is a potential for hazardous fill failures. A good example of stacked roads is the 7400 Road where it climbs out of Fish Creek (NE1/4 NW1/4 sec 5, T.23S, R.10W). The risk in these situations is that failure of the upper section of roadway may result in debris torrents or concentrated volumes of water to the lower roadway. In some cases, the lower road may catch the flows; however, serial failures can exponentially increase sediment delivery downslope. Hazards resulting from stacked roads can be reduced by insuring continuity of drainage from top to bottom, correct culvert sizing at each crossing, and that each culvert has a appropriately- sized downspout routing drain water to stable slopes.

Streamside roads and stream crossings are of particular concern given their ability to contribute coarse sediments and suspended fine sediments directly to streams. While not prevalent, portions of Forest roads along streams in confined valleys that encroach upon the stream channels create a hazard if the fill slides into or is eroded by the stream. Additionally during grading, small berms of maintenance cast may be created along the edge of the road and has the potential to slide directly into the channel. While minor as episodic events, these sources are chronic sediment contributors especially during the first rains after grading, on heavy haul roads where gravel is broken down, or during wet hauling. Streamside road mileage has been progressively reduced in the Forest through road closures and roadway decommissioning. However, there are still several roads that encroach on streams, especially in the West and East Forks of the Millicoma River watershed. The 1000 Road along Marlow Creek is an example where this situation is most evident.

Road Slope

Road sections with sustained high gradients generally yield greater amounts of sediment than low slope roads (Mills 1997). Road water and sediment discharge may affect the hillslope that a road traverses. Discharge on steep slopes has high stream power and erosive capability. The mean sediment particle size also increases with the road surface slope (Piehl et al. 1988, Bilby et al. 1989). Identification of road segments with higher slopes and categorizing ditch lengths delivering to streams assists in evaluating chronic sediment yield into streams from roads.

Methods

Based on an analysis of the scientific literature previously cited and best management practice guidelines, a road slope sedimentation hazard rating was developed to assess road segments on the Forest. A "high hazard" rating was given to any road segment that contained at least one of the highest slope classes (or both), with the other slope being in at least the second highest category. This classification is shown as shaded in Table 6-9. Road segments within 100 feet of streams also are considered to have a high potential hazard of delivering sediments to streams.

To determine the hazard ratings, road slope values were determined using the DEM developed for this project and the Forest roads layer. Slope values were recoded into the same slope classes used for the Water Erosion Potential Predictive XDRAIN road sediment yield model (Elliot and Hall 1997). Side-slope values were also determined from the DEM. The five side-slope classes are based on parameter values in the XDRAIN model included with Water Erosion Potential Predictive model FSWEPP (USDA 1999). The resulting grid GIS layer (road slope vs. side-slope grid) provides information on locations where the steepest road grades coincide with the steepest side-slope terrain.

Table 6-9. Coding scheme for road slope hazard analysis.

			Side Slope (%)				
Road Slope (%)	**Slope Ranges***		**0 ≤ x < 4%**	**4% ≤ x < 10%**	**10% ≤ x < 25%**	**25% ≤ x < 60%**	**60% +**
		Code	1	2	3	4	5
	0 ≤ x < 2%	1	2	3	4	5	6
	2% ≤ x < 4%	2	3	4	5	6	7
	4% ≤ x < 8%	3	4	5	7	7	8
	8% ≤ x < 16%	4	5	6	7	8	**9**
	16% +	5	6	7	8	**9**	**10**

Results

Road slopes and side slopes provide a good starting point to evaluate sediment delivery hazards. Map 6.4 provides the high gradient/high side-slope road segments shown against the hill-shaded background. While it is difficult at the level of detail available in the map to

identify specific hazard locations, the results in Table 6-10 show that high gradient/high side-slope road segments are distributed across the entire Forest. Also, it is possible to generally identify specific roadways within the Forest as having numerous areas of high potential hazard due to a combination of steep road gradients and steep side slopes (also see Table 6-20).

No road segments in the Forest have less than a 2% slope according to the GIS analysis. About one fifth of the road miles (17.8%) are in the 2%-4% road slope class, with slightly under a third (31.6%) in the 4%-8% class. A plurality of roads (35.5%) is in the 8%-16% slope class. Slightly over 15% of the road mileage in the Forest has a road gradient of 16% or greater. These latter two classes are places where the condition of roads and ditches becomes important, especially when the road gradient exceeds 13% (Mills 1997).

Road gradient is not the only factor determining how well roads perform with respect to sediment generation and delivery to streams. The slope of hillsides above and below the road provides an important indicator of potential sediment delivery. Steep hillslopes indicate areas where cut banks may ravel and generate sediment, and where small slides may block ditches. Only about 5% of Forest roads pass through generally flat lands (<10% side slope), while about a quarter traverse areas with 10%-25% side slopes. Slightly over half of Forest roads traverse side slopes from 25%-60%. Another 93 miles (17.4%) traverse slopes greater than 60%.

In terms of sediment delivery and fill failure, the highest hazard is for steep roads crossing steep terrain. Approximately 6.9% of Forest roads have segments with a road gradient of 16% or greater traversing slopes of 60% or greater. The Forest-wide average is lowered by the high number of miles of road (235 miles out of 269 miles) in the Millicoma River 5th field HUC that traverse side slopes of less than 60%. However, over half of these miles are on slopes between 25%-60% where potential sediment delivery hazards may exist. In the Umpqua watershed, road segments having 16% or greater road slope and passing through areas with greater than 60% side slope comprise 9.27% of Forest roads in the Lower Umpqua River 5th field HUC and 5.91% in the Mill Creek 5th field HUC. Steep road and hill-slope roads comprise 9.22% of the roads in the Tenmile Lakes 5th field HUC.

Discussion

The utility of the slope analysis is that it can be used as a filter to identify potential road segments where the combination of road gradient, position, and hillslope may result in hazardous conditions. The “steep-on-steep” roadway locations identify road segments perched in inherently precarious positions where additional investigation, enhanced maintenance, and remediation may be needed. The results also identify those steep road segments that are adjacent to, and may be hydrologically connected with, stream channels.

Table 6-10. Miles of Forest roads by road and side-slope class (high hazard areas shaded).

5th Field HUC	Side Slope Class	Road Gradient Class (miles)					Total	Percent
		2	3	4	5	Unident.		
Lower Umpqua River	1	0.5	---	---	---	---	0.5	0.6%
	2	2.3	0.9	---	---	---	3.2	4.1%
	3	5.6	5.1	2.5	0.7	---	13.9	17.9%
	4	7.0	15.5	13.9	**4.8**	---	41.2	53.0%
	5	1.4	3.0	**9.9**	**4.7**	---	19.0	24.4%
	Total	*16.8*	*24.5*	*26.3*	*10.2*	---	*77.8*	---
	Percent	*21.6%*	*31.5%*	*33.8%*	*13.1%*	---	---	---
Mill Creek	1	0.5	---	---	---	---	0.5	0.9%
	2	2.3	0.1	---	---	---	2.4	4.4%
	3	4.3	4.5	3.6	0.3	---	12.7	23.3%
	4	3.3	11.8	10.0	**4.9**	0.1	30.1	55.1%
	5	0.5	2.3	**2.3**	**3.8**		8.9	16.3%
	Total	*10.9*	*18.7*	*15.9*	*9.0*	*0.1*	*54.6*	---
	Percent	20.0%	34.2%	29.1%	16.5%	0.2%	---	---
Tenmile Lakes	1	0.2	0.1	---	---	---	0.3	0.3%
	2	1.0	0.3	1.2	---	---	2.5	2.5%
	3	5.4	5.2	4.8	1.6	---	17.0	17.2%
	4	6.4	13.8	21.9	**11.1**	---	53.2	54.0%
	5	3.1	5.6	**6.8**	**9.8**	---	25.3	25.7%
	Unident.	0.1	0.1	---	---	0.1	0.3	0.3%
	Total	*16.2*	*25.1*	*34.7*	*22.5*	*0.1*	*98.6*	---
	Percent	16.4%	25.5%	35.2%	22.8%	0.1%	---	---
Coos Bay	1	0.2	---	---	---	---	0.2	0.6%
	2	0.7	---	---	---	---	0.7	2.0%
	3	1.3	4.8	1.0	---	---	7.1	20.6%
	4	4.3	4.9	8.8	**2.8**	---	20.8	60.5%
	5	---	1.6	**1.3**	**2.7**	---	5.6	16.3%
	Total	6.5	11.3	11.1	5.5		34.4	---
	Percent	*18.9%*	*32.8%*	*32.3%*	*16.0%*	---	---	---
Millicoma River	1	1.6	5.0	---	---	---	6.6	2.5%
	2	6.4	3.8	0.2	---	---	10.4	3.9%
	3	18.7	33.9	20.3	1.3	---	74.2	27.6%
	4	16.7	41.3	65.4	**19.8**	---	143.2	53.2%
	5	1.6	4.9	**15.7**	**12.2**	---	34.4	12.8%
	Unident.	---	0.3	0.1	---	---	0.4	0.1%
	Total	*45.0*	*89.2*	*101.7*	*33.3*	---	*269.2*	---
	Percent	16.7%	33.1%	37.8%	12.4%	---	---	---
Elliott State Forest Totals	1	3.0	5.1	---	---	---	8.1	1.5%
	2	12.7	5.1	1.4	---	---	19.2	3.6%
	3	35.3	53.5	32.2	3.9	---	124.9	23.4%
	4	37.7	87.3	120.0	**43.4**	0.1	288.5	54.0%
	5	6.6	17.4	**36.0**	**33.2**	---	93.2	17.4%
	Unident.	0.1	0.4	0.1	---	0.1	0.7	0.1%
	Total	*95.4*	*168.8*	*189.7*	*80.5*	*0.2*	*534.6*	---
	Percent	*17.8%*	*31.6%*	*35.5%*	*15.1%*	*0.0%*	---	---

*Includes roads in 211 acres of the Middle Umpqua 5th field HUC.

High-slope hazard locations are not restricted to mid-slope roads. The analysis also found steep grades along ridgeline roads. The results presented in Table 6-10 should not be attributed solely to climbing side-slope roads. This finding stresses the importance of ditch relief along ridges despite their overall landscape position advantage. The objective of this relief would be to prevent road drainage from concentrating on unstable headwalls below the ridgeline saddle axes.

Steep-on-steep roadways adjacent (within ~100 feet) to stream channels are of greatest concern. These roadways can disproportionately contribute fines directly to stream channels. The mid-slope and lower 2 miles of the 7500 Road along Footlog Creek is an example of where this has occurred. The realignment, relocation, or removal of steep, hydrologically connected roadways is one way to reduce these effects. Increasing drainage structure frequency (reducing ditch lengths) may help where adequate buffers exist between outlet and stream. Improving the quality of road surfacing material also is an option for reducing, but not eliminating, the impact potential of streamside roads to stream water quality.

Forest staff, consistent with the Forest Practice Rules, is essentially retrofitting and upgrading the Forest road system. Ditch relief structures are included in these upgrades. However, because all Forest ditch relief structures were not inventoried during the 1997-1998 survey, and many improvements have been made since that survey, the findings in this section point to both the need for a detailed assessment of the status of ditch relief culverts.

Road Age

Chapter 3, *Historical Overview*, discusses the development sequence and age of the Forest road system. Road age has been shown to be an important factor of road-related landslides, particularly due to previous periods when side-cast construction was common. The Forest road system is of sufficient age to have developed roadbed stability, and is subject to fewer slides as compared to roads constructed prior to the 1980s.

For over 20 years, it has been known that side-casting cut bank material (rather than end hauling it) increases the risk of road-related landslides. The higher costs associated with using best management practices, such as end hauling, can be offset by using ridge locations while keeping mid-slope roads to a minimum (Sessions et al. 1987). Nevertheless, best management practices require the constant attention and maintenance of drainage features to reduce or prevent road-related landslides.

Historical narrative and Forest construction/stand sale histories were used to recount the sequence of roads constructed through specific Forest areas. Currently, the Forest is adding initial road construction dates and specifications to the road information database. All timber sales files are being examined; information about roads constructed as a part of timber sales (most were) is being extracted, entered into a database, and mapped in the Forest GIS. When available, this information will allow road age to be incorporated into future road analyses.

Road-related Landslides

Landslides originating from roads due to prism failures or the diversion of water onto downhill terrain are evaluated in this section. This section relies on the results of a study on landslides done following intense rainfall in February and November 1996 (Robison et al. 1999). All landslides were identified and characterized in the field for three study areas located in steep, sandstone geology in the central Coast Range and were particularly hard-hit by the 1996 storms. One area was Elk Creek in the upper West Fork Millicoma River on the Forest. Another area, Scottsburg, was along the northeast boundary of the Forest overlooking the Umpqua River and Mill Creek. A third area, Mapleton, was 35 miles to the north in similar terrain and geology. Additional information on road-related landslides was extracted from the ODF's 1997-1998 Forest-wide road inventory.

Methods

The original data in the Robison and others (1999) study was reworked with the intent of focusing on those landslides that directly influenced fish-bearing streams. Supplemental information on road-related landslides was extracted from the ODF 1997-1998 road inventory. This inventory included locations of past landslides and locations where the surveyor felt that landslides were likely to occur because unstable road prisms existed (impending landslides). A number of these potential landslide spots have since been repaired. For all sites, the surveyor determined whether or not the landslide entered (or would enter) a stream channel.

Results

Only 8% of all landslides surveyed in the three study areas were related to roads, even with a relatively high road density along streams in the Elk Creek area (Table 6-11). The Elk Creek area had a road density of 5.6 miles per square mile, while the Mapleton area had a density of 1.8 miles per square mile. Because half of the Mapleton area was unmanaged and had no roads, the road density for the managed portion was about twice that of the area average. In all three areas, most roads (those with and without landslides) had been constructed 15-30 years ago.

Within the two areas for which information is available (Scottsburg and Mapleton), 47% of landslides resulted from road fill failing and 26% were caused by water discharging to sidecast or other steep slopes below the road. Another 21% were related to cut slopes failing and diverting water across the road and onto sidecast or steep slopes below the road. Because most of the roads had been built prior to the current requirement of end-hauling excavated material, most road fills were unconsolidated material that had been bulldozed to the downhill side of the road.

The percentage of road-related landslides entering fish-bearing streams varied widely among areas, averaging 40% over the three areas (Table 6-11). Although the volume of material originating from road-related landslides entering fish-bearing streams was small to moderate

at most sites, the presence of a few large landslides makes the average volume greater than that associated with upslope landslides within two of the three areas (Table 6-11).

Table 6-11. Landslide characteristics for three study areas in steep sandstone terrain of the central Coast Range following the 1996 storms.

Parameter	Elk Creek	Scottsburg	Mapleton
Storm during which most landslides occurred	Nov. 1996	Nov. 1996	Feb. 1996
Study area (sq. mi.)	6.53	7.10	8.29
Landslide density; all (#/sq. mi.)			
Upslope	15.6	10.8	7.1
Channel	7.5	2.5	4.3
Road	1.2	1.4	1.6
Combined	24.3	14.8	13.0
Landslide density; entered fish-bearing streams (#/sq. mi.)			
Upslope	6.9	7.0	2.4
Channel	2.3	1.8	0.6
Road	0.2	0.6	0.2
Combined	9.3	9.4	3.3
Density of fish-bearing streams (mi./sq. mi.)			
Road along stream	1.5	0.7	0.4
No road along stream	0.2	0.9	1.1
Combined	1.7	1.6	1.7
Percentage of landslides that entered fish-bearing streams			
Upslope	44	85	34
Channel	31	87	14
Road	38	67	15
Total # of landslides that occurred within the study area	159	105	108
Number of landslides that would have ended up in fish-bearing streams if not intercepted by a streamside road	15	1	1
Number of landslides that ended up in fish-bearing streams in spite of a streamside road	3	1	2
Average volume of landslide material that entered fish-bearing streams (cu. yd.)			
Upslope	521	412	773
Channel	40	27	259
Road	691	181	3,492

Road-related landslides tallied within the 1997-1998 Forest-wide inventory also were relatively infrequent. The density of past landslides averaged 1.8 per square mile with two-thirds of these reaching a stream channel, but not necessarily a fish-bearing stream (Table 6-12, Map 6.2). The density of impending landslides was only 0.2 per square mile. Of the 26 impending landslides that had potential of reaching a stream channel, 14 have since been treated. Usually this involved pulling back a failing fill slope, removing a failed cut slope from the roadbed, or routing drainage water away from vulnerable portions of the road prism. The remaining impending landslides were evaluated and determined not to pose an imminent threat to downstream waters.

Table 6-12. Road-related landslides included in the 1997-1998 road inventory of the Forest by analysis basin.

Region	Analysis Basin	Area (sq. mi.)	Number of Landslides*				Density of Landslides*			
			Past Landslides		Impending Landslides		Past Landslides		Impending Landslides	
			Delivery	No Delivery	Delivery	No Delivery	Delivery	No Delivery	Delivery	No Delivery
Umpqua	1	8.37	7	12	0	0	0.8	1.4	0.0	0.0
	2	10.03	9	4	0	0	0.9	0.4	0.0	0.0
	3	11.40	12	9	0	0	1.1	0.8	0.0	0.0
	4	7.80	20	12	1	1	2.6	1.5	0.1	0.1
	13*	6.46	3	1	0	0	0.5	0.2	0.0	0.0
	Combined	44.06	51	38	1	1	1.2	0.9	0.0	0.0
Tenmile	5	12.22	43	24	0	1	3.5	2.0	0.0	0.1
	6	11.45	6	12	1	0	0.5	1.0	0.1	0.0
	7	9.88	5	4	5	1	0.5	0.4	0.5	0.1
	Combined	33.55	54	40	6	2	1.6	1.2	0.2	0.1
Coos	8	10.24	16	2	1	0	1.6	0.2	0.1	0.0
	9	13.18	14	1	2	0	1.1	0.1	0.2	0.0
	10	10.18	13	0	0	0	1.3	0.0	0.0	0.0
	11	16.99	20	3	7	0	1.2	0.2	0.4	0.0
	12	17.69	5	3	5	0	0.3	0.2	0.3	0.0
	Combined	111.69	68	9	15	0	0.6	0.1	0.1	0.0
	Overall	**145.36**	**174**	**93**	**26**	**4**	**1.2**	**0.6**	**0.2**	**0.0**

*Scattered tracts are not included. For past slides, delivery means that the landslide entered a stream channel when it occurred.
For impending landslides, delivery means that the landslide would probably end up in a stream channel when the landslide occurs.

The densities of road-related landslides in analysis basins in the northwest corner of the Forest that include Scholfield (basin #4, Lower Umpqua 5th field HUC) and Big, Murphy, and Noble Creeks (basin #5, Tenmile Lakes 5th field HUC) were two to three times the Forest average (Table 6-12, Map 6.2). Although the landslides occurred mainly on ridgeline roads, nearly two-thirds of landslides made their way into stream channels.

Despite the term ridgeline road, these roads are usually not restricted to just the center of a ridge. Often segments of road are built across steep slopes between saddles. These road segments on steep slopes are often the headwaters of drainages. Therefore, road failures in these concave headwater locations often have a direct route for moving soil into downstream waters. The landslides in analysis basins #4 and #5 tended to be clustered along a few roads. Roads with unusual numbers of landslides included the 2800, 5240, and 5500 Roads in analysis basin #4 and the 5730, 5420, 4500, and 2580 Roads in analysis basin #5. The oldest clearcuts along these roads are 20-30 years old, which dates road construction back to the 1970s and early 1980s.

Discussion

Road-related landslides tallied in the Forest were relatively infrequent during the 1997-1998 inventory and in the landslide study areas following the 1996 storm (Robison et al. 1999). The aging of the road system, whereby weak sections of road fail and then are repaired, combined with an aggressive road maintenance program by the Forest, probably contribute to the current infrequency of road-related landslides.

The Robison and others (1999) study illustrates to what degree streamside roads intercept loads of gravel and wood contained within landslides as they approach fish-bearing streams. In the Elk Creek area, where roads border nearly 90% of fish-bearing stream miles, the roads along streams kept 20% of landslides from entering fish-bearing streams. The interception of landslides by roads was negligible in the other two study areas, where a majority of fish-bearing stream miles were not bordered by roads. Few other subbasins in the Forest have as many roads along fish-bearing streams as Elk Creek.

Currently, the load of gravel, boulders, and large wood within a landslide that is intercepted by a road prism is typically piled along the upper stream banks and road edges or hauled off-site. An opportunity exists to instead place the boulders and wood directly into the stream channel. However, such a strategy would need approval by federal and state agencies such as the U.S. Army Corps of Engineers and the Oregon Division of State Lands, possibly through the General Permits (federal) and General Authorizations (state) permit process.

Road Surface Type and Level of Use

Another significant determinant of sediment yield from roads is the type of surfacing and the level and type of traffic on the road. Bilby and others (1989) discuss the greater risk posed to streams from differing types of road surfacing material. Specifically, they found that fines production derived from the rapid decomposition of road surfacing materials was greater from submarine basalt sources compared to harder surfacing material such as andesite. Unfortunately, local gravel available for use on the Forest is submarine basalt.

Paved roads produce very little sediment from their surfaces. No paved roads exist on the Forest; in the area, the Douglas County Road up Mill Creek to Loon Lake is paved. However, while reducing turbidity, paving may increase peak discharge in connected stream channels and this should be evaluated in a cost-benefit relationship prior to choosing a surface material.

Table 6-13 shows an order of magnitude increase in sediment produced from high use (wet-haul) versus low use (wet-haul) roads. High use, wet-haul roads can be significant contributors of fine sediment to drainage ditches and subsequently to streams. However, the Reid and Dunne (1984) study evaluated very weak surfacing from submarine basalt, and may show higher sediment yield due to pulling ditch spoils back onto the road surface. Nonetheless, the results presented in Table 6-13 are similar to the findings of Robben and Dent (2002) that form the scientific basis for ODF's current forest practices rules. Strategies to reduce chronic sediment inputs from riparian roads include using high-use and wet-haul roads away from stream sides, closing roads during wet weather, improving rock quality, or paving roads.

Table 6-13. Calculated sediment yield per kilometer of road for various road types and use levels (Pacific Northwest Study).

Road Type	Sediment Yield 1977-1978 (tons/km./yr.)	Average Sediment Yield (tons/km./yr.)
Heavy use	440	500
Temporary non-use	58	66
Moderate use	36	42
Light use	3.4	3.8
Paved	1.9	2.0
Abandoned	0.43	0.51

Excerpted from Reid and Dunne 1984.

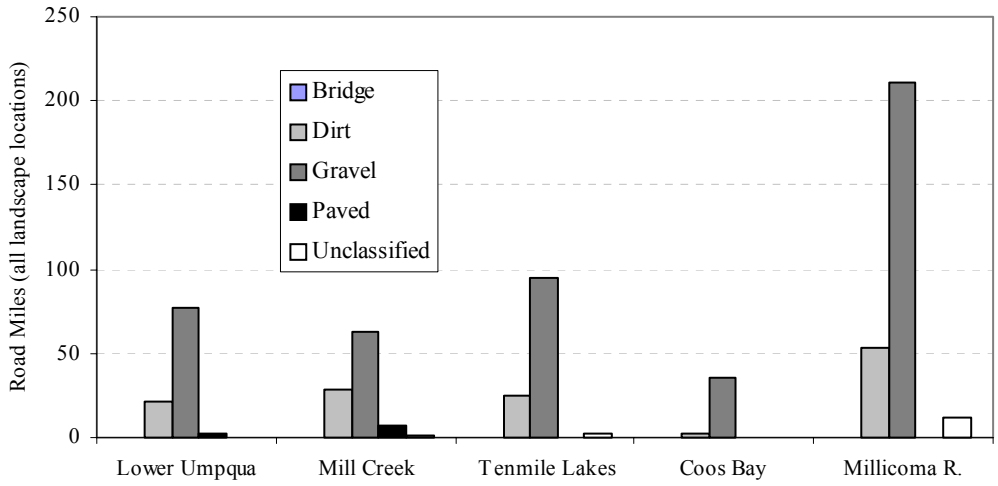
Methods

The road position and surface type information found in Table 6-7 was used for this analysis. It was assumed that all road wash from roads within approximately 100 feet of streams will deliver sediment load to the nearby stream (ODF 2003, Rashin et al. 1999). Admittedly, this criterion may over estimate the extent of hydrological connectivity between roads and streams. However, in the absence of better road survey data, this provides a first approximation of the extent of connectivity between roads and streams.

Results

Most roads on the Forest (75%) are graveled (Figure 6-4). The remaining roads are dirt and only used in dry weather. No Forest roads are currently paved; in the area, the Douglas County Road between Loon Lake and Highway 38 is paved.

Figure 6-4. Road miles by surface type and 5th field HUC.



In the absence of road use intensity information, which is needed to accurately determine sediment yields from Forest roads, the lengths of road within 100 feet of streams (both fish-bearing and non-fish-bearing streams) are shown in Table 6-14.

Table 6-14. Roads within 100 feet of streams.

Road Length >1Mile		Road Length 0.1-1.0 Mile		Road Length <0.1 Mile	
Road #	**Miles**	**Road #**	**Miles**	**Road #**	**Miles**
1000	3.90	400	0.77	2060	0.09
8000	3.80	100	0.70	2310	0.08
9000	3.07	900	0.70	6000	0.08
7400	2.56	7800	0.55	7510	0.08
8100	2.51	200	0.46	3500	0.07
2300	1.74	2000	0.40	2311	0.07
7600	1.67	7630	0.30	9500	0.06
7500	1.27	1100	0.23	9300	0.05
1600	1.12	9380	0.18	7620	0.04
2100	1.10	1822	0.18	9040	0.04
Unident.	7.56	1900	0.18	2110	0.03
		9200	0.15	9360	0.03
		300	0.14	CR 16	0.03
		5100	0.13	1870	0.01
		3300	0.13	9100	0.01
		3595	0.13		
		1820	0.13		
		503	0.12		
		7420	0.12		
		9400	0.10		
			Grand Total	**36.85 miles**	

As shown in Table 6-14, there are 10 roads in the Forest that have over 1 mile of their length within 100 feet of streams. These are the 1000 Road (Marlow Creek), 8000 Road (Joes Creek and the West Fork Millicoma River), 9000 Road (Elk Creek), 7400 Road (Fish Creek), 8100 Road (West Fork Millicoma River), 2300 Road Trout and Beaver Creeks), 7600 Road (Cougar Creek), 7500 Road (Footlog Creek), and the 1600 Road (Elk Creek). In addition, another 7.56 miles of Forest roads are within 100 feet of streams but are not identified by road number in the database.

Discussion

A roadway's surface determines its resistance to erosion. Paved, graveled and dirt types ranked from least to greatest contributors of road wash particulates. Road surfaces typically yield fine-sized sediments that adversely affect the interstitial spaces between streambed gravels used by aquatic organisms and species of concern.

A very limited number of road surface problems were identified in the 1997-1998 road inventory; because little actual site information was collected, the extent of any problems cannot be quantified. In the absence of field measured road-wash sediment yield data and calibrated sediment loads in streams of the Forest, there can be no quantifiable sediment budget developed. Currently, stream turbidity information is being compiled for calibration with rainfall response and suspended sediment discharge volume at the Marlow Creek stream gauging station (immediately above the Forest property boundary). However, this information is not yet suitable for an analysis of road wash yields.

Sediment delivered from the breakdown of road surfacing can have significant detrimental water quality effects, especially during wet hauling periods (ODF 2003). Critical determinants in the amount (and particle size distribution) of road surface-derived sediment delivered to streams is the road slope, spacing of ditch relief culverts, surfacing material quality and the effective buffer distance between the road surface and the receiving stream.

The ODF recently released new Forest Practice Rules concerning the use of durable surfacing for forest roads (ODF 2003). The ODF defines and sets testing criteria/standards for the surface material properties such as penetration and abrasion testing in order to reduce fine sediment production rates from high-traffic roadways. The new Forest Practice Rules provide a basis for evaluating where and how to protect streams from road surface related sediment (ODF 2003). While the guidance in the *Technical Notes* arrived too late to be included in this analysis, the base GIS data layers and initial analyses can be used to identify opportunities for remedial measures.

Road Drainage Features

Hydrologic connectivity occurs when road drainage is discharged directly into channels via culvert outflow or drainage ditch relief near stream channels (assumed to be within 100 feet). Either one of these conditions will potentially increases sediment transport volumes and flood stage elevations downstream. Road surveys were conducted on the Forest for three primary purposes: (1) to identify fish passage impediments at road stream crossings, (2) to

determine the degree of road failure risk, and (3) to identify potential locations where hydrologic connectivity of road drainage ditches to fish-bearing stream networks should be examined for stream-sediment abatement.

Methods

The effectiveness of road drainage features was evaluated using the Forest's 1997-1998 road survey. Key fields that describe sediment hazard included road gradient and side slopes, ditch length, proximity to stream channels, and potential delivery volumes. Sites were classified and ranked based on the Water Erosion Prediction Project (WEPP) input protocols (Foltz 1996, Elliot and Hall 1997). Each stream crossing culvert was placed into one of three categories based on its contributing ditch length. Ditches potentially contributing sediments to a stream were considered "short" if ditch lengths were less than 100 feet, "medium" if ditch lengths were between 100-360 feet, and "long" if ditch lengths were greater than 360 feet. Ditch length is only one of three factors, the other two being gradient and soil type (permeability), that determine erosion potential and sediment transport from ditches. Ditch length was the only factor consistently reported in the 1997-1998 road survey.

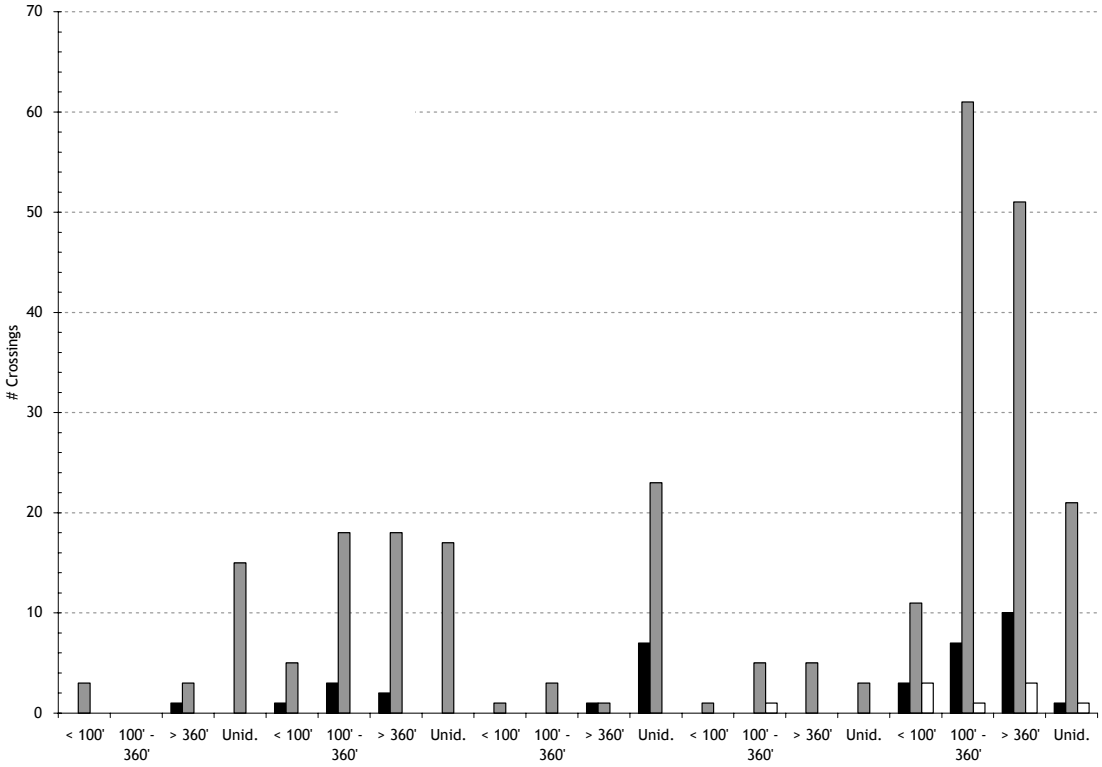
Results

The 1997-1998 road database was searched for stream crossings that were identified as having diversion potential. In these surveys, all stream crossing culverts were evaluated as sites; in addition, ditch relief culverts were included that potentially contributed sediment directly to streams. Three hundred and nine crossings met this criterion and form the basis for the evaluation of the relationship between ditch length and diversion potential (see Map 6.5). Forest road crossings with diversion potential were reported by contributing ditch length class (<100 feet, 100-360 feet, >360 feet) and by stream type (fish-bearing stream, non-fish-bearing stream, unidentified) in Figure 6-5 on a 5th field HUC basis. Table 6-15 provides similar information in numerical form including stream size.

Eighty-five percent of stream crossings in the Forest are located on non-fish-bearing streams (type N). Roads crossing small non-fish-bearing streams represent 75% of all crossings on a Forest-wide basis. Only 12% of the crossings are on fish-bearing streams (type F), divided about 40% on large and 60% on medium classified streams. At 3% of the crossings, the stream classification could not be determined.

Road ditches contributing water (and potentially sediment) into streams evidenced significant sediment. Only 9% of stream crossings had contributing ditch lengths considered "short" (<100 feet), while 32% of the crossings were in the medium (100-360 feet) length class. Thirty-one percent of stream crossings had contributing ditch lengths considered "long." In the remaining 28% of the stream crossings, contributing ditch length could not be determined.

Figure 6-5. Number of Forest road crossings with diversion potential by ditch length class.



Most stream crossings (30 out of 36) in the Tenmile Lakes 5th field HUC do not have ditch length information in the database. A similar situation (15 out of 22 unidentified) exists in the Lower Umpqua 5th field HUC. In the Middle Umpqua and Coos Bay 5th field HUCs, about one third of stream crossing records did not have information on ditch lengths. Only 13% of the sites in the Millicoma 5th field HUC failed to include ditch length information.

Discussion

Sediment resulting from ditch connectivity to streams increases the fine particulate ratios relative to background stream turbidity. The primary source of these fines is breakdown of road surfacing gravel and raveling of cut banks and ditch downcutting. These fine silt and clay particles have low settling rates and will remain in suspension longer than coarser silts and sands. Therefore, the major concern associated with these fine suspensions is not solely oriented toward the interstitial deposition in spawning gravels, but rather in water quality and potential impacts to primary and secondary (invertebrate) stream productivity.

When larger sands and silts are entrained by road ditches and delivered to the stream system, there is risk to the viability of spawning beds. This undesirable condition has led to the development of best management practices that focus on disconnecting road drainage systems from streams. Common practices include decommissioning unneeded roads,

densification of cross-drains and reduction of ditch lengths above each connected culvert or outlet, and limiting ditch maintenance frequency to maintain desirable grass cover.

Table 6-15. Contributing ditch lengths to stream crossings on Forest roads.

Watershed	Ditch Length Class	Stream Classification							Grand Total
		LF	MF	SF	LN	MN	SN	Unident.	
Lower Umpqua River 5th field HUC	<100 ft.	---	---	---	---	---	3	---	3
	100-360 ft.	---	---	---	---	---	---	---	---
	>360 ft.	---	1	---	---	---	3	---	4
	Unident.	---	---	---	---	2	13	---	15
	Total	**---**	**1**	**---**	**---**	**2**	**19**	**---**	**22**
Middle Umpqua River 5th field HUC	<100 ft.	---	1	---	---	1	4	---	6
	100-360 ft.	2	1	---	---	1	17	---	21
	>360 ft.	2	---	---	---	1	17	---	20
	Unident.	---	---	---	1	2	14	---	17
	Total	**4**	**2**	**---**	**1**	**5**	**52**	**---**	**64**
Tenmile Lakes 5th field HUC	<100 ft.	---	---	---	---	---	1	---	1
	100-360 ft.	---	---	---	---	---	3	---	3
	>360 ft.	---	1	---	---	---	1	---	2
	Unident.	---	7	---	---	1	22	---	30
	Total	**---**	**8**	**---**	**---**	**1**	**27**	**---**	**36**
Coos Bay 5th field HUC	<100 ft.	---	---	---	---	---	1	---	1
	100-360 ft.	---	---	---	---	---	5	1	6
	>360 ft.	---	---	---	---	---	5	---	5
	Unident.	---		---	---	2	1	---	3
	Total	**---**	**---**	**---**	**---**	**2**	**12**	**1**	**15**
Millicoma River 5th field HUC	<100 ft.	1	2	---	---	1	10	3	17
	100-360 ft.	2	4	1	---	8	53	1	69
	>360 ft.	3	7	---	---	10	41	3	64
	Unident.	---	1	---	---	3	18	1	23
	Total	**6**	**14**	**1**	**---**	**22**	**121**	**8**	**172**
Grand Total		**10**	**25**	**1**	**1**	**32**	**231**	**9**	**309**

LF = large fish-bearing stream; MF = medium fish-bearing stream; SF = small fish-bearing stream.
LN = large non-fish-bearing stream; MN = medium non-fish-bearing stream; SN = small non-fish-bearing stream.

Table 6-16 provides a list of Forest roads with stream crossings that have a potential to contribute sediment from ditches into streams. Roads are listed if they had at least one crossing (site) where ditch lengths were greater than 360 feet. Within this set of sites, roads are listed in declining order according to the number of failed sites on fish-bearing streams, then by number of sites "at risk." As can be seen from Table 6-16, few fish-bearing streams (type F) have long ditch lengths; a total of 10 sites with ditches longer than 360 feet and 7 sites with ditch lengths between 100-360 feet. However, there are greater numbers of sites with long ditches delivering to non-fish-bearing streams. Table 6-16 lists those sites only on roads where at least one site had a ditch length greater than 360 feet. At the time of the 1997-1998 road survey, the 8000 Road had the greatest number of sites, while another 5 roads had more than 10 sites with ditch lengths longer than 100 feet.

Table 6-16. Forest roads with sediment delivery potential from ditch delivery into stream crossing culverts.

Road	Receiving Stream	Ditch Length >360 feet				Ditch Length 100-360 feet				Total #
		Total #	F	N	Unident.	Total #	F	N	Unident.	
7400	Fish Cr.	10	2	8		3	1	2		13
2300	Trout/Beaver Crs.	4	2	2		5	1	4		9
8000	Joe's Cr./WF Millicoma	11	1	10		12	1	11		23
3000	Sullivan Cr.	6		6		3		2	1	9
2000	WF Millicoma/Dean Cr.	6	1	5		8	1	7		14
1000	Marlow Cr.	6	1	4	1	7	1	6		13
7500	Footlog Cr.	5	1	4		4	1	3		9
9000	Elk Cr.	5	1	2	2	4		4		9
7600	Cougar Cr.	4	1	3		7	1	6		11
1600	Upper Elk Cr.	3	1	2		8		7	1	11
1900	Baker/Bickford Crs.	2	1	1						2
6000	Charlotte Ridge	1	1							1
0400	Puckett Cr./Mill Cr.	2		2		5	1	4		7
1850	Glenn/Surprise Crs.	1		1		3	1	2		4
9200	Skunk Cr.	4		4		3		3		7
1840	Cedar Cr.	3		3		1		1		4
3300	Daggett/Totten Crs.	3		3		3		3		6
0320	Mill Cr. Trib.	2		2						2
7800	Salander Cr.	2		2		3		3		5
1100	Marlow Cr.	1		1		2		2		3
1860	Glenn Cr.	1		1						1
5000	Scholfield Ridge	1		1						1
7100	Knife Ridge	1		1						1
7640	Cougar Cr.	1		1						1
8200	Deer Cr. (decomm.)	1		1		1		1		2
9300	Elkhorn Ridge	1		1		1		1		2
9500	Hidden Valley Cr.	1		1						1
	Total	**76**	**10**	**63**	**3**	**76**	**7**	**67**	**2**	**152**

F = fish-bearing stream; N = non-fish-bearing stream.

The difficulty in determining hydrological connectivity (and thus sediment delivery potential) from road ditches into streams is the result of data gaps in existing Forest road surveys. Table 6-17 shows the relative types of information that can be gained from various survey intensities. The initial surveys in 1993-1994 focused on culverts that presented fish passage barriers (see discussion in Chapter 7, *Riparian Vegetation and Large Wood*). The ability to identify and analyze road sediment yield also improves as surveys are structured to collect additional variables such as road surface types, upslope road fill failures, and road use levels. Road surface types are important factors in ranking sediment production from road system elements, especially when used in conjunction with road use level and road landscape position attributes. This information also may be needed for the new ODF road inventory and maintenance database program.

Table 6-17. Road and landing surveys conducted in the Forest.

Survey Type	Culvert Inventory and Size			Road Surface Condition			Cross Drains, Berm Relieved (Ditch-outs)			Road Slides Site Volume		
	Coos	Tenmile	Umpqua	Coos	Tenmile	Umpqua	Coos	Tenmile	Umpqua	Coos	Tenmile	Umpqua
Fish passage culverts (1993-1994)	C	C	C									
All stream crossing culverts and contributing ditch relief culverts (1997-1998)	C	C	C	P*	P*	P*	P			P	P	P
All ditch relief culverts (1998-2002)	P			P			P					
All road drainage features	P			P			P, I			P		

* Road condition was noted in comments only prior to 2002; damage type and affected road length attributes were added for post-2002 surveys (Elk Creek Basin) only. Codes: C=complete, P = partial, I = Incomplete.

Road Washouts

In this section, the potential risks to streams of various sizes and fish-bearing status from road washouts is evaluated. Road washouts occur at stream crossings when flows exceed culvert capacity and go over (and along) the road. They also occur when culverts are damaged or clogged by debris and sediment, thus reducing the design capacity. Washouts also may occur where steep roads capture road ditch drainage diverted by cut bank collapse. Whatever their cause, these washouts may incise the road and eventually deliver road surface and prism sediments into streams.

Methods

The sediment transport rating used in this section was developed in the field by 1997-1998 road inventory survey personnel based upon protocols from the Pacific Watershed Associates Road Sediment Reduction Survey guidelines (PWA 1997). The database was queried to develop information on stream crossing records attributed with sediment transport capability for analysis. The sediment transport rating is an estimation of the relative capability of the stream to transport sediment (and thereby move sediment and debris down to the culvert inlet). The ranking is expressed in high, medium and low categories.

Results

The sediment transport rating at stream crossing locations was identified in the GIS and cross-referenced to the presence of fish-bearing and non-fish-bearing streams. The results of this analysis are presented in Table 6-18 by region and 5th field HUC, the number of culverts

by stream type (fish and non-fish), and size (small, medium, and large) against the sediment transport rating (high, medium, and low) at that stream crossing.

Table 6-18. Distribution of sediment transport capacity at stream crossing culverts.

5th field HUC	Sediment Transport Rating	Fish-bearing Streams			Non-fish-bearing Streams			Unident. Streams	Grand Total
		Large	Medium	Small	Large	Medium	Small		
Lower Umpqua	High	---	---	---	---	---	2	----	2
	Medium	---	2	---	---	4	20	---	26
	Low	---	---	---	---	---	4	---	4
	Unident.	---	---	---	---	---	1	---	1
	Total	**---**	**2**	**---**	**---**	**2**	**27**	**---**	**31**
Mill Creek*	High	6	2	---	2	---	2	---	12
	Medium	2	2	---	---	10	55	---	69
	Low	---	---	---	---	---	37	---	37
	Unident.	---	---	---	---	---	---	---	---
	Total	**8**	**4**	**---**	**2**	**10**	**94**	**---**	**118**
Tenmile Lakes	High	---	6	---	---	---	4	---	10
	Medium	---	10	---	---	2	34	---	46
	Low	---	---	---	---	---	5	---	5
	Unident.	---	---	---	---	---	---	---	---
	Total	**---**	**16**	**----**	**---**	**2**	**43**	**---**	**61**
Coos Bay	High	---	---	----	---	---	---	---	---
	Medium	---	---	---	---	2	2	---	4
	Low	---	---	---	---	1	16	2	19
	Unident.	---	---	---	---	---	1	---	1
	Total	**---**	**---**	**---**	**---**	**3**	**19**	**2**	**24**
Millicoma River	High	6	2	---	---	4	1	2	15
	Medium	4	17	---	---	26	66	8	121
	Low	2	6	2	---	11	174	8	203
	Unident.	---	2	---	---	3	9	---	14
	Total	**12**	**27**	**2**	**---**	**44**	**250**	**18**	**353**
Grand Total		**20**	**49**	**2**	**2**	**61**	**433**	**20**	**587**

*Includes 211 acres of the Forest in the Middle Umpqua 5th field HUC.

Patterns observed in the GIS examination of the spatial distribution of those sites considered as high hazard showed that they tended to be concentrated on certain roads. These roads are listed in Table 6-19.

Discussion

The use of the sediment transport rating in this analysis sought to identify those roads where drainage features were at greater risk of clogging from sedimentation. Culvert failures from clogging (or from under-estimated culvert discharge capacities) may lead to road washouts, a costly and undesirable source of sediment reaching streams.

Table 6-19. Forest roads with High and Moderate Sediment Transport Ratings

Road	Creek	High Washout Hazard				Moderate Washout Hazard			
		# Sites	F	N	Unident.	# Sites	F	N	Unident.
400	Puckett Cr.	1	1	---	---	7	1	6	---
1900	Bickford Cr.	1	1	---	---	---	---	---	---
2100	Johnson Cr.	3	2	1	---	9	1	8	---
2780	(Ridge)	1	---	1	---	---	---	---	---
5100	Big (closed)	4	2	2	---	15	4	11	---
7400	Fish Cr.	4	2	2	---	6	1	5	---
7500	Footlog Cr.	3	2	1	---	9	0	9	---
8100	W.F. Millicoma R.	1	1	---	---	4	0	4	---
9000	Elk Cr.	1	---	---	1	9	1	7	1
9200	Skunk Cr.	1	---	1	---	1	0	1	---

F = fish-bearing stream; N = non-fish-bearing stream.

Confidence in these results is difficult to express due to the subjective and site-specific nature of the rating method. However, when evaluated in context with road position, road gradient, ditch length, stream adjacency and culvert failures, there appears to be merit to this method as presented in the Pacific Watershed Associates report (PWA 1997), as well as in other evaluations of sediment contributions from forest roads (Rashin et al. 1999). The roads (and stream crossing sites) identified in the GIS and listed in Table 6-19 are ones that should be periodically examined and evaluated to determine whether maintenance, upgrade, or replacement is necessary.

ANALYSIS AND RECOMMENDATIONS

This chapter focused on sediment production, erosion and mass wasting, and deposition in watersheds of the Forest. Sedimentation is the result of several interlinked processes, including colluvial deep-seated and shallow landsliding and soil creep, as well as fluvial processes such as surface wash and channel bedload. While not fully within human control, large magnitude natural disturbances such as flood events and stand-replacing wildfire have the potential to produce large pulses of sediments to fish-bearing streams and tributaries. These natural processes are modified by management activities including road construction, use intensity, and drainage structure maintenance. The effects of roads on watersheds in the Forest are emphasized since they are usually the largest human-caused source of sediment.

The driving force dominating sedimentation process regimes in the Forest is the cyclic climates of the Oregon Coast Range interacting with the Forest's steep slopes. Cycles of cool and wet years, interspersed with hot, dry years, dictate fire recurrence intervals and vegetation growth. Fire and vegetation work in opposition to control resistance to surface erosion, precipitation infiltration, and mechanical reinforcement of soil.

The tectonic history and geology of the Forest also influence its propensity for landslides. These slides develop natural landforms of the Coastal Range exemplified by the Forest knife-edge ridge and ravine terrain. Massive deep-seated slides, though infrequent, may

affect large portions of the landscape. These mass movements are not readily triggered by management activities. Conversely, shallow rapidly moving landslides are more frequent, and can be affected by management activity, including road and landing location and drainage.

Aquatic organisms and ecosystems have adapted to the cycles of sedimentation driven by the variable climate of the Coast Range. Aquatic systems have evolved with the punctuated deliveries of sediment from slides, and are adapted to use the gravels and wood delivered by the slides. However, aquatic systems and populations are dependent on refugia from repeated disturbance, so it important that not all streams and areas are in flux at the same time.

Roads, as compared to in-unit harvest activities (including site preparation burns), harbor the greatest year-to-year risk for the sediment delivery to streams in the Forest. Forest roads are largely a legacy of past practices. This older road system has stabilized through time but is still subject to fill failures due to road location, road drainage malfunctions, and sections of roadways remaining with side-cast construction.

The potential for a catastrophic road fill failure delivering sediment to fish-bearing streams is a major concern for legacy roads that do not substantially meet current forest practice guidelines. Data from studies on the Forest indicate that interior roads were fairly stable during large precipitation events, such as the storms of 1996. Despite this, there were still a number of fill failure related landslides, some even originating along presumably more stable ridgeline roads where side-cast fill existed. These failures delivered significant sediment volumes to streams, including a number of sites in the northwest portion of the Forest.

Much improvement has been made to Forest roads since the 1996 storms and current maintenance practices generally keep roads in good condition. However, using road position, terrain and road slope, ditch length, diversion potential, and sediment transport rating information from the 1997-1998 Forest road inventory, potential road failure hazards were ranked to identify areas where remedial actions may be needed, if not already completed. Table 6-20 provides a listing of these potential road sediment delivery “hotspots” based on concentrations of sites identified in the individual hazard analyses.

Roads which had at least one high or moderate sediment transport hazard site were included on Table 6-20. If a road was included for other criteria, the total number of sediment transport hazard sites also was noted. Culvert and fill failure information in Table 6-20 came from Table 6-18 and associated data tables. Steep slopes (side- and road-slopes) are from data used to prepare Table 6-10. Ditch hazard sites are from Table 6-16. Road position information comes from Table 6-7. Sediment transport hazard data is from Table 6-18 for high and moderate classes on both fish-bearing and non-fish-bearing streams. The mileage of roads within 100 feet of streams is from Table 6-14.

Table 6-20. Cumulative road sediment hazard ratings by Forest road number.

Road No.	Receiving Stream(s)	Ditch Lengths (# Sites)	Culvert Failure (# Sites)	Steep Slopes (mi.)	Road Position (% sideslope & riparian)	High Sediment Transport (# Sites)	Stream Adjacent (mi.)
7400	Fish Cr.	13	10	0.30	75.2%	10	2.56
2300	Trout/Beaver Cr.	9		1.19	82.0%	4	1.74
8000	Joes Cr/W.F. Millicoma	23		0.86	88.4%	7	3.80
2000	W.F. Millicoma/Dean Cr	14		3.67	22.4%	6	0.40
1000	Marlow Cr.	13		1.11	60.9%	5	3.90
7500	Footlog Cr.	9	12	1.05	43.6%	12	1.27
9000	Elk Cr.	9	10	0.30	84.9%	8	3.07
7600	Cougar Cr.	11		0.35	70.9%	4	1.67
1600	Upper Elk Cr.	11		<0.25	90.5%	3	1.12
1900	Baker/Bickford Cr.	2	1	0.51	77.8%	2	0.18
6000	Charlotte Ridge	1		1.35	11.2%	1	0.08
400	Puckett	7	8	0.99	66.4%	8	0.77
5000	Schofield Ridge	1		1.36	30.0%	1	0
7700	Cougar Pass			0.82	66.9%		0
3000	Larson/Sullivan Cr.	9		0.82	33.8%	1	0
3500	Palouse/S.F. Johnson Cr.			0.74	18.5%		0.07
3400	Larson/Palouse			1.01	35.9%		0
7800	Salander Cr.	5		0.72	89.6%		0.55
8100	W.F. Millicoma		5	0.60	83.4%	5	2.51
9200	Skunk Cr.	7	2	<0.25	94.6%	2	0.15
1850	Glenn Cr.				20.3%	3	0

Recommendations Related to Shallow Landsliding

1. The analysis team recommends that Forest staff begin to build a database of shallow landsliding. This database could help the Forest track locations and extent of landslides over the entire Forest. The database could begin with the information from the Robison and others (1999) study and include the TLBP's survey information once additional details are resolved. This database should include in-unit landslides as well as road-related landslides. In-unit landslide information could be collected as a normal course during other management activities; road-related landslide information can be collected as part of a larger road condition inventories. The analysis team recommends that roads identified as having an unusual number of landslides in the 1997-1998 road inventory be periodically examined to see if other impending landslides continue to develop. Roads with unusual numbers of landslides included the 2800, 5240, and 5500 Roads in analysis basin #4 and 5730, 5420, 4500, and 2580 Roads in analysis basin #5.

2. The analysis team recommends that Forest staff explore strategies for providing steep draws with more wood over time so that future landslides are capable of delivering sufficient amounts of large wood, as well as gravel and boulders to fish-bearing streams.

3. The analysis team recommends that Forest staff examine the current practice of piling or removing landslide material ending up on streamside roads, and look for opportunities to place logs, boulders, and gravel in the nearby stream as the road is being cleared.

4. The analysis team recommends that the Forest improve the resolution and quality of digital elevation data. The quality of digital elevation data could be improved by following the recommendations in Robison and others (1999) and Roering and others (2003). LiDAR signals that are suitably processed into high-resolution DEMs can provide this level of information. Despite the lack of this information, the ODF practices as implemented by the Forest and ODF technical staff that provide for detailed site examination and treatment overcome many of the limitations of the existing DEM.

5. The analysis team recommends that the Forest collaborate with other state entities, such as state universities and the State Climatologist Office, to improve precipitation data and maps for the Forest. The PRISM models generated by the Oregon State Climatologist should be integrated into the official 50-year discharge maps to better evaluate runoff for culvert sizing and other hazard evaluations.

Recommendations to Reduce Road-related Sedimentation

The Forest road system is generally stable and well maintained. The ODF has improved conditions in many sites that were identified in past road surveys, but there remains a number of roads and road segments where additional investment in improvements would provide benefits to water quality and fish. These roads were identified in Table 6-20; the following discussion will use the information in Table 6-20, along with more detailed analyses found in this chapter, to identify specific roads and locations where various improvement/mitigation actions may be appropriate. The recommendations that follow were discussed with Forest road staff; however the specifics are the responsibility of the analysis team. The final decision on appropriateness of any recommendation lies with ODF, based not only on watershed benefits but also on cost and operability considerations.

Continue Investing in High Levels of Road Maintenance

The generally good road conditions in the Forest are the result of previous investments in upgrades and maintenance. Continued investments are the most cost-effective way to prevent future problems. Specific maintenance practices that will reduce hazards are:

- ⇒ Maintain and/or improve gravel quality, particularly for top-dressing and along heavily traveled roads adjacent to streams.
- ⇒ Consider “spot-treating” rather than periodic entire road segment ditch pulling to clean out sediments from bank ravel and small slides.
- ⇒ Establish a schedule for periodic re-rocking of major haul routes to insure an adequate, clean, gravel surface based on road use intensity and location.
- ⇒ Insure that outside berms are cleared after grading operations, especially on roads adjacent to streams.

⇒ Reduce the potential for hydrological connectivity by reducing outlet water velocities at drainage culverts.

Roads Where Additional Ditch Relief Culverts Appear Needed

Much road improvement work has been accomplished on the Forest since the 1997-1998 survey was completed. It is difficult without updated information to determine the extent to which ditch relief culverts have remedied problems identified in the 1997-1998 survey. However, based on those survey results, the following roads would most benefit from a program to upgrade ditch relief culverts throughout their length to insure that their diameter, spacing, and discharge points meet current best management practices:

⇒ 1000 Road along Marlow Creek (Millicoma R. 5th field HUC).
⇒ 1600 Upper Elk Creek Road (Millicoma R. 5th field HUC).
⇒ 2300 Road along Trout and Beaver Creeks (Millicoma R. 5th field HUC).
⇒ 5000 Road along Scholfield Ridge (Lower Umpqua R. 5th field HUC).
⇒ 6000 Road along Charlotte Ridge (Lower Umpqua R. 5th field HUC).
⇒ 8000 Road along Joes Creek and W.F. Millicoma (Millicoma R. 5th field HUC).
⇒ 9000 Road along Elk Creek (Millicoma R. 5th field HUC).

The above roads are listed because they combine of high numbers of stream crossings outside best management practices criteria (<100 feet) and a large proportion of "steep-on-steep" terrain with roads predominantly side-slope in their landscape location.

Roads Where Paving may Reduce Sediment Delivery

On roads where wet hauling is infeasible or undesirable, and continued high maintenance costs are incurred for repeated gravelling, paving may become a more cost-effective option for reducing road surface derived fine sediments delivery to streams. Roads where partial or full paving would provide chronic sediment production benefits include:

⇒ 1000 Road along Marlow Creek (Millicoma R. 5th field HUC).
⇒ 8000 Road along the West Fork Millicoma River (Millicoma R. 5th field HUC).
⇒ 9000 Road along Elk Creek (Millicoma R. 5th field HUC).

There are possible places where paving may be the best mechanism to reduce chronic sediment delivery into these high-quality salmon streams. In the case of the Marlow Creek roadway where valley confinement forces road proximity to the stream channel, a strong case could be made for paving. The 8000 and 9000 Roads also are in adverse locations relative to fish-bearing streams and should be of concern to management due primarily to their ditch lengths draining into streams (ODF 2003). For these latter two roads, spot paving along portions adjacent to streams and on approaches to bridges may be a cost-effective solution.

Roads Where Re-engineering may be Needed to Reduce Road-related Sediment Hazards

A few roads in the Forest have a legacy of road-related hazards (see Table 6-20) but are still crucial to the Forest for its transportation network. For these roads, significant investments and re-engineering may be required to bring them up to current best management practice standards. Roads that should be evaluated to this type of upgrade include:

- ⇒ 0400 Road along Puckett Creek (Mill Creek 5th field HUC)
- ⇒ 2000 Road on Allegany side around the 2.0 – 2.5 mile markers
- ⇒ 3000 Road along Sullivan Ridge
- ⇒ 3300 Road along Daggett Creek
- ⇒ 3400 Road along Larson Ridge
- ⇒ 3500 Road above Palouse Creek
- ⇒ 7400 Road along Fish Creek (W.F. Millicoma R. 5th field HUC)
- ⇒ 7500 Road along Footlog Creek (Mill Creek 5th field HUC)

With the exception of the 0400 Road along Puckett Creek and the 7500 Road along Footlog Creek, the remaining roads are all located in the Coos watershed, mostly in the Coos Bay 5th field HUC. The primary concern for these roads is their legacy of side-cast construction that results in periodic slides from fill failure. The 7400 Road along Fish Creek has been upgraded since the 1996 storm, but may still need additional work along its mid-slope portion based on the GIS analysis. The partial closure through relocating access from mainline roads may be preferable for 0400 Road, which has future timber sales scheduled.

The 7500 Road along Footlog Creek has drainage problems along its mid-slope portion and considerable debris between the road and creek along its lower two miles. This road continually showed up as being at risk for most all the hazard criteria; and field inspection verified a number of problem types and locations. Because it is a major hauling route between the Umpcoos Ridge Road and Highway 38, the Footlog Creek Road (7500) would be difficult to replace. However, the Charlotte Ridge (6000) and Dean Mountain (2000) Roads are alternate mainline routes towards Reedsport, while the Cougar Pass (7700) is an alternate connector to Highway 38 towards Scottsburg.

Roads Where Decommissioning may Reduce Road-related Sediment Hazards

A few roads in the Forest have such a concentration of road-related hazards (see Table 6-19) that closure and/or relocation may be the preferable management action. Closure may be desirable for these roads because their location adjacent to streams means that relocation would be expensive while incurring additional environmental impacts. These roads include:

- ⇒ 0100 Road along Charlotte Creek (Lower Umpqua R. 5th field HUC)
- ⇒ 0200 Road along Luder Creek (Lower Umpqua R. 5th field HUC)
- ⇒ 0900 Road along Johanneson Creek (Lower Umpqua R. 5th field HUC)

- ⇒ 7600 Road along Cougar Creek (W.F. Millicoma R. 5th field HUC)
- ⇒ 8100 Road along the W.F. Millicoma River (W.F. Millicoma R. 5th field HUC)

The ODF should evaluate whether these roads can be brought up to current standard or whether the amount of work needed exceeds their value. The Cougar Creek Road has a long reach parallel to high quality coho salmon spawning and rearing areas. Alternate roads, such as Kelly Ridge (7650) and Fish Ridge (7300), may provide (or could be improved to provide) adequate haul routes.

The 8100 Road along the West Fork Millicoma River is a special case because it is used more for recreational, rather than forest management, purposes. The ODF has periodically (and largely unsuccessfully) attempted to block access into this area. A case can be made that water quality and fish could benefit from road closure, especially once additional in-stream habitat improvement work is complete.

Past Road Closures to be Evaluated

Five major roads along high-quality fish-bearing streams have been closed by ODF. These include:

- ⇒ Big Creek Road (Tenmile Lakes 5th field HUC).
- ⇒ Johnson Creek Road (Tenmile Lakes 5th field HUC).
- ⇒ Deer Creek Road (Millicoma R. 5th field HUC).
- ⇒ Knife Creek Road (Millicoma R. 5th field HUC).
- ⇒ Crane Creek Road (Millicoma R. 5th field HUC).

Inspection of a past closure in Crane Creek showed that the work was incomplete. The closed Crane Creek road needs additional culvert removal, fill pullback, and revegetation to reduce sediment delivery hazards. The status of other closures is not yet fully known; they should be inspected and any needed remedial measures implemented.

Additional Road Surveys Needed

The 1997-1998 Forest-wide road survey emphasized identifying stream crossing culvert sites that posed a catastrophic sediment delivery risk. Subsequent to those surveys, much road improvement work has been completed. However, the 1997-1998 surveys are noticeably lacking on information about chronic sediment yield. As part of this assessment, road surveys in the Elk Creek watershed were updated by the Coos Watershed Association. The results of this partial study indicated that chronic sediment yields could be determined, and management options developed, if roads are re-surveyed using current protocols.

New road surveys and survey protocols need to better assess hydrologic connectivity downslope of all drainage outfalls. It cannot be established through the existing survey data that there is strong connectivity of ridgeline and side-slope roads draining to fluvial channels via debris torrent tracks.

The analysis team recommends that ODF conduct or fund a resurvey of Forest roads beginning with those mainline roads listed in Table 6-20 as having high ditch length, steep road/steep slope and road position hazard levels. Additional priority could be given to those roads identified for improvement through paving and/or the addition of ditch relief culverts. An alternate prioritizing strategy would be to survey high hazard sites based on criteria found in the recent *Forest Practice Technical Notes* (ODF 2003) and identifiable through the GIS process used for this chapter.

Need for Road Use Intensity Information

A more important factor governing sediment wash from road surfaces is the level of use intensity accrued on wet surfaces. This factor and the degree of surface breakdown between precipitation events govern the transport and supply of road fines to fish-bearing streams. High use intensity on wet roads proximal to streams typically produces the least desirable stream water quality. Unfortunately, the use intensity and spatial patterns can be quite irregular and difficult to assess due to lack of data and dynamic nature of the harvest unit access routes.

While road use intensity changes reflecting the pattern of forest management operations use levels is a critical data requirement for understanding the effects of roads on watersheds. The analysis team recommends that ODF consider cost-effective strategies to obtain this information for use in their new road inventory database.