Willamette National Forest Pilot Road Analysis

Appendix A

Economics Process Paper

October 1998

Errata Correction Sheet (02/09/2001)

Willamette National Forest

Pilot Road Analysis

Page 5 Executive Summary

1.2. Key Analysis Results and Findings

Second paragraph should read:

- Economics alone (financial efficiency) does not support large-scale road ~~closures or~~ decommissioning in spite of the current imbalance in funding available for road system management.

Appendix A: Economics Process Paper

Page A-5, Item 3 of the 5th paragraph should read:

3. To close the same road would cost $2,000 for closure, $100 a year in minimal maintenance. ~~and $1,600 expected every 10 years for repairs~~.

Page A-5, Item 3 of the 6th paragraph should read

The goal is to find which scenario(s) prove to be financial viable over the next 20 years by requiring a 20 year discounted investment less than the no change alternative. Under the above assumptions, the no change scenario would require a discounted investment of $5,459. To decommission the same road would require an upfront investment of $10,000 with no additional expenses expected. The second scenario does not make sense to implement for solely fiscal reasons. It is far cheaper to maintain the road at $5,459 as opposed to spending $10,000 to decommission. To close the road would require a discounted investment of ~~$5,270~~ $3459. In other words it would be cheaper to close the road than to keep it open. ~~however, the two scenarios are very close.~~

Introduction

The history behind the Willamette's current road system has an important role in how we look into its financial efficiency. The Forest's roads were built primarily to access timber harvest units and for other administrative purposes. Some of those same roads also provided the primary access to lakes, trails, campgrounds, and much needed access during firefighting operations. High timber revenues coupled with recreation benefits, and access for firefighters made the roads financially efficient to build and maintain. This was also reinforced in the 1990 Willamette Forest Plan where continued road building to ``complete'' the Forest's road system was part of the preferred alternative (USDA 1990). Lawsuits and court injunctions ensued over spotted owl habitat limiting harvest levels. In 1994 the Northwest Forest Plan was implemented and resulted in more than 75% of the timber suited lands available for timber harvest now in no-harvest land allocations. With this series of events the primary source of revenue that maintained the current road system, fundamentally changed. The objective of the economic questions is to address costs, budget, and overall financial efficiency of the current road system.

Process Description and Documentation

In this analysis we addressed three key questions listed in the order they are dealt with in this paper:

EC-1: *How does the road system affect the direct costs and direct revenues to the Agency as used in assessing financial efficiency?*

EC-2: *What is the Net Public Benefit of the forest road system?*

Closely related to the above questions but address in Appendix M is key question EC-3 which asks:

"What are the maintenance costs of the existing road system? How does that compare to recent forest road budgets and projections of future road budgets?"

When stated the analysis of question EC-1 relies on data presented by key question EC-3.

EC-1: *How does the road system affect the direct costs and direct revenues to the Agency as used in assessing financial efficiency?*

General Analytical Process

In this analysis we examined whether the Agency's revenues covers its direct budget costs, as specifically related to roads. With timber revenues a driving force in generating road maintenance funds, we stratified the analysis by timber suitable and timber unsuitable lands. Timber suitability was defined by land management allocations outside of riparian reserves. Other factors such as soil and wildlife management requirements were not considered deciding factors. This coarse stratification is a sufficient for a forestwide analysis. Most timber haul routes will need to travel some distance through timber unsuitable lands to reach the mill; however, these roads will mostly be primary and secondary roads which are not considered a

changing element in this analysis. Objectives for private lands are not controlled by the Forest, however, money is spent on maintaining roads within the Forest's private land inholdings and therefore these areas are included in the analysis. The stratification of the Forest Plan management allocations is shown in the table below.

Table 1. Stratification of Land Management Allocations

Classified	Management Areas
Harvest	10A, 10B, 11A, 11B, 11C, 11D, 11E, 11F, 14A, 17,
Noharvest	1, 1-6E, 2A, 2B, 4, 5A, 6D, 6E, 7, 8, 9B, 9C, 9D, 10C, 10E, 10F, 12A, 12B, 13A, 13B, 16A, 16B
Private	All nonfederal land within the forest proclaimed boundary
Water	All water bodies within the forest proclaimed boundary

Using the above stratification, the current transportation system is describe as an inventory of direct costs and direct revenues of the roads on the Forest. External costs were not included in this analysis. An external cost is one caused by the agency and imposed on some other party without compensation, such as polluting water, or degrading scenic beauty. In this same token external benefits such as enhanced property values were also not investigated. Revenues include estimation of future revenues from timber harvest from both harvest and no harvest allocations.

A primary goal of this analysis is to examine the fiscal effectiveness of maintaining or decommissioning roads in areas with and without a flow of long-term revenues. Because of their direct applicability, the results and interpretation of this analysis will utilize the same costs presented in the Results section for key question EC-3.

Results

As presented in key question EC-1, to maintain the current road system to its prescribed maintenance level would require approximately $3.4 million dollars. This is the total amount regardless of its current stratification. The table below breaks down the $3.4 million dollars according to harvest, nonharvestable, and private lands.

Table 2. Road Inventory and maintenance costs.

Category	Maintenance level	Miles	Unit cost/mile	Average cost
Harvest	none	318		
	1	417	$ 50-$ 100	31,275
	2	2,406	$ 100-$ 400	601,500
	3	671	$ 500-$1,500	671,000
	4	56	$ 800-$3,000	106,400
	5	105	$2,500-$5,000	393,750
			subtotal	1,803,925
No-harvest	none	187		
	1	188	$ 50-$ 100	14,100
	2	1,213	$ 100-$ 400	303,250
	3	373	$ 500-$1,500	373,000
	4	61	$ 800-$3,000	115,900
	5	138	$2,500-$5,000	517,500
			subtotal	1,323,750
Private	none	411		
	1	30	$ 50-$ 100	2,250
	2	279	$ 100-$ 400	69,750
	3	108	$ 500-$1,500	108,000
	4	12	$ 800-$3,000	22,800
	5	12	$2,500-$5,000	45,000
			subtotal	247,800
			total	**3,375,475**

Using the road maintenance costs presented under key question EC-3, the approximate expenditure to maintain roads located matrix lands is $1.8 million and $1.3 million in lands where no programmed timber harvest is planned. Roads located on private land are expected to cost approximately $248,000 a year.

Roads in all stratifications provide direct revenues. Revenues below are based on a compilation of several sources. The predicted future volume of timber on our harvestable lands is base on estimations calculated during implementation of the Northwest Forest Plan and represent our best look into the future production of timber commodities. Predicted timber volume of thinnings on non-harvestable lands was predicted in the Mid Willamette Late Successional Reserve Assessment (USDA 1998). This estimate is limited to only Late Successional Reserves. Value per unit for timber volume was estimated based on the 1997 TSPIRS report. The value of $197/mbf accounts for all timber direct and indirect costs (costs associated with appeals and litigation) outside of road revenues and expenses. The value of $197/mbf for is the resulting balance for 1997s regeneration harvest and commercial thins volumes combined. The value of timber from LSRs which will be strictly commercial thins can be expected to be lower.

Table 3. Timber related revenues

Stratification	Product	Predicted future volume (MBF)	Revenue/MBF	Revenue from commodity harvest and recreation per year	
				First decade	Out decades
Harvest	Regen/thin	136,000	$197	$26,792,000	$26,792,000
No-harvest	thin	32,000	$197	$6,304,000	0
			Total	$33,096,000	$26,792,000

Sources of additional revenues outside of timber include grazing, land uses, minerals, recreation and special uses. During fiscal year 1997 we collected $341,311 (USDA, 1997). These collections are historically very small compared to timber revenues; however, would not exist without the availability of roads. These additional revenues were derived from the National Forest Statement of Receipts for fiscal year 1997.

When revenues from commodity harvest are compared to road maintenance costs, costs on harvestable lands are well below the revenues they generate. This is also true for nonharvestable lands for the next decade as commercial thinning continues to promote late successional conditions. These results are supported by the 1997 TSPIRS report where timber harvest netted $17 million dollars once all costs were accounted. Costs accounted for include KV related activities; however, do not include payments to states. If payments to states (25 million in 1997) were included the forest would have a net loss in revenue. Important to point out; however, is payments to states must be met regardless of timber revenues. With no timber revenues the net loss would be much greater than 8 million.

Regardless of sufficient timber revenues, the road maintenance budget does not fund roads to prescribed maintenance levels. Decommissioned roads provides an opportunity to make an initial investment and reduce future long-term maintenance costs. Decommissioning a sufficient number of roads will bring our current maintenance costs in alignment with the budget. This is discussed in the next section.

Decommissioning Costs

Decommission costs range greatly depending on the unique characteristics of the road and its surrounding topography. Below is a reiteration of the decommission costs from key question EC-3.

Table 4. Decommissioning Costs

Risk level	Unit cost per mile
low	$ 2,000-$ 5,000
moderate	$ 5,000-$15,000
severe	$15,000-$30,000

Most roads in areas of no harvest (primarily LSRs) and private land will not financially pay for themselves after the next decade. An analysis was completed to study 3 opportunities for these roads. Maintenance level 2 roads are used in these examples because of they make up the bulk of the roads under consideration for change.

1. No change, continue to maintain the road at its prescribed level
2. Decommission the road so no additional maintenance or repairs are needed
3. Close the road and drop its maintenance and repairs to a minimal level.

Under these three scenarios the following assumptions were made:

1. Under the no change scenario, maintenance costs are $250 a year, repair costs are $1,600 expected every 10 years.
2. To decommission the same mile of road would cost $10,000 of initial investment and no additional expenses such as repairs would be expected.
3. To close the same road would cost $2,000 for closure, $100 a year in minimal maintenance, and $1,600 expected every 10 years for repairs.

The goal is to find which scenario(s) prove to be financial viable over the next 20 years by requiring a 20 year discounted investment less than the no change alternative. Under the above assumptions, the no change scenario would require a discounted investment of $5,459. To decommission the same road would require an upfront investment of $10,000 with no additional expenses expected. The second scenario does not make sense to implement for solely fiscal reasons. It is far cheaper to maintain the road at $5,459 as opposed to spending $10,000 to decommission. To close the road would require a discounted investment of $5,270. In other words it would be cheaper to close the road than to keep it open; however, the two scenarios are very close.

An increase or decrease in any one of the above assumptions would change the 20 year discounted investment and possibly alter its status as financially viable or not.

Below is a summary of the sensitivity of the assumptions under each opportunity:

1. Under the no change scenario, if maintenance costs were greater than $600 a year then decommissioning the road would make sense. A maintenance cost of greater than $600 a year, however, is unlikely. The highest maintenance cost estimated for a maintenance level 2 road is $400 dollars a year. If repair costs exceed $5000 every ten years then decommissioning the road would make sense. This change is also highly unlikely. Repair costs are derived from actual repair costs from two large storm events over the last 44 years on the forest and inflated to 1998 dollars. To account for smaller storms where repair costs records were not located, anticipated repair costs were increased approximately 20%. Increasing the costs to 5,000 per mile per decade requires the expectation for damage to increase three fold over the next twenty years from that of the last 44 years.
2. If decommissioning costs were reduced to or below $5,500 per mile then decommissioning would be a viable option over maintaining the road at its current prescribed level.
3. If closing the road increased from $2,000 to $2,500 or maintenance costs increase from $100 to $125, or repair costs increase to more than $1,800 every ten years then it would no longer make sense to close the road but to maintain.

Under these scenarios a typical road not posing a high risk to the environment or safety would not make economic sense to decommission. Decommissioning roads with an objective to bring the road maintenance costs in alignment with the budget is not recommended. Closing roads may be a viable option under the above assumptions; however, the difference in the 20 year discounted investment is less than $200 dollars, so careful analysis of costs would be important.

Interpretation

This assessment presents a disturbing picture of the current road system and its budget. To continue to maintain the roads as efficiently as possible with the current budget will eventual result in roads not maintained to a level safe for users and managers nor environmentally sound. Currently a one-time investment of dollars to decommission roads strictly to bring the road system in alignment with the current budget levels is also not fiscally responsible unless costs presented in this paper change significantly. There will, however, be roads that need to be decommissioned because they pose environmental costs that make them worthy of decommissioning.

Worthy goals of the Forest should be:

- Decommission roads that pose environmental hazards and/or safety hazards.
- Look for opportunities to reduce the miles of roads that do not or will not contribute substantially to future timber commodities, recreation, or other legitimate uses on the forest.
- Close roads after careful analysis of their costs versus other opportunities.

- ✧ On the remaining roads minimize direct road costs in order to maximize financial efficiency.

A one-time investment of dollars to decommission roads strictly to bring the road system in alignment with the current budget level is not recommended under current decommissioning costs.

EC-2: ***What is the Net Public Benefit of the forest road system?***

Discussion

An economic analysis of net public benefit played a small role in the Road Analysis. The overall objective discussed during the first Road Analysis meeting was providing an assessment that will help managers decide the merits of closing, relocating, upgrading, or decomissioning exisiting roads and building new roads. Driving forces meeting this objective will most probably be biophysical and financial factors and not specifically measured by net public benefits. In addition, the true measure of net public benefit can not be obtained. Some outputs and effects cannot be adequately valued in the time frame allocated and without the use of social analysis techniques.

During subsequent NEPA analyses where alternatives are evaluated, an economic analysis that results in a ranking of alternatives in relation to their Net Public Benefit and benefit/cost ratio would be useful to the decision maker. Results from the ecological and social analyses completed for this assessment will provide input for the economic analysis of alternatives from which response coefficients can be applied. Scale for this project will be driven more by the scale from which specific alternatives are analyzed.

Process Critique - All questions

External costs were not included in this analysis. An external cost is one caused by the agency and imposed on some other party without compensation, such as polluting water, or degrading scenic beauty. In this same token external benefits such as enhanced property values were also not investigated. Attempts to measure the value of the costs in benefits in dollars can be largely subjective. These factors, however, do influence the decision making process. In cases where non-priced benefits are impossible to value in a marketplace they still need to be weighed by the decision maker.

Examples of information not considered or known in this economic analysis are listed below. These items also represent examples of cost and benefits that may necessitate decommissioning roads despite the direct costs.

Following is a list of incomplete accounting costs for closing or decommissioning existing roads:

- ✓ Less fragmentation of habitat
- ✓ Less erosion and stream sedimentation
- ✓ Increased soil productivity

- ✓ Less introduction of exotic species
- ✓ Less risk of fire
- ✓ Less litter and other human impacts
- ✓ Less wildlife stress
- ✓ Less modification of ecological processes
- ✓ Less noise
- ✓ Less pollution
- ✓ Less road kill
- ✓ Potential increase in unroaded area
- ✓ Loss for excluded uses and users
- ✓ Increased management cost
- ✓ Increased cost for research that requires access
- ✓ Increased inventory and monitoring cost

Another key piece of missing information is future revenues from timber commodities. Though actual revenues for 1997 were used, timber values and overall revenue are sensitive to the marketplace, harvest levels, and current management practices.

References

USDA Forest Service, Willamette National Forest. 1955-1998. Willamette National Forest Annual Report.

USDA Forest Service. 1990. *Land and Resource Management Plan*, Willamette National Forest.

USDA Forest Service, Forest Service Handbook 1909. 19 88. Economic and Social Analysis Handbook, 1909.17.

USDA Forest Service, Willamette National Forest. 1997a. Statement of Timber Sale Revenues and Expenses, TSPIRS.

USDA Forest Service, Willamette National Forest. 1997b. National Forest Statement of Receipts, All Resources Reporting.

USDA Forest Service, Willamette National Forest. 1998. Mid Willamette Late Successional Reserve Assessment.

USDA Forest Service, Washington Office. 1998. Road Analysis: A Procedure for Informing Management Decisions on the Future Characteristics of the National Forest Transportation System.

Phillips, Richard. 1998. Personal communication. Region 6, Regional Economist.

Willamette National Forest Pilot Road Analysis

Appendix B

Aquatic and Water Quality Process Paper

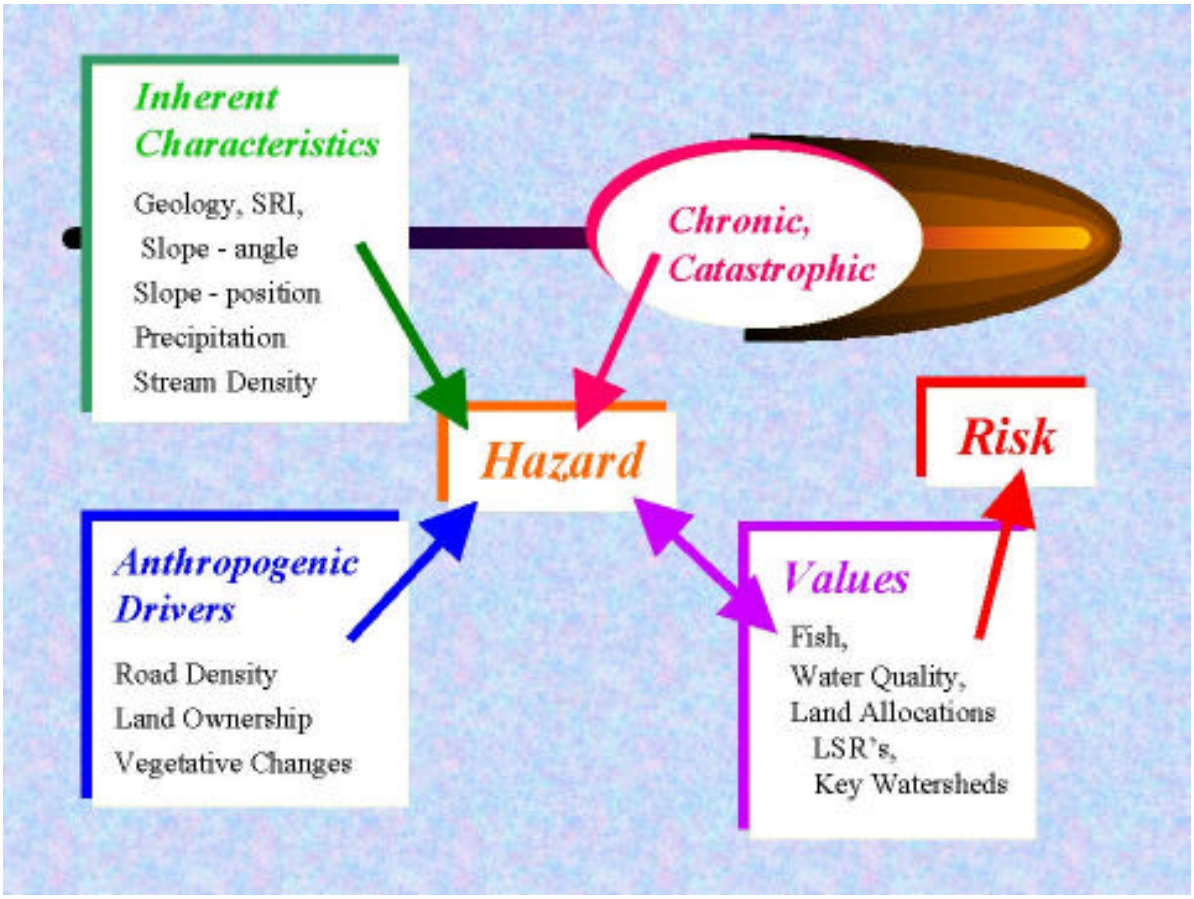
October 1998

Introduction

Roads interact and affect watershed resources and processes in four principle ways in westside Cascade Mountains of the Pacific Northwest Region. Roads interact and influence the production of both fine and coarse textured sediment thus influencing water quality, their position on steep hillsides often intercepts and daylights subsurface flow, routing such flow more quickly to adjacent channels potentially increasing peak flows. Additionally, road location within riparian reserves can influence the meander patterns of adjacent streams effecting a streams' ability to move its sediment and finally, roads within riparian reserves potentially affect a host of processes and resources associated with such reserves - everything from the availability of large wood, access to streams by recreationists, and movement of wildlife from upland areas to and through riparian areas.

While we will be doing a Forest-wide look at road conditions it is only by examining the distribution of various parameters of impact at a watershed and perhaps subwatershed scale that we can begin to understand the spacial distribution and intensity of those impacts.

The following simplified conceptual diagram will serve to order the process thinking about how watershed resources were assessed in this analysis.



Each watershed or landscape has a set of Inherent Characteristics which predispose it to impacts from Anthropogenic Drivers. These Inherent Characteristics are such things as the underlying geologic types, the soil characteristics, the slopes, the amount and distribution of precipitation and the stream density. All of these can be displayed as frequency distributions. Displaying information in this manner allows the analyst to view the distribution between various watersheds and to determine those more or less predisposed to impacts. Once this is determined a set of change agents, called Anthropogenic Drivers in the above diagram, act upon the Inherent characteristics to produce a Hazard. Hazards will vary across a watershed in response to different characteristics being acted upon and the spatial distribution of hazards will likewise be variably distributed.

Acting upon these various hazard areas are a set of physical processes, either chronic or catastrophic in nature, that produce impacts in terms of the four broad issues listed below. An example of such processes is the interception of subsurface flow by roads in middle slope positions within a watershed and the routing of such flows more quickly to adjacent channels potentially increasing peak flows and moving additional fine and coarse textured sediment. This is the point in the analysis process where Key Questions are asked in an analytical mode and the results displayed as frequency histograms.

Since the real work of Roads Analysis is basically a risk analysis the results of the interactions of the physical processes on various hazards must be analyzed in light of the particular value that we assign to a given area. Such values could include areas of known bull trout habitat, municipal watersheds, and the various land management allocations shown in Forest plans. It is at this point that the bias of the analyst, which reflects in some cases, the bias of society plays a role in determining the risk associated with a particular road segment.

Issues and Key Questions

As stated above roads can affect watershed conditions and process in four general areas which define the broad **Issues**:

1 - Water Quality-- as reflected by sedimentation from both surface erosion and potential increases in mass movement such as debris avalanches and debris flows and potential impacts to toes of earthflows producing fine grained sediment. Due to a stochastic climate acting upon a highly variable landscape, both in terms of process and formation, sediment is produced in a series of pulses often associated with periods of high flow. A risk assessment must be set in terms of the driving variable, i.e., sediment is not produced at all times within a watershed and is not produced in equal quantities for each individual storm event. Some are bigger than others and climate is the driving variable.

2. Water Quantity-- as reflected by potential increases in peak flows due to interception of subsurface flow particularly in mid-slope positions by roads and routing of water more quickly to stream channels.

3. Geomorphic- as reflected by the position of a roads or road segments adjacent to major stream channels - potentially reflected by flood plain location. Assessment would be for areas adjacent to major streams that potentially have their meander bends truncated due to road location.

4. Riparian - as reflected by the presence of roads within NWFP riparian reserves. Assessment would not be for Wildlife impacts to riparian reserves but the two may end up coincidental.

Key Questions for Water Quality:

AQ1 - ***How does the road system affect fine sediment that enters streams, lakes and wetlands?***

AQ2 - ***How does the road system affect mass soil movements that affect aquatic or riparian ecosystems?***

AQ4 - ***How does the road system modify drainage density which affects water quality and quantity?***

AQ10 - ***How does the road system affect risks to water quality from chemical spills or roadway applied chemicals, such as oil, de-icing salts, herbicides, and fertilizers?***

AQ12 - ***How does the road system affect wetlands?***

Key Questions for Water Quantity:

AQ4 - ***How does the road system modify drainage density which affects water quality and quantity?***

AQ5 - ***How does the road system affect movement of groundwater?***

Key Questions for Geomorphic:

AQ8 - ***How does the road system affect key interactions between aquatic and terrestrial systems?***

AQ9 - ***How does the road system alter the storage capacity of stream channels for coarse woody debris, sediment, and organic matter?***

AQ11 - ***How does the road system affect channel structure and geometry, and isolation of floodplains from their channels?***

Key Questions for Riparian:

AQ2 - ***How does the road system affect mass soil movements that affect aquatic or riparian ecosystems?***

AQ5 - ***How does the road system affect movement of groundwater?***

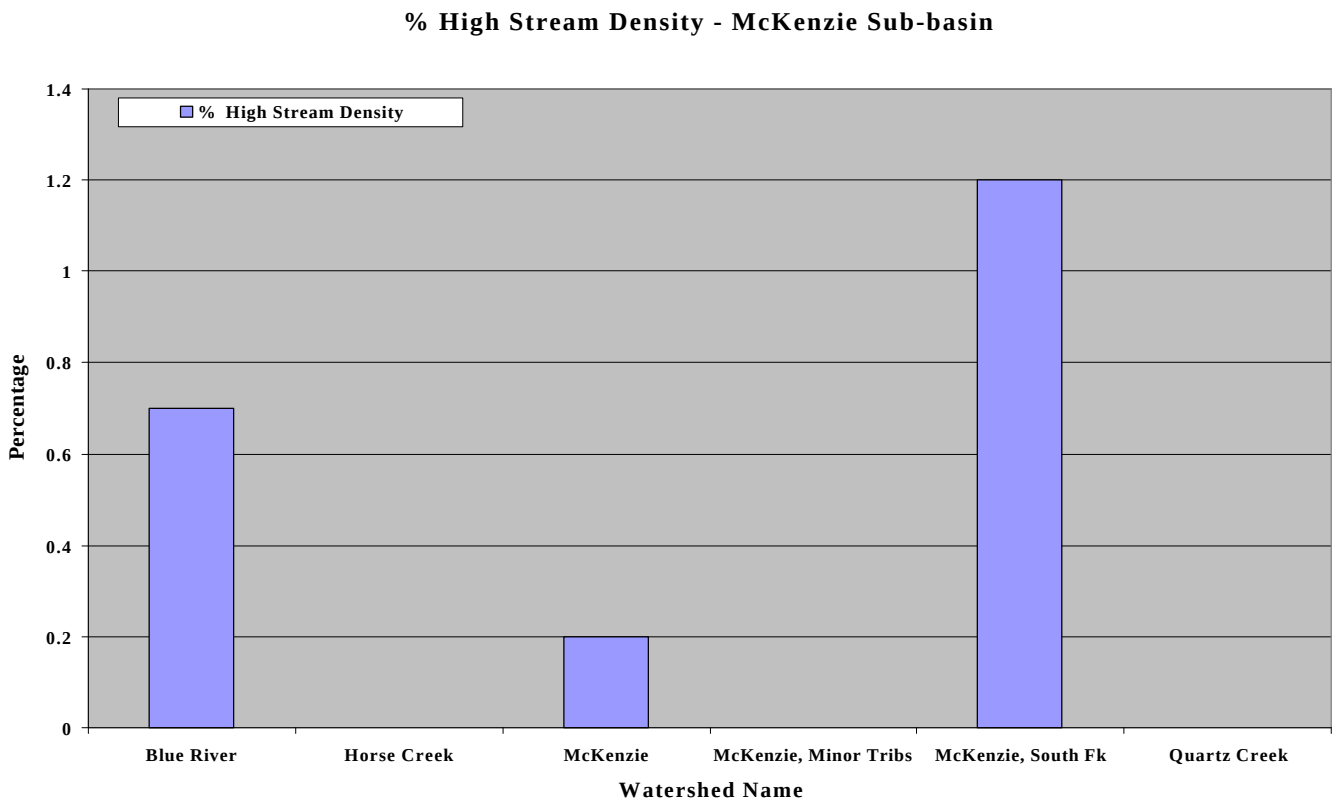
AQ8 - ***How does the road system affect key interactions between aquatic and terrestrial systems?***

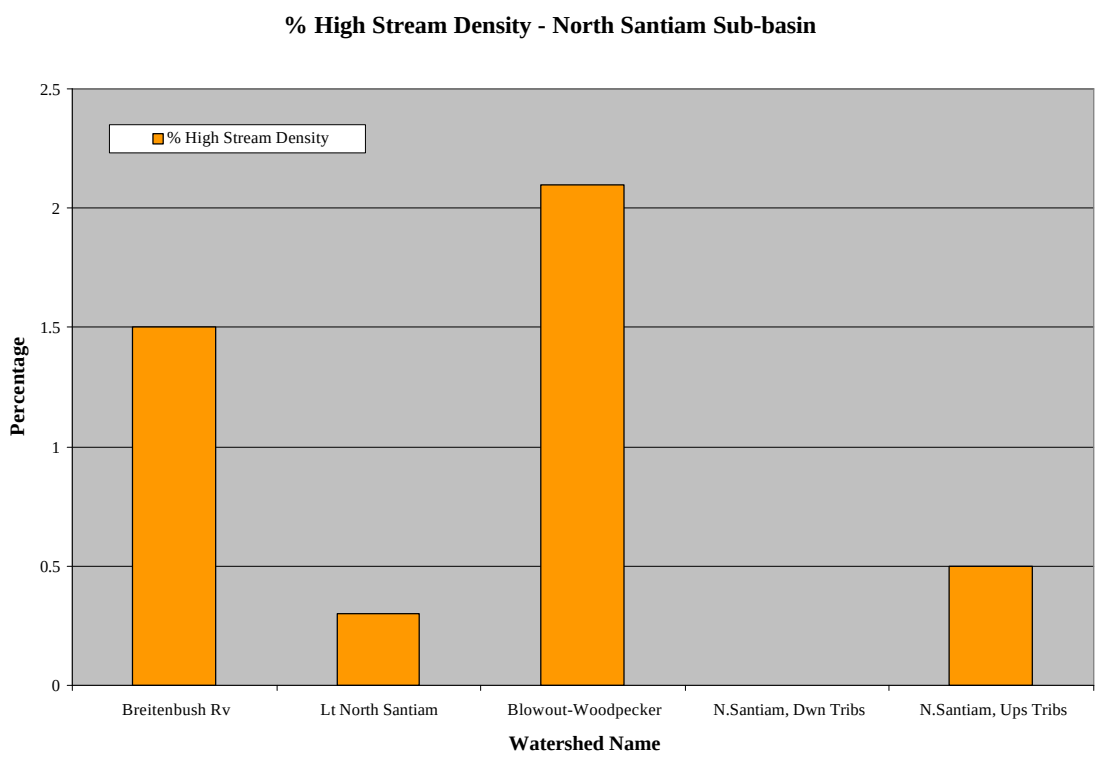
AQ11 - ***How does the road system affect channel structure and geometry, and isolation of floodplains from their channels?***

AQ12 - ***How does the road system affect wetlands?***

Analysis Techniques and Tools

A series of initial maps and associated data were produced to assess inherent conditions of watersheds across the Forest. **Map ra5: Stream Density** was constructed using the Moving Windows AML in ARC-INFO and was initially meant to assess particular locations in a given watershed that have higher stream densities and to help to sort between watersheds having a higher percentage of area in high stream density. This map pointed up the difficulties of doing this at a Forest scale. Intermittent streams were not mapped in a consistent manner across the Forest and thus some watershed, i.e., South Fork of the McKenzie River, show extremely high levels of stream density. In this watershed intermittent streams were extended into all of the contour crenulations shown on a topographic map. Field verification of streams was done in other watersheds. Thus comparisons of streams density across the Forest, between watersheds, becomes a relatively meaningless exercise. Comparisons of stream density by sub-watershed within each larger watershed may be more meaningful if consistent mapping techniques were applied in the watershed. In an attempt to deal with this discrepancy we determined stream density using only perennial streams, as their known locations and mapping are more consistent across the Forest (**Map ra5: Stream Density - Illustrating density of Class 1-3 only)** The following two histograms illustrate that there are only minor portions of each watershed in high stream density classifications but those areas should be the ones that are of particular interest for further investigation. (Note: I did not display all of the watersheds on the Forest - the histograms are for demonstration purposes. They serve to point out the type of analysis that should be done on a sub-basin level.)


% High Stream Density - McKenzie Sub-basin
% High Stream Density
Percentage
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Blue River
Horse Creek
McKenzie
McKenzie, Minor Tribs
McKenzie, South Fk
Quartz Creek
Watershed Name

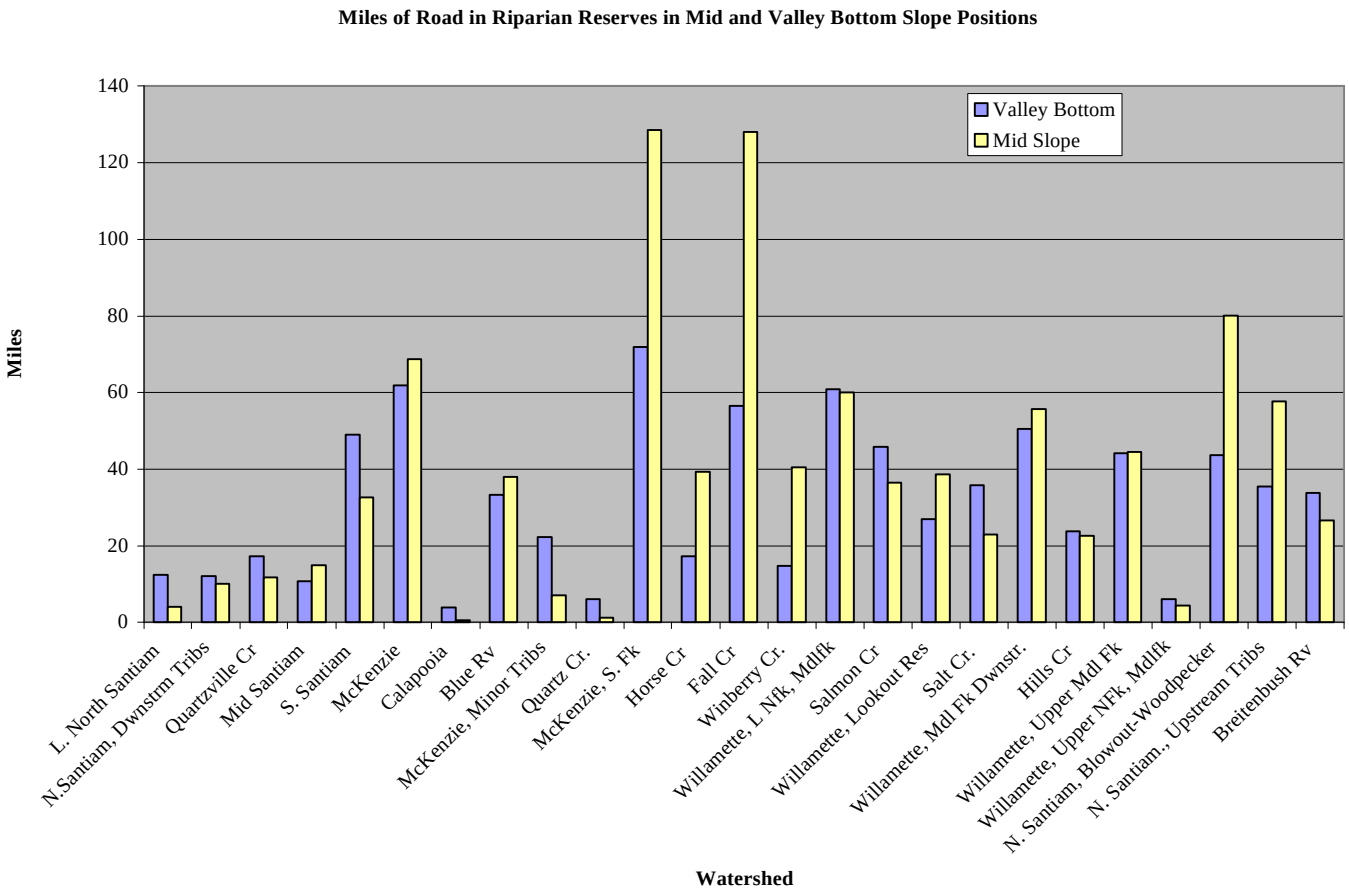

% High Stream Density - North Santiam Sub-basin
% High Stream Density
Percentage
2.5
2
1.5
1
0.5
0
Breitenbush Rv
Lt North Santiam
Blowout-Woodpecker
N.Santiam, Dwn Tribs
N.Santiam, Ups Tribs
Watershed Name

While this exercise helped to point out some areas in particular watersheds of high stream density it does not deal with periods of flooding and sediment movement when all of the stream network is active. Thus a consistently mapped GIS stream layer is critical to a Forest-wide analysis.

Map ra4: Road Densitywas constructed using the Moving Windows AML in ARC-INFO and the most current transportation layer in our GIS. .

SLOPE ANGLEdistribution and**SLOPE POSITION**distribution was also done Forest-wide. Slope angle was done from a 10 meter DEM. Slope Angle was determined using 0-20, 21-40, 41-60, 61-80 and > than 80% slope categories. Slope Position distributions were done from the 10 meter DEM using the SLOPEPOSITION command in ARC-INFO originally designed by David Hatfield, R6PNW Regional Office. The command creates a grid of slope position from a grid of elevation. In order to deal with sinks and peaks in the slope profile a 50 meter default value was used to smooth the slopes. This was done to level small peaks so that the uphill flow accumulation of data is continuous along the ridgetops. The grouping of valley bottom, mid-slope and ridgetop were done by grouping the bottom 10% into valley bottom, the middle 80% into mid-slope, and the upper 10% into ridgetop.

Soil Resource Inventory (SRI) and Geology map layers were used directly from the Willamette National Forest GIS data layers. SRI data is updated through field verification on an on-going basis by District soil scientists.



Findings and Results

AQ1 - How does the road system affect fine sediment that enters streams, lakes and wetlands?

This question was addressed using a combination of mapped Quaternary Landslides (earthflows) with streams and roads located on such terrain. **Map qa1** shows the distribution of the combination of road, stream and earthflow areas and as such would indicate areas of greater concern for the production of fine sediment. Watersheds shown in pink on the map: North Santiam River - Blowout to Woodpecker, South Fork McKenzie River, Salmon Creek and Upper Middle Fork Willamette River are the watersheds that contain a high percentage of area in the above combination. In the combined chart and map of sub-watersheds with areas of environmental concern all of the subwatersheds that contained these earthflows were listed.

AQ2 - How does the road system affect mass soil movements that affect aquatic or riparian ecosystems?

Map ra6: Unstable soils and Quaternary Landslides was developed to show areas of concern for mass soil movements. Soil mapping units (SRI) designated as Unstable and units designated as Potentially Unstable were mapped in an attempt to show areas that could become involved in surficial landslides, debris flows and debris torrents. Quaternary Landslides were mapped as areas of mass movement that could be impacted by roads and potentially produce greater quantities of fine sediment. This map was originally designed to be an overlay for other layers but due to mapping and viewing considerations it became very problematic. It would be appropriate to use as a combination of road density with the particular unstable area classifications. The hazard in this case would increase with higher road densities within each category. Due to time limitations we did not attempt to define areas.

While culvert and bridge crossings do not affect the drainage density in a watershed they do affect streams and drainages in a watershed by constricting flows during periods of high runoff. Additionally, they often are the focus points for damage from culvert plugging and subsequent road failure adding to the amount of soil mass movement. **Map aq2a: Road and Stream Intersections** was developed to begin to address this question of channel change as a result of road crossing. Two levels of analysis were attempted with this map. First we tried to densify the map using 100 foot contour intervals to see if crossing varied by position in the watershed. The second method of examining this data involved determining the distribution of crossings by slope position.

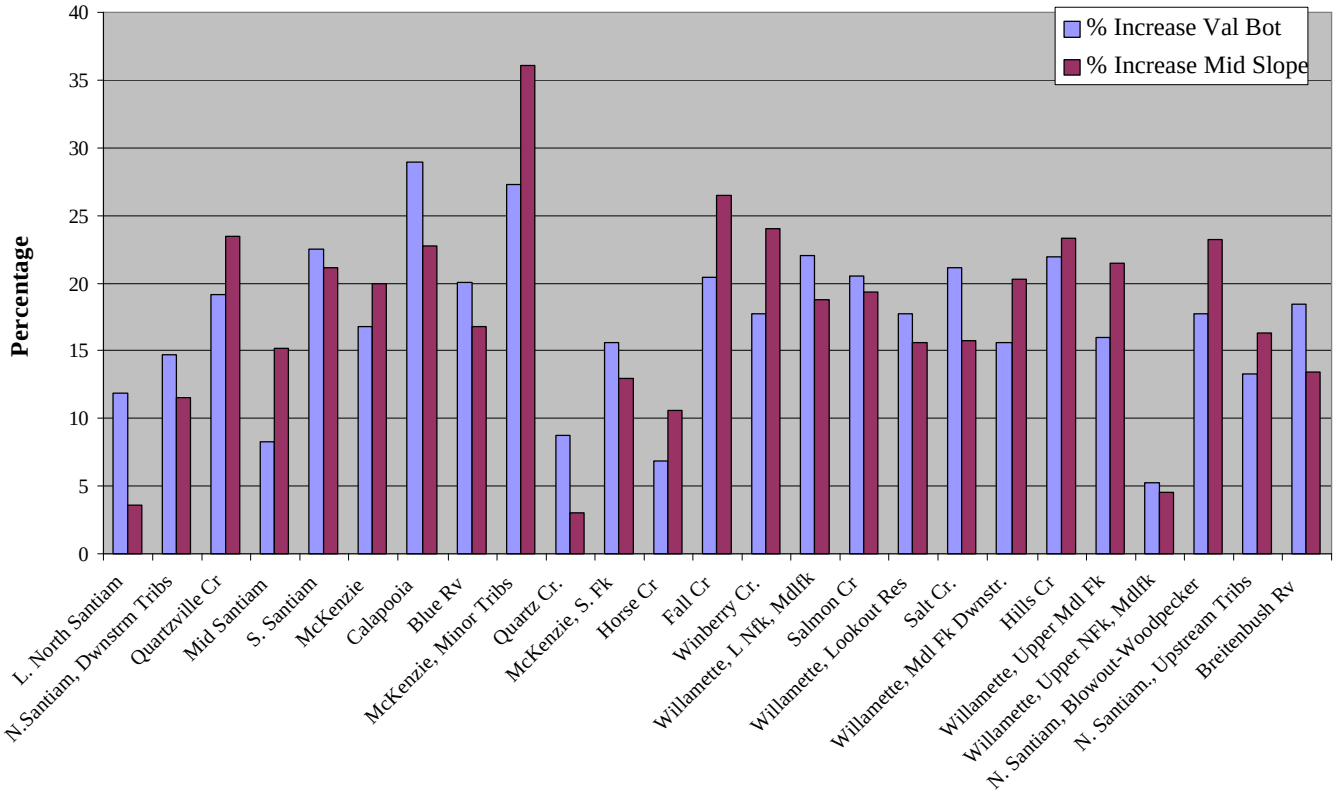
AQ4 - How does the road system modify drainage density which affects water quality and quantity?

A combination of road mileage with slope position in riparian reserves was developed in order to assess the impact of roads in mid-slope and valley bottom slope positions on the potential for increases in peak flows due to interception of subsurface flow and more efficient routing of water to channels. The concept of hydrologic connectivity is important in determining the extent of these impacts. To determine the extent of channel extension we used the miles of road within riparian reserves, as defined in the Northwest Forest Plan, as an indicator of hydrologic connectivity. Field verification of such connectivity would be ideal but beyond the

scope of this analysis. The following histogram displays the miles of road by watershed within riparian reserves.

The issue of different stream mapping causing different stream densities shows up once again in the above histogram with the South Fork of the McKenzie River and Fall Creek showing the highest number of miles in mid-slope riparian reserves. This undoubtedly is an artifact of the mapping problem mentioned above. To address the question of increases in peak flows due to interception of subsurface flow by roads it is important to take into both slope positions shown in the histogram. (See below for discussion on riparian impacts) To attempt to account for the differences in mapping techniques used by different Districts, a histogram of percent change in stream miles was developed by assuming that the miles of road within riparian reserves became part of the active stream network, especially during a storm event.

Percent Increase in Stream Miles from Roads in Riparian Reserves in Mid Slope and Valley Bottom Slope positions



As with the earlier histogram this one presents a somewhat bias picture of the potential for actual channel change due to increases in the stream network from roads within the riparian reserves. For instance, the Calapooia River watershed only contains 13.5 miles of Valley Bottom streams and 2.2 miles of Mid Slope streams (as mapped on National Forest Land) and there are 3.9 and 0.5 miles of road in each of the respective classes. Thus a percent increase is rather dramatic but an actual channel impact will be negligible due to small overall amount

of road. The average percent increase in Valley Bottom stream miles was 17.14% with a median value of 17.75%. The average percent increase in Mid-Slope stream miles is 17.57% with a median value of 18.81%.

AQ8 - How does the road system affect key interactions between aquatic and terrestrial systems?

AQ9 - How does the road system alter the storage capacity of stream channels for coarse woody debris, sediment, and organic matter?

AQ11- How does the road system affect channel structure and geometry, and isolation of floodplains from their channels?

The above three questions were addressed by combining the Road Density mapping with the Riparian Reserves as identified for individual stream segments in the Northwest Forest Plan **(Map w2 - Road Densities in Riparian Reserves)** It is not possible at the Forest level of analysis to determine how the functions of floodplains and channel structure and geometry are affected by a particular road location. However by knowing the locations of high road density, defined in this analysis as > 4 mi/sq mi, a District analyst could prioritize field locations for on the ground examination. Additionally, by looking at the miles of road in riparian reserves in valley bottom slope positions an approximation of riparian impacts to areas along major streams becomes possible.

AQ10- How does the road system affect risks to water quality from chemical spills or roadway applied chemicals, such as oil, de-icing salts, herbicides, and fertilizers?

Due to time limitations we did not address this question. Major transportation routes thru the Forest, namely Oregon State highways, are where the majority of the de-icing and herbicide applications take place and they transport a great deal of chemicals via truck traffic. A risk assessment was done by the Eugene Water and Electric Board, the water purveyor for the city of Eugene, and other risk assessments were done by the Oregon Department of Transportation on these cross state routes. These documents are available from the various agencies.

AQ12- How does the road system affect wetlands?

(see Appendix E, Botany process paper)

Synthesis of Data

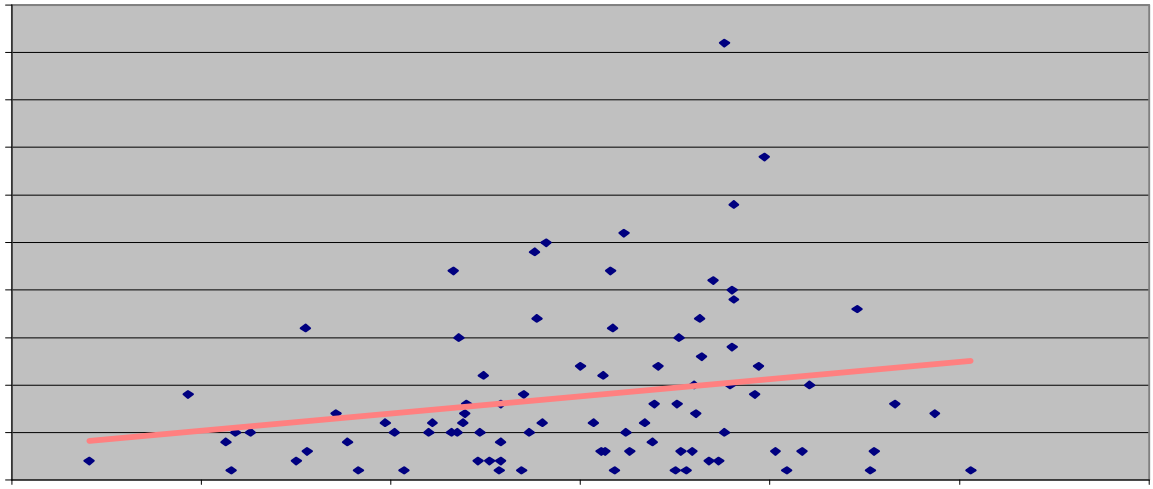
In order to develop areas of particular concern two maps were developed **(Maps ra3 - Slope Position).** These maps show combined areas of high road density, mid-slope position, high stream density on earthflow terrain. Initially a map was developed using a high road density calculation of >4 mi/sq mi. Numerous areas across the Forest showed up as meeting the above criteria in the combination. So much so as to not be extremely helpful in prioritizing areas for on the ground examination where various road repair or removal options could be applied. The reason we chose >4mi/sq mi was to correspond to stated levels of concern for fish species resulting from that road density. A second iteration of this map was completed using a >6 mi/sq mi criteria for road density and this proved to be much more definitive. Small areas that could be called 'hot spots' showed up and would be useful of watershed scale,

on the ground examinations. In the combined chart and map of sub-watersheds with areas of environmental concern all of the subwatersheds that contained the areas of >6 mi/sq mi were listed (see Map ra3 – Slope Position).

Further Investigations:

The Forest has catalogued all of the ERFO and the majority of the non-ERFO sites resulting from the floods of 1996. This information will serve to validate in a real sense some of the projections of inherent vulnerability about particular portions of watersheds. There are over 1,000 ERFO sites catalogued from the 1996 storms and an additional 200+ non-ERFO sites. In addition we have ERFO sites from the 1986 storm event and are currently working on other past storm events. Investigations using this data will allow us to validate some of the assumptions we have made around the driving variables for flood damage. For instance, we examined the relationship between road density by sub-watershed across the Forest with number of ERFO sites recorded for each. The following figure is a scatter chart of this data with a linear regression line fit to it.

As is clearly evident there is a lot of variability in the data and road density alone does not expla the distribution of ERFO sites across the Forest. Further investigations of this data using such parameters as Bedrock Geology, Geomorphology, Precipitation Intensity, Slope Position, Slope Angle etc. could all be combined or mixed in various ways to attempt to analyze the data and validate the



biases used in our analysis.

The roads analysis will nest nicely with the need for new techniques for assessing Watershed Cumulative Effects. Much of the conceptual structure and the analysis techniques can be used and augmented for this type of analysis. This work will continue during this year with a completion date around the end of calendar year 1999.

Process critique

Doing a roads analysis at the Forest level presents some problems for the analysis of watershed resources. Comparisons of such things as stream and road density is only possible if consistent mapping was used across the Forest for identifying such items. In the case of streams this was not done. One District had field verified streams, including intermittents, while another extended the drainage network to all contour crenulations. Such differences result in different stream densities between watersheds, i.e., the watershed with the extended contour crenulation mapping, showed much higher stream density than those elsewhere on the Forest. Thus while it may be possible to discriminate between subwatersheds in a watershed where the same mapping techniques were employed it becomes problematic when comparing between watersheds across the Forest.

Sediment production in Pacific Northwest watersheds is closely tied with climatic variability and the process does not contain a temporal component that would allow an analyst to set the hazard in terms of their potential for occurrence.

There has been some discussion about accuracy of the data. It is my opinion that consistency is more important than accuracy especially for stream mapping. It is doubtful if we will ever be able to accurately map all of the streams on the Forest, especially when dealing with the extent of the intermittent channels. Consistency of mapping would allow us to make comparisons between watersheds and sub-basins. Under the current mapping this is not possible.

References

Benda, L.E., Miller, D.J., Dunne, T., Reeves, G.H., Agee J.K.,Dynamic Landscape Systems, in River Ecology and Management, Chapter 11, edited by R. Naiman and R.Bilby, Springer-Verlug, N.Y., 1998.

Caine, N.,: Rainfall intensity-duration control on shallow landslides and debris flows, Geografika Annaler 62A:23-27, 1980.

Jones, J.A., Grant, G.E., 1996, Peak Flow Responses to Clearcutting and Roads in Small and Large Basins, Western Cascades, Oregon, Water Resources Research, Vol. 32, No.4, Pages 959-974.

Lewis, H.W.,Technological Risk,Chapter 2, W.W. Norton and Company, N.Y., 1990.

Sidle, R.C., Pearce, A.J., O'Loughlin, C.L.,Hillslope Stability and Land Use,American Geophysical Union, Water Resources Monograph 11, 1985, p 90.

Ziemer, R.R.,Temporal and Spatial Scales,in Watershed Restoration:principles and pracitces, edited by J.E. Williams, C.A. Wood and M.P. Dombeck, American Fisheries Society, 1997,