Appendix G - Physical Environment--Model Processes, Data and Assumptions

Table of Contents

Appendix G - Physical Environment--Model Processes, Data and Assumptions

Much of the detail utilized in the discussions of this EIS has been abbreviated from the process records. The process records display computational techniques and data used to interpret consequences relating to the physical environment. Because of the volume, much of the data is left in process records held at the Forest Supervisor's Office in Yreka, California.

Information that may assist in the understanding of interpretations and conclusions is included in this appendix. This information will allow the public understanding of the process, without impeding the flow of the document for the reader. The information in this appendix focuses on the geologic and hydrologic analyses.

Geological Resource

Table G-1 displays how geologic hazards and resources interact with other natural processes and features. How geologial hazards and resources can affect or can be affected by forest management activities are also displayed in Table G-1. The following section describes the interactions with landslide hazards.

Interactions: Landsliding, the Physical Environment and Forest Management

Landslide processes interact with the soil, climate, groundwater, surface water, seismic events, vegetation, fire and certain forest management practices. Some of the most important of these interactions are described below.

Soils

Soil type and soil processes play an important role in the occurrence of landslides by determining cohesion, shear strength, porosity and permeability of slope materials. Certain clay-rich soils typically experience slumps and earthflows while sandy soils commonly experience debris slides. In turn, landsliding affects the soil-forming process and can reduce site productivity by removing soil from a slope and delivering it to the channel system.

Climate

Climate is one of the most important factors in the occurrence of landslides. All recorded landslide episodes on the Forest have occurred during wet periods or floods. Landslide-causing precipitation events occurred in the winters of 1955-56, 1964-65, 1973-74 and 1982-83.

The 1964 flood had a severe effect on channels and riparian areas in many streams and rivers on the Forest, such as the Salmon River, Indian Creek near Happy Camp and Grider Creek near the community of Seiad Valley. In Grider Creek, landslides associated with the 1964 storm were responsible for 68% of the total landslide-derived sediment which the creek received from 1944-87.

Additionally, the effects of this event may have influenced landslide potential for many years afterward. This is due to the fact that many landslides were activated in 1964, and may have moved more readily during subsequent years. This concept is supported by the observation that the 1975 air photos of the Grider Creek drainage show enlargement of several of the landslides which were activated by the 1964 flood.

Examination of the style and revegetation rates of the debris slide scars and damaged riparian areas associated with the 1964 flood in Grider Creek suggests that a landslide-causing event of this magnitude had not occurred in the area for at least 60 years (and probably much longer than that). Similar observations are reported by Stewart (1967) at Coffee Creek, a tributary to the Trinity River.

In the Van Duzen River Basin, Kelsey (1977) concluded that the 1964 flood had a return period of several hundred years, in terms of sediment production. In the Grider Creek watershed, the 1964 flood occurred when only a small proportion of the watershed was roaded and logged (mostly in Cliff Valley Creek). There was a high concentration of road-associated landslides in the inner gorge in the managed area.

The landslide-producing storms described above occurred during a wet cycle, that lasted from about 1950 to the present (Baldwin & de la Fuente, 1986). The long dry cycle that occurred early in this century may explain the absence of a landslide-producing climatic event in Grider Creek in the 60 years preceeding the first air photo coverage in 1944.

Groundwater

The introduction of water into the subsurface increases landslide potential by increasing the weight of a soil mass and by creating a bouyant force, which reduces frictional resistance to sliding along a potential failure plane. In addition, increased groundwater can lead to high seepage rates and accelerated subsurface erosion (suffusion). Such erosion can cause collapse of subsurface conduits, and facilitate landsliding.

Surface Water (Stream Processes)

Interactions between landsliding and stream processes are extremely important. In addition to creating pronounced adverse effects at the site of occurrence, some rapidly moving landslides enter streams and form water-charged slurries, damaging the channel for great distances downslope. Such events are commonly called debris torrents. As a debris torrent travels through a channel, it scours the bottom and sides, and when the gradient decreases, soil, rock and logs are deposited, filling pools and forming dams. The scouring effect on channel banks often initiates debris slides within the inner gorge.

The vast majority of debris torrents documented on the Forest have been initiated by landslides during winter storms. However, a few have been caused by high flows associated with summer storms in the absence of landsliding. Since most landslides occur in association with flood events when stream flow is at a maximum, debris torrents are relatively common events during such episodes.

In the Grider Creek drainage near Seiad Valley, debris slides that occurred in the wilderness before 1964 stripped away riparian vegetation and deposited debris in the channel of Stones Valley Creek and Grider Valley Creeks for distances of 1 and 2 miles respectively. It is likely that these landslides occurred during the 1955 flood. During the 1964 flood, Grider Creek was scoured and aggraded from the mouth to the headwaters, as were all the main tributaries south of Fish Creek.

Observations of the relationship between debris slides and scoured channels in Grider Creek reveals that a single debris slide of a few hundred cubic yards high in the watershed can have large adverse effects for a considerable distance from the point of origin. Similarly, larger debris slides in the inner gorge, such as those associated with roads in Cliff Valley Creek can remove all riparian vegetation, and radically alter the channel further downstream. Landslides have formed several large temporary dams on the Salmon River (Bloomer and Murderers Bar Landslides) and on North Russian Creek. These dams have had long term effects on fish habitat.

Seismic Events

Seismic shaking can initiate landsliding by affecting pore water pressures, applying dynamic loads and by physically dislodging material from very steep slopes. There is only 1 documented instance on the Forest where seismic shaking likely played a role in the occurrence of a rock slide (U.S. Forest Service Memo, 3-13-90). However, abundant evidence of this relationship has been documented in other parts of the world, particularly in California. The most recent of these was the Loma Prieta Earthquake of 1989. Also, it is likely that seismic shaking played a role in the development of the large landslide complexes that make up about 25% of the Forest. Thus, the potential for earthquake-induced landsliding is quite real.

Vegetation

Vegetation plays an important role in the landslide process by removing groundwater from the slope (transpiration), enhancing evaporation and adding mechanical strength to the soil due to the reinforcement of its roots. Vegetation also influences snow accumulation and melt rates, and thereby affects the rate at which meltwater is introduced into the soil. Other effects of vegetation are described in the Geologic Analysis of the Management Situation (AMS). Landslides frequently incorporate large trees and transport them to stream channels where they become an important component of the large woody debris within the stream.

Fire

Fire influences landslide potential in 2 primary ways. One is to remove vegetation, affecting evapotranspiration, root support and snow accumulation and melt rates. The other is to alter the patterns of surface and subsurface flow on a slope by: (a) creating water repellency, (b) removing woody obstructions to overland flow and channel flow, creating conditions conducive to the formation of rills, and (c) removing organic litter. Removal of organic litter allows more efficient overland flow and makes the soil more susceptible to freezing, thus reducing the infiltration capacity.

Long-Term Erosion of the Landscape

Most published studies indicate that landsliding is the source of the majority of the sediment delivered to the stream system during large winter storms in the Pacific Northwest. They also suggest that landsliding is the primary erosion mechanism that sculpts the landscape over geologic time (Raines and Kelsey, 1990).

Forest Management

Forest management activities that disturb the vegetation and/or soil can affect slope and channel hydrology, soil characteristics, mass distribution, evapotranspiration rates and root support. These effects can result in increased landslide risk as described below:

***Vegetative Manipulation** - Timber Harvest-Conversion of Vegetative Types, Grazing, Control of Undesirable Vegetation.*

Activities that remove vegetative cover, affect evapotranspiration, and root support, along with affecting the accumulation and melt rate of snow, increase the amount of water available to infiltrate into slopes.

This additional water can result in elevated pore pressures that, in turn, can increase landslide potential. In areas of thick soil, the significance of these effects is generally accepted by most earth scientists. However, in areas of thin soils, where groundwater is depleted on an annual basis, some earth scientists are skeptical of the significance.

Harvest-associated changes in the accumulation and melting of snow in clearcut patches can cause higher peak groundwater levels and thus increase slide risk (Megahan and Gray, 1981). This effect is important in cumulative mass wasting effects assessments if landslide risk is increased over a large area. Reduction in evapotranspiration alters hydrologic conditions, both on- and off-site (downslope).

Reduction in vegetative cover also results in a reduction of root support, and can increase landslide risk. This is a site-specific effect. However, since this loss of support can increase slide risk (above natural levels) over large areas, such as in wildfires or large harvest units, there is a potential for cumulative effects.

***Surface Disturbance** - Timber Yarding, Site Preparation, Grazing*

Activities that disturb the ground can result in changes in infiltration rates of water and disruption of shallow subsurface and overland flow patterns. Timber management activities can greatly alter infiltration rates due to compaction associated with yarding activities, disruption of the soil and by burning of logging slash. Fire causes water repellency in some soils.

These activities change the pattern of surface and sub-surface flow on a slope by reducing infiltration in compacted or burned areas. Reduced infiltration makes less water available to initiate landsliding at one site, but the concentrated overland flow which results is then available to infiltrate in topographic low points downslope, thereby increasing landslide risk there. Grazing can cause soil compaction and remove organic cover, thereby facilitating overland flow.

***Excavations** - Road Construction, Mining, Building Foundations, Dams*

Excavations into natural slopes and construction of earthen fills can undercut weak slopes and place destabilizing loads on landslides. Additionally, they can also disrupt waterways and create unstable man-made embankments. Slope cuts associated with roads, skid trails, landings, or mining: can change mass distribution on a slope by undermining slopes, and increase slide risk. Similarly, earthen fills can alter mass distribution and initiate sliding in the foundation by placing heavy loads on unstable sites. Earthen fills can also fail and initiate debris sliding. This a particularly severe problem in granitic terrane. Both cuts and fills can alter slope hydrology and initiate landsliding. Road drainage structures, such as culverts and dips also modify natural drainage patterns.

Summary

In summary, landsliding plays a significant role in stream channel processes, strongly influencing the condition of the channel in terms of the distribution of boulders, cobbles, sand, silt and clay, and large woody debris. Landslides can form dams that are barriers to stream flow and fish migration, and damage riparian vegetation in and adjacent to the stream. Water quality is affected during high flows, and also during low flows in the case of large earthflows that can shed fine sediment for many days or even weeks after storm events.

Landslides also directly affect roads by damaging or removing road segments, and damaging culverts or bridges. Structures built on large slumps have been damaged in the past (for example, Somes Bar Work Center). Also, debris slides have damaged or threatened buildings in Indian Creek (Happy Camp), Forks of Salmon, and Beaver Creek (Oak Knoll).

Consequence Assessment Techniques

Consequence Assessment for Landslide Hazards (Slope Stability)

Method

Three steps were used to predict the landslide sediment production for the Sediment Model. Refer to Appendix B for information on the Klamath National Forest Sediment Model. For more detailed information on the model, the Sediment Model Process Paper is available at the Forest Supervisor's Office (Kesner, 1992).

Stratification of the Landscape - The Forest landscape was subdivided into 13 types of land, or geomorphic terrane types. The area within each terrane type has similar landslide potential.

Determination of Landslide Production Rates - The rate at which each of these terrane types delivers sediment to the stream system (in response to a 10-year return period storm) was estimated in cubic yards of sediment per acre of land for the following conditions:

1. Undisturbed
2. Harvested before 1975
3. Harvested after 1975, or burned in the 1987 Fires at a high or moderate intensity
4. Roaded

These landslide production rates were developed by reviewing published studies dealing with areas of similar climate and geomorphic characteristics, and by measuring actual landslide rates in the Grider Creek Watershed on the Oak Knoll Ranger District and the Salmon River Basin (USFS, 1988; de la Fuente and Haessig, 1993). These watersheds are representative of much of the westside of the Forest in terms of topography, climate and geology. Landslide rates for the period from 1965-1975 were used as in index for a 10-year return period storm.

Computation of Landslide Volumes - Once the terrane types and their landslide production rates were defined, landslide volumes were calculated under 1987 conditions (that is, accounting for all roads, timber harvesting and recently burned areas that existed at the end of 1987).

Existing Landslide Production Rate

The predicted landslide sediment production for the entire Forest for each of the 13 geomorphic terrane types under 1987 conditions was used to operate the model. Many of the rates have been developed from the Grider Creek and Salmon River Basin studies and have been compared to other studies on and adjacent to the Forest. This analysis includes all land (public and private) within the Forest boundary.

Pristine (Undisturbed) Landslide Production Rate

Background rates, or those anticipated under undisturbed conditions, were determined by assuming that there were no roads, harvest areas or burned areas, and applying the coefficients for undisturbed conditions to the all acres.

Projected Future Landslide Production Rates

The effects of future harvest and road construction were computed by taking harvest volumes calculated by the FORPLAN model, converting these volumes to acres, and disaggregating these acres proportionally across the landscape of capable, available and suitable lands (refer to the Glossary for definitions of these lands). Future roads were handled similarly. This process addresses public land only, since the Forest cannot predict future management of private lands.

Utility of the Computed Values For Future Landslide Sediment Production

The landslide portion of the sediment model takes into account what activities are being planned (timber harvest or road construction), how much is planned (acres or miles), when it will occur, and where it will occur (on geologically sensitive or non-sensitive land). As a result, the tables the sediment model generates are very useful in the consequence assessment because the tables provide a basis for:

1) comparing alternatives in terms of total landslide volume that is likely to be produced,
2) comparing the landslide volume predicted for each alternative to pristine or undisturbed landslide volume,
3) describing the magnitude of watershed response that is likely to occur under each alternative, and
4) comparing cumulative watershed effects that are associated with landsliding for each alternative.

Assumptions

The following are important assumptions used in the sediment model.

Effects of Management - Activities that disturb the soil or vegetation, such as road construction, timber harvest or mining, increase the frequency and magnitude of landsliding above undisturbed levels.

Land Response to Future Storms - The identified geomorphic terrane units will produce landslides in the future at rates which are similar to those that have been observed in the past under similar climatic conditions.

Vegetative Recovery - Harvested and burned areas will return to pre-activity conditions after 50 years of vegetative regrowth. This includes hydrologic as well as root support conditions. It is recognized that some aspects of vegetative recovery may take longer, while others may take less time. The rate of recovery used in the sediment model is given by the following table:

Years	Percent Recovery
0-10 years	0
20 years	50
30 years	85
40 years	95
50 years	100

Road Recovery - The recovery of roads, in terms of landslide potential, is negligible over time due to the permanent changes in mass distribution and slope hydrology that they create. It is recognized that some stabilization occurs over time as cuts and fills revegetate and consolidate.

Limitations

Predictive Ability of the Model - Due to the complexity of the natural system that determines landslide rates, it is not possible to predict precise landslide volumes that a watershed will produce under a given set of conditions in the future. However, the range of landslide response that is likely under a given set of climatic conditions can be described.

Landslide production associated with the 1964 flood event was measured for the Grider Creek drainage. It was assumed that a 10-year event would be considerably lower than this. Landslide production for the period from 1965-1974 was measured and used as an index for a 10-year return period storm. In summary, the landslide sediment volumes are imprecise, but allow a reasonable assessment of effects within well-defined bounds.

Geomorphic Mapping - The accuracy of geomorphic mapping is considered to be appropriate for this level of analysis. Refer to the Geologic AMS for a detailed description of the data collection process. However, errors are known to exist in the database. They are currently being rectified. Errors identified to date have been random, so Forest totals are not significantly affected. A general observation is that some inner gorges on main streams are too large, particularly where a wide floodplain exists. However, this is offset by the fact that many smaller inner gorges under a timber canopy were not identified at this level of inventory.

Accuracy of Landslide Production Coefficients - The landslide coefficients were developed primarily from a study in the Grider Creek watershed. This watershed occupies about 28,000 acres in the center of the westside of the Forest. These coefficients were modified using findings from additional studies in the upper South Fork of the Salmon River (30,000 acres), Negro Creek, a tributary to the South Fork Salmon River (3400 acres), and the Little North Fork of the Salmon River (20,000 acres).

Applicability of the Model to the Goosenest Ranger District - Landsliding is uncommon on most of the Goosenest Ranger District due to the predominance of gentle slopes and low precipitation. Exceptions occur in the Klamath River Gorge and in some steep areas with shallow soils, such as in the Rainbow Mountain area. Over most of the District, surface erosion is the primary erosion process. A large proportion of this occurs in response to intense summer storms. The surface erosion model addresses this problem.

Harvesting on Private Land - Current data regarding levels of harvest on private land was not available. Therefore, the private land contribution to the total landslide sediment production will be under-estimated.

A Forest Service study by Amaranthus (1985) compared the results of 7 landslide inventories in the Pacific Northwest. Combining Amaranthus' results with our findings in Grider Creek and the Salmon River Basin reveals the following observations. Roads increased landslide rates by an average of 163 times, with a range from 25 to 434 times. Harvesting resulted in an average increase of 2.9 times, with a range of 2.2 to 11.5.

It is not surprising that the range for increased landslide production for roads is large. This is mostly because design standards and mitigation measures vary greatly. Also, these factors have a large effect on landslide susceptibility. The sediment model assumes that timber harvest causes a 5-fold increase and roading 20-fold.

Table G-1. Interactions Chart for Geologic Hazards and Resources

Geologic Hazard/ Resource	Interactions with Other Natural Processes and Features	Effects of this Hazard/Resource on Forest Management	Effects of Forest Management on this Hazard/Resource	Consequence Assessment Technique
Landslide Hazard	Climate, volcanism, seismicity, slope hydrology, channel hydrology, soil processes, fire, plants and animals	Threat to human life and property, fisheries, soil, water, costly roads approx. 10-year return, archaeology	Soil and vegetation disturbance can increase risk of landsliding	Sediment model, land allocation, standards and guidelines, budget
Snow Avalanche Hazard	Climate, seismicity, vegetation	Potential threat to winter users of high mountains	Avalanches can be triggered by ground shaking	Winter recreation use, standards and guidelines
Volcanic Hazard	Landslide, seismic subsidence	Threat to life and property, but low frequency return (can be hundreds of years)	None	Standards and guidelines, inventory and monitoring, new facility disaster plan
Seismic Hazard	Landslide-volcanic	Threat to life and property, return period greater than 50 years (approx.)	None	Same as volcanic hazard
Subsidence and Collapse Hazard	Seismic, volcanic , groundwater, geologic SIAs	Underground voids can pose collapse hazard or possess cave values	Groundwater withdrawal can cause subsidence, roads can collapse voids	Standards and guidelines, inventory and monitoring
Asbestos Hazard	Wind, groundwater, wildfire	Can restrict use of some rock for roads	Earth disturbance can introduce fibers to atmosphere	Miles of new roads, standards and guidelines, inventory and monitoring
Radon Hazard	Groundwater, presence of radium, permeability of soil and rock	May require special ventilation in habitation sites	Buildings can concentrate the gas, smoke and dust particles collect gas	Inventory and monitoring, standards and guidelines
Minerals Resource	None	Mineral deposits open to development	Exploration and development disturbs soil and vegetation	Refer to Minerals section
Oil-Gas-Geothermal Resource	None	This resource is open to leasing	Exploration and development disturbs soil and vegetation	Refer to Minerals section
Rock-Soil and Earth Resource	None	Rock is necessary to surface new roads	Exploration and development disturbs soil and vegetation	Miles of new roads, standards and guidelines, inventory and monitoring
Geologic Special Areas Resource	None	Can attract recreation use	Can be damaged by soil and vegetation disturbance and by air or water pollution	Number of sites, standards and guidelines, inventory and monitoring
Groundwater Resource	Subsidence, landsliding	Useful for facilities, can promote landsliding when near surface	Finite resource, can be over-drawn, recharge areas can be polluted	Volume used, standards and guidelines, inventory and monitoring

Cumulative Watershed Effects

The entire Klamath National Forest is divided into spatial zones, called timber compartments. These compartment include all of the land within the National Forest boundary, private as well as public land. Some compartments contain a large proportion of private land relative to public; others contain little or no private land. The compartments are rarely true watersheds and can rarely be combined to form true watersheds. However, compartment clusters have been designated that approximate true watersheds. The compartment clusters, the compartments that make up each compartment cluster, and the total acreage of each compartment cluster are displayed in Table G-2. These make up the basis for examining cumulative watershed effects from the perspective of Equivalent Roaded Acres. While many aspects of watershed analysis are considered in the development of interpretations and conclusions, this technique focuses on the additional volume of water produced from management activities that manipulate forest vegetation.

Table G-2. Acreages and Compartments per Cluster

luster Key	Cluster Name	Compartments	Acres
1010	Walker	101	8,875
1020	Grider	102, 106, 107, 108, 550	27,636
1030	West Grider	103, 139	5,125
1040	O'Neil	104	7,005
1050	Tom Martin	105	5,997
1060	Fort Goff	109	9,193
1070	Portuguese	110	6,219
1080	Seiad	111, 112, 113	24,521
1090	Horse	114, 115, 117, 118	39,079
1100	Hamburg Gulch	116	9,390
1110	Doggett	119	15,204
1120	Beaver, Lower	120, 121, 122	36,088
1130	Beaver, Upper	123, 124, 125, 126, 127	45,230
1140	Empire	128	10,937
1150	Lime	129	10,760
1160	Collins	130	8,386
1170	McKinney	131	10,661
1180	Barkhouse	132, 133	18,145
1190	Vesa	135	7,253
1200	Humbug	134, 136, 137, 138	28,028
1210	Yreka Creek	140, 544, 545	6,865
1220	Hutton	141	2,937
1230	Indian, Upper	201, 202, 210, 211	20,642
1240	Indian, South Fork	212, 213, 215, 216, 217, 225	41,872
1250	Indian, East	203, 209, 218	17,784
1260	Cade	219, 220	7,848
1270	China	221, 222, 223	12,553
1280	Elk, West	224, 244	9,287
1290	Elk, East	245, 246	11,870
1300	Thompson	204, 208, 229, 256	27,488
1310	Elk, Upper	205, 206, 207, 247, 248, 249, 250	48,702
1320	Clear, Lower	230, 239, 240	21,928
1330	Clear, Upper	214, 231, 232, 233, 234, 235, 236, 237, 238	52,692
1340	Coon	241, 242, 265	9,111
1350	Swillup	257	5,571
1360	Oak Flat	228	6,183
1370	Little Grider	226, 227	9,951
1380	Buzzard	243	6,631
1390	Titus	251	6,239
1400	Independence	252, 253	8,955
1410	King	254	3,795
1420	Ukonom	255, 263, 266, 816, 818, 822	15,033
1430	Salmon, Upper North Fork	404, 405, 406, 408, 414	31,948
1440	Little North Fork	407, 409, 449, 450	28,072
1450	Crapo	411, 424	14,000
1460	Russian, North	415, 416	13,636
1470	Russian, South	417, 420, 421	15,586
1480	Robinson	418	7,160
1490	Big	419	5,394
1500	Jessups	422, 433	19,611
1510	Salmon, Upper South Fork	412, 413, 443, 444, 447, 448	51,048
1520	St. Claire	445	9,834
1530	Plummer	446	8,394

Table G-2. Acreages and Compartments per Cluster

Cluster Key	Cluster Name	Compartments	Acres
1540	Knownothing	432, 434, 435	29,506
1550	Nordheimer	425, 426, 427	25,716
1560	Salmon, Lower North Fork	423, 428	8,296
1570	Negro	429	5,653
1580	Indian (Salmon River RD)	430, 431	14,001
1590	Matthews	436	8,900
1600	South Fork, Lower East Fork,Salmon River	437, 438, 439, 440	28,253
1610	Taylor	441, 442	15,543
1620	South Fork, Upper East Fork, Salmon River	510, 511	11,353
1630	Crater	501, 548	5,472
1640	Cabin Meadows	502	5,783
1650	Rail	503	4,498
1660	Kangaroo	504	3,961
1670	Mill (Callahan)	505, 506, 507	20,563
1680	Boulder(Callahan)	508	9,196
1690	Fox	509	10,921
1700	Jackson	512	7,086
1710	Sugar	513, 514, 515, 516	21,997
1720	Etna	517, 518	11,636
1730	Kidder	519, 520, 523	20,137
1740	Boulder(ScottBar)	524	5,111
1750	Canyon	525, 526	16,317
1760	Kelsey	527, 528	12,651
1770	Middle	529	4,653
1780	Tompkins	530, 531	14,399
1790	McGuffy	532	5,716
1800	Scott Bar Mtn Drainages	533, 534	7,756
1810	Ferry	535	4,682
1820	Franklin	536	4,883
1830	Mill (Scott Bar)	537, 538	12,560
1840	Indian (Scott River RD)	539, 540	9,943
1850	McAdams	541, 542, 549	13,472
1860	Moffett	543, 546	2,553
1870	Dillon, Main	259, 261, 803, 805, 806, 809	26,023
1880	Dillon, North	260, 262	11,945
1890	Dillon, West	801, 802, 804	14,408
1900	Rock	807, 808, 810, 811, 812	25,242
1910	Reynolds	813	5,463
1920	Teneyek	814	4,074
1930	Sandy Bar	820, 821	8,155
1940	Ti	815, 817, 819	12,983
1950	Rogers	824, 825, 828, 829	13,969
1960	Merrill	830	4,725
1970	Monte	833	5,935
1980	Tom Payne	834	6,132
1990	Morehouse	410, 835	9,351
2000	Butler	836	5,742
2010	Lewis	837	3,893
2020	Wooley	401, 402, 403, 521, 522, 823, 826, 827, 831, 832, 838, 839	96,523
2030	Willow 1	701, 725, 726, 727, 728, 746, 747	46,300
2040	Antelope	722, 723, 724, 729, 730, 743, 744, 745, 748, 749, 750, 751	90,452
2050	Meiss	710, 714, 720, 755	39,398
2060	Butte	719, 721, 731, 732, 733, 739, 740, 741, 742, 752, 753, 754	88,740
2070	Little Shasta	712, 713, 715, 716, 718	14,043
2080	Shovel	702, 703, 704, 705, 706, 707, 708	33,029
2090	Willow 2	709, 711	998
2100	Shasta	717, 734, 735, 736, 737, 738, 756	36,536
2110	Mesner	547	948

Equivalent Roaded Area Calculation

Equivalent Roaded Area (ERA) is a measure of hydrologic disturbance of a watershed. Disturbances, such as roads, timber harvest and wildfire, are converted to ERAs, approximately the amount of disturbance associated with 1 acre of road.

Road mileage has been approximated for each compartment. The Forest database contains the acreage of wildfire, plantations and private land for each compartment. This mileage and acreage is multiplied by the appropriate factor, listed in Table G-3, and added together to obtain the existing situation ERA for each compartment cluster. This number is divided by the acreage of each cluster and multiplied by 100% to obtain the percent ERA. This number is compared to the Threshold of Concern (TOC) for analysis of effects to each cluster.

The FORPLAN model uses the existing situation ERA, decays existing disturbance according to Table G-4, and adds in projected disturbance to calculate Forest-wide ERA by alternative by decade. This number is disaggregated to the compartments to calculate cluster percent ERA and risk ratios.

The disaggregation process involves recognizing the land allocations and timber types in each compartment and proportioning the Forest-wide projections based on these allocations and timber types. For instance, if FORPLAN outputs project that one-half of the D4G timber type in Regulation Class 1 is to be clearcut in the next decade and a compartment contains 100 acres of Regulation Class 1 D4G land, than it is assumed that 50 acres of this land will be clearcut in the next decade.

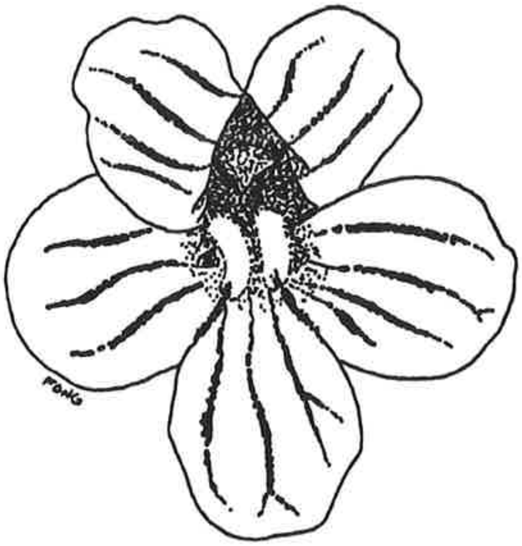

Table G-3. ERA Coefficients

Disturbance	Coefficient (ERA per mile)
All existing and planned roads	4.1
P 0 plantations (plantations less than 10 years old)	0.21
P 1 plantations (plantations between 10 and 20 years)	0.21
P 2 plantations (plantations between 20 and 30 years)	0.17
P 3 plantations (plantations between 30 and 40 years)	0.06
High Intensity Burn Acres (1987 wildfires)	0.21
Moderately Burned P 0 Areas	0.21
Moderately Burned P 1 Areas	0.21
Moderately Burned P 2 Areas	0.19
Moderately Burned P 3 Areas	0.12
Moderately Burned Other Areas	0.17
All Other Public Land	0
Private Land, Moderately Burned Plantations	0.18
Private Land, Moderately Burned Other Areas	0.17
Private Land, Plantations	0.18
Private Land, Other Areas	0.16

Table G-4. Carryover Coefficients

Decade 1	Clearcut	0.80	Partial Cut	0.500
Decade 2	Clearcut	0.72	Partial Cut	0.125
Decade 3	Clearcut	0.32	Partial Cut	0.025
Decade 4	Clearcut	0.08	Partial Cut	0
Decade 5	Clearcut	0.016	Partial Cut	0

Threshold of Concern Calculation

A Threshold of Concern has been calculated for each compartment cluster. Five paramenters are combined by the equation "2B + 3C + E + H + S= Watershed Sensitivity," where B is beneficial use, C is channel condition, E is soil erodibility, S is slope stability and H is hydrologic response potential. Watershed Sensitivity is converted to TOC by the equation "(43 - Watershed Sensitivity) / 2=TOC." (Refer to Table G-6 for the actual TOC and Watershed Sensitivity factors calculated by cluster.)

This index calculation method is not field verified. It assumes that the sensitivity of a watershed is additive, relative to circumstances that occur within a watershed, rather than operating as a limiting factor that would have the most sensitive factor set the threshold. This concept requires monitoring to validate it. The thresholds set by this method are generally lower than those used on project studies to date locally. This is a different use of TOC than that used by most other forests in Region 5.

The actual indexes used for the 5 parameters are shown in Table G-5.

Table G-5. Indexes Used for the 5 Parameters

Code	Type	Significance	Index
B	Beneficial Use	Very Highly Significant	5
		Highly Significant	4
		Moderately Significant	3
		Significant	2
		Not Significant	1
C	Channel Condition	Very Poor	5
		Poor	4
		Fair	3
		Good	2
		Excellent	1
E	Soil Erodibility	Very High	5
		High	4
		Moderate	3
		Low	2
		Very Low	1
H	Hydrologic Response	High Peak Runoff Potential	5
		Moderately High Potential	4
		Moderate Potential	3
		Low Peak Runoff Potential	2
S	Slope Stability	Extremely Unstable	5
		Highly Unstable	4
		Moderately Unstable	3
		Stable	2
		Very Stable	1

These factors are chosen for each compartment cluster and used in the equations to compute the TOC for each cluster. A list of all the compartment clusters and the sensitivity factors are displayed in Table G-6, along with examples of how the equations were used. Refer to Table G-5 for explanations of the parameters and indexes used.

Professional judgement was used to assign the factors rather than specific measureable criteria. This increases the need for further study in this area and comparison to monitoring results from future studies.

Table G-6. Compartment Clusters and Associated Sensitivity Factors[1]

Cluster Key	Cluster Name	Watershed Sensitivity	Parameters (Indexes)					TOC
			B	C	E	H	S	
1010	Walker	30	4	3	4	4	5	6.5
1020	Grider	27	5	2	3	4	4	8.0
1030	West Grider	23	4	2	3	3	3	10.0
1040	O'Neil	25	4	2	3	4	4	9.0
1050	Tom Martin	29	5	3	3	4	3	7.0
1060	Fort Goff	29	5	3	3	4	3	7.0
1070	Portuguese	24	4	2	3	4	3	9.5
1080	Seiad	27	4	3	3	4	3	8.0
1090	Horse	32	5	3	5	4	4	5.5
1100	Hamburg Gulch	24	2	3	4	3	4	9.5
1110	Doggett	27	3	3	4	4	4	8.0
1120	Beaver, Lower	28	5	2	3	5	4	7.5
1130	Beaver, Upper	31	5	3	4	5	3	6.0
1140	Empire	26	4	3	2	5	2	8.5
1150	Lime	23	3	3	2	4	2	10.0
1160	Collins	23	3	3	2	3	3	10.0
1170	Mc-Kinney	25	3	3	3	3	4	9.0
1180	Bark-house	21	3	2	2	3	4	11.0
1190	Vesa	22	1	3	3	4	4	10.5
1200	Humbug	25	4	3	2	4	2	9.0
1210	Yreka Creek	25	4	3	2	5	1	9.0

Table G-6. Compartment Clusters and Associated Sensitivity Factors[1]

Cluster Key	Cluster Name	Watershed Sensitivity	Parameters (Indexes)					TOC
			B	C	E	H	S	
1220	Hutton	22	3	3	1	4	2	10.5
1230	Indian, Upper	30	5	3	3	4	4	6.5
1240	Indian, South Fork	29	5	3	3	4	3	7.0
1250	Indian, East	31	5	3	3	5	4	6.0
1260	Cade	32	5	4	3	3	4	5.5
1270	China	26	4	3	3	3	3	8.5
1280	Elk, West	28	5	3	3	3	3	7.5
1290	Elk, East	29	5	3	4	4	2	7.0
1300	Thompson	29	5	3	3	4	3	7.0
1310	Elk, Upper	30	5	3	4	4	3	6.5
1320	Clear, Lower	26	5	2	3	3	4	8.5
1330	Clear, Upper	29	5	3	2	5	3	7.0
1340	Coon	27	4	3	3	3	4	8.0
1350	Swillup	30	4	3	4	4	5	6.5
1360	Oak Flat	26	4	3	3	4	2	8.5
1370	Little Grider	29	4	4	3	3	3	7.0
1380	Buzzard	21	1	3	3	3	4	11.0
1390	Titus	29	4	3	4	3	5	7.0
1400	Independence	29	4	3	4	4	4	7.0
1410	King	22	3	2	4	3	3	10.5
1420	Ukonom	29	5	2	5	4	4	7.0
1430	Salmon, Upper North Fk	29	5	3	3	5	2	7.0
1440	Little North Fk.	31	5	3	4	5	3	6.0
1450	Crapo	34	5	4	5	4	3	4.5
1460	Russian, North	27	5	2	3	5	3	8.0
1470	Russian, South	28	4	3	4	5	2	7.5
1480	Robinson	28	5	3	3	4	2	7.5
1490	Big	39	5	5	5	4	5	2.0
1500	Jessups	29	5	3	2	5	3	7.0
1510	Salmon, Upper South Fk.	32	5	3	4	5	4	5.5
1520	St. Claire	30	5	3	3	5	3	6.5
1530	Plummer	24	4	2	3	5	2	9.5
1540	Know-nothing	29	5	3	2	4	4	7.0
1550	Nordheimer	31	5	3	3	4	5	6.0
1560	Salmon, Lower North Fork	26	5	2	3	3	4	8.5
1570	Negro	24	3	3	2	3	4	9.5
1580	Indian (Salmon River RD)	25	4	2	3	5	3	9.0
1590	Matthews	24	5	2	2	3	3	9.5
1600	South Fork, Lower East Fork Salmon	30	5	3	3	5	3	6.5
1610	Taylor	31	5	3	4	5	3	6.0
1620	South Fk, Upper East Fork Salmon	22	4	2	2	4	2	10.5
1630	Crater	24	4	3	2	4	1	9.5
1640	Cabin Meadows	27	4	4	2	4	1	8.0
1650	Rail	23	3	3	2	5	1	10.0
1660	Kangaroo	22	2	3	3	5	1	10.5
1670	Mill (Callahan)	25	4	3	2	5	1	9.0
1680	Boulder (Callahan)	28	5	3	4	4	1	7.5
1690	Fox	24	3	3	3	4	2	9.5
1700	Jackson	25	4	3	3	4	1	9.0
1710	Sugar	26	4	3	4	4	1	8.5
1720	Etna	29	5	3	3	4	3	7.0
1730	Kidder	30	5	4	3	4	1	6.5

Table G-6. Compartment Clusters and Associated Sensitivity Factors[1]

Cluster Key	Cluster Name	Watershed Sensitivity	Parameters (Indexes)					TOC
			B	C	E	H	S	
1740	Boulder (Scott Bar)	25	4	3	2	4	2	9.0
1750	Canyon	26	5	3	2	4	1	8.5
1760	Kelsey	30	5	3	3	5	3	6.5
1770	Middle	26	4	2	2	5	5	8.5
1780	Tompkins	31	5	3	3	5	4	6.0
1790	McGuffy	24	4	2	3	4	3	9.5
1800	Scott Bar Mtn. Drainages	20	2	2	2	4	4	11.5
1810	Ferry	19	2	2	2	4	3	12.0
1820	Franklin	20	2	2	4	3	3	11.5
1830	Mill (Scott Bar)	24	4	2	2	5	3	9.5
1840	Indian (Scott River RD)	25	4	3	1	5	2	9.0
1850	Mc-Adams	29	3	5	2	5	1	7.0
1860	Moffett	29	3	5	2	5	1	7.0
1870	Dillon, Main	31	5	3	4	3	5	6.0
1880	Dillon, North	30	5	3	3	5	3	6.5
1890	Dillon, West	32	5	3	3	5	5	5.5
1900	Rock	28	4	3	3	3	5	7.5
1910	Reynolds	27	3	3	4	3	5	8.0
1920	Teneyek	22	1	3	3	3	5	10.5
1930	Sandy Bar	31	5	3	4	4	4	6.0
1940	Ti	27	4	3	3	3	4	8.0
1950	Rogers	29	3	4	4	3	4	7.0
1960	Merrill	24	3	3	3	3	3	9.5
1970	Monte	29	3	4	4	3	4	7.0
1980	Tom Payne	25	2	3	4	3	5	9.0
1990	More-house	24	2	3	4	4	3	9.5
2000	Butler	28	4	3	4	3	4	7.5
2010	Lewis	26	3	3	4	3	4	8.5
2020	Wooley	25	5	1	4	4	4	9.0
2030	Willow 1	15	1	3	1	2	1	14.0
2040	Antelope	27	5	4	1	3	1	8.0
2050	Meiss	24	3	4	2	3	1	9.5
2060	Butte	24	4	4	1	2	1	9.5
2070	Little Shasta	22	4	3	1	3	1	10.5
2080	Shovel	24	5	3	1	3	1	9.5
2090	Willow 2	18	2	3	1	3	1	12.5
2100	Shasta	17	2	3	1	2	1	13.0
2110	Mesner	19	2	3	1	4	1	12.0

[1] Using the equations mentioned previously, here is an example of how the Watershed Sensitivity and TOC numbers were calculated: For Watershed Sensitivity, the equation is 2(B) + 3(C) + E + H + S. For the Walker Cluster, this is the equation: "2(4) + 3(3) + 4 + 4 + 5 = 30." To calculate TOC, the equation is (43-Watershed Sensitivity) / 2. For the Walker Cluster, this is the equation: "(43 - 30) / 2 = 6.5."

The existing situation ERA (in percent), the Threshold of Concern and the resulting risk ratio (percent ERA divided by TOC) have been calculated for each compartment cluster watershed (Table G-7).

Table G-7. Existing Situation ERA, TOC and Resulting Risk Ratio by Cluster[2]

Cluster Key	Cluster Name	Existing ERA (%)	TOC	Risk Ratio
1010	Walker	7.2	6.5	1.1
1020	Grider	0.5	8.0	0.6
1030	West Grider	7.0	10.0	0.7
1040	O'Neil	4.5	9.0	0.5
1050	Tom Martin	0.3	7.0	0.4
1060	Fort Goff	11.2	7.0	1.6
1070	Portuguese	10.4	9.5	1.1
1080	Seiad	8.8	8.0	1.1
1090	Horse	11.0	5.5	2.0
1100	Hamburg Gulch	7.6	9.5	0.8
1110	Doggett	13.6	8.0	1.7
1120	Beaver, Lower	11.2	7.5	1.5
1130	Beaver, Upper	10.4	6.0	1.3
1140	Empire	13.6	8.5	1.6
1150	Lime	7.0	10.0	0.7
1160	Collins	10.0	10.0	1.0
1170	McKinney	12.6	9.0	1.4
1180	Barkhouse	7.7	11.0	0.7
1190	Vesa	4.2	10.5	0.4
1200	Humbug	7.2	9.0	0.8
1210	Yreka Creek	N/A	9.0	N/A
1220	Hutton	13.6	10.5	1.3
1230	Indian, Upper	6.5	6.5	1.0
1240	Indian, South Fork	4.2	7.0	0.6
1250	Indian, East	8.4	6.0	1.4
1260	Cade	13.8	5.5	2.5
1270	China	11.0	8.5	1.3
1280	Elk, West	9.0	7.5	1.2
1290	Elk, East	9.8	7.0	1.4
1300	Thompson	7.0	7.0	1.0
1310	Elk, Upper	4.6	6.5	0.7
1320	Clear, Lower	6.8	8.5	0.8
1330	Clear, Upper	1.4	7.0	0.2
1340	Coon	6.4	8.0	0.8
1350	Swillup	3.2	6.5	0.5
1360	Oak Flat	2.6	8.5	0.3
1370	Little Grider	4.9	7.0	0.7
1380	Buzzard	5.5	11.0	0.5
1390	Titus	8.4	7.0	1.2
1400	Independence	9.8	7.0	1.4
1410	King	5.2	10.5	0.5
1420	Ukonom	6.3	7.0	0.9
1430	Salmon, Upper North Fork	0.7	7.0	0.1
1440	Little North Fork	8.6	6.0	1.4
1450	Crapo	8.6	4.5	1.9
1460	Russian, North	2.4	8.0	0.3
1470	Russian, South	1.5	7.5	0.2
1480	Robinson	1.5	7.5	0.2
1490	Big	14.4	2.0	7.2
1500	Jessups	4.2	7.0	0.6
1510	Salmon, Upper South Fork	1.1	5.5	0.2
1520	St. Claire	5.2	6.5	0.8
1530	Plummer	1.0	9.5	0.1
1540	Knownothing	6.3	7.0	0.9
1550	Nordheimer	3.0	6.0	0.5
1560	Salmon, Lower North Fork	7.6	8.5	0.9
1570	Negro	15.2	9.5	1.6
1580	Indian (Salmon River RD)	9.0	9.0	1.0
1590	Mathews	2.8	9.5	0.3
1600	South Fork, Lower East Fork Salmon	2.6	6.5	0.4
1610	Taylor	1.8	6.0	0.3
1620	South Fork, Upper East Fork Salmon	2.1	10.5	0.2
1630	Crater	10.4	9.5	1.1
1640	Cabin Meadows	9.6	8.0	1.2
1650	Rail	14.0	10.0	1.4
1660	Kangaroo	14.7	10.5	1.4
1670	Mill (Callahan)	9.9	9.0	1.1
1680	Boulder (Callahan)	9.0	7.5	1.2

Table G-7. Existing Situation ERA, TOC and Resulting Risk Ratio by Cluster[2]

Cluster Key	Cluster Name	Existing ERA (%)	TOC	Risk Ratio
1690	Fox	4.8	9.5	0.5
1700	Jackson	5.4	9.0	0.6
1710	Sugar	11.9	8.5	1.4
1720	Etna	10.5	7.0	1.5
1730	Kidder	11.0	6.5	1.7
1740	Boulder (Scott Bar)	7.2	9.0	0.8
1750	Canyon	0.1	8.5	0.2
1760	Kelsey	4.6	6.5	0.7
1770	Middle	6.0	8.5	0.7
1780	Tompkins	5.4	6.0	0.9
1790	McGuffy	1.9	9.5	0.2
1800	Scott Bar Mtn. Drainages	5.8	11.5	0.5
1810	Ferry	12.0	12.0	1.0
1820	Franklin	5.8	11.5	0.5
1830	Mill (Scott Bar)	12.4	9.5	1.3
1840	Indian (Scott River RD)	16.2	9.0	1.8
1850	McAdams	11.2	7.0	1.6
1860	Moffett	15.4	7.0	2.2
1870	Dillon, Main	1.8	6.0	0.3
1880	Dillon, North	1.3	6.5	0.2
1890	Dillon, West	1.1	5.5	0.2
1900	Rock	5.2	7.5	0.7
1910	Reynolds	8.8	8.0	1.1
1920	Teneyek	7.4	10.5	0.7
1930	Sandy Bar	6.6	6.0	1.1
1940	Ti	7.2	8.0	0.9
1950	Rogers	6.3	7.0	0.9
1960	Merrill	4.8	9.5	0.5
1970	Monte	1.4	7.0	0.2
1980	Tom Payne	6.3	9.0	0.7
1990	Morehouse	3.8	9.5	0.4
2000	Butler	1.5	7.5	0.2
2010	Lewis	0.8	8.5	0.1
2020	Wooley	0.9	9.0	0.1
2030	Willow 1	2.8	14.0	0.2
2040	Antelope	8.0	8.0	1.0
2050	Meiss	1.9	9.5	0.2
2060	Butte	10.4	9.5	1.1
2070	Little Shasta	4.2	10.5	0.4
2080	Shovel	5.7	9.5	0.6
2090	Willow 2	1.2	12.5	0.1
2100	Shasta	0.5	13.0	0.1
2110	Mesner	15.6	12.0	1.3

[2] An example of how the Risk Ratio was calculated is where the ERA (%) is divided by the TOC. For the Walker Cluster it is: 7.2 / 6.5 = 1.1.

Watershed Condition and Water Quality

Watershed condition is estimated through the use of the geomorphic terrane types and disturbances. All active landslides are considered to be entirely Watershed Condition Class 3 (water quality impacts per Watershed Condition Class is explained below). Roads and plantations in the other geomorphic types are considered to be in Watershed Condition Class 2 or 3, based on the proportions listed in Table G-8. The remainder is considered to be in Watershed Condition Class 1. Areas effected by wildfire are estimated to be in Watershed Condition Classes 2 and 3, as listed in Table G-9.

Water quality is estimated using the watershed condition estimates. For this estimate, Watershed Condition Class 1 land is assumed to always produce water meeting water quality objectives. Watershed Condition Class 2 land is assumed to produce water meeting water quality objectives 85% of the time, while Watershed Condition Class 3 land assumes this 35% of the time. These proportions are multiplied by the water yield to give water quality outputs in terms of acre feet of water meeting and not meeting water quality objectives (refer to the Water Section in Chapter 3 of the EIS).

Table G-8. Percent of Roads and Plantations in Watershed Condition Classes 2 and 3 by Geomorphic Terrane Type

Geomorphic Terrane Type[3]	Percent of Roads		Percent of Plantations	
	Watershed Condition Class 2	Watershed Condition Class 3	Watershed Condition Class 2	Watershed Condition Class 3
Toe Zones of Dormant Slides	20	10	10	0
Dormant Landslides	10	0	10	0
Steep Granitic Mountain Slopes	20	10	20	10
Moderately Steep Granitic Mountain Slopes	10	0	10	0
Steep Non-Granitic Mountain Slopes	10	0	10	0
All Mountain Slopes on Goosenest Ranger District (not Dormant Slides)	0	0	0	0
Moderately Steep Non-Granitic Mountain Slopes	0	0	0	0
Inner Gorge, Developed on Unconsolidated Deposits	30	20	20	10
Inner Gorge, Granitic	30	20	30	20
Other Inner Gorge	20	10	20	10
Debris Basins	20	10	10	0
Glacial Deposits	0	0	0	0

[3] Geomorphic Terrane Type "Active Landslides" is considered to be entirely Watershed Condition Class 3.

Table G-9. Percent Wildfire Intensity by Watershed Condition Class

Geomorphic Terrane Type	Moderate Intensity Wildfire (%)		High Intensity Wildfire (%)	
	Watershed Condition Class 2	Watershed Condition Class 3	Watershed Condition Class 2	Watershed Condition Class 3
All Terrane Types	10	0	10	10