Willamette National Forest Pilot Road Analysis

Appendix B

Aquatic and Water Quality Process Paper

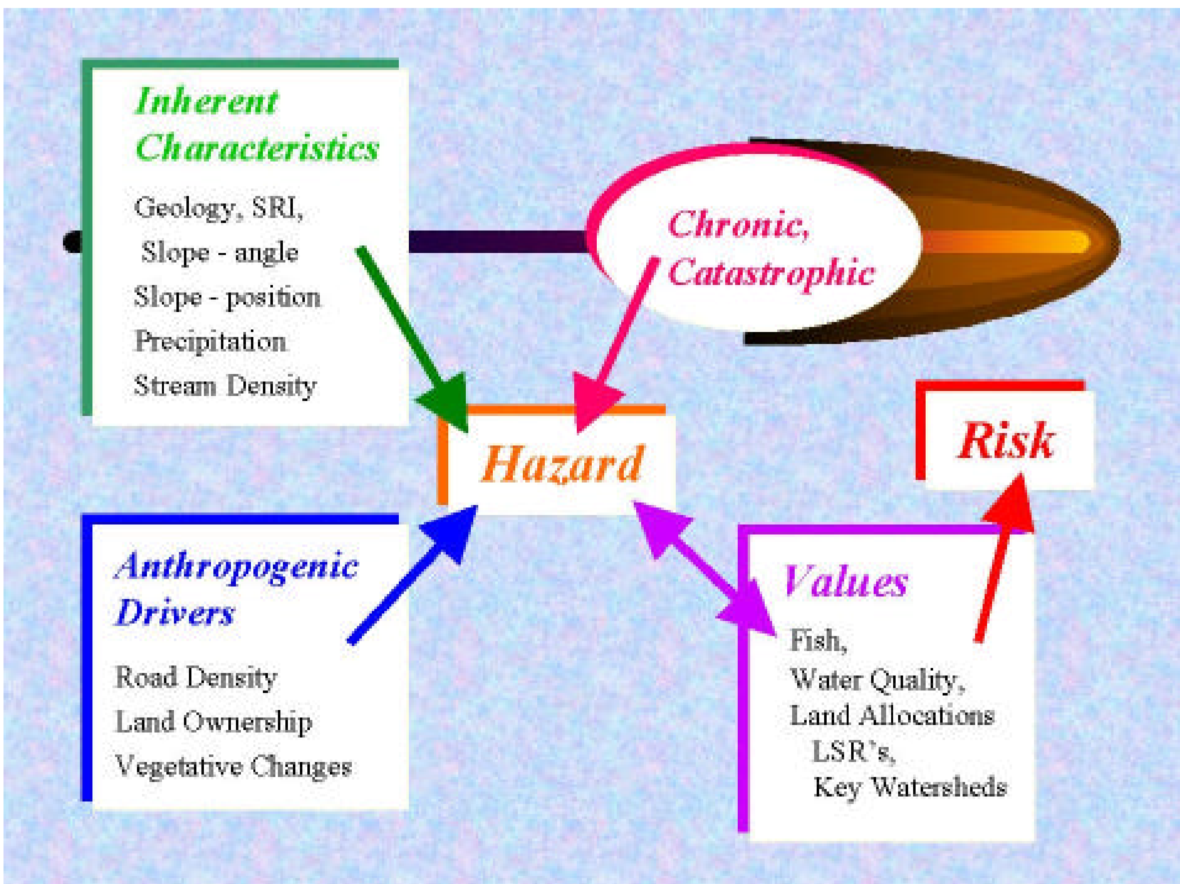
October 1998

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?***

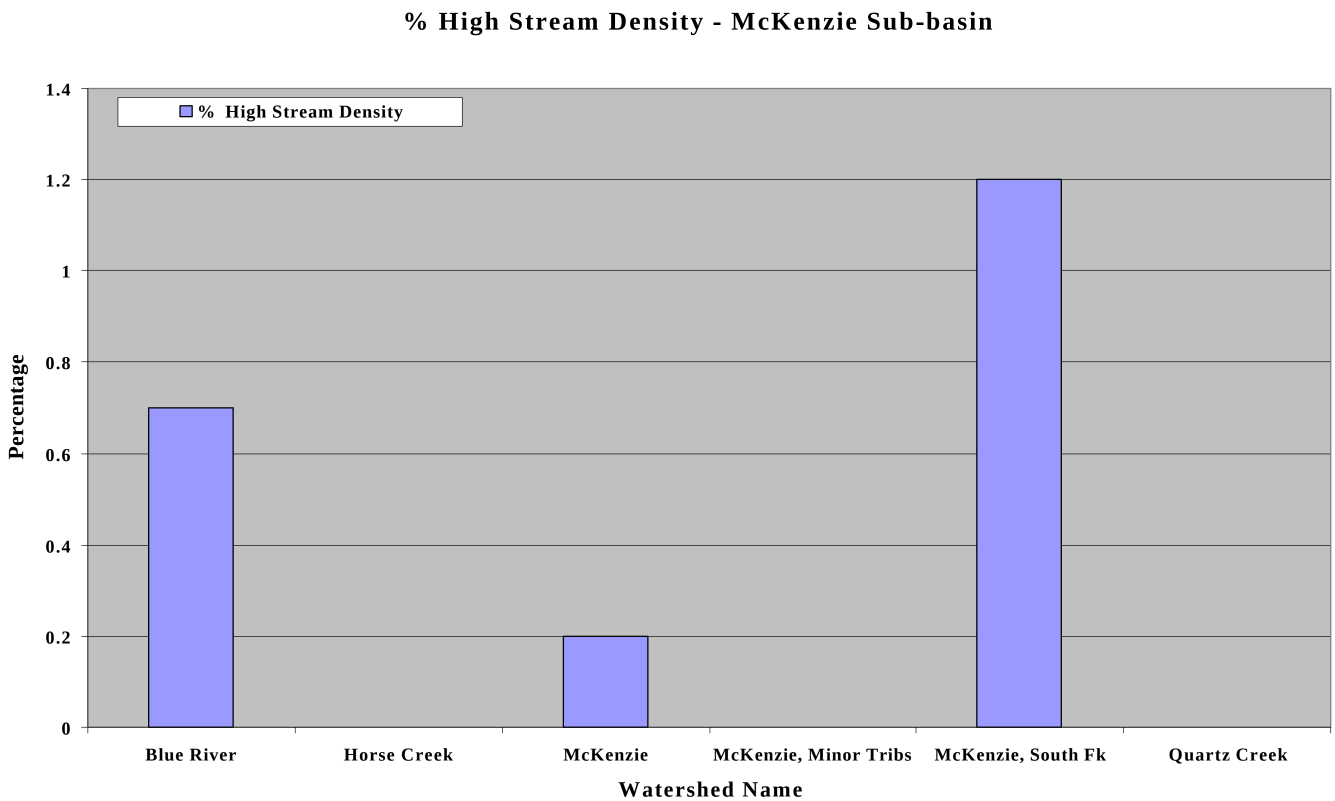
AQ8 - ***How does the road system affect key interactions between aquatic and terrestrial systems?***

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

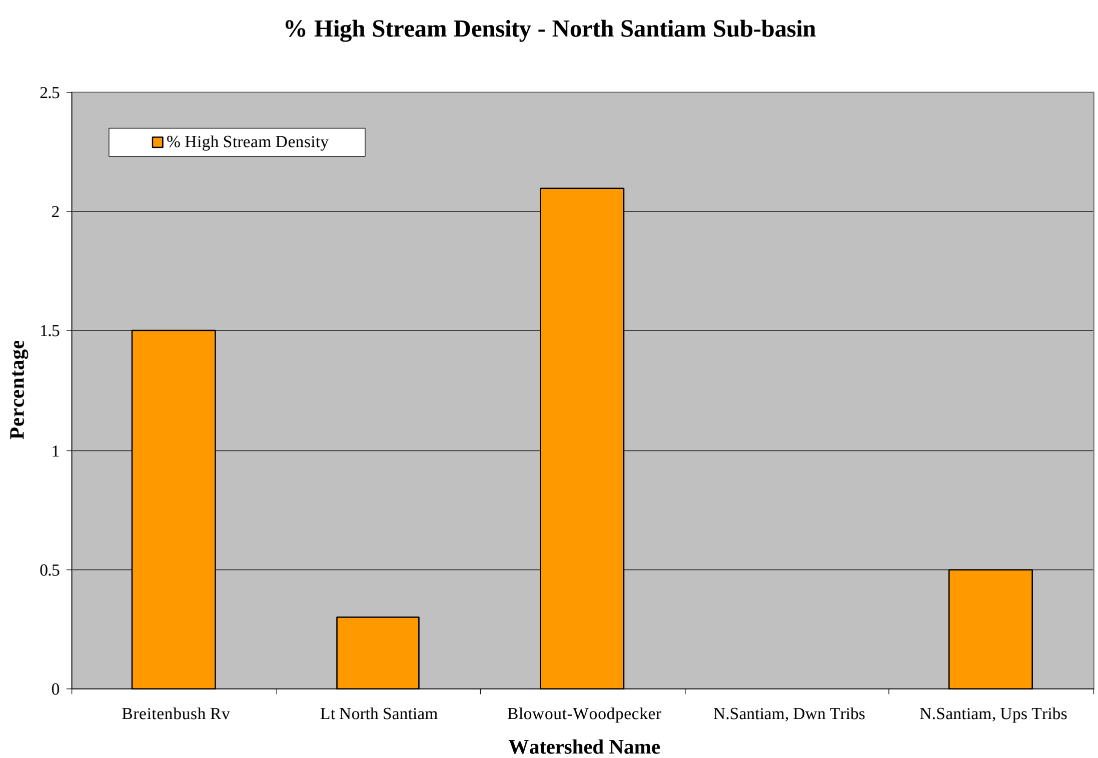
AQ12 - ***How does the road system affect wetlands?***

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



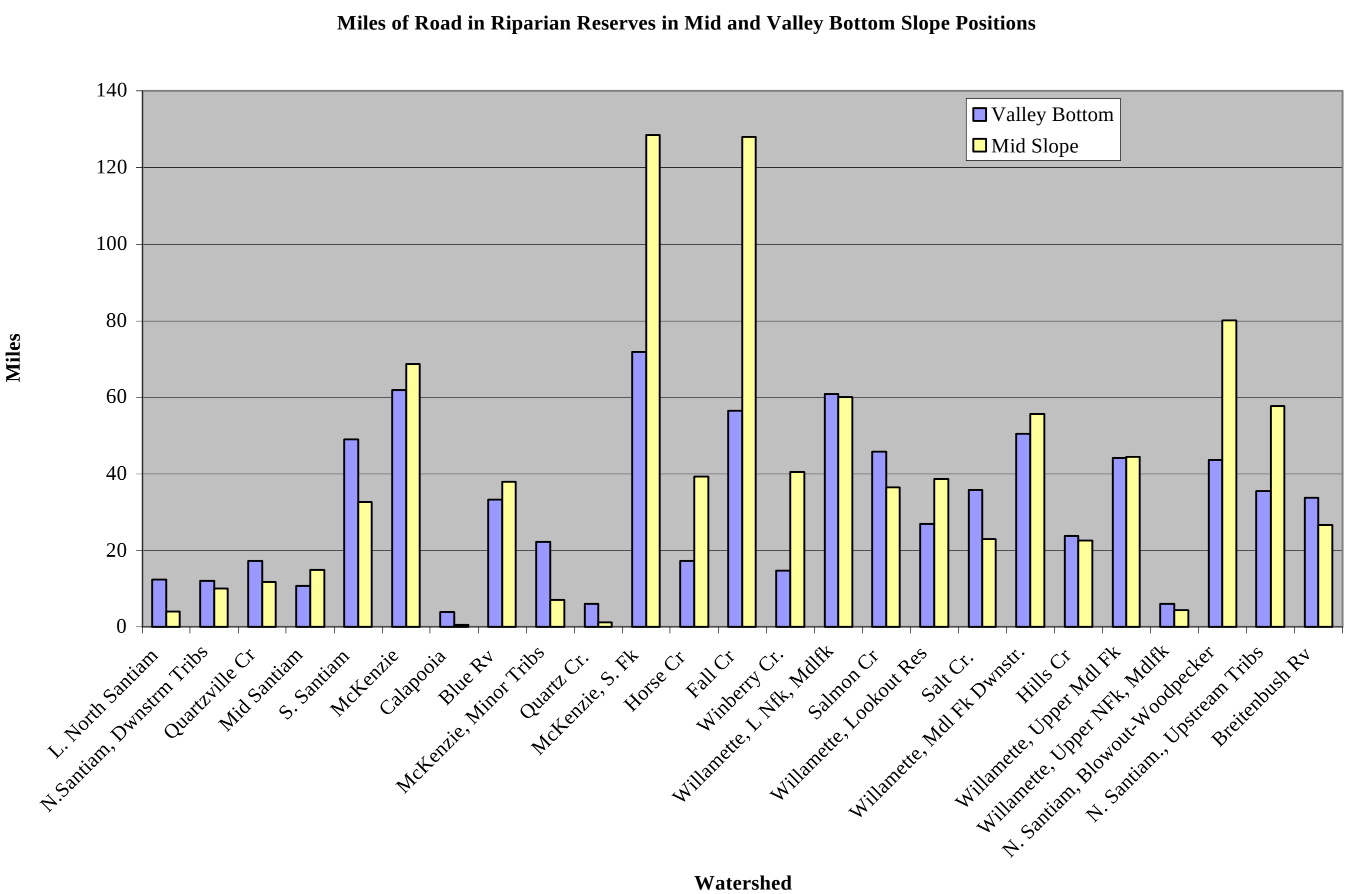
% High Stream Density - North Santiam Sub-basin
% High Stream Density
Percentage
2.5
2
1.5
1
0.5
0
Breitenbush Rv
Lt North Santiam
Blowout-Woodpecker
N.Santiam, Dwn Tribs
N.Santiam, Ups Tribs
Watershed Name

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 Density was constructed using the Moving Windows AML in ARC-INFO and the most current transportation layer in our GIS. .

SLOPE ANGLE distribution 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.

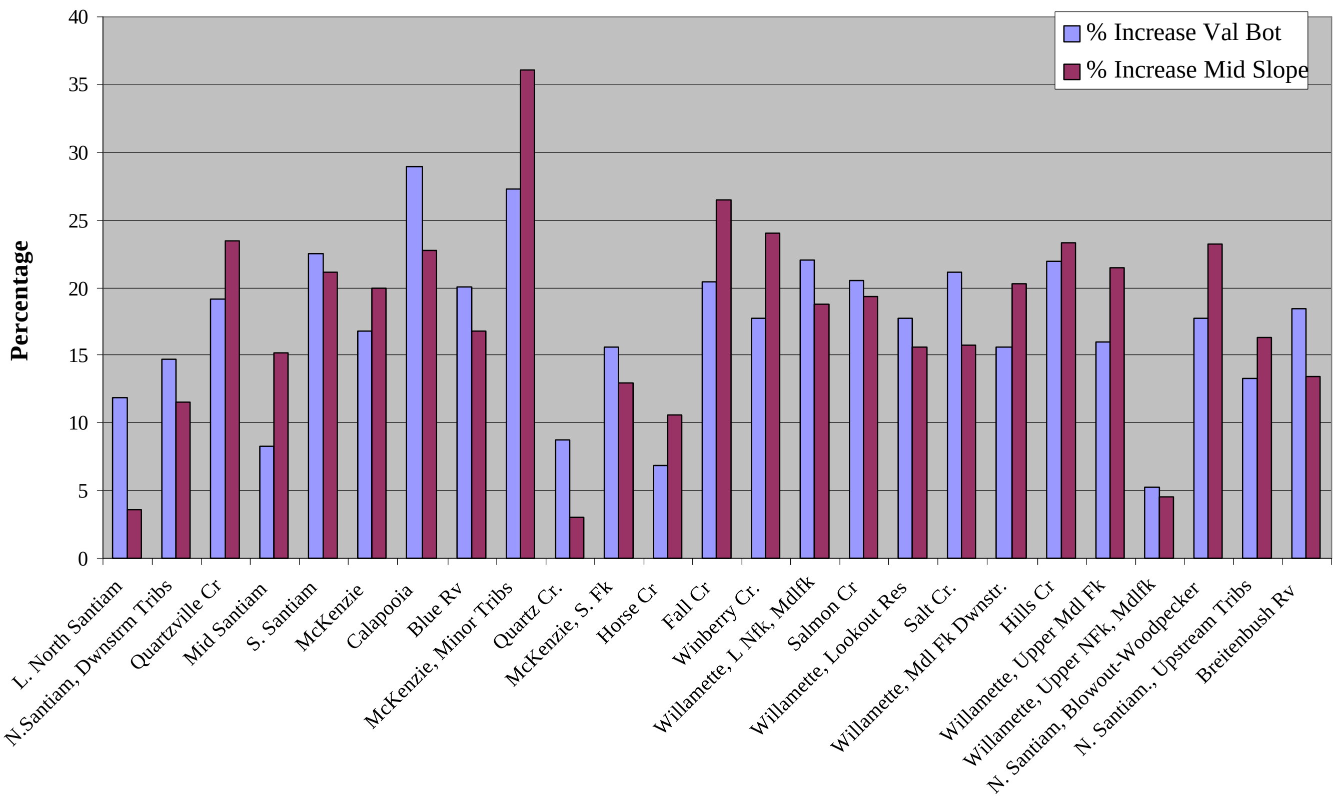
While culvert and bridge crossings do not affect the drainage density in a watershed they do affect streams and drainages in a watershed by constricting flows during periods of high runoff. Additionally, they often are the focus points for damage from culvert plugging and subsequent road failure adding 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)

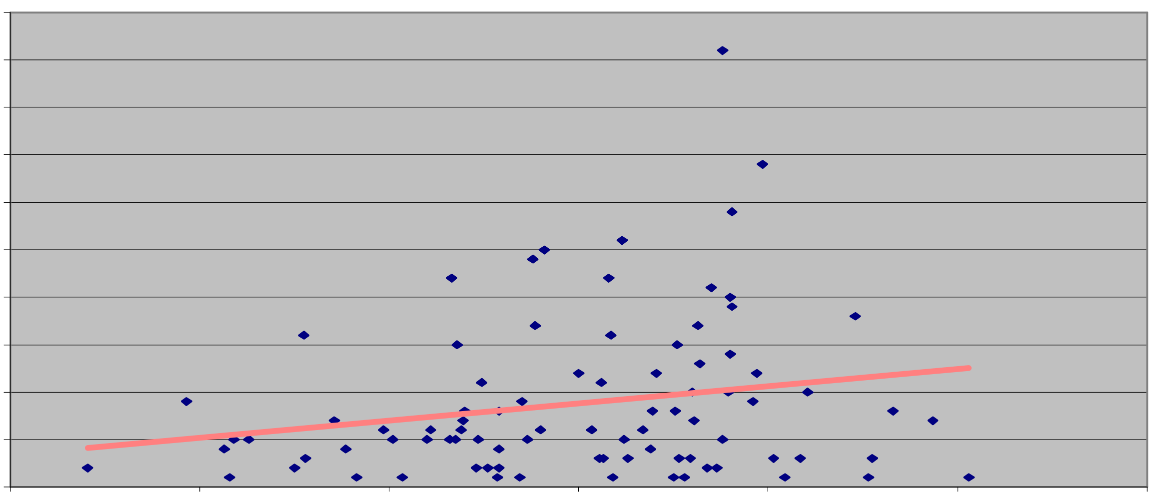
Synthesis of Data

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.

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