Water

Key Points

- Watersheds and subwatersheds (10,000 to 250,000 acres) are the most relevant scales to describe hydrologic processes and the cumulative effects of forest management.
- The BLM typically manages only a small percentage of the land and streams within any particular fifth/sixth field watershed.
- Streams that occur on BLM-administered lands are mostly smaller, headwater streams that are important to determining the condition of larger streams and rivers.
- Stream temperature 303(d) water quality listings often are made from mouth to headwaters and are the most common listing on BLM and intermingled private lands. More than 90% of BLM riparian forests provide excellent shading of the streams.
- Landsliding and road runoff are the primary routes of sediment delivery to stream channels.
- Forest management generally has little to do with enhancing peak flows at a fifth-field watershed scale.
- Changes to peak flows at small scales may occur through the removal of forest vegetation and the changes to infiltration and runoff caused by forest roads. As storm size increases, there is little evidence that forest harvest increases peak flows at any scale with recurrence intervals greater than six years.

There are 143,044 miles of streams and rivers within the planning area. See *Table 3-52* (*Miles of streams with BLM ownership within the planning area*). They occur in a variety of landscapes from coastal rain-influenced streams to snowmelt-influenced streams in the Cascades Mountains and in eastern Oregon near Klamath Falls. Within this distribution, there are 20,407 miles of streams and rivers and 218,199 acres of lakes, ponds, and wetlands on BLM-administered land. These water features support aquatic ecosystems under varying conditions according to past disturbance, topography, geomorphology, elevation, and physiographic province.

Large river basins are a mosaic of smaller watersheds linked by stream, riparian, and subsurface networks. Within basins, links among headwater tributaries and downstream channels are important paths for water, sediment, and disturbances.

The causes of change to hydrologic processes include removal of forest vegetation and changes to infiltration and the flow of surface and subsurface water. Changes in hydrologic processes are manifested in such water quality parameters as temperature and sediment.

Hydrologic features (including stream patterns, stream density, stream relief, stream bed and bank characteristics, and natural streamflow response) vary by physiographic province (FEMAT 1993, Appendix

Table 3-52. Miles Of Streams With BLM Ownership Within The Planning Area

Stream Periodicity	Planning Area Streams (miles)	BLM Streams (miles)	BLM Stream Miles (%)
Perennial[a]	57,626	6,728	**12**
Intermittent[b]	85,418	13,679	**16**
Totals	**143,044**	**20,407**	**14**

[a] Perennial streams have varying but continuous discharge year round. Their base level is at, or below, the water table.

[b] Intermittent streams are a nonpermanent drainage feature with a dry period, normally for three months or more. Flowing water forms a channel feature with well-defined bed and banks, and bed-forms showing annual scour or deposition, within a continuous channel network.

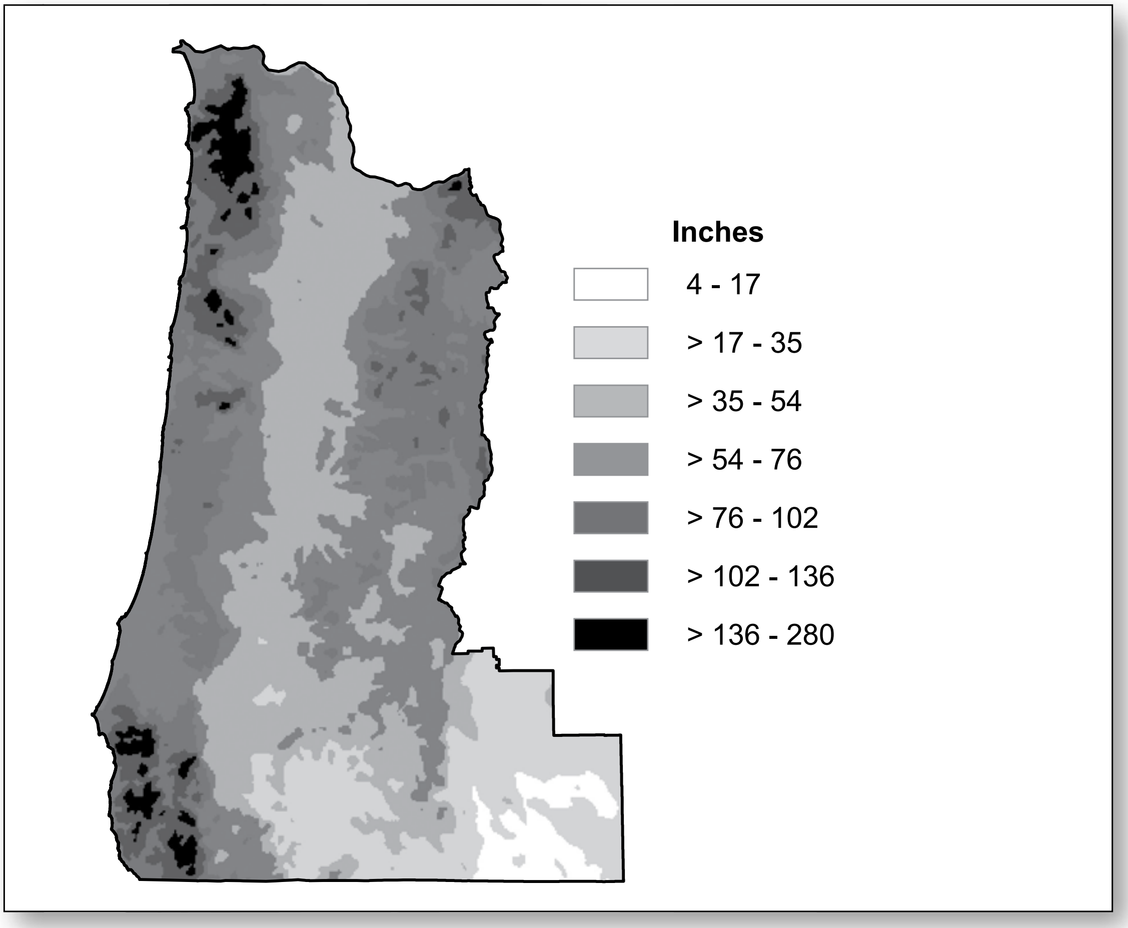
V-G). Riparian vegetation community types also reflect differences in geology, landforms, aspect, soil mineralogy and development, and influencing hillslope processes.

Climate factors, such as precipitation and temperature, interact with physiography to provide the setting for hydrologic processes and disturbance events. Peakflow results from the rainfall of winter storms moving onshore from the Pacific Ocean, snowmelt, and also from convective storms (southern part of the state).

There is great variation in the precipitation and temperature regimes within the planning area. See *Figure 3-73* (*Normal annual precipitation*). Typically, moisture-laden maritime fronts move onshore from the west. These fronts drop moisture as they move east and encounter mountains. Temperatures vary with proximity to the ocean, changes in elevation, and latitude.

- The Coast Range provides intense rapid lift and receives annual precipitation depths varying from 40 inches to greater than 180 inches. Heavy precipitation amounts (combined with steep landforms, concave headwalls, thin soils, weak bedding planes, and weathering) contribute to high landslide frequency. Snowfall seldom occurs in the Coast Range but, when it does, it is usually transitory and above 2,000 feet of elevation.
- The Willamette Valley has less precipitation because storm fronts drop much of their moisture as they move over the Coast Range. The mildness of the Willamette Valley and other western Oregon inland valleys causes snow to be rare even though moisture is relatively abundant.

Figure 3-73. Normal Annual Precipitation



- The West Cascades Mountains and Klamath Mountains see an increase in precipitation because storm fronts gain moisture as they move over the valley and have renewed uplift. Precipitation amounts vary from 80-100 inches in the north Cascades, to 50-60 inches in the south Cascades and Klamath region. Precipitation drops rapidly to less than 45 inches in the eastern Klamath Mountains. Temperatures are lower and moisture is still abundant, so snow is more frequent. Intermittent snow accumulation occurs in the western Cascade Mountains from 1,500 to 3,500 feet in the north, and from 2,000 to 4,500 feet in the south Cascades and Klamath Mountains. Winter snow pack occurs in the high and eastern Cascade Mountains.
- Once over the Cascade Mountains, precipitation diminishes rapidly to less than 15 inches on the eastern edge of the planning area near Klamath Falls. Eastern Oregon receives most of its winter precipitation in the form of snow, although the lower annual precipitation makes the actual snowfall amounts much lower than in the Cascade Mountains.

More than 85% of peak flows from rain and rain-on-snow occur in winter between November and February (Cooper 2005). Snowmelt from winter accumulation in upper elevations occurs in the spring, and thunderstorms bring precipitation in the summer.

A drainage basin is an area of land that catches precipitation falling within its perimeter and moves the precipitation downslope as surface or subsurface flow under the influence of gravity to a creek, stream, or river, until the water drains into an ocean or a closed basin lake.

Hydrologic units (HUC) are a way of classifying drainage basins (Seaber et al. 2007) in a manner that nests them into a multi-level hierarchical drainage system.

- The largest hydrologic unit of classification divides the nation into 21 major geographic regions with an average size of 177,000 square miles. These geographic areas contain either the drainage area of a major river, or the combined drainage areas of a series of rivers.
- An intermediate unit is called a watershed. They are generally 40,000 to 250,000 acres in size. There are 260 watersheds in the planning area. Of these, 176 watersheds contain BLM ownership.
- The smallest hydrologic unit is called a subwatershed, which ranges from 10,000 to 40,000 acres in size.

See *Table 3-53* (*Major river basins within the planning area*) for the major river basins within the planning area and the number of BLM watersheds within each basin province.

Dunne et al. (2001) have proposed that watersheds and subwatersheds are the most relevant for describing hydrologic processes and the effects for cumulative watershed effects analysis.

Geographic areas must be large enough to capture an assemblage of small source areas within mountainous terrain with varying forest environments. These headwater source areas contribute to a range of stream channels, from juvenile steep gradient channels confined by hillslopes, to more well-developed, low-gradient alluvial types with associated floodplains (Montgomery and Buffington 1997). Typically, the watershed scale is necessary to typify the complexity of stream development.

In mountainous areas, streams gain size in a downstream direction and become perennial at a high enough watershed area and difference in relief where the water table stays above the surface.

Downstream mainstem streams at the lower end of watersheds are normally low gradient, except for geologic disconformities. These streams are receptors of the combination of nonpoint pollutants (e.g., temperature and sediment) associated with management activities. Typically, within the planning area, these mainstem streams involve less than 40% of the total stream network and are in areas where a cumulative effect on water would occur.

Table 3-53. Major River Basins Within The Planning Area

Hydrologic Unit Code (HUC)	River Basin	Total Area (square miles)	Proportion within the Planning Area	Number of Watersheds
170800	Lower Columbia: The drainage into the Pacific Ocean including downstream tributaries including the Sandy River (Oregon)	6,250	22%	24
170900	Willamette	11,400	12%	48
171002	Northern Oregon Coastal: The drainage into the Pacific Ocean from the Columbia River Basin boundary to the Umpqua River Basin boundary	4,312	100%	34
171003	Southern Oregon Coastal: The drainage into the Pacific Ocean from and including the Umpqua and Rogue River basins to the Smith River Basin boundary (California and Oregon)	12,582	100%	72
180102	Klamath: The Klamath River Basin (California and Oregon)	15,500	32%	23

The BLM typically manages only a small percentage of the land and stream miles within any particular watershed. See *Figure 3-74* (*Contrasting BLM ownership in the Evans Creek and Eagle Creek watersheds*). The combined actions across all ownerships determine the total impacts to the physical, chemical, and biological condition of downstream rivers. The intermingled land ownership pattern within the planning area can also make it difficult to separate out the amount of impact caused by any particular owner.

Stream type and size are important because:

- The BLM-administered lands are more heavily concentrated in headwaters, typified by small, typically steep-gradient high-energy streams.
- Forest roads that cross small streams are potential flow and sediment delivery augmentation points.
- Many small streams on BLM-administered lands do not flow continuously by late summer.
- Small streams are important in determining the condition of larger streams and rivers.
- Floodplains are associated with larger streams.
- The BLM often manages a small percentage of the riparian areas along larger streams.

See *Table 3-52* (*Miles of streams with BLM ownership within the planning area*) for the miles of streams within the planning area by stream periodicity. See *Table 3-54* (*Stream type descriptions*) for the primary stream type descriptions and their relative proportion within the planning area.

Water Quality

High-quality water is essential for consumptive use and survival, growth, reproduction, and the migration of individuals that comprise aquatic and riparian communities (FEMAT 1993, V-14). This includes an abundance of cold (generally, less than 64°F), well-oxygenated water that is present at all times of the year, and is also free of excessive amounts of suspended sediments (Sullivan et al.1987) and other pollutants (Cordone and Kelley 1961, Lloyd et al. 1987).

Figure 3-74. Contrasting BLM Ownership In The Evans Creek And Eagle Creek Watersheds

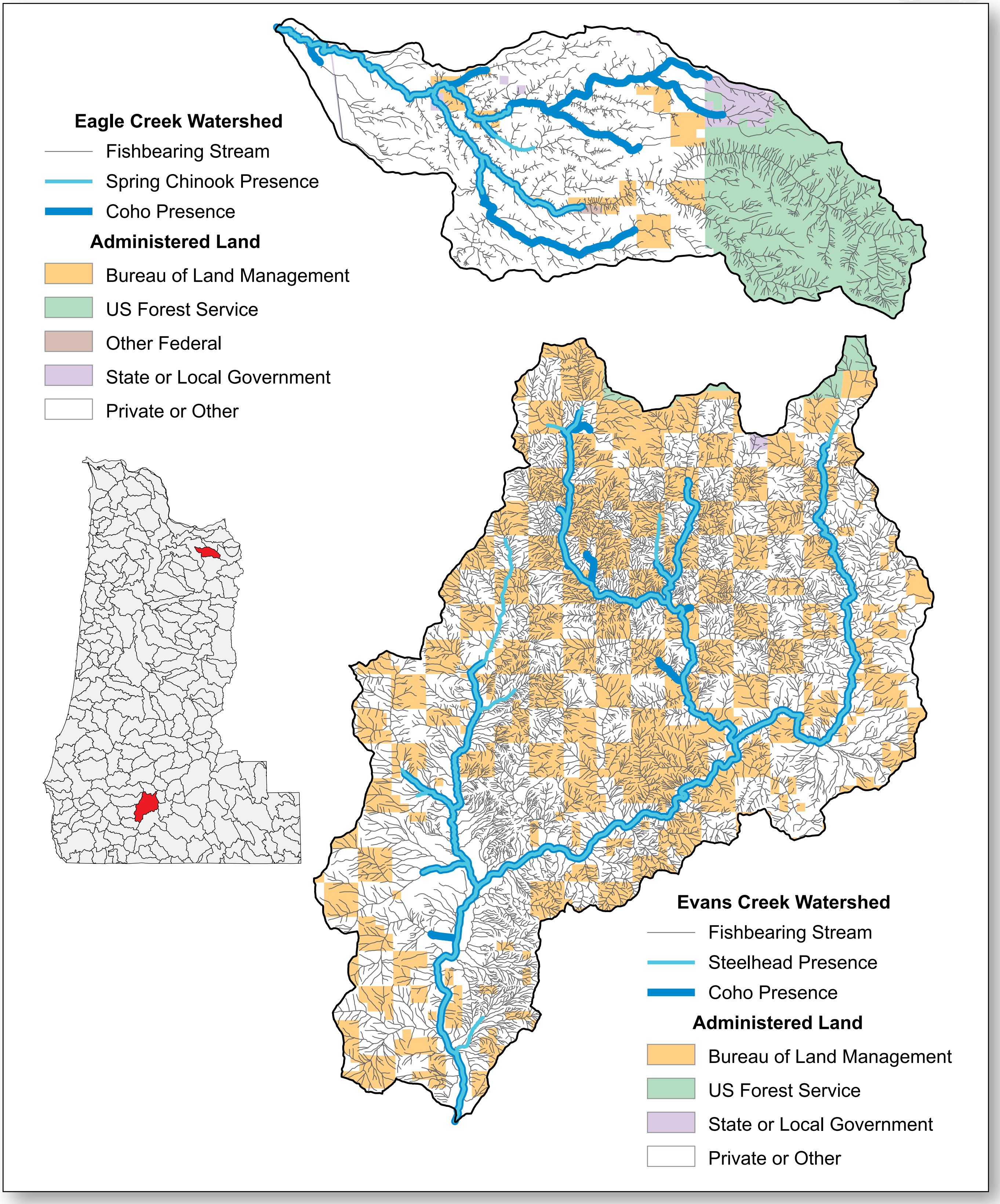


Table 3-54. Stream Type Descriptions

Primary Stream Types	Gradient (feet)	Confinement	Valley Bottom Type	Relative Proportion Within the Planning Area
Cascade	> 20%	Confined	None	60%[a]
Steep	4 to 20%	Confined	None	
Step-pool	2 to 3.9%	Moderately confined	None or narrow, and occasional floodplain feature	40%
Pool-riffle	< 2%	Unconfined	Narrow to wide and floodplains present	
Braided	< 4%	Unconfined	Wide and floodplains present	
Flat	< 2%	Confined	Narrow to wide	

[a] ODEQ estimates 85% in this category for 1 to 3 order streams (ODEQ 2004b).

The Clean Water Act (§ 101[a]) was intended to restore and maintain the physical, chemical, and biological integrity of the nation's waters. The Oregon Department of Environmental Quality is responsible for developing water quality standards and determining where there is impairment of Oregon's streams and lakes as outlined in DEQ's 2004/2006 integrated report. By agreement with the Oregon Department of Environmental Quality, the BLM is recognized as a designated management agency for implementing the federal Clean Water Act (as amended by the Water Quality Act of 1987) on BLM-administered lands in Oregon. This includes selecting appropriate best management practices to maintain water quality for the variety of ongoing forest activities.

Of the 143,044 miles of streams and rivers within the planning area, there are 10,611 miles of streams that are listed as impaired (303[d] listed) for at least one water quality measure. Of these, 948 miles (9%)[8] occur in watersheds with BLM ownership. See *Table 3-55 (Miles of BLM streams on the Oregon Department of Environmental Quality 303[d] list*) and *Figure 3-75* (*303[d] listed streams within the planning area*). The most common listing on BLM-administered lands is water temperature.

Stream Temperature

Highly shaded streams often enjoy cooler stream temperatures due to reduced input of solar energy (Brown 1969, Beschta et al. 1987, Holaday 1992, Lee et al. 2004). Increased stream temperatures can result from removal of shade-producing riparian vegetation along fish-bearing streams and smaller tributary streams that supply cold water to the fish-bearing streams (Beschta et al. 1987, Bisson et al. 1987). Stream morphology, flow, climate, and geographic location also influence stream temperature.

The key factors that produce highly shaded streams include:

- The trees that are closest to a stream channel, including overhanging branches, provide the most shade.
- Narrower riparian areas with closely spaced trees have nearly the same shading effect as wider riparian areas with broadly spaced trees.
- There is little shade gained from trees that are more than 100 feet away from a stream's edge.
- The majority of riparian forests along perennial streams on BLM-administered land are well stocked stands, 40 to 150 years of age, that are tall and dense enough to offer shade.

Solar radiation is the most important source of radiant energy affecting stream temperature (Brown 1969, Beschta 1997). Effectiveness of streamside vegetation to provide shade varies with topography, stream orientation, extent of canopy opening above the channel, and forest structure (USDA USDI 2005b).

TABLE 3-55. MILES OF BLM STREAMS ON THE OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY (ODEQ) 303(D) LIST

ODEQ 303(d) Listing	Stream Impairment Identified on BLM Streams (miles)	Affected BLM Fifth-Field Watersheds (number)
Temperature	760	105
Dissolved oxygen	108	29
Bacteria	77	26
Sediment	44	7
Heavy metals	28	4

Note: Based on ODEQ's 2004-2006 303(d) list.

Forest trees near stream channels and dense stands can block solar radiation and cast shadows across the stream. Angular canopy density is the measure of canopy closure, projected in a straight line from the stream surface to the sun, as it varies through the day. The angular canopy density value for a given buffer depends on the spacing and depth of crowns in the forest canopy. As vegetation becomes more open through wider spacing, more width of vegetation is needed to achieve the same angular canopy density for the similar vegetation with closer spacing. Higher angular canopy density is achieved with a combination of higher canopy density and/or increased buffer strip width. See *Figure 3-76* (*Angular canopy density and buffer widths for small streams within the planning area*) (Brazier and Brown 1972) to see how angular canopy density varies with riparian area width.

Disturbance plays an important role in the density of riparian forests. Climate variation, windstorms, landslides, floods, and insect and disease infestations are disturbance agents within the planning area. Tree blowdown is the most common, especially when regeneration harvests are adjacent to riparian leave areas. Topography (such as narrow valleys, ridges, or saddles) exposed to the prevailing wind can channel windflow and cause damaging effects. Ordinarily, riparian buffers along perennial streams are in relatively sheltered valley locations. A study by Steimblums et al. 1984 examined 40 sites in the West Cascades from 1-15 years after harvest, where blowdown was present, and found the percentage of windthrow was from 11

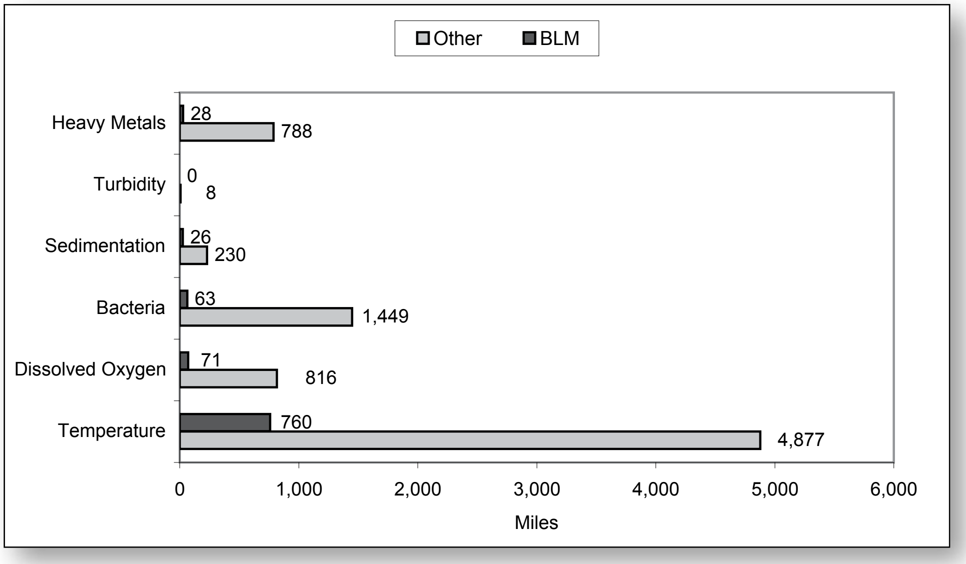
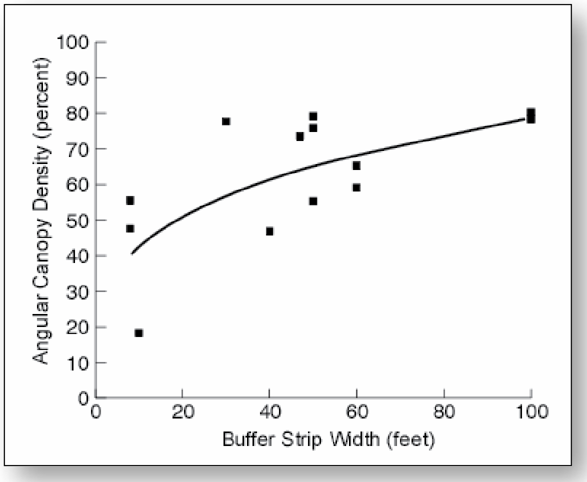


FIGURE 3-75. 303(D) LISTED STREAMS WITHIN THE PLANNING AREA

Figure 3-76. Angular Canopy Density And Buffer Widths For Small Streams Within The Planning Area



to 54 percent within forest species groups. In order of most to least windfirm were western red cedar, western hemlock, Douglas-fir and the true firs. When study results are converted from percentage of trees lost to the effect on angular canopy density, it suggests that a wider riparian leave area width is needed to provide the same amount of shade. See *Figure 3-77 (Angular canopy density and buffer widths with blowdown for small streams within the planning area.)*. Comparing *Figures 3-77* and *3-78,* it can be seen that the buffer strip width must increase from approximately 100 feet to 120 feet to maintain the same angular canopy density of 80%. Disturbance, such as blowdown, results in forest canopy gaps where greater width of the riparian leave area is required to provide a similar shade density.

Angular canopy density is also related to the effective stream shade. See *Figure 3-78 (Angular canopy density and stream shade*) (Park 1991). Effective shade is the total solar radiation blocked from reaching the stream over a 24-hour period (USDA USDI 2005b). Effective shade is defined as:

$$\frac{\text{Total Solar Radiation} - \text{Total Solar Radiation Reaching the Stream}}{\text{Total Solar Radiation}}$$

Effective shade is influenced by slope steepness, vegetation species composition, tree height vegetation density, tree distance from the stream bank, and stream width. Thus, although riparian vegetation is a physical barrier between the stream and incoming solar radiation, only a portion of the riparian canopy contributes to effective shade (USDA USDI 2005b). The relationship and interplay of the variables that affect effective shade can be simplified, to some degree, using geometry and computer models that simulate shade (Boyd 1996, Park 1993).

See *Figure 3-79* (*Stream shade and change in water temperature*) for an illustration of the results of modeling

Figure 3-77. Angular Canopy Density And Buffer Widths With Blowdown For Small Streams Within The Planning Area.

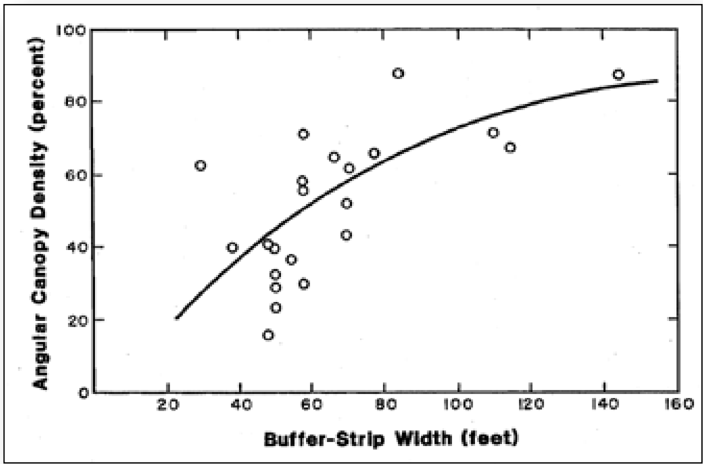
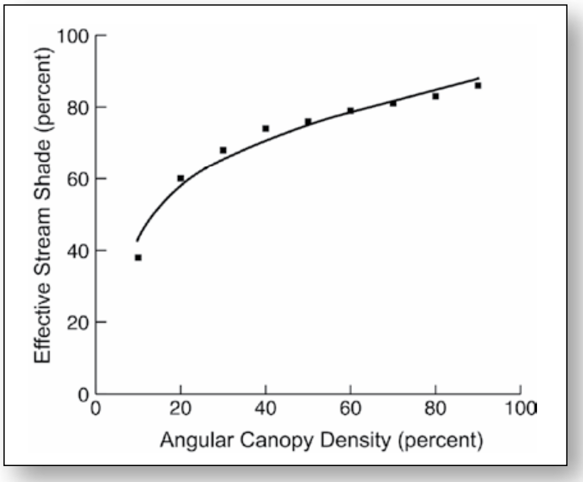


Figure 3-78. Angular Canopy Density And Stream Shade



to represent the downstream change in water temperature relative to effective shade (USDA USDI 2005b). This figure illustrates that as effective shade increases beyond 40%, there is a corresponding reduction in stream temperature to a point (e.g., approximately 80%) beyond which further reduction in stream temperature as a function of shade may not be measurable (Boyd 1996). Furthermore, as is shown in Figures 3-103, 3-104 and 3-105, for this 80% angular canopy density and 80% effective shade level, there is marginal improvement in stream shade for riparian areas wider than 100 feet, or 120 feet with blowdown. This marginal improvement is due to the variables of total solar radiation reaching a stream being diminished by the blocking ability of the riparian forest.

One way of describing these riparian management areas is by assigning average primary and secondary shade zone distances. See *Table 3-56* (*Shade zones*) for the primary and secondary shade zone distances of riparian trees as a function of tree height and slope steepness.

The period of greatest solar heating occurs between 10 a.m. and 2 p.m. Vegetation that intercepts solar radiation between these hours is critical for providing stream shade (USDA USDI 2005b). This vegetation constitutes the primary shade zone. During the morning and afternoon hours, trees outside the primary shade zone can also provide stream shade (USDA USDI 2005b). This area is referred to as the secondary shade zone. See *Figure 3-80* (*Relationship of primary and secondary shade zones*) for an illustration of these two shade zones (USDA USDI 2005b).

Site potential tree heights vary among tree species, with mature conifers being substantially taller than mature hardwoods. Soil quality, aspect, elevation, and physiographic province are also important in determining site potential tree height capability. See *Figure 3-81* (*Riparian tree heights by physiographic province and percent of BLM area*) for the range of tree heights for site potential conifers by each physiographic province within the planning area.

Both the young and mature structural stage classes of forests have tree heights and crown areas that provide effective shading. This is because the tree heights are tall enough to cast shadows from 20 to 100 feet, and the stand density is normally higher than in older forests. Higher density leads to greater sun-blocking ability and greater shade quality. Forests provide the most shade when tree crowns grow closed, and somewhat less shade (through stand competition and individual tree mortality) as the trees mature over time.

Natural fire has been suppressed during the last century, and prescribed fire interacts with the landscape in different ways. These small and large disturbances over time have influenced the trajectory of forest stands. The historical percentage of old growth forest at a given time within the planning area ranged from 35 to 80% (Agee 1993).

Riparian forest microclimate (air temperature and relative humidity) gradients for unmanaged forests and riparian buffers are greatest within 33 feet of streams. For riparian buffers beyond 66 feet of streams, evidence for increasing air temperature or relative humidity is not distinguishable from the upslope (Rykken et al. 2007). Chan et al. (2004) found that the greatest change in microclimate was from stream center to 15 feet, and there were few differences in treatment plots outside this area. Their findings indicate that buffers beyond 15 feet from the stream channel are moderating microclimate more slowly, and that thinning

Table 3-56. Shade Zones

Shade Zones	Height of Riparian Tree	Shade Zone Distance from Edge of Stream		
		Slope < 30%	Slope 30 to 60%	Slope > 60%
Primary	< 20 feet	12 feet	14 feet	15 feet
	20 to 60 feet	28 feet	33.feet	55 feet
	> 60 to 100 feet	50 feet	55 feet	60 feet
Secondary		>50 feet	>55 feet	>60 feet

Source: USDA USDI 2005b

FIGURE 3-79. STREAM SHADE AND CHANGE IN WATER TEMPERATURE

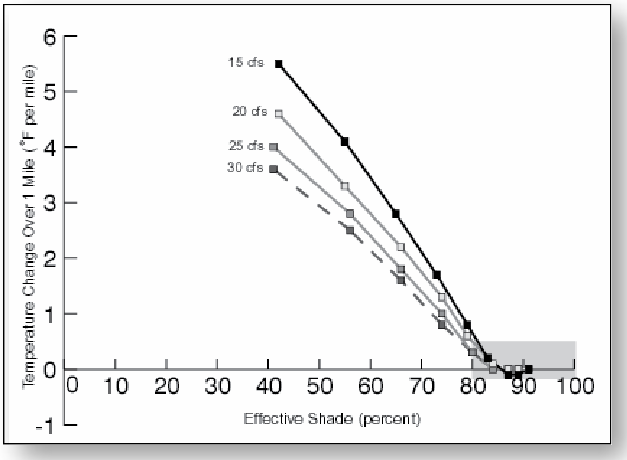


FIGURE 3-80. RELATIONSHIP OF PRIMARY AND SECONDARY SHADE ZONES

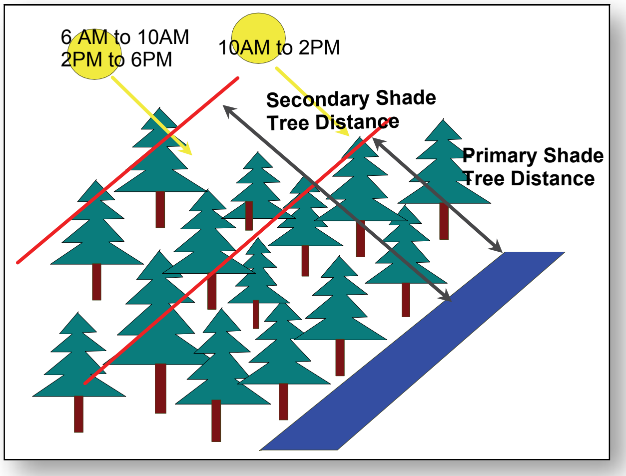
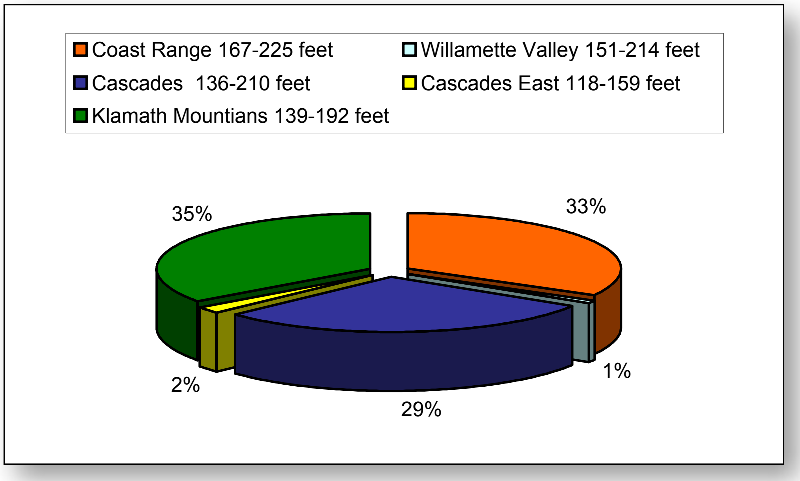


FIGURE 3-81. RIPARIAN TREE HEIGHTS BY PHYSIOGRAPHIC PROVINCE AND PERCENT OF BLM AREA



to 40 trees per acre may not significantly raise soil or air temperatures, or decrease relative humidity.

The composition and pattern of riparian forest land varies within the planning area. In prelogged riparian forests in the Coast Range, less than 45% of riparian areas were in old forests (Ripple et al. 2000). Sample plots show that historic crown closure was greater than 70% with stands consisting of:

- 49% conifer
- 30% conifer-dominated mixed stands
- 19% hardwood-dominated and mixed stands
- 2% nonforest

Although infrequent, large-scale natural disturbances occur within riparian areas. Sampled plots in the Coast Range show that the five disturbances which altered regeneration of shade-intolerant species occurred in the last 100 years for each mile of stream since a stand-replacing fire (Nierenberg and Hibbs 2000).

Nierenberg and Hibbs (2000) also found that 52% of riparian areas along first to fourth order streams on the first terrace had no trees. This suggests that early competition from shrubs following a stand-replacing fire, lack of a seed source, or infrequent large floods causing deposition are factors that control the dominance and the seral stage of vegetation close to the stream. With increasing distance from these streams, the amount of hardwoods and nonforest decreases. This is evidence that hardwoods and shrubs are the largest limiting factor to conifer growth in or near stream areas, and that historic conifer abundance in unmanaged riparian areas is lower than widely believed.

Harvesting practices during the period from the 1950s to 1980s often removed much of the standing marketable timber from riparian areas along larger streams. This is because transportation systems were first developed along ridge tops and valley bottoms before more difficult midslope roads were attempted. During the 1970s, there was a large salvage program within riparian areas because the breaking up of debris jams was thought to benefit fish migration. This thinking was reversed by the early 1980s, but much of the long-lasting stream-structural-forming large wood (such as western red cedar and Port-Orford-cedar) had been removed.

The Northwest Forest Plan's 10-year monitoring report titled *Northwest Forest Plan – The First 10 Years (1994-2003): Synthesis of Monitoring and Research Results* (Haynes et al. 2006) reported that condition scores for 161 of the 250 sampled watersheds improved from 1994 to 2003. The change in watershed condition scores was attributed primarily to changes in the riparian vegetation, specifically the number of large trees in the riparian areas. The number of large trees increased an estimated 2 to 4% during this time, which was most likely the result of tree growth into the greater than 20-inch diameter at breast height category (Gallo et al. 2005).

Shade in the riparian areas along perennial streams on BLM-administered lands continues to improve, because there has been little regeneration harvesting (limited to small-scale species conversion) in riparian areas in the last 20 years. The OPTIONS modeling indicates that, of the riparian trees within 100 feet of all perennial and intermittent fish-bearing streams, the trees are currently as follows:

- 4% in the stand establishment structural stage
- 41% are young
- 28% are mature
- 27% are structurally complex

Based on near stream riparian forest structure alone at a plan level, there is a high confidence that 80% effective shade goals are currently being met on more than 90% of the riparian management areas. In many cases, BLM thinning treatments along perennial streams have left high levels of canopy closure or retention areas adjacent to streams and waterbodies. The area beyond 100 feet, or 120 feet with blowdown (as shown in *Figures* 3-103, 3-104 and 3-105) has little effect on increased shading of streams, particularly when a thinned forest stand is left to provide additional tree shading.

Dissolved Oxygen

High loading of fine organic matter, such as tree branches and needles, when combined with sediment and increased water temperature can deplete dissolved oxygen in small mountain streams (Wringler and Hall 1975). However, these streams are often steep with high turbulence, which quickly replenishes the dissolved oxygen (Ice 1978). A review of the oxygen requirements of aquatic organisms does not attribute changes in intergravel dissolved oxygen to management activities in the Pacific Northwest (Chapman and Mcleod 1987).

The growth and respiration of attached algae cause day and night fluctuations in dissolved oxygen concentrations. Algae photosynthesis releases oxygen into the water during the day and respiration consumes oxygen at night, which contributes to a dissolved oxygen depression. This cyclic process is limited to low-gradient river systems where nutrient inputs have caused extensive algae growth on the stream bottoms. Algae growth is most apparent during low flows, which may be aggravated by organic inputs and higher stream temperatures.

Bacteria

In forested and rangeland settings, the total coliform and fecal coliform bacteria are monitored depending on the extent of human and animal use. Many of the coliform bacteria include an array of aerobic and anaerobic bacteria, and many of those are nonpathogenic or associated with human waste. Fecal coliform are bacteria that are found in the gut of warm-blooded animals. A variety of diseases may be spread by these bacteria. The presence of coliform bacteria in the water on BLM-administered lands is associated with wild animals, concentrated livestock use, or poor waste disposal by recreation users. In 1996, the state of Oregon adopted a water quality standard based on *Escherichia coli* (E. coli), recognizing E. coli as an indicator of pathogenic potential (Cude and Curtis 2005.) Dispersing activities away from water normally solves bacteria concentrations, because soils act as a filtering system.

Sediment

The planning area is underlain by portions of five physiographic provinces with geologic features that lead to differences in soil development:

- The Coast Range is part of a large, uplifted basin. Much of the soils in this region are derived from sedimentary rock and are shallow to moderately deep, moderately steep to very steep, gravelly and loamy soils.
- The Cascade Province was created by two volcanic episodes resulting in the West Cascades (earliest) and the high Cascades (latest). Mountain rock types include basalt, andesite and associated tuffs, and tephra. Erosion of these systems has produced fine and coarse sediment-based soil parent material, including large volcanic landslides deposits.
- The Willamette Province lies between the Cascade and Coast mountain ranges in western Oregon. This province includes almost the entire Willamette River drainage, a tributary to the Columbia River. Along the valley floor, the river has recent alluvial terraces and floodplains; further out, the river has old valley fill and ancient high terraces. The area is bounded by low elevation hills.
- The Klamath Province is the most geologically complex province in southwestern Oregon. This province is comprised of very old (over 144 million years) sedimentary, volcanic, and metamorphic rocks. The rocks are locally and regionally altered by heat and pressure, and have intrusions of granite and serpentine.
- The Eastern Cascades Province (Basin and Range) is dominated by volcanic rocks including basalts, tuffs, and tuffaceous sediments. Numerous large calderas in the southeastern part of the state erupted thick ash deposits, which were the source of voluminous stream-deposited sediments in the basin. As vast freshwater lakes receded from the Ice Age, there were fluvial and lacustrine deposits laid down in valley fill.

The Medford District within the Klamath Province includes an area of very erodible granitic, schist, and pyroclastic soils. The largest concentration of these soils that formed from decomposed schist and/or granite parent material occurs in Evans, Snow, Sugar, and Meadow Creeks; the upper portions of Williams Creek; and the headwaters of Birdseye Creek. Granitic soils are highly erosive. Once disturbed, these soils are extremely difficult to stabilize. Soils that formed in highly weathered, pyroclastic parent materials are predominantly in the foothills of the Cascades. Pyroclastic flows are fluid mixtures of hot rock fragments, ash, and gases that sweep down the flanks of volcanoes during eruptions. Pyroclastic soil parent material is coarse, with a sand and gravel texture, and has very high erodibility when disturbed.

On-site soil loss is a natural weathering process. Fragmental rock, soil, and organic material that are detached can be redistributed by gravity, wind, and water. When this material arrives at, is eroded from, or is transported in a waterbody, it is known as sediment. Sediment moves in water when water velocities are great enough to cause suspension and entrainment (i.e., mobilization). Sediment moves as a suspended load in a water column, or as larger particles rolling along the stream bottom. Sediment is freely transported through high-gradient stream reaches and is deposited on bars and channel margins in low-gradient streams.

Natural rates of on-site soil loss vary greatly within the planning area, depending on the physiographic area where differences in parent materials lead to differential rock and soil weathering. Equally important factors include landslope and shape where gravity assists a material's movement on steeper slopes. Ameliorating effects that slow down on-site soil loss include vegetation, soil surface organic matter, and/or surface rock content and roughness. Seasonal climatology with the variable effects of wind and water cause erosion in unprotected areas, and particularly large storms may trigger landsliding. Cleanup activities associated with landslides account for the largest portion of the annual sediment budget.

Only a portion of on-site soil loss results in delivery as sediment to a stream or waterbody. More often, soil is redistributed on the slope (Swanson et al. 1982). Sediment delivery depends on land and vegetation factors, as well as drainage density. When sediment is delivered, the stream channel geometry, slope, and substrate affect sediment movement through stream systems. In small stream channels, instream large woody debris functions as a long-term storage site for sediment deposits (Swanson et al. 1982). For these reasons, natural rates of sediment yields from watersheds are highly variable from year to year. For example, Flynn Creek Experimental Watershed, which served as a control in the Alsea study in the Coast Range, reported natural annual sediment yields that varied from 59 tons to 1,237 tons per square mile per year (Brown and Krygier 1971).

Fine sediment (particle sizes less than 2 millimeters) is of most interest, because it is more easily mobilized and capable of traveling the distances necessary to reach a stream or waterbody. Various studies show that average annual sediment yield from natural and human-made sources in the Coast Range Province varies from 200 to 800 tons per square mile per year, compared to the West Cascades Province where it varies from 100 to 500 tons (Swanson et al. 1982, Grant et al. 1991, Stallman et al. 2005).

Sediment Delivery from Roads

Forest management activities (including road building, timber harvesting, and site preparation activities) can lead to accelerated rates of erosion and sediment yield (FEMAT 1993, V-16). In one study on the USFS H. J. Andrews experimental forest, sediment input from roads accounted for 67% of the total annual sediment input (Swanson et al. 1982). This was attributed to poor road building practices of the time, compounded by large storm events.

Roads may divert water and sediment from natural paths through the watershed, introducing new and multiple flowpaths for water and sediment. Road networks can change the flow of water and sediment in a watershed through:

- road surfaces draining directly into streams
- roads intercepting road surface and hillslope water, and rerouting as concentrated flow with eroded sediment by way of ditchlines to streams (Wemple 1998, Jones et al. 2000). (If improperly installed, roadside ditch relief culverts can deliver water and sediments to streams.)
- floatable debris plugging stream crossing culverts during flood flows, causing water to impound behind the road fill with possible stream diversions or road failures
- road construction on steep and unstable ground, leading to accelerated rates of erosion in a watershed (Swanston and Swanson 1976, Reid and Dunne 1984)

Road runoff and landsliding are the primary routes of sediment delivery to stream channels. Road parent material, location, design, use, and density can be important in affecting the extent and magnitude of road-related sediment impacts (Reiter et al. 1995).

Roads differ in their inherent erodibility, or erosion potential, due to the geology of a parent material on which they are constructed. See *Figure 3-82 (Surface erosion classes within the planning area)* (Walker and King 1969). Sediment yields by erosion from older roads (> two years old) with undisturbed ditches are much smaller than sediment yields from newer roads (< two years old) or roads with disturbed ditches. See *Table 3-57 (Basic erosion rates for roads based on the underlying geology)*. The BLM controls approximately 14,000 miles of road within the planning area. Much of the road network length is on ridgetops or traverses areas well away from stream channels. See *Figure 3-83* (*Road distribution in a representative watershed*).

Sediment travel distances along roadways vary by geologic parent material and physiographic province as shown in *Table 3-58* (*Reported sediment travel distances along roadways*).

Primary road sediment sources include:

- Exposed surfaces that can erode, including roadways without surfacing and also poorly vegetated

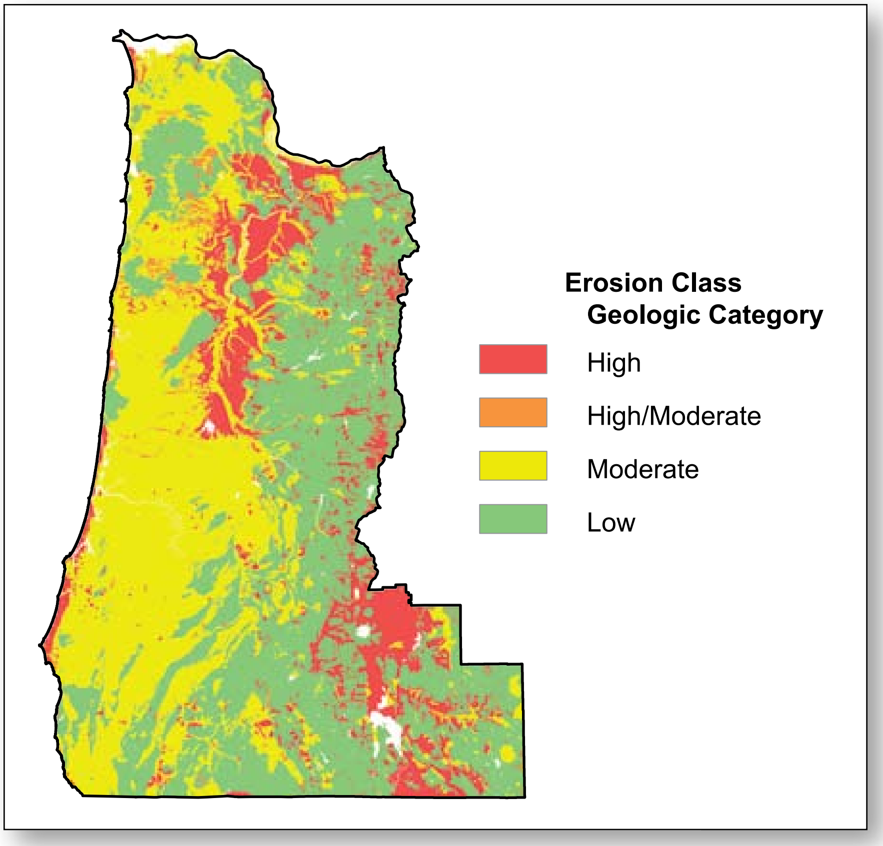


Figure 3-82. Surface Erosion Classes Within The Planning Area

Table 3-57. Basic Erosion Rates For Roads Based On The Underlying Geology

Erosion Category	**Geologic Parent Material**	**Erosion Rates** (tons/acre/year)	
		New Roads (0 to 2 years)	**Old Roads** (> 2 years)
High	• Mica schist • Volcanic ash • Highly weathered sedimentary rock	110	60
High/Moderate	• Quartzite • Coarse-grained granite	110	30
Moderate	• Fine-grained granite • Moderately weathered rock • Sedimentary rocks	60	30
Low	• Competent granite • Basalt • Metamorphic rocks • Relatively unweathered rocks	20	10

Note: Basic erosion rates (tons per acre per year) are an estimate of erodibility, which is based on the geologic parent material. This rate is for bare ground and is further reduced depending on road surface type, vegetation of cut -and fill-slopes, and traffic level.

Sources: Kochendorfer and Helvey 1984, Hayden et al. 1991, Megahan and Kidd 1972, Reid and Dunne 1984, Sullivan and Duncan 1980.

Figure 3-83. Road Distribution In A Representative Watershed

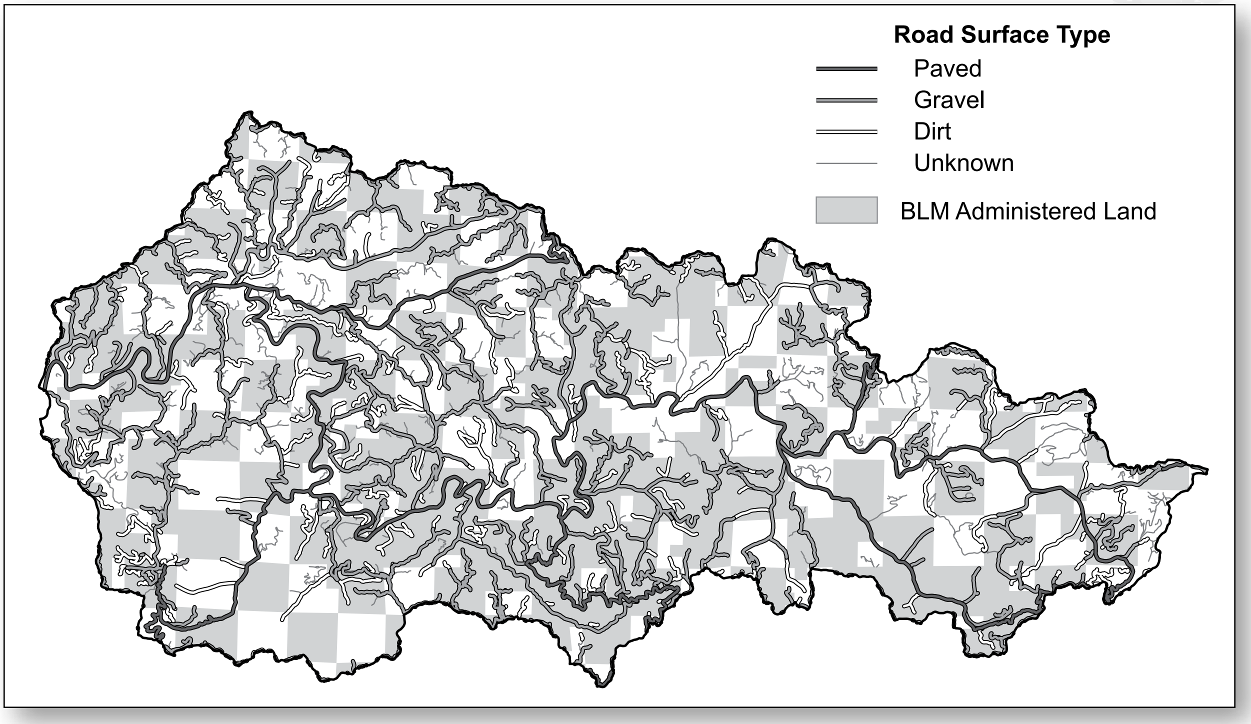


Table 3-58. Reported Sediment Travel Distances Along Roadways

Study	Geology	Location	Range (feet)	Mean (feet)
Brake et al. 1997	Sandstone/Siltstone	Culvert, road < 5 years old	3 - 132	31
		Culvert, road > 5 years old	0 - 76	17
Brake et al. 1997	Sandstone/Siltstone	Debris below culvert opening	< 33	
Packer 1967	Volcanics/Basalt	Below road fill slopes	35 - 127	
Burroughs and King 1989	Gneiss and Schist	Below road fill slopes	< 88	
Ketcheson and Megahan 1996	Granitic	Fill slope	1 - 217	12
		Rockdrain	4 – 111	12
Burroughs and King 1989	Granitic	Culvert	0 - 639	126
Swift 1986	Metamorphosed Igneous	Grass fill and forest litter	30 - 314	45
Swift 1986	Metamorphosed Igneous	Grass fill and brush barrier with brush barrier	2 - 287	34

cuts and fills. Erosion may result by overland flow from rainwater or snowmelt, or from concentrated flow in ditches. Of note is that:

  - New road construction has much higher erosion than older roads (>two years old) if revegetation is not promptly completed.
  - The BLM controls approximately 1,000 miles of natural surface road within the planning area that is more susceptible to erosion than roads with surfacing.

- Breakdown of the road tread by hauling on aggregate-surfaced roads. Winter haul is of particular concern since heavy trucks traveling over wet roads are more likely to break down the road tread. About 30 to 40% of the total BLM timber log truck miles occurs during the higher precipitation months (November-April). One study in the Cascades reported that 12 logging truck making round-trips each day of a work week during the November to January period resulted in a 17% increase in sediment yield (Luce and Black 2001).
- Inadequate ditch relief culverts, resulting in elevated ditch flow that can mobilize sediment to streams.
- Stream crossings with undersized pipes or crossings that traverse debris-flow streams. Roads in upland areas cross small seasonal streams more frequently and therefore have greater potential for delivery of fine sediment.
- Older roads in poor locations, or built without improved construction practices. Mid-slope roads with steep and unstable road cuts and deep fills (particularly those within the slide-out range of a stream channel) pose the highest risk for landslides. Older roads that were side-cast constructed, built on fills with organic material, or crossed slide-prone ground that have not yet failed are also at higher risk. In the West Cascades Province, road fill failures were found to represent the most frequent cause of debris flow initiation (Swanson et al. 1982).
- Road grading and blading of ditches. Studies show the following:
  - Frequent road maintenance of ditchlines can increase sediment yields by removing an armor layer and the stabilizing vegetation (Luce and Black 2001). However, maintenance is necessary for safe travel and to prevent failure of the drainage system. One study showed that ditch-blading resulted in average sediment yield equal to 12 log trucks per day of winter haul traffic on aggregate roads (Luce and Black 2001). Effects are site specific to the travelway and recover rapidly.

Modeling was used to determine the effects of the alternatives on fine sediment delivery from roads within the stream influence zone. The model was based on the concept of using reference roads. See *Appendix J - Fish*.

The 185 watersheds with varying amounts of BLM-administered lands were included in the analysis. A 200-feet sediment delivery buffer was created around all stream channels in all ownerships. The BLM roads data layer, which includes roads on all lands, was intersected with the 200-feet sediment delivery buffer. Road segments that crossed streams were selected since they are most likely to deliver fine sediment to streams. The amount of potential fine sediment delivery was calculated for thousands of these road segments. Factors used to estimate the amount of fine sediment included road erodibility, road surfacing, vegetation on road cut and fill slopes, and traffic level.

See *Table 3-59* (*Potential fine sediment delivery from existing roads*) for the potential fine sediment delivery for the existing condition. Approximately 36% of all roads on BLM-administered lands are within the likely sediment delivery distance (5,096 miles of 14,273 total BLM miles). When considering all roads, the highest yield is from natural surface roads, which average 9.61 tons per square mile per year. The lowest yield is from paved roads, which average 1.58 tons per square mile per year.

See *Figure 3-84* (*Watersheds with the highest fine sediment delivery from roads)* for the highest (25%) fine sediment delivery watersheds that contain BLM-administered lands. Sediment delivery to stream channels

Table 3-59. Potential Fine Sediment Delivery From Existing Roads

Existing Roads[a]	Roads Within Fine Sediment Delivery Distance (miles)[b]		Potential Fine Sediment Delivery (tons/year)[c]		Watershed Potential Fine Sediment Delivery (tons/mile^2/year)[c]	
	BLM	**Other**	**BLM**	**Other**	**BLM**	**Other**
Natural	1,738	15,874	23,050	233,054	0.86	8.75
Aggregate	2,590	22,938	28,938	30,765	1.09	1.15
Paved	767	2,436	8,277	33,807	0.31	1.27
Totals	**5,096**	**21,249**	**60,265**	**297,626**	**2.26**	**11.17**

[a] Includes BLM-controlled roads and private roads within the planning area from BLM GIS GTRN (roads) coverage.

[b] Includes road segments within 200 feet of a stream channel where ditch flow, carrying fine sediment, could enter streams.

[c] Planning criteria estimate in which calculations are based on surface type for each fifth-field watershed and summed for the planning area.

within these watersheds ranges from 34 to 77 tons per mile per year, which averages 43 tons per mile per year. Elsewhere, sediment delivery to stream channels ranges from zero to 43 tons per mile per year, which averages 17 tons per mile per year. The Klamath and Coast Range Provinces contain the highest number of these sensitive watersheds. This is likely due to underlying geology and landforms.

Sediment Delivery from Mass Wasting

Landslides occur on a small percentage of forest lands, over a variety of forest types, whether managed or unmanaged. Timber harvesting activities can influence the rate of shallow colluvial landsliding, mass failures, and debris torrents depending on the harvest location, type of harvest, design, and operation.

The BLM uses the timber productivity capability classification (TPCC) to screen for low forest productivity timberlands and landslide-prone areas, and withdraws them from general forest management. This classification is ongoing and periodically updated by silviculturalists and soil specialists based on interpretations of aerial photography and ground review. Approximately 89,937 acres of BLM-administered lands (3.8% of BLM-administered lands) within the planning area are withdrawn from harvest due to forest capability or land stability concerns. See *Figure 3-85 (Timber productivity capability classification withdrawn areas in a representative watershed)* for an example of a representative watershed with these withdrawals.

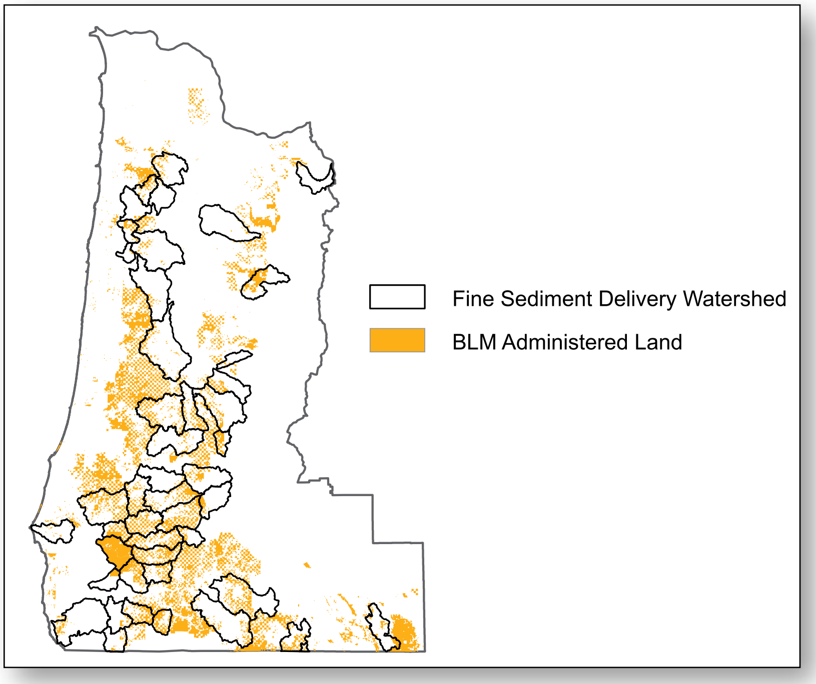


Figure 3-84. Watersheds With The Highest Fine Sediment Delivery From Roads

Most landsliding occurs during large storms when soils are fully saturated. Landsliding factors include:

- topography shape
- steepness of slope
- soil depth and texture

- underlying rock bedding planes
- forest cover
- water runoff pathways

Western Oregon has the highest hazard for landslides in the planning area where failures occur more frequently on steep slopes over 70 to 80% (ODF 1999). Basal area retention of forest trees can be important in preventing landslides on unstable terrain. Retention trees transpire water and intercept moisture in their canopies, and live roots increase soil strength, both of which increase stability. For the 1996 extreme storms, landslide densities and size in the Coast Range were the highest for regeneration harvests that were zero to 9 years old, lower for mature forests, and lowest for forested areas between 10 to 100 years (ODF 1999). In another Coast Range study (Miller and Burnett 2007), reported landslide density for unforested areas and forests <10years of 21.76 per square mile; mixed forests 10-80 years and 4 to 20 inches DBH and hardwoods of 8.03 per square mile; and large forests >80 years and 20-inches DBH of 6.47 per square mile. Landslide area ranged from 0.002 acres to 12 acres, with a mean of 0.25 acres.

Miller (2003), Miller and Benda (2005) and Miller and Burnett (2007) have developed a GIS-based mass wasting hazard model for western Oregon and throughout the planning area to estimate the susceptibility to shallow colluvial landsliding and wood recruitment to stream channels. Although the model was used to predict landslides for different forest age-classes, regeneration harvest is of more interest in forest management, because of increased landslide susceptibility on fragile ground for a short period of time. After regeneration harvest, the root strength of dead roots declines, whereas root reinforcement of live roots increases as the new forest stand grows. Root strength drops to a low point in seven years in the Northwest's coniferous forests and then improves rapidly (Ziemer 1981). Susceptible landslide areas and probability of failure are highly correlated with extreme storms and forest vegetation at that time. For recently regeneration-harvested forests, with no large storms in the regrowth period, the vegetation and root reinforcement increases; and after 10 years, lowers the landslide susceptibility substantially, similar to mixed forests or hardwood stands (Ziemer 1981, Miller and Burnett 2007).The mass wasting hazard model

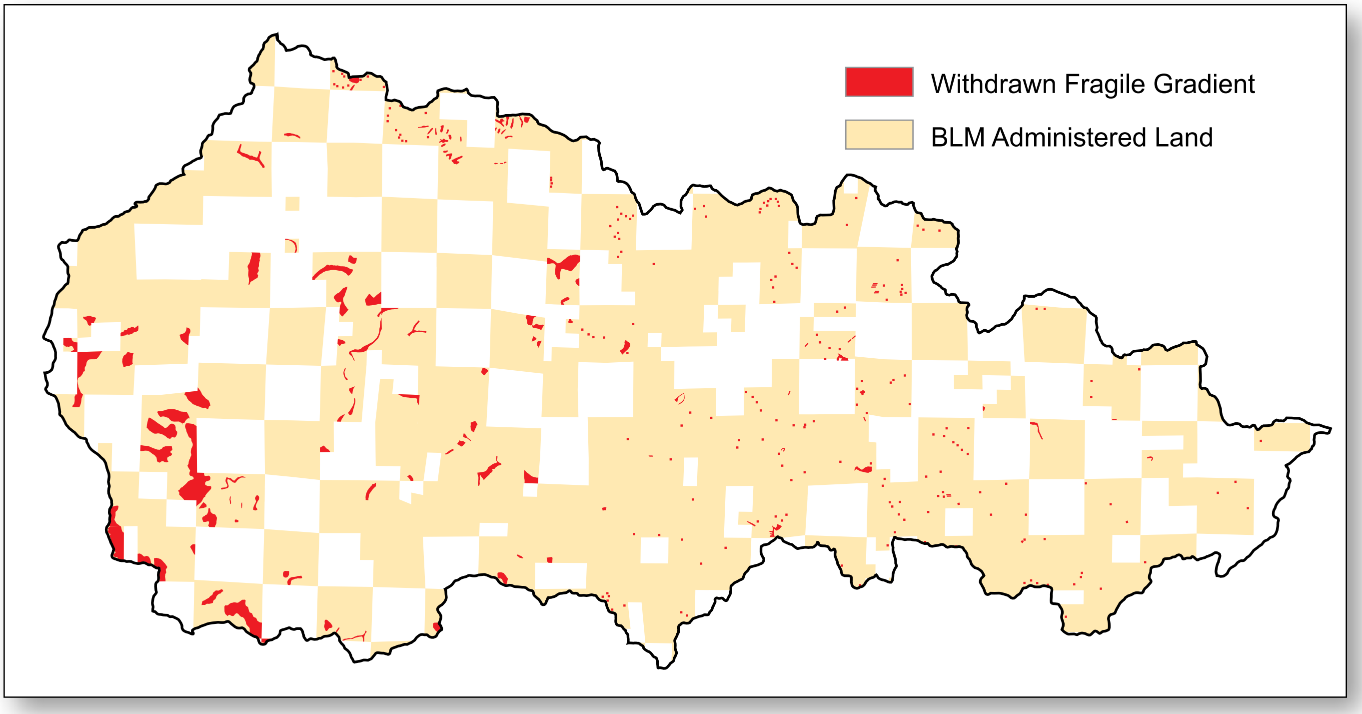


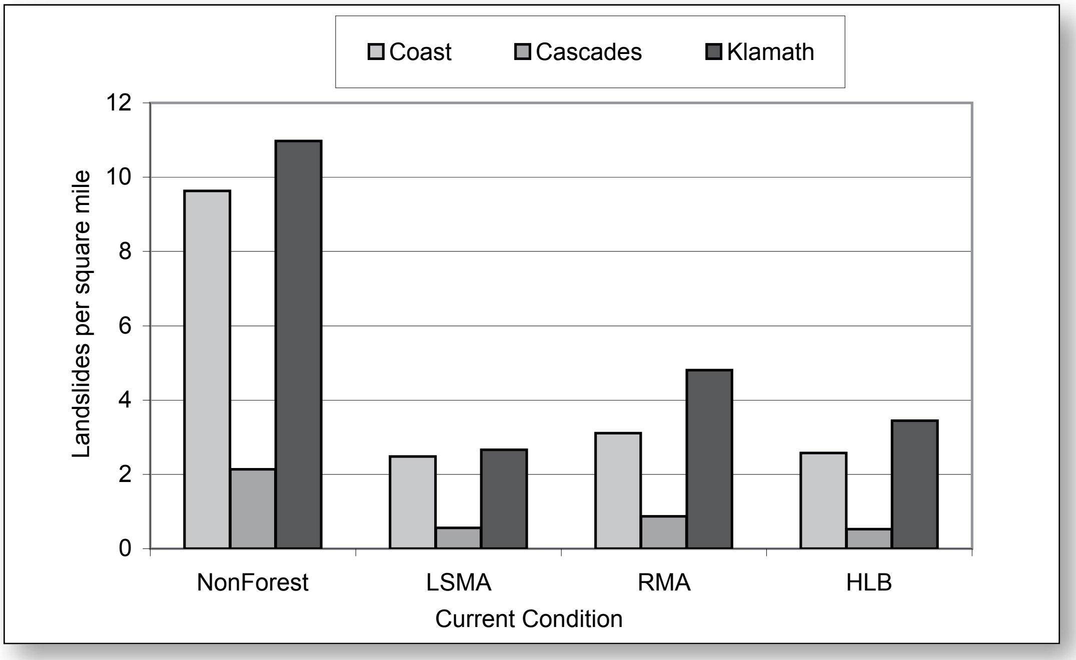
Figure 3-85. Timber Productivity Capability Classification Withdrawn Areas In A Representative Watershed

was calibrated using landslide inventories from the Coast Range, West Cascades, and Klamath Provinces. Observed landslides from the 1996 storms in the Coast Range and 1997 storms in the Cascades and Klamath Mountains were matched with topographic attributes. These storms are considered infrequent or extreme storms with 70-year to 100-year return periods. Of particular importance is the steepness of slope, watershed convergence, and source area.

Relative landslide density was modeled for the plan revision. For a forest cover type, the landslide model isolates susceptible topographic areas and reports a landslide density, based on the calibration landslide dataset where landslides have been observed. The dataset is further modified by the influence of roads. See planning criteria in *Appendix J - Fish*. Further, the landslide density model determined which susceptible topographic areas may deliver to a stream channel. *Figure 3-86* (*Relative landslide density that could deliver to stream channels on BLM-administered lands*) shows a bar graph of relative landslide densities by province for the current conditions of non-forest area, riparian management area, late-successional management area, and the harvest land base. Across the planning area, the relative landslide density varies, being higher within the Klamath Province, somewhat lower in the Coast Range Province, and lowest in the Cascade Provinces. Within provinces, non-forest has the highest relative landslide density, followed by riparian areas, with the late-successional management areas and the harvest land base being the lowest and relatively comparable. Timber productivity capability classification withdrawals were not separated in these results. In intensively managed landscapes, a range of relative landslide densities that could deliver to a stream channel, as modeled, varied from 0 to 15 landslides per square mile.

Fire effects on sediment yields vary, depending on fire severity, frequency, climate, vegetation, and geomorphic factors such as topography, geology, and soils (Swanson 1981). Soil erosion after fires can vary from 0.4 to 2.6 tons per acre per year in prescribed burns. More intense wildfires can create soil erosion that is an order of magnitude higher (Megahan and Molitor 1975). Recovery rate is rapid as grass, forbs, and

Figure 3-86. Relative Landslide Density That Could Deliver To Stream Channels On BLM-Administered Lands



Relative landslide densities are weighted averages for non-forest, recent harvest areas, young forest, and mature forest for a set of watersheds comprising each province. Landslide delivery is to stream channels <20% gradient. (LSMA: Late-successional management area, RMA: riparian management area, and HLB: harvest land base) shrubs occupy the site. Swift (1986) found that sediment travel distances on a burned forest floor may vary from zero to 198 feet, with an average of 96 feet.

Many older roads on poor locations (i.e., with inadequate design and maintenance) pose high risks of erosion and sedimentation to stream channels and habitats from mass failure (FEMAT 1993, V-16). Where failures occurred, these landslides have been the most important source of management-accelerated delivery of sediment to anadromous fish habitats within the planning area (Ice 1985, Swanson et al. 1985).

Landslides are highly correlated with flood flows. The largest floods in the last half century were the 1953 flood, 1955-1956 floods, the 1964 flood (all long duration, high intensity, rain-on-snow events); the February 1996 flood (long duration, high intensity, rain-on-snow event); November 1996 flood (short duration, high intensity, rain event); and the January 1997 event (high intensity rainfall and snowmelt). See *Figure 3-87* (*November 1996 precipitation return period for western Oregon*) for the return period for daily precipitation for western Oregon for the November 1996 storm (Oregon Climate Service).

Observed landslides from an aerial reconnaissance survey of 83 watersheds in the Coast Range and West Cascades Provinces from the February 1996 storm revealed that 36% of the observed landslides were associated with roads, and 65% of all landslides resulted in stream torrents (Weaver and Hagans 1996). Based on samples in wildland Forest Service watersheds, failed stream crossings from the 1996 floods depended on the size of the storm events with more debris torrents occurring during the larger February 1996 event (Furniss et al. 1997). In the Furniss study, the most common failure mechanism in the West Cascades was debris torrents. In the Coast Range, channel bed mobilization from high rainfall was the most common failure mechanism. Woody debris obstructions and culvert capacity exceedance were also important failure mechanisms.

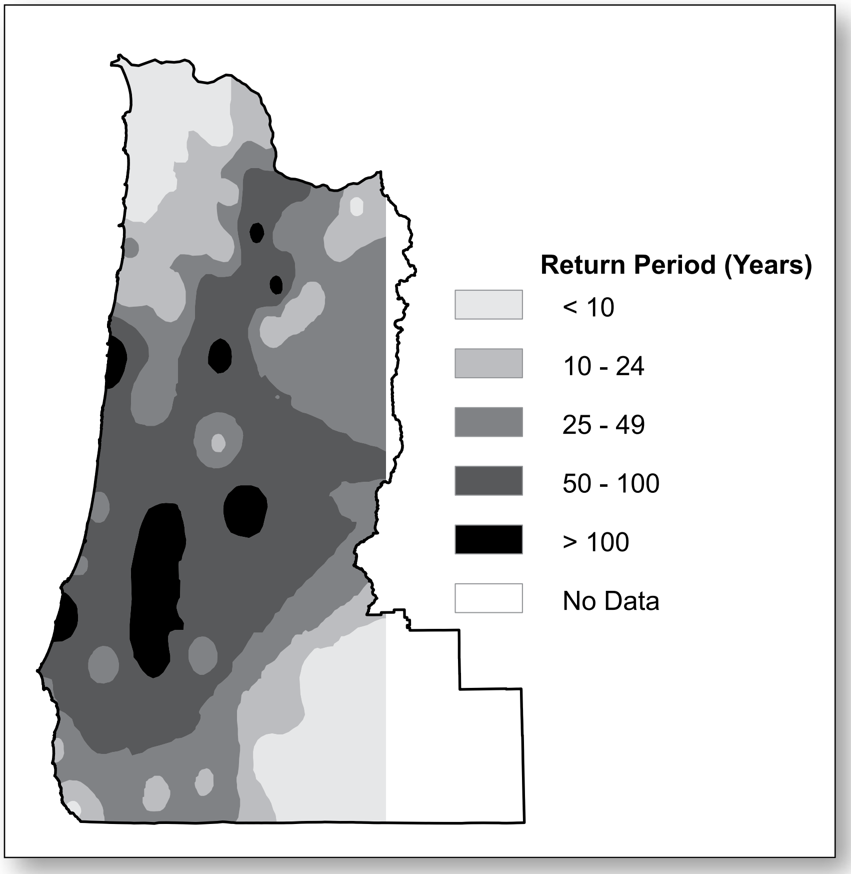


Figure 3-87. November 1996 Precipitation Return Period For Western Oregon

Currently, roads that are damaged from flooding and rebuilt are designed to higher standards than in the past. For example, the BLM abandoned sidecasting of waste material in the 1980s and planned lower fill heights over culverts at stream crossings. A road inventory in Washington state found that roads constructed in the last 15 years had minimal damage rates from large storms compared to roads constructed in earlier years (Toth 1991). Observations by the Oregon Department of Forestry for the 1996 storms show that road-related landslides were fewer and smaller than in previous studies and concluded that current improved road management practices were responsible (ODF 1999).

With development of road networks in the early 20th century, valley bottom roads along streams were constructed to salvage riparian timber and access upper watershed areas. There was often little regard for riparian areas. Streams were sometimes straightened and stream banks were lined with boulders to accommodate roads on floodplain terraces. Many of these arterial roads still remain and most are surfaced with few stream crossings. Road systems associated with forest management have been constructed on ridges and across middle slopes (between valley bottoms and ridge tops). There are many more road crossings in these upper watershed areas. There are minimal miles of roads within riparian areas along streams in these upper watershed areas.

Within the last decade, the BLM has decommissioned 588 miles (4%) of roads on BLM-administered lands within the planning area. These road closure segments were scattered with many being outside of the riparian reserves and not connected to stream channels. The Northwest Forest Plan 10-year monitoring effort regarding watershed condition found that the condition scores of watersheds, as influenced by roads, generally did not change significantly since the Northwest Forest Plan was implemented (Gallo et al. 2005). The amount of roads removed from any given watershed may have been relatively small and insufficient to change the watershed condition. There were 3,324 miles of roads decommissioned from 1995 to 2002 on U.S. Forest Service and BLM-administered lands, and there were an estimated 354 miles of new permanent roads constructed during the same period (Baker and Palmer *in press*).

Approximately 3,800 miles (25%) of the BLM road system are maintained in a given year. See *Table 3-60* (*Miles of BLM road decommissioning, improvement and maintenance in the past 10 years).* Maintenance reduces sediment delivery through road surface grading and replacement, pavement maintenance and replacement, and slough and slide removal. Culvert clearing and replacement can increase sediment delivery in the short term (1-2 years), but is necessary to prevent failure of the road drainage system.

Stormproofing and road improvements are used to maintain roads that receive infrequent road maintenance. Stormproofing puts the road into more of a self-maintaining condition, and projects are completed as funds allow. Road renovation and improvements are normally completed with timber sale contracts.

Heavy Metals

Heavy metals in streams and rivers in the forested and rangeland areas are normally associated with natural sources, agricultural runoff, and mine drainage. Natural sources may be increased by land erosion rates. Urban and industrial point sources (such as manufacturing, storm water runoff, and landfills) provide additional inputs. Heavy metals may assimilate near the point source or in large rivers outside the majority of BLM ownership. Mercury is the most common heavy metal of concern.

Water Quantity

The timing, magnitude, duration, and spatial distribution of peak flows must be sufficient to create and sustain riparian and aquatic system habitat, and to retain the patterns of sediment, nutrient, and wood routing (FEMAT 1993, V-19). Aquatic organisms require adequate flows during migration, spawning, and rearing to satisfy the requirements of various life stages (FEMAT 1993, V-19).

Table 3-60. Miles Of BLM Road Decommissioning, Improvement, And Maintenance In The Past 10 Years

Activity	10-Year Total (miles)
Road decommission (non-continuous use)	588
Road maintenance	38,115
Road improvement (renovation and improvement)	2,184

Timber harvesting and associated activities in maritime mountainous watersheds alter the amount and timing of peak flows by changing site-level hydrologic processes (Keppeler and Ziemer 1990, LaMarche and Lettenmaier 1998, Wemple and Jones 2003, Wright et al. 1990). These hydrologic processes include changes in evapotranspiration of forest trees, forest canopy interception of water, snow and snowmelt rates, roads intercepting surface and subsurface flow, and changes in soils infiltration rates and soil structure.

Changes in hydrologic processes affecting peak flows can be grouped by the following primary forest management actions:

- reduction in forest vegetation through harvesting
- construction of forest access roads and skid-roads

Reduction of forest vegetation through harvesting can affect processes that control snow accumulation in tree canopies and on the ground. Snowmelt can be accelerated where wind with warm air temperatures cross forest openings.

Low intensity winter precipitation of various durations is common within the planning area. Some of this precipitation falls as rain or snow, depending on the prevailing storm air temperature and watershed elevation. Snow acts as stored water within the mountainous watersheds. Lower valleys are below the snow line, except for extreme cold fronts. Snow comes and goes within the intermediate elevations, whereas the higher elevations have a winter permanent snowpack. These precipitation zones are displayed as hydroregions. See *Figure 3-88* (*Precipitation hydroregions within the planning area*). The use of hydroregions helps to distinguish how peak flows would be affected by different-sized openings in areas that mimic regeneration harvested and stand establishment conditions.

A spatial analysis to determine susceptibility to peak flow increase from vegetative management was developed for the planning area for both rain-dominated and rain-on-snow-dominated areas. The analysis uses sixth-field subwatersheds (a U.S.Geological Survey hydrologic unit), because they are small enough areas to capture the patterns of BLM forest lands and because tributary streams are more sensitive to vegetation and runoff-related changes. Subwatersheds are generally 10,000 to 40,000 acres in size and have a single outlet. There are 1,191 subwatersheds within the planning area. When separated by hydroregion, 634 subwatersheds are rain-dominated, 471 subwatersheds are rain-on-snow-dominated, and 86 watersheds are snow-dominated. Snow-dominated watersheds involve higher elevation (important for sustaining spring flows), but have minor contributions to the elevation of winter peak flows (Grant et al.2008).

Cutting of forest trees stops transpiration of water from the soil up into leaves, lowering evapotranspiration rates in the forest area. This results in variable but higher moisture content in soils during the summer months in regeneration harvest units. When precipitation occurs in the fall, the soils pore spaces are filled sooner, resulting in subsurface downslope movement of water. Where the subsurface flow meets a channel, it appears as streamflow. In a general forest environment, with a mosaic of forest age classes and treatments, low flows can increase up to 100% or more (Harr 1976, Ziemer 1981). This effect disappears after a few fall storms, because soils fill to capacity and behave similarly to uncut stands. These types of increases in low flows do not carry sediment nor affect channel form and are considered geomorphically insignificant (Grant et al. 2008).

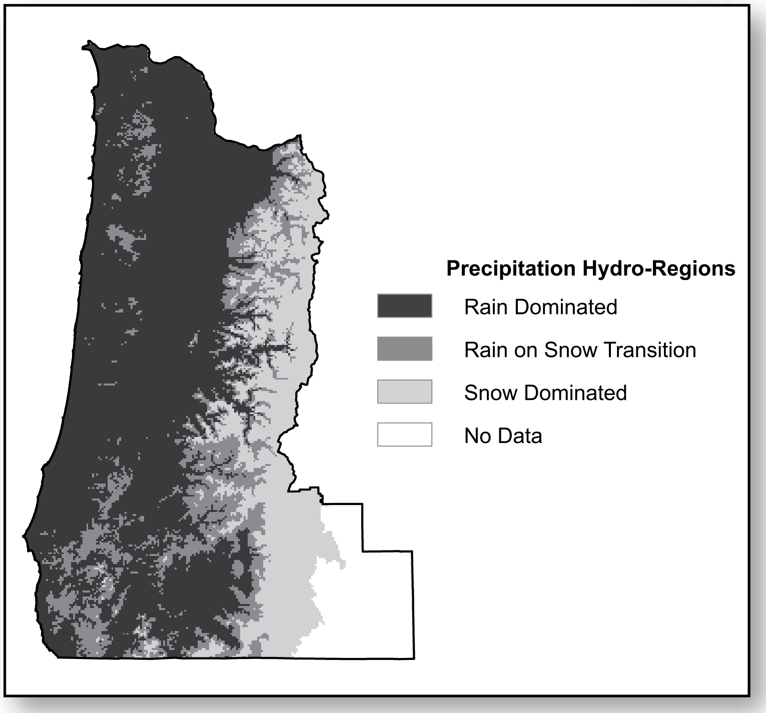
Hydroregion

Hydroregions are a means for classifying the dominant precipitation type of a region as either rain or snow. With regards to snow, hydroregions also distinguish the depth of winter snow and the longevity of accumulated snow.

Rain-Dominated Areas

Within the rain-dominated hydroregion, decreases in evapotranspiration are expected to correspond somewhat linearly with the amount of vegetation removed by forest harvest (Rothacher 1973, Harr 1976). Additional runoff from

Figure 3-88. Precipitation By Hdyroregions Within The Planning Area



evapotranspiration losses is roughly proportional to the watershed area where forest basal area was removed. See *Figure 3-89 (Envelope curve of reported percent change in peak flow with percent area harvested in the rain hydroregion*).

- Based on a compilation of watershed studies in the Northwest, completed in small catchments, a peak flow response is only detected where at least 29% of the drainage area is harvested (Grant et al. 2008). As suggested by the upper line in *Figure 3-116*, there are no peak-flow experimental study results in the rain-dominated hydroregion showing a peak-flow increase where less than 29% of a drainage area is harvested. (This is understood by noting where the upper line crosses the 10% detection peak-flow response level).
- The mean of the data suggests that a peak-flow response only occurs where 45% of the area is harvested. This detectable range would be even higher for areas without roads or at watershed scales (Grant et al. 2008).

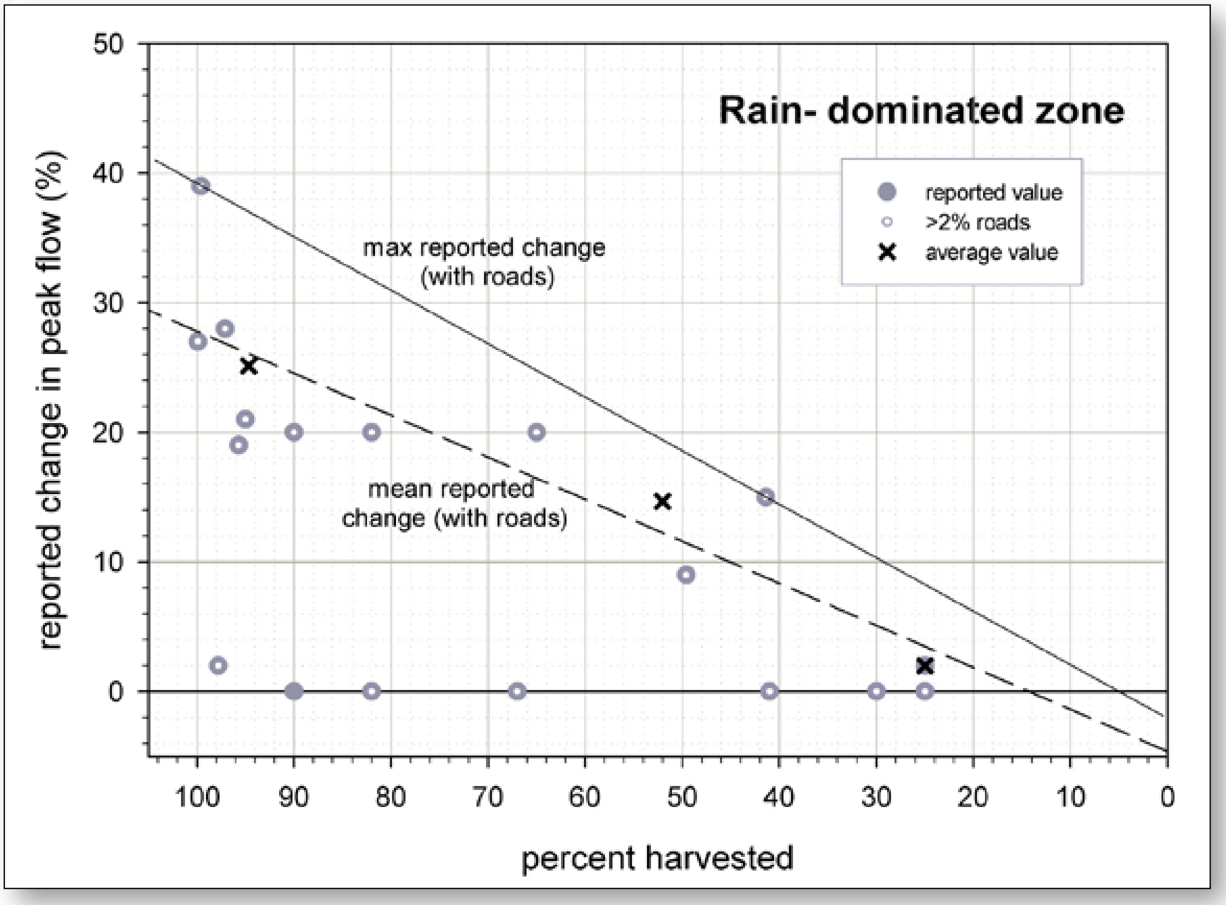
Ziemer (1981, 1995) found a nonstatistical (4%) increase in peak flow for 80-year-old conifer stands that were harvested where 50% of the basal area was retained. This study suggests that a totally cleared forest in a watershed is more important in demonstrating a detectable peak flow response in the rain-dominated hydroregion. It is presumed that hydrologic impacts (peak flow increase) decrease with the intensity of treatment from regeneration harvest (many acres), small patch cuts (<1 acre to several acres), and thinning in descending order, although past experimental studies in the Northwest did not fully examine the differences (Grant et al 2008). Compared to the rain-on-snow dominated hydroregion, for harvests greater than 1 acre, patch size or arrangement is not a primary factor in explaining greater flow volume or timing.

The analysis of the effects of the alternatives on peak flows within the rain-dominated hydroregion used the degree of forest vegetation harvested from all lands, also referred to as an equivalent clearcut area. On BLM-administered lands, the vegetation projections were derived from the OPTIONS modeling for the existing condition. The stand establishment structural stage was used as a surrogate for the removal of basal area or degree of equivalent clearcut area. On other lands, high quality vegetative crown closure datasets of satellite imagery were used from the 1996 Interagency Vegetation Mapping Project, with added "harvest history" change detection datasets through 2004. Forest acres of stand establishment on BLM-administered lands, and acres of less than 30% crown closure on other lands, were summed using GIS processes, by subwatersheds, as a surrogate for the removal of basal area. See *Appendix J - Fish.*

Of the 634 sixth-field subwatersheds in the planning area:

- Two currently include 14,035 acres of BLM-administered lands susceptible to peak flow increase where the equivalent clearcut area within the watersheds on all lands is greater than 40%, (see

Figure 3-89. Envelope Curve Of Reported Percent Change In Peak Flow With Percent Area Harvested In The Rain Hydroregion



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Note: Detection level set at 10% reported change in peak flow, due to measurement error in natural stream systems.

explanation of interpreting *Figure 3-89* described above), which is near a mean for reported change in peak flow in the rain-dominated hydroregion. These subwatersheds are Cooper Creek and Elk Creek-Flat Creek.

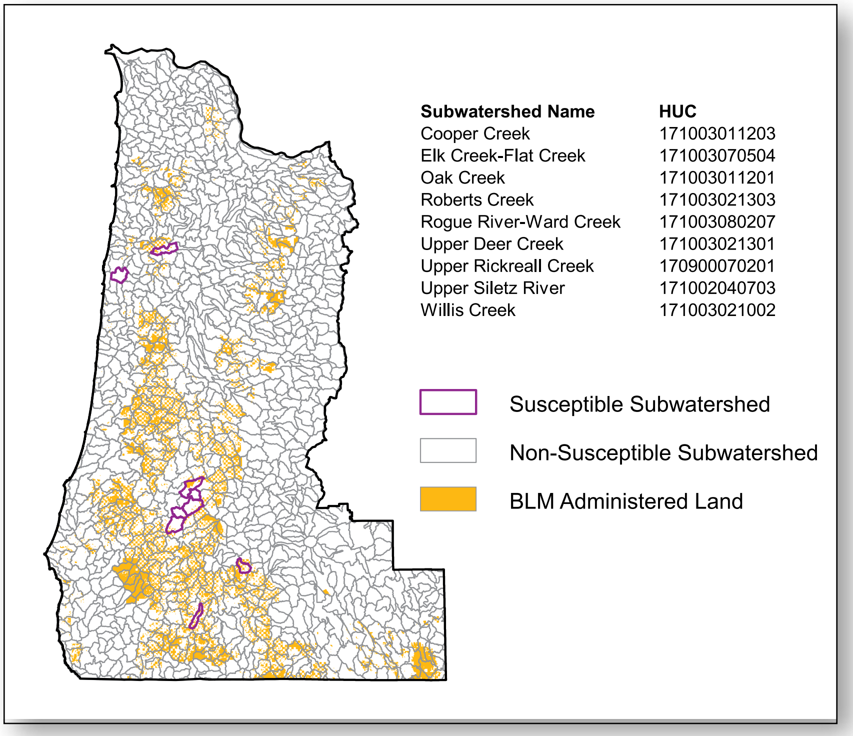
- An additional six currently have a total of 15,554 acres of BLM-administered lands above the maximum 29% equivalent clearcut area curve at the detection level for a reported change in peak flow.

See *Figure 3-90* (*Subwatersheds currently susceptible to peak flows in the rain-dominated hydroregion*). For the existing condition, the total BLM area in these eight subwatersheds is 29,589 acres, which is less than 2% of BLM-administered lands in the planning area. Within these subwatersheds susceptible to peak flow enhancement, the BLM susceptibility area varies from 0.2% to 18%, with a mean of 5%. Several of these subwatersheds have natural openings because of the existing vegetation community types and are not entirely attributable to forest harvest. This includes the susceptible Cooper Creek, which is predominantly oak savannah. Five additional sixth-field subwatersheds would be susceptible when examining those subwatersheds without any BLM ownership.

Rain-on-Snow Areas

A rain-on-snow storm involves prolonged rainfall under warm and windy conditions. Rain-on-snow events are of particular interest because the melt of shallow snow packs can enhance storm runoff. Also, rain-on-snow events have been associated with landsliding and downstream flooding (Christner and Harr 1982, Harr 1986, Berris and Harr 1987, Jones and Grant 1996, Grant et al. 2008).

Large openings in a forest canopy (greater than two tree heights where wind can accelerate), which are commonly found in areas that have had regeneration harvests or forest stand conversions, affect precipitation and snow interception and melt. The melting or vaporization of snow in large openings may occur before rain-on-snow storms, in contrast to increased snow accumulation and melt during winter storms when the freezing levels are initially low but subsequently rise.



Subwatershed Name	HUC
Cooper Creek	171003011203
Elk Creek-Flat Creek	171003070504
Oak Creek	171003011201
Roberts Creek	171003021303
Rogue River-Ward Creek	171003080207
Upper Deer Creek	171003021301
Upper Rickreall Creek	170900070201
Upper Siletz River	171002040703
Willis Creek	171003021002

Figure 3-90. Subwatersheds Currently Susceptible To Peak Flows In The Rain-Dominated Hydroregion

Snowmelt can provide extra water for runoff. Regeneration harvests or forest conversions with large open areas provide additional melt contributions under rain-on-snow conditions (Harr 1981, Storck 1997). This is primarily due to more snow accumulation in the openings and increased wind speeds. In contrast, research suggests that forest thinning treatments maintain patterns of snow accumulation that are similar to mature forests and reduce turbulent air near the ground. Furthermore, it is concluded that thinning treatments have little effect on snowmelt rates during rain-on-snow events (Poggi et al. 2004).

The largest floods in the world are caused by sustained rates of rainfall or dam-break floods (Naiman and Bilby 1998). Within the planning area, warm subtropical air from winter storms with sustained rates of rainfall and mild temperatures combine with snow on the ground to produce the largest floods. For example, the largest documented historic floods on record (during the years 1861, 1890, and 1964) were rain-on-snow events. Harr (1981) concluded that 23 of 25 of the largest annual peak flows of the Willamette River at Salem, Oregon between 1814 and 1977 were caused by rapid snowmelt during rainfall. Harr also concluded that the effect of these wet mantle floods overwhelmed the peak flow response to forest management. A severe rain-on-snow flood comparable with the 1964 flood occurred in February 1996 in northern Oregon where intense rain with warm temperatures combined with snow on the ground (Taylor and Hatton 1999). Again, the severity of these events diminishes the effects of vegetation management.

Forest roads, skid roads, and landings change the infiltration of soil and the flow of surface and subsurface water in watersheds. These compacted areas are relatively impermeable and are a source of overland flow. Increases in peak flow were found when roads and other impermeable areas occupied more than 12% of a catchment scale watershed (Harr et al. 1975, Harr 1976). The road and its cut slope can advance the timing of surface runoff, compared to slower subsurface flow routes (Harr et al. 1975, 1979; Megahan et al. 1981; 1992; Wemple et al. 1996). During large storm events, roads intercept larger contributions of subsurface flow and route it to drainage ditches. This additional runoff contributes to rising flows where drainage ditches connect to streams. (Megahan 1972, LaMarche and Lettenmaier 2001, Luce 2002, Wemple and Jones 2003).

There are approximately 14,000 miles of BLM roads within the planning area. Many of these roads are crowned or insloped with a drainage ditch between the road shoulder and the backslope. This drainage ditch and stream connectivity effectively extends the stream channel network at stream crossings. However, where road drainage intersects ditch relief culverts, stream extension is appreciably reduced. Any remaining extension is short and often terminated at the point of the first ditch relief culvert. Some surface runoff and interception of subsurface flow could enter stream channels below this juncture.

A rain-on-snow empirical analytical technique was used to identify susceptible subwatersheds to peak flow increase within the rain-on-snow hydroregion. The procedure was patterned after the Washington State Department of Natural Resources hydrologic change watershed analysis methodology (Washington State DNR 1997a). This screening technique (with modifications) was converted to GIS spatial analysis (See *Appendix J - Fish*).

An appropriate method of describing the peak flows of various exceedance probabilities for unregulated streams in ungauged watersheds is to use the basin characteristics regression analysis with gauged watersheds that have long-term records. The Harris et al (1979) flood frequency equations were chosen as reference points because they cover the various hydrologic regions within the planning area and have long-term records (10 to 70 years). The base period of streamflow data for use in the analysis was collected prior to the maximum forest conversion in many watersheds (with much of the streamflow data being gathered before 1960). The base period data set may include some chance rain-on-snow events, but with considerably fewer forest openings. Rain-on-snow occurrences of interest correspond to a streamflow return period of 2 to 8 years where research has shown that prelogging and postlogging regressions were significantly different (Harr and Coffin 1992). The 2-year, 24-hour and the 5-year, 24-hour stream flows were calculated for each sixth-field subwatershed with these equations and serve as reference points for a rain-on-snow watershed response level (See *Appendix J - Fish*).

Rain-on-snow areas, where shallow snow accumulations can come and go, have been reported by (Harr 1981, Harr and Coffin 1992) to be in the elevation range of 1,200 to 3,600 feet in western Oregon and from 2,500 to 5,000 feet in the southern Cascades (Lindell 2006). Forest openings commonly receive greater snow accumulation (two to three times more snow water equivalent) than adjacent forests (Harr 1992). These openings also receive greater wind speeds and twice the amount of heat during rain-on-snow events, which provides greater melt compared to a mature forest (Harr 1981, Harr and Coffin 1992, Storck 1997). For BLM-administered lands, acres of stand establishment were taken from the OPTIONS model vegetation modeling for each alternative. Satellite imagery from the 1996 Interagency Vegetation Mapping Project was used to determine the forest cover on other lands.

Published regression equations were used to generate a winter snowpack (Greenburg and Welch 1988) that relates to snow accumulation by elevation using the snow telemetry (SNOWTEL) data from the National Resources Conservation Service for January 1 snow accumulation. Large forest openings within the rain-on-snow hydroregion receive greater snow accumulation (two to three times more snow water equivalent) than adjacent forests (Harr 1992). Further adjustments for regeneration harvest areas (Brunengo, unpublished) were used to estimate snow cover in openings.

Snowmelt equations from the U.S. Army Corps of Engineers (USACE 1956, 1998) were used to melt snow in the rain-on-snow elevation to approximate a 2-year, 24-hour storm using average environmental conditions. The water from snowmelt for all vegetation cover types for each sixth-field subwatershed was averaged for the watershed and added to the precipitation for the 2-year, 24-hour storm. The water available for runoff (precipitation plus snowmelt) was rerun in the 2-year, 24-hour peak flow basin characteristics runoff equations. Water available for runoff was substituted as precipitation. The 2-year, 24-hour peak streamflow was then compared with a 5-year, 24-hour peak streamflow. Where it exceeded the 5-year, 24-hour peak streamflow, the watershed was considered susceptible to peak flow increase.

There are currently three sixth-field subwatersheds (out of 471) that are susceptible to peak flow increase in the rain-on-snow hydroregion on BLM-administered lands. See *Figure 3-91* (*Subwatersheds currently susceptible to peak flow in the rain-on-snow-dominated hydroregion*). No additional sixth-field subwatersheds would be susceptible when considering management activity across all land ownership for these 471 subwatersheds.

Peak Flow Research

There has long been debate regarding the magnitude of peak flows resulting from timber harvesting and road building. Much of the discussion has centered on the timing and scale at which peak flows are detected as well as the type, size, and intensity of management activities that result in channel changing peak flows. Many of the existing research studies have used very small scale watersheds. Following is a summary of recent research on peak flows that is relevant to this plan revision.

Research from primary hydrologic study sites in the Cascades, Coast Range, and in northern California since the late 1950s show that a peak flow change from regeneration harvesting is detectable at the catchment scale (small experimental watersheds, oftentimes <100 acres). The greatest response is from the first stream flow peaks in the fall that can be increased up to 100% or more after logging (Harr 1976, Ziemer 1981). These early fall storms produce small peaks, which had little, if any, consequence on channel form because stream flow is very low at this time (Grant et al. 2008). This effect of logging on peak flow through the winter storm season has shown to diminish with each subsequent storm by a variable representing the percentage of the area logged divided by the sequential storm number (Ziemer 1981). This trend appears to diminish exponentially with increasing storm size (Grant et al. 2008).

Combinations of roads and regeneration harvests interact differently at the catchment scale. Studies show that there was a statistical increase in peak flows for smaller

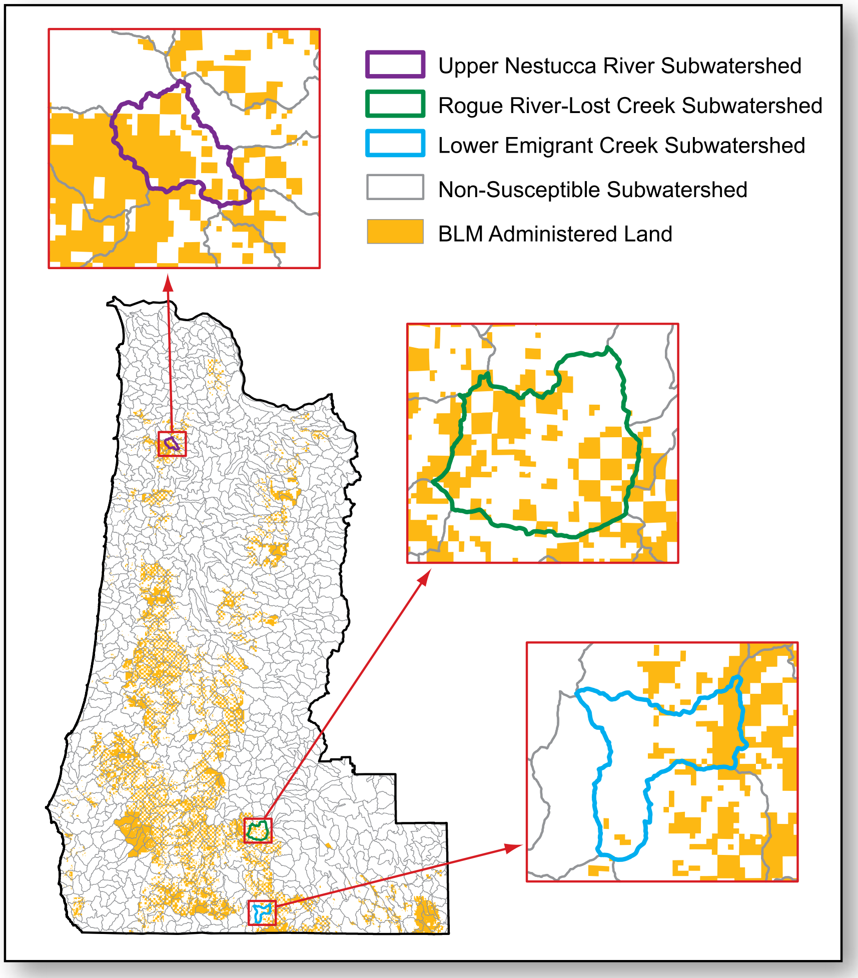


Figure 3-91. Subwatersheds Currently Susceptible To Peak Flow In The Rain-On-Snow-Dominated Hydroregion

Shown is the peak flow susceptibility for sixth-field watersheds where the 2-year, 24-hour bankfull channel forming peak flow is greater than the 5-year, 24-hour peak flow. Includes the current rate of harvest on private land from 1996 IVMP imagery.

peak flows (those with a return interval of less than 1 year) looking only at regeneration harvest (without considering roads). This effect diminished rapidly within 5 years (Jones and Grant 1996). Further, Jones and Grant (1996) found no statistical increase in peak flows when considering only roads (without regeneration harvest). When roads and regeneration harvest occurred together and covered more than 25% of the area, they observed that peak flows increased 50% for all event sizes.

A recent literature review by Grant et al. (2008) grouped most Pacific Northwest catchment-scale experimental watershed studies over the last 40 years by areas of similar hydrological processes called hydroregions. The effects on peak flow from forest harvest and roads were examined for the rain-dominated and rain-on-snow hydroregions. (The findings for the rain-dominated hydro-region are previously discussed in this section).

At the catchment scale, within the rain-on-snow hydroregion, the maximum response at the detection level for peak flow increases is 15% forest basal area removed (without considering roads), and the mean is 19% when including roads. See *Figure 3-92* (*Envelope curve of reported percent change in peak flow with percent area harvested in the rain-on-snow hydroregion*). For this hydroregion, the shape of the outermost line (curve) is shown to be linear for a change in detection of peak flows with percent harvested. This line may not always be linear. It may take more harvested area than shown for a peak flow change to become apparent. This is because there are very few studies in the data set with partial harvest, and the curve was anchored with total harvest and no harvest. However, peak flows in this hydroregion are very sensitive to forest patch size and density and the corresponding influence of wind speeds that are a primary driver of melt (Harr 1981, 1992). Therefore, it would be expected that the levels of forest harvest would be much higher than the reported 15% level before a peak flow response would be observed.

Further, the authors state that the data and curves used to derive these findings are at the maximum end of the range of effects. Grant et al. (2008) suggest using the mean values for larger watersheds along with the application of modifiers. These considerations include stream gradient and channel structure affecting the transport and deposition of fine sediment, the amount and distribution of roads in a watershed, drainage efficiency, forest patch size, and riparian leave areas.

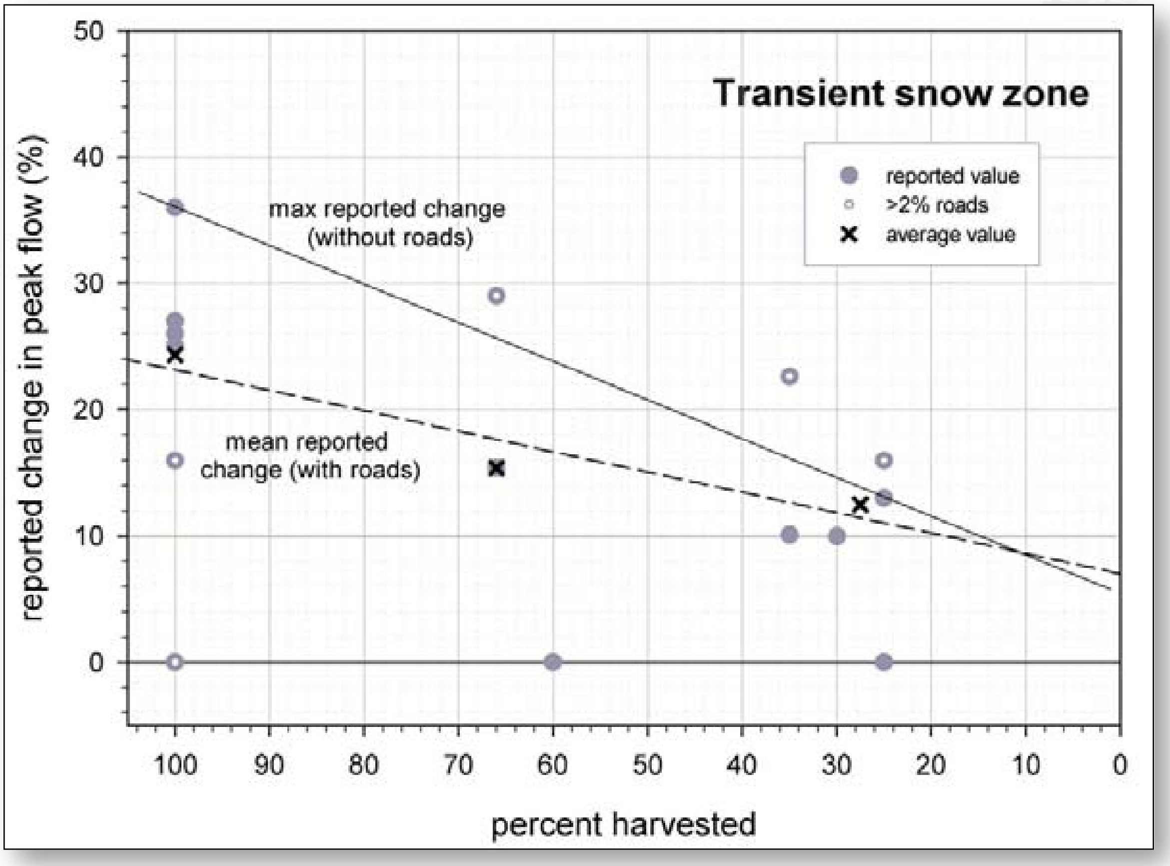
While this EIS was being prepared, the envelope curves were still under development and therefore were not used. Rather, the analysis of effects for the rain-on-snow hydroregion was based on an established empirical model used in Washington State (see *Appendix J - Fish*). This model (as described earlier) evaluates the processes of snow accumulation and melt, and also the snowmelt water additive effect to runoff, in subwatershed-sized basins during runoff events. See *Appendix J - Fish*.

Jones and Grant (1996) reported that smaller peak discharges (a return interval of less than one year) have increased by as much as 100% in the last 50 years. However, the data set was skewed toward smaller peak flows. Greater than 75% of the data set had a return period of less than one year, and gauged areas were small catchments that were not representative of the watershed-size basins (10,000 to 250,000 acres). Further analysis of the same data set by others (Beschta 1997, Thomas and Megahan 1988) either could not detect any changes for the fifth- or sixth-field watersheds or were inconclusive.

Grant et al. (2008) point out that the magnitude of peak flows from management practices diminishes with increasing watershed area (such as the sixth-field watershed size). This diminished magnitude of the peak flow is due to channel resistance, floodplain storage, transmission losses, storm size, and origin and timing of tributary inputs. Reductions in stream flows of 50% or greater have been observed due to stream tributary timing effects (Woltemade and Potter 1994). For these reasons, the authors conclude that streamflows diminish in a downstream direction as watershed size increases (measured as a percent change in unit area).

Large peak flows (those with return intervals of greater than 6 years) were not significantly affected by regeneration harvest logging or roads in the H. J. Andrews (Rothacher 1973) and Alsea (Harr 1976) studies,

Figure 3-92. Envelope Curve Of Reported Percent Change In Peak Flow With Percent Area Harvested In The Rain-On-Snow Hydroregion



From Grant et al 2008, used by permission_
Note: Detection level set at 10% change in peak flow.

or elsewhere in the region (Grant et al. 2008). The sheer amount of runoff from the maritime climate event overwhelms the difference in streamflow from management activity. These are the flows that can scour stream channels, modify floodplains, and carry tremendous quantities of sediment.

Some authors have reported that equivalent clearcut or aggregate recovery procedures (King 1989, Christner and Harr 1976) are an effective way to determine runoff effects in rain-on-snow areas for subwatersheds and watersheds. These procedures may be useful in the rain-dominated hydroregion, since response is roughly proportional to area harvested. However, merely tallying acres of harvest in a watershed does not address the underlying mechanisms of how snow accumulates and melts in the rain-on-snow hydroregion. The vertical and horizontal dimensions of forest openings and their size, as well as their distribution and juxtaposition at the stand level, are sensitive to snow accumulation and melt processes (Harr and Coffin 1992). In this hydroregion, melt is enhanced by energy released from condensation of moisture onto snowpacks during warm and windy weather. This relationship is scaled by size; there are greater wind speeds in larger openings that promote the process (Harr and McCorison 1979). Grant et al. (2008) recognize and expect this effect to be present in the rain-on-snow hydroregion, but they make no attempt to rectify these processes with their envelope curve (*Figure 3-119*), presumably because of insufficient experimental watershed information at larger watershed scales.

Source Water Protection

The 1996 Safe Water Drinking Act amendments require the identification and management of source water protection areas for public water systems. States are required to develop source water assessments for public drinking water supply systems that include surface water and groundwater sources. The assessments include mapping of the surface or groundwater area, an inventory of the potential sources of contamination, and an evaluation of watershed sensitivity. See *Table 3-61* (*Potential contaminant sources affecting waterbodies within source water watersheds*) for the activities on BLM-administered lands that could affect drinking water supplies.

See *Figure 3-93* (*Source water watersheds percentage on BLM-administered lands within the planning area*). These watersheds are primarily in rural settings and do not involve industrialized contaminant sources. See *Appendix J - Fish* for descriptions of specific community public water systems using surface water, population served, and land area affected for each district.

With settlement of the Pacific Northwest in the late-18th and early-19th centuries, along with increasing populations, concerns arose about the quality of drinking water. Early focus centered on the characterization of disease-causing microbes in public water supplies and methods to immobilize or remove them.

As a matter of necessity, small cities in rural areas set up points of diversion from surface waters from federal lands. They generally enjoyed excellent water quality during most of the year with minimal treatment. During the 1950s and 1960s, timber harvesting increased. A water system survey conducted by the Public Health Service in 1969 showed that only 60% of the public water systems surveyed delivered water that met Public Health Service standards (EPA 2000). Small systems, such as those found in rural communities, were most at risk. Deficiencies related more to water system equipment (including filtration, disinfection, and a safe distribution system), rather than to surface water quality.

The height of road construction and harvesting on BLM timber lands occurred in the 1950s through the 1980s. Watersheds have been generally on an improving trend during the last 15 years. On rangelands, from the late-1930s to date, there has been a declining trend of grazing use, with a reduction of 80% or more in the late-1930s and another 30-40% reduction in the late-1950s. The rangeland use diminished gradually due to re-surveys and rangeland monitoring studies.

Table 3-61. Potential Contaminant Sources Affecting Waterbodies Within Source Water Watersheds

Contaminant	Activity	Causal Mechanism
Temperature	• Harvesting within riparian zones on perennial streams	• Decrease in stream shade affected by canopy removal
Sediment	• Existing road network • New road construction	• Sediment delivery near stream crossings of roads
	• Harvest areas • Recent burns • Cattle grazing	• Landslides and debris torrents • Erosion and dry ravel • Concentrated animal grazing in riparian areas leading to erosion or streambank collapse
Bacteria	• Recreation at campgrounds • Dispersed sites	• Failing sewage systems • Improper waste disposal
	• Cattle grazing	• Cattle holding areas within riparian areas • On-stream watering
Nutrients	• Forest fertilization	• Fertilizer entering watercourses
	• Recent burns	• Mobilization from adjacent areas to streams
Pesticides	• Forest pesticide application	• Application to nontargeted areas by drift or runoff
Petroleum products	• Refueling of equipment • Transportation and fuel storage	• Spills

FIGURE 3-93. SOURCE WATER WATERSHEDS PERCENTAGE ON BLM-ADMINISTERED LANDS WITHIN THE PLANNING AREA