Spencer Creek Road Inventory and Sediment Assessment
Status Report
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I. Introduction

Concerns regarding production and delivery of fine sediment from roads in the Spencer Creek watershed were raised in a Watershed Analysis (WA) prepared in 1995. Macroinvertebrate metrics and field observations of stream substrate suggested that fine sediment was impairing the quality of fish habitat (Pages 4-142 and 4-160). The WA indicated that roads were the largest contributors of fine sediment (page 4-153). Based on the WA discussion of management-induced stream sedimentation, the Oregon DEQ included Spencer, Clover, and Miners Creeks on the 1998 303(d) list of water quality impaired streams.

In order to address the WA recommendation to conduct "quantitative measurements to determine the source and relative contribution of fine sediments" (page 5-44) and develop information for the Sediment TMDL, the BLM initiated development of a cooperative road inventory/sediment study. Key partners in this effort are the USFS Rocky Mountain Research Station (RMRS), the Winema National Forest, Inland Fiber (formerly US Timberlands), and the USFWS Ecosystem Restoration Office.

II. Methods and Geographic Scope

A. Geographic Scope

The study encompassed the Spencer Creek watershed, an 84 mi^2 (219 km^2) area tributary to the Klamath River. The study area is 15 to 20 miles (20 to 30 km) west of Klamath Falls (Figure 1). Elevations range from 3800 feet (1160 m) at the mouth to 8200 feet (2500 m) at Aspen Butte. Drainage density in the watershed is relatively low as a consequence of highly porous and deep volcanic soils. Hydrologic features include Spencer Creek, two main tributaries, and Buck Lake, an ephemeral lakebed wetland in the northwest portion of the watershed that has been drained for agricultural use. Land uses in the study area include forest management (the dominant land use), agriculture, and recreation. 9.3 mi^2 (24 km^2) in the northern portion of the watershed is within the Mountain Lakes Wilderness. Primary land managers are the BLM (16% of watershed), USFS (41%), and Inland Fiber (32%).

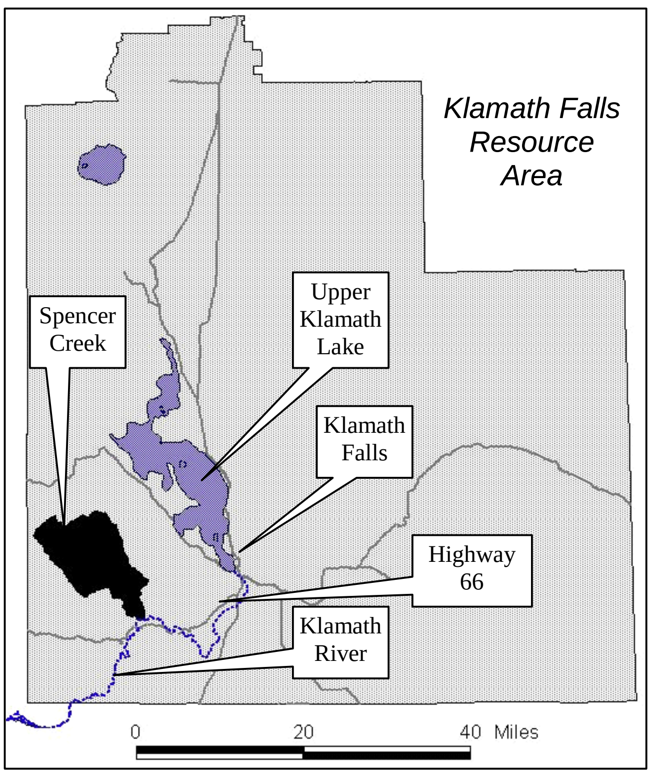

Figure 1. Location map of the Spencer Creek study area.

B. Methods

Two major elements comprise the Spencer Creek sediment study: a comprehensive road inventory and annual monitoring of road sediment production. Together, these data can be used to estimate the magnitude, character, and distribution of road-related sediment production. A weather station located near the sediment plots measured precipitation and other parameters.

1. Road Inventory

Accurate mapping of the location and character of all roads and associated drainage features in the watershed was necessary to develop sediment production and delivery estimates. Using GPS and GIS technology and methods developed by the RMRS, the inventory focused on determining the fate of road runoff and characterizing factors related to sediment production. Data collected for each road segment and each drainage feature was linked using a "Drain ID" unique to each drainage feature and associated flow paths (Figure 2). The start and end point of each road segment was based on hydrologic connectivity and road conditions (e.g., surfacing). A drain ID was shared by multiple flow paths draining multiple road segments if those flow paths were tributary to the same drainage feature (e.g., Flow Path #2 in Figure 2).

The specific elements of the road inventory "data dictionary" are included in Appendix A and can be summarized as follows:

- Road Segments
  - Drain ID
  - Surface type
  - Surface condition (rutted, rocky, etc.)
  - Flow path type(s) (i.e., ditch, wheel track, etc.)
  - Ditch condition (% vegetation cover)
  - Cutslope height and condition
- Drainage features
  - Drain ID
  - Feature type (i.e., cross-drain culvert, waterbar, stream crossing, non-engineered, etc.)
  - Stream connectivity

2. Sediment Production

Measurements of sediment production relied on methods developed by scientists at the RMRS that have been applied elsewhere in Oregon (see Luce and Black 1999). During November 2000, fifteen sediment measurement plots (five each on native, cinder, and gravel roads) were installed on BLM and Inland Fiber roads. Plots were approximately 80 meters in length and were hydrologically isolated from upslope and downslope road segments by waterbars made of wood and rubber (Figure 3). At the downslope end of the plot, runoff from the road surface and ditch (if present) was directed into 300 gallon stilling ponds.

Variables like slope, length, traffic, height of cut slopes, and flow paths can strongly affect sediment production. As much as possible, selection of sediment plots attempted to reduce sources of variability not related to road surface type (Table 1). The cinder and gravel roads were "crowned" to direct flow from one half of the road into roadside ditches and thence to the stilling ponds. The native roads were graded, but did not have ditches; on these plots berms either existed previously or were created to ensure that runoff from the entire road segment was directed into the stilling pond. This discrepancy between flow path types was addressed in the sediment production calculations described below.

Sediment production from each plot was measured each October from 2001 to 2003 using the "Tripod Method" developed by the RMRS (see Appendix B).

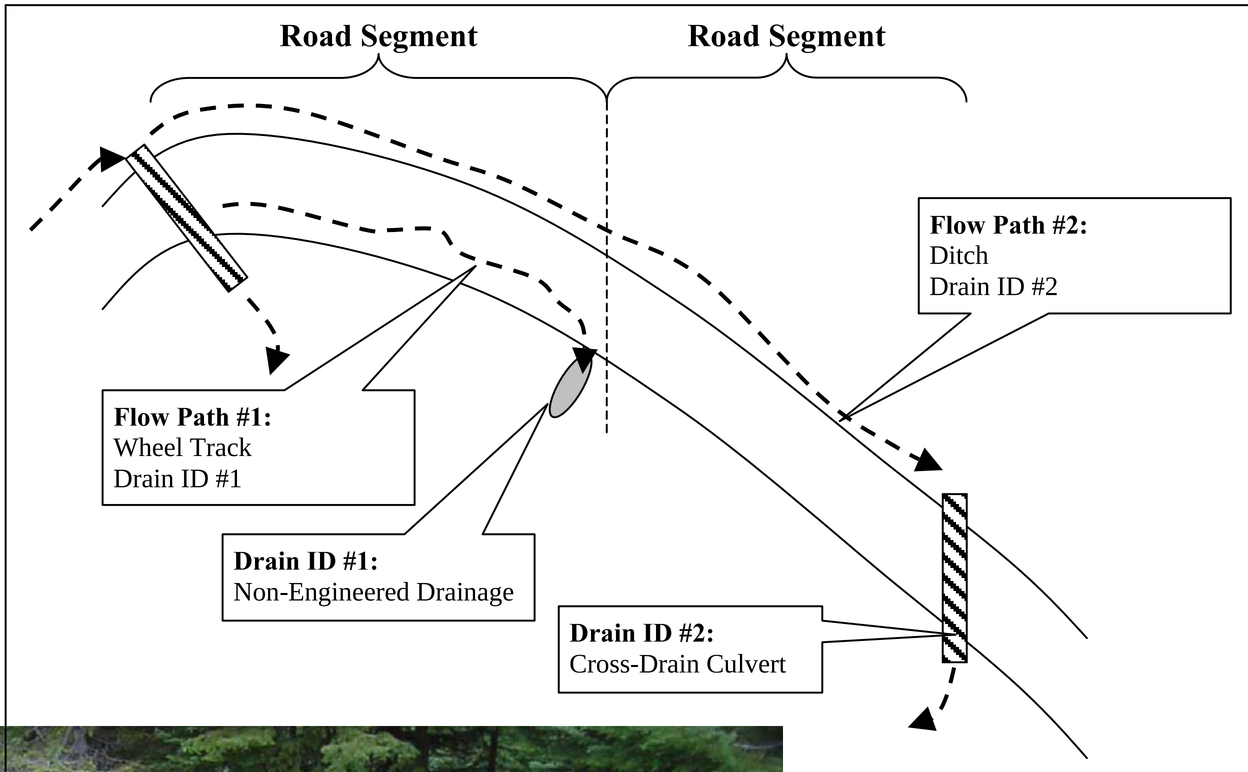

Figure 2. Schematic plan view of road segments, flow paths, and drainage features.

Figure 3. Photos of (A) waterbar and "ditch dam" at the downslope end of plot directing water into pipe that drains to (B) stilling pond.

Table 1. Characteristics of Spencer Creek watershed road sediment plots.

Plot[1]	Length	Average Width	Area	Total Elevation	Road Slope	Additional Sediment Sources
	(m)	(m)	(m^2)	(m)		
C3	86.6	2.4	211	7.0	0.08	
C4	82.8	2.8	232	6.3	0.08	
C5	83.9	2.6	219	5.7	0.07	
C6	83.5	3.3	274	5.8	0.07	1.5 m cutslope
C7	83.8	2.8	236	6.0	0.07	1 m cutslope
G1	81.7	2.1	174	5.9	0.07	short cutslope
G2	80.9	2.4	197	5.8	0.07	short cutslope
G3	77.2	2.5	197	5.6	0.07	
G4	83.5	2.6	220	6.1	0.07	
G5	82.7	2.9	239	6.1	0.07	short cutslope
N3	78.3	3.8	297	6.4	0.08	0.3 m cutslope
N4	78.2	4.0	311	6.2	0.08	1 m cutslope and berm
N5	78.2	3.9	305	5.5	0.07	1 m cutslope and berm
N6	78.8	3.1	246	7.2	0.09	
N7	78.8	4.0	312	5.2	0.07	berm, landing, spur road, spoil pile, 2 m cutslope
Notes: (1) “C”, Cinder; “G”, Gravel; “N”, Native.						

3. Weather

RMRS and BLM staff installed and maintained a weather station near the sediment plots. The station included a weighing bucket precipitation gage, a thermometer, a solar radiation meter, and an anemometer. Precipitation data was collected every fifteen minutes and other data was collected hourly from December 2000 to May 2003. Monthly visits to the station were required to change data loggers and maintain equipment. Antifreeze and household-type oil was added to the precipitation gage to prevent freezing and evaporation. The precipitation gage was toppled by wind, ungulates, or vandals several times during the study.

III. Results

A. Road Inventory

Approximately 300 miles (480 km) of road were inventoried by BLM and USFS during 2000 and 2001 (Figure 4). Safety concerns precluded inventory of two major paved roads, as these roads are county highways with heavy and fast traffic. Of the inventoried roads, 43% were surfaced with native materials and 47% were surfaced with either cinder or gravel (Table 2). Paved and vegetated roads each comprised 5% of the road mileage.

The majority of the inventoried roads were located on private land, with the remainder divided evenly between the BLM and the USFS (Table 3). Most roads that cross BLM-administered lands are surfaced with either cinder or gravel, while USFS roads are evenly split between native and surfaced.

Of the four subwatersheds in the study area, the Lower Spencer Creek area has the highest road density (Table 4). The remaining subwatersheds all have similar and substantially lower road densities, a consequence of Buck Lake, the wilderness area, and relatively sparse road networks in some areas administered by the USFS.

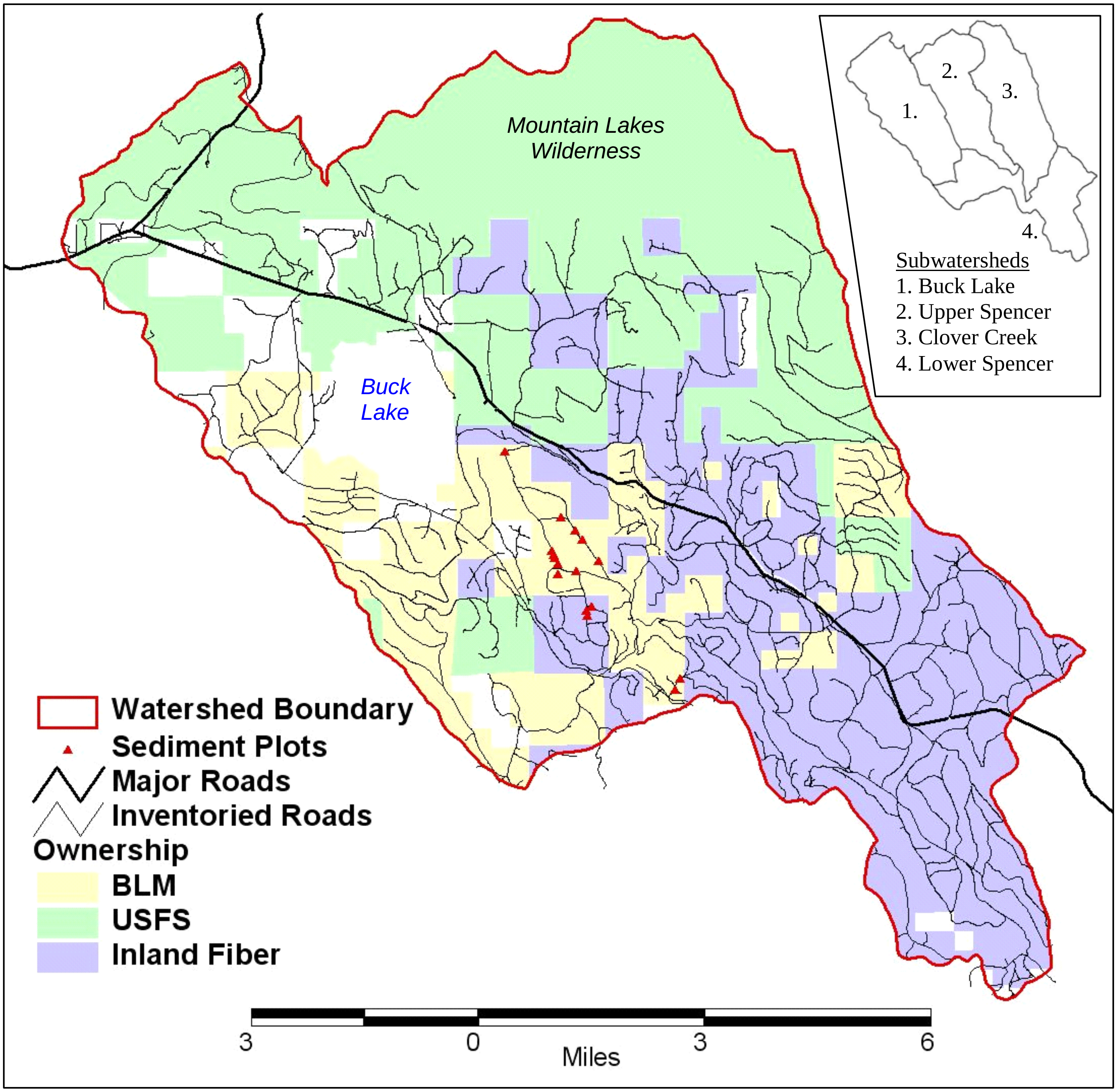

Figure 4. Inventoried roads in the Spencer Creek watershed. Note also the location of the 15 sediment plots and the inset map showing subwatersheds.

Table 2. Distribution of surface types of inventoried roads.

Surfacing	# of Road Segments	Total Length		Average Segment Length		Average Slope
		(km)	(miles)	(km)	(miles)	
Native	2328	208.3	130.2	0.089	0.056	0.051
Cinder	1409	155.5	97.2	0.110	0.069	0.047
Gravel	648	71.0	44.4	0.110	0.069	0.046
Vegetated	244	24.1	15.1	0.099	0.062	0.053
Paved[1]	162	22.5	14.1	0.139	0.087	0.038
Total[2]	**4791**	**481.4**	**300.9**	**0.100**	**0.063**	**0.049**
Notes: (1) Not all paved roads were inventoried due to safety concerns; (2) Total includes some roads that are outside of the watershed						

Table 3. Surface types of roads, by land owner.

Owner	Surface Type				Total (miles)	% of All Inventoried Roads
	Native	Cinder	Gravel	Other		
BLM	12.0 miles	34.3	12.3	7.3	65.9	22
USFS	27.3	9.5	17.6	9.5	63.9	21
Inland Fiber	72.2	45.1	12.9	9.9	140.1	47
Other Private	18.7	8.3	1.6	2.5	31.0	10

Table 4. Road network characteristics, by subwatershed.

Subwatershed	Area		Road Length		Road Density	
	(km^2)	($miles^2$)	(km)	(miles)	(km/km^2)	($miles/miles^2$)
Clover Creek	57.0	22.0	110.5	69.1	1.9	3.1
Upper Spencer	47.3	18.3	82.7	51.7	1.7	2.8
Buck Lake	61.0	23.6	115.8	72.4	1.9	3.1
Lower Spencer	53.8	20.8	165.9	103.7	3.1	5.0
Total	**219.2**	**84.6**	**474.9**	**296.8**	**2.2**	**3.5**

B. Sediment Production

Measured annual sediment production shows a clear difference between road segments surfaced with cinder or gravel and those surfaced with native materials. The median production from surfaced plots ranged from one to two kilograms (Table 5), with production from individual plots ranging from 0.3 to 3.5 kilograms. Median annual production from native plots was ten to sixty times greater, on the order of 15 to 72 kilograms. Individual plots produced between five to 130 kilograms (one plot produced between 190 and 380 kilograms each year but was found to receive contributions from disturbed hillslope areas).

Higher production rates from plots surfaced with native materials are the result of two processes related to sediment supply:

- First, native surface roads provide a greater supply of fine material that is readily entrained by road runoff. Surfaced roads supply less fine sediment because finer material is protected (or "armored") by larger particles that are less likely to be transported by road runoff. This difference in the supply of fine sediment is an important distinction that is directly related to road surface type.
- Second, runoff from native plots flowed against berms, in wheel tracks, or across the road surface. As flow paths shifted during the study period, new areas of the road became disturbed and provided fine sediment. Runoff from surfaced plots was typically concentrated in roadside ditches, some of which were well-vegetated. These areas tend to become armored over time as the readily available supply of fine sediment is exhausted. This difference in sediment supply is a result of road drainage, not road surfacing, and is addressed in the calculations used to estimate overall sediment production.

Table 5. Measured sediment production from Spencer Creek watershed plots.

Surface Type	Median Sediment Production (kg)		
	2001	2002	2003
Gravel	1.5	1.0	0.9
Cinder	1.3	1.2	1.2
Native[1]	15.5	72.3	41.5
Notes: (1) Plot N7 excluded due to contributions from other sediment sources.			

Sediment production from one plot (Native #7) was augmented by contributions from adjacent disturbed areas. Annual sediment yield from the combined contributing area was quite high, and indicates the potential role of roads in transporting sediment from disturbed areas (landings, skid trails, etc.) located on certain soil types. While the data from this plot cannot be used to represent watershed-wide sediment production from roads, it indicates that roads may be important as sediment transport vectors in some areas.

C. Weather

Total water year (October through September) precipitation at the weather station ranged from 22 to about 35 inches (56 to 89 cm) (Figure 5). Water year 2001 was the driest of the three years, with 2002 and 2003 each progressively more wet. The majority of precipitation fell before the end of April each year.

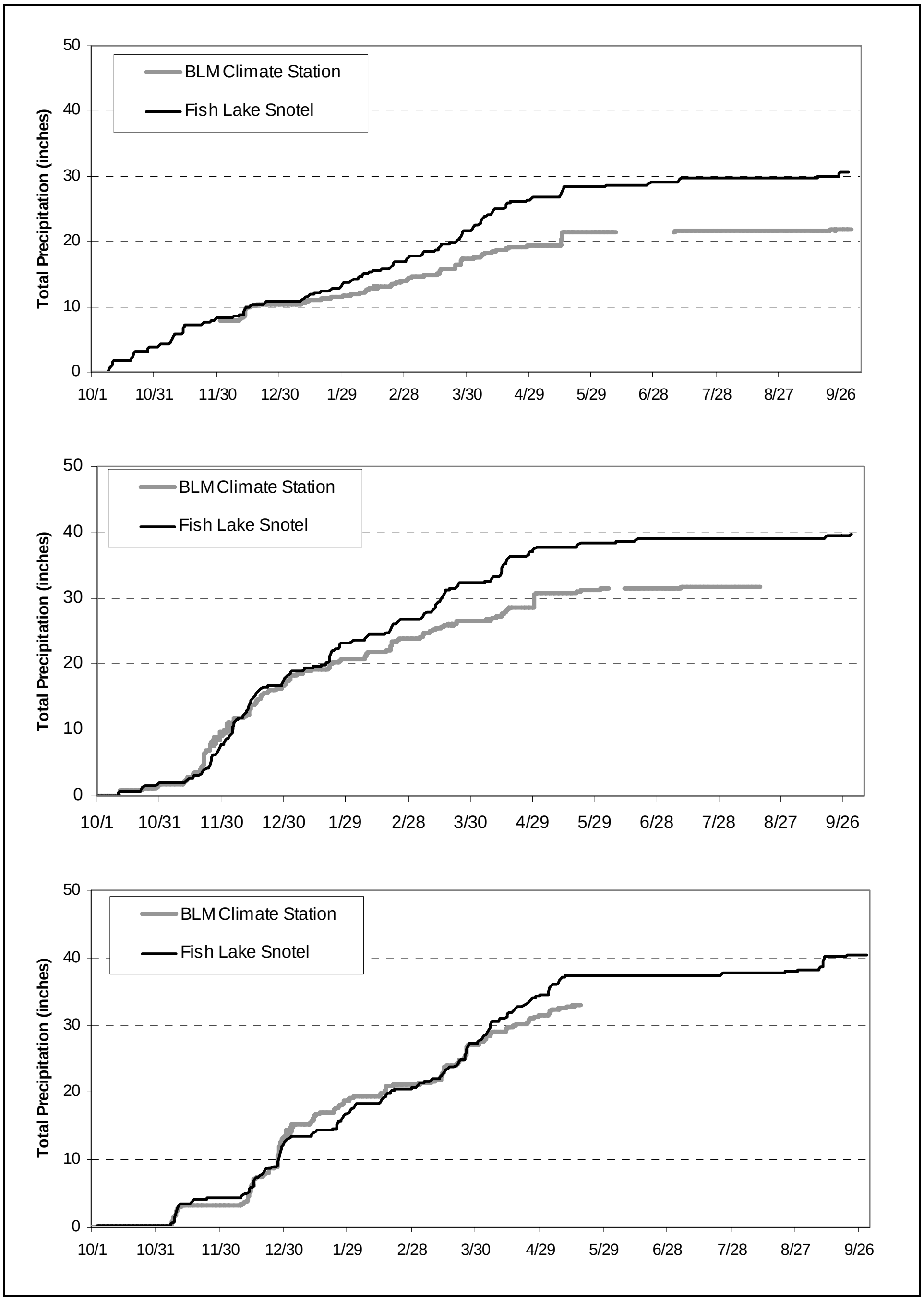

Figure 5. Cumulative water year precipitation at the NRCS Fish Lake snotel station and the BLM climate station for 2001 (top), 2002 (middle), and 2003 (bottom).

IV. Sediment Production and Delivery Calculations

A. Analysis

1. Production

Estimates of sediment production and delivery were calculated using the methods described in Appendix C. These calculations involved multiplying the "base rate" of sediment production by various factors to account for important variables. The base rate was calculated as follows:

1. The measured annual sediment production from the cinder and gravel plots was multiplied by 2, so that data from all plots is standardized to the full road width.
2. The three years of data from each plot was averaged and then divided by the elevation range of the plot.
3. For each set of plots (native, cinder, and gravel), the average production value was multiplied by 7, to model the effects of ditch disturbance. This resulted in a base rate of 2.7 kilograms per meter for surfaced roads. Sediment production from native roads was 21.7 times greater than from surfaced roads The 7x factor was derived from RMRS research in the Oregon Coast Range

Four variables were incorporated in calculations of sediment production:

- Length was determined in GIS using road inventory data.
- Slope was determined in GIS using road inventory data and a Digital Elevation Model.
- Surface multipliers account for the observed differences in sediment production for different road surface types. Gravel, cinder, and vegetated (>50%) roads were assigned a value of 1.0, paved roads were assigned a value of 0.2, and native roads were assigned a value of 3.0 (this value was derived by dividing the native road factor of 21.7 by 7 to account for the effects of continual surface disturbance).
- Values for flow path modifiers account for the amount of vegetation within flow paths. Roads with high levels (>25%) of ditch vegetation were assigned a value of 0.14 for the flow path value; roads with little or no ditch vegetation (<25%) or with flow in wheel tracks, against berms, or on a rilled or rutted road surface were assigned values of 1.0 for this modifier.

Sediment production for each flow path of each road segment was calculated as:

Production = Base Rate (kg/m) * Length (m) * Slope (m/m) * Surface Multiplier * Flow Path Modifier

The value for each road segment was derived by summing the value of the two flow paths or, if there was only one flow path, multiplying the value by two.

2. Delivery

Sediment delivery was determined by linking road segment data with drainage feature data. If the drainage feature to which a given road feature was linked was determined to be connected to a stream or wetland (based on observations of the field crews), production from the associated road segment(s) was marked as being delivered to the stream network. This method may overestimate average sediment delivery, because the connection between drainage features and hydrologic features may not be 100% effective (i.e., some sediment may be stored enroute).

B. Analytical Findings

1. Production

Average annual sediment production from roads is on the order of 77000 kilograms (Table 6). The majority of this is generated by native surface roads. These roads comprise 43% of the road network but produce 83% of the sediment. Surfaced roads produce about 12000 kilograms annually and account for 16% of the total sediment yield (from about 47% of the road network).

The modal sediment production per road segment from native roads was on the order of 5 to 20 kilograms. The modal values for cinder and gravel roads were on the order of 1 to 5 kilograms (Figure 6). Although it was rare for modeled sediment production from surfaced road segments to exceed 20 to 30 kilograms, several native road segments were estimated to produce more than 100 kilograms.

Table 6. Estimates of sediment production and delivery derived from road inventory and sediment trap data, rounded to the nearest hundred kilograms.

Surfacing	Average Annual Sediment Production		Average Annual Sediment Delivery		Ratio of Delivery to Production	
	(kg/year)	Number of Segments	(kg/year)	Number of Segments	Mass	Number of Segments
Native	64000	2328	5400	251	8.4%	10.8%
Cinder	9100	1409	700	187	7.7%	13.3%
Gravel	3200	648	500	123	15.6%	19.0%
Vegetated	800	244	100	32	12.5%	13.1%
Total[1]	**77100**	**4629**	**6700**	**593**	**8.7%**	**12.8%**
Notes: (1) Total includes some roads that are outside of the watershed.						

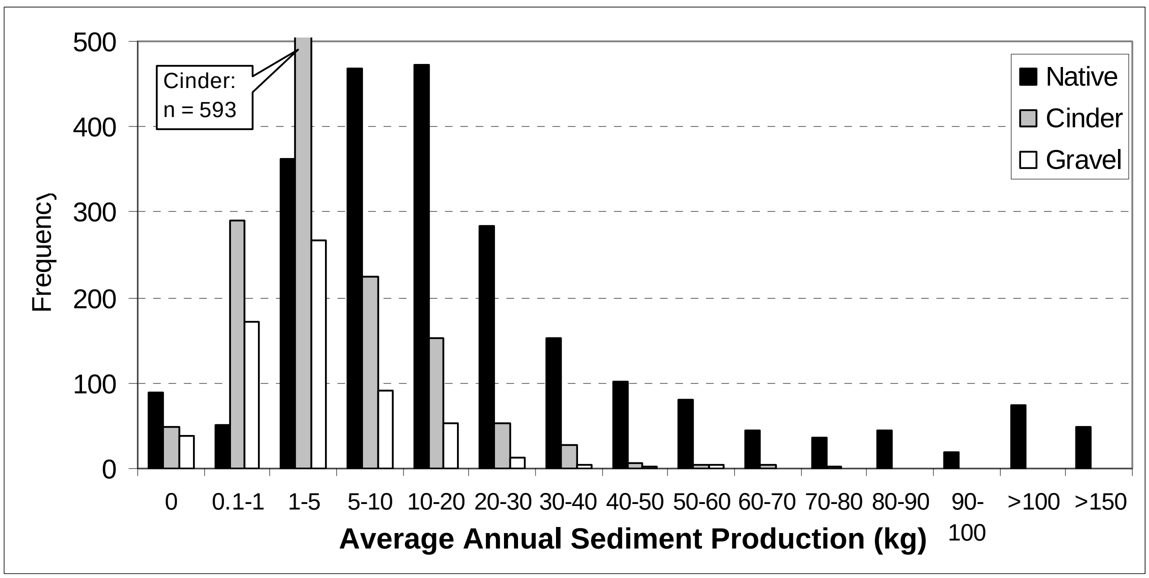

Figure 6. Histogram of sediment production from individual road segments (excluding vegetated and paved roads).

The rate of sediment production per meter of road surface did not vary greatly for cinder and gravel roads, as illustrated by the relatively straight line of the relationship between cumulative sediment production and cumulative road length (Figure 7). Alternatively, it a small portion of the native surface roads produce sediment at a much greater rate than the majority of native roads, as indicated by the steepening curve in Figure 7. Figures 6 and 7 both suggest that about 50% of the sediment produced by native roads is generated from about 25% of the road length.

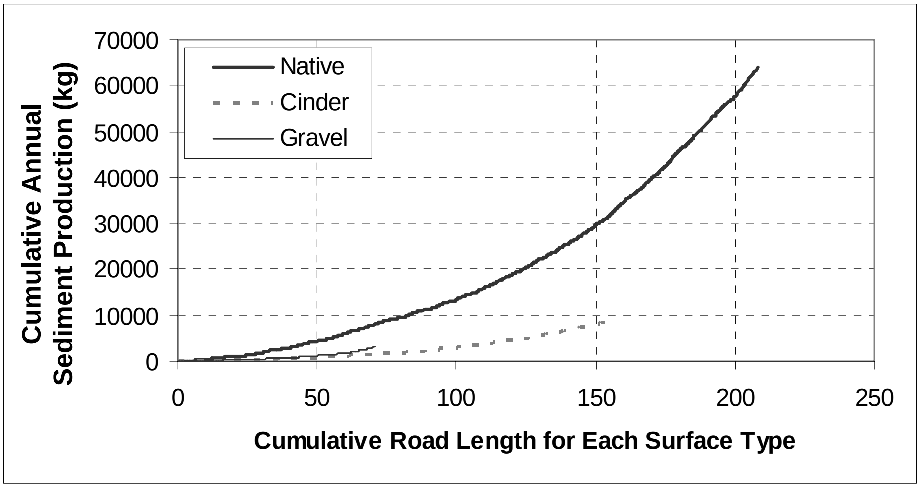

Figure 7. Cumulative sediment production and road length (km) for each surface type, expressed in absolute measurements.

2. Delivery

Annual sediment delivery is on the order of 6700 kilograms. 80% of this is derived from native surface roads. Sediment delivery rates are highest in the Upper Spencer and Lower Spencer subwatersheds, both in terms of total yield and yield per unit area (Table 7). The average mass of sediment delivered from each drainage feature is on the order of two kilograms for all subwatersheds except for Upper Spencer, where each drain delivers about 6 kilograms.

Although almost all road segments produce sediment, only a small proportion of road segments delivered sediment to the stream network. In terms of mass, the ratio of delivery to production varied by surface type and ranged from 8 to 16%, and was highest for gravel roads (Table 6). In terms of the number of road segments, the ratio ranged from 11 to 19% and was also highest for gravel roads.

Of the road segments delivering sediment, modal rates were on the order of 0.1 to 1 kilogram fro gravel roads, 0.1 to 5 kilograms for cinder roads, and 1 to 20 kilograms for native roads (Figure 8). It was not uncommon for estimates of sediment delivery from native roads to exceed 30 kilograms.

Relationships between cumulative delivery and cumulative road length illustrate the important role of a small proportion of the road network (Figure 9). Further, these relationships indicate that smaller sub-sets of the delivering cinder and gravel road segments are responsible for relatively large contributions. The relationship for native roads, on the other hand, indicates more consistent contributions from all delivering road segments.

Table 7. Sediment delivery, by subwatershed.

Subwatershed	Number of Drains	Sediment Delivery (kg)		
		Total	Average Per Drain	Average Yield
		(kg)	(kg)	(kg/km^2)
Clover Creek	691	1441	2.1	25.3
Upper Spencer	453	2684	5.9	56.7
Buck Lake	544	1062	2.0	17.4
Lower Spencer	903	1743	1.9	32.4
Total	**2591**	**6930**	**2.7**	**31.6**

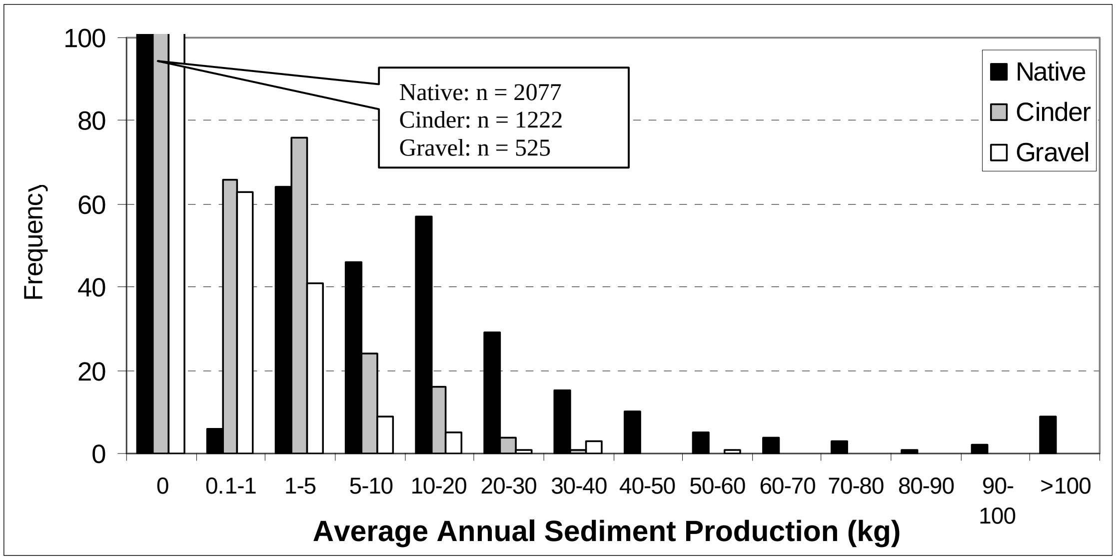

Figure 8. Histogram of sediment delivery from individual road segments (excluding vegetated and paved roads).

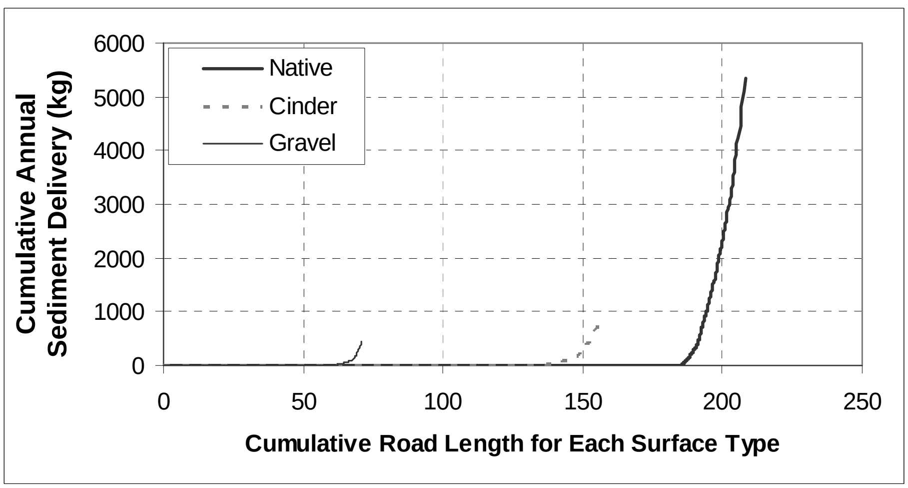

Figure 9. Cumulative sediment delivery and road length (km) for each surface type, expressed in absolute measurements.

V. Management Implications and Information Gaps

Results of this study clearly indicate the role of roads as a source of fine sediment in the Spencer Creek watershed. Roads produce large volumes of sediment, some of which is delivered directly to streams. Native surface roads are the largest source of road sediment. For each of the various road surface types, only a small fraction of the road network (10 to 15% of the road length) contributes sediment directly to streams.

Overall, 14% of the road network in the study area delivers runoff to the stream system (Table 8). A study of road-stream connectivity in a portion of the McKenzie River sub-basin in the Western Cascades found that 57% of the road network was connected to the stream network (Wemple et al., 1996). In the Oregon Coast Range, 16% of the road network in one watershed was connected to streams (Black, pers. comm., 2004). The wide discrepancy in the findings of these studies highlight the need to consider differences in climate, slope steepness, soil porosity, and road network design when comparing different watersheds and applying site-specific research findings to broader areas or different ecoregions.

Table 8. Road network connectivity to streams, by subwatershed.

Subwatershed	Road Length Connected to Streams/Wetlands		Total Road Length		Proportion of Road Length Connected to Stream Network
	(km)	(miles)	(km)	(miles)	(%)
Clover Creek	9.3	5.8	110.5	69.1	8.4
Upper Spencer	14.8	9.3	82.7	51.7	17.9
Buck Lake	21.3	13.3	115.8	72.4	18.4
Lower Spencer	22.0	13.8	165.9	103.7	13.3
Total	**67.4**	**42.2**	**474.8**	**296.9**	**14.2**

The road segments identified as delivering sediment provide a basis for development of a strategy to reduce stream sedimentation (Figure 10). As funding is available, projects should be undertaken to address the causes of sediment production and delivery from these roads. Management options include adding cinder or gravel surfacing to native roads, adding or retrofitting drainage features to direct runoff away from streams, closing roads to traffic, realigning roads that are near streams or that tend to collect surface runoff, and obliterating roads. Road closures reduce road damage and sediment production but should be preceded by waterbarring or other appropriate means of reducing road runoff. Removal of stream crossings is an appropriate strategy in some areas; crossing removal may not have a noticeable impact on average annual sediment delivery but can have a beneficial impact as regards reduced potential for culvert failure during peak flows.

The BLM and Inland Fiber have been pursuing sediment reduction strategies in the watershed. Since 2002, 8 miles (13 km) of road have been treated to reduce sediment production and delivery (Table 9). Treatments have focused on areas that deliver sediment to stream channels (Figure 11) and have included realignment, decommissioning, obliteration, stream crossing removal, and road closures. Additional treatments are planned in 2004. The cumulative effect of the completed and planned treatments will be to reduce average sediment delivery by up to 660 kg, a 10% reduction from pre-2002 conditions.

At least three important data gaps remain. The first regards the rate and pattern of sediment routing through the stream system, as well as the role of roads as transport pathways for sediment generated from hillslopes. The stream network component of this question can be addressed through additional modeling of existing data. The road transport component might be best addressed through application of Best Management Practices: land managers should identify disturbed areas and attempt to disconnect them from road flow paths (especially those that route water into streams). The second data gap regards the relative importance of other fine sediment sources and identification of opportunities for sediment reduction. These other sources might include stream banks destabilized by livestock and hillslopes disturbed during land management activities. The third data gap regards the effect of ditch disturbance on sediment production. The flow path modifier used in sediment production estimates relies on findings from the Oregon Coast Range that have not been validated in the study area. This data gap could be filled by grading the ditches of the cinder and gravel study plots and comparing pre- and post-disturbance sediment production.

Table 9. Extent of road treatments[1] in the Spencer Creek watershed, and associated sediment production and delivery estimates.

Year	Area of Watershed	Length (km)	Production (kg)	Delivery (kg)
2002	Miners Creek	3.4	500	160
2003	Upper/Lower Spencer Creek	9.5	1940	480
2004	Tributaries to Buck Lake	3.7	180	20
Total		**16.6**	**2620**	**660**

Notes: (1) Improvements intended to address sediment delivery to stream channels. Does not include extensive road closures implemented by Inland Fiber in 2003.

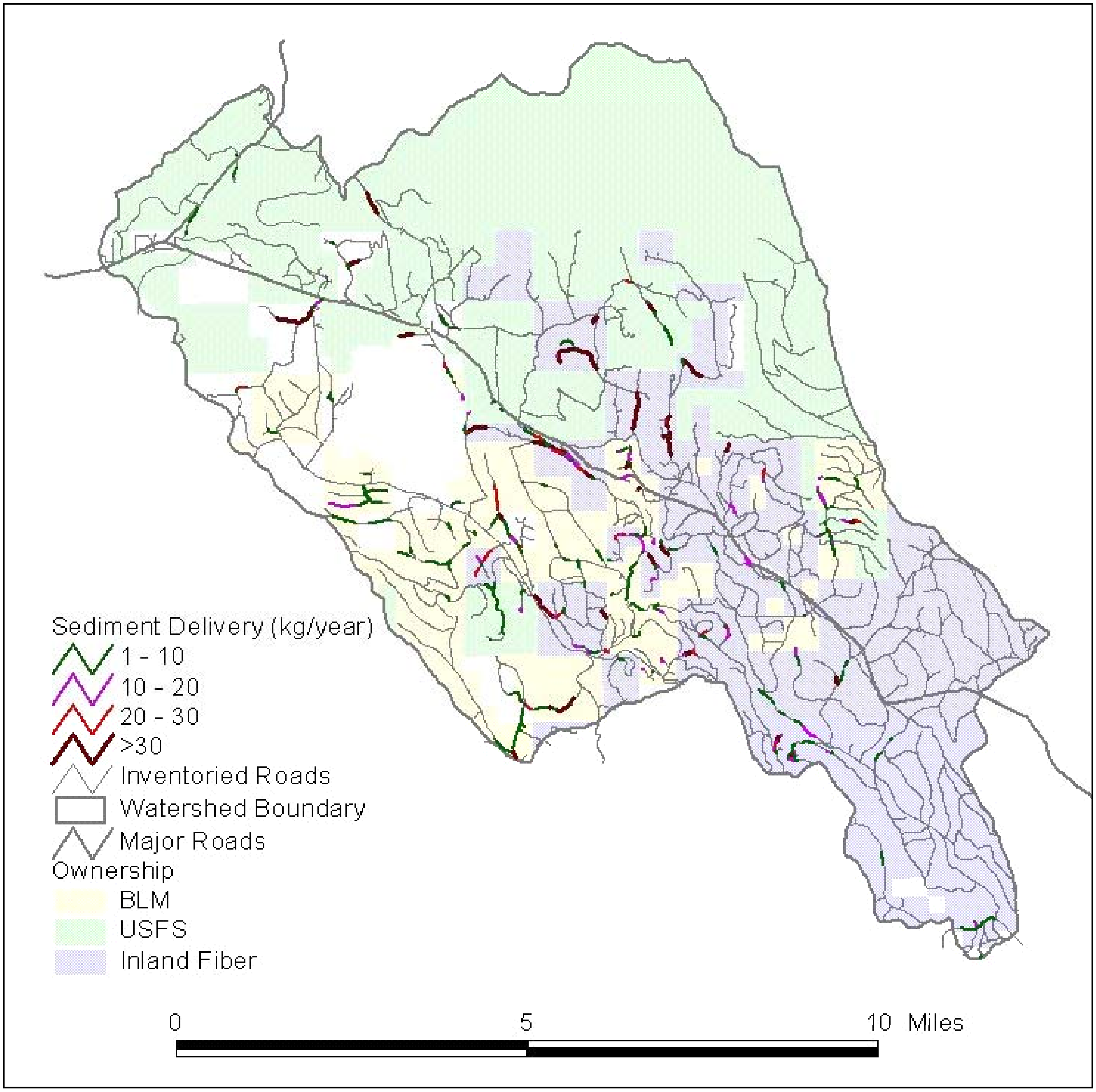

Figure 10. Road segments identified as delivering sediment directly to streams or wetlands.

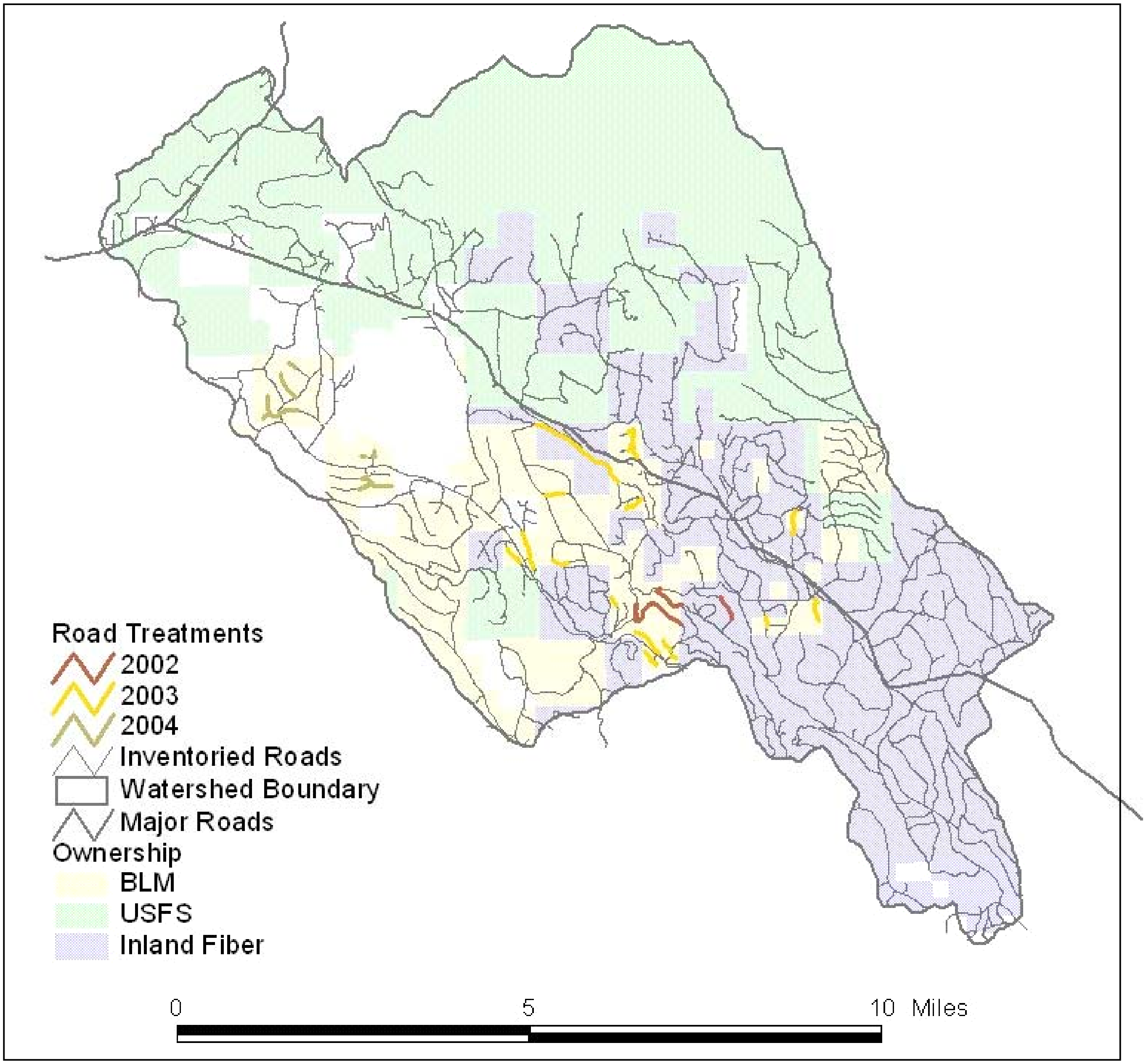

Figure 11. Road treatments completed and planned by the BLM and Inland Fiber (excluding extensive road closures implemented by Inland Fiber in 2003).

VI. Acknowledgements

The watershed-scale scope of this effort would not have been possible without the cooperation of Inland Fiber and Timber Resource Services (collectively the former US Timberlands). Scientists from the Rocky Mountain Research Station played an integral role throughout the study: Tom Black provided expertise during sediment plot selection and installation, development of the inventory protocol, annual sediment measurements, and interpretation of results. The Winema National Forest contributed funding for road inventory crews. Funding from the USFWS Ecosystem Restoration Office supported this study and the road treatments described above, as did the BLM Oregon State Office. Rosy Mazaika at the OSO provided assistance with managing the interagency agreement with the RMRS. The BLM Klamath Falls Fuels Crew 7 and the Lakeview Interagency Force Account, along with Gary Garrison and Harvey Santos, assisted mightily during sediment plot installation. The road inventory crews performed admirably day after day for two years. Scott Miller reviewed and edited the road inventory data.

Appendix A: Road Inventory Data Dictionary

P:\HYDROLOGY\Road Inventories\spencer road seds\KFALLS12.ddf
KFALLS12
updated 6/5/01

Road Line Feature, Label 1 = 1 Drain ID, Label 2 = 2 Drain ID

1 Drain ID Numeric, Decimal Places = 2, Main road drainage feature Minimum = 0, Maximum = 123199999.99, Default Value = 0 Required, Required

2 Drain ID Numeric, Decimal Places = 2, Secondary road drainage Minimum = 0, Maximum = 123199999.99, Default Value = 0 Required, Required

Surfacing Menu, Normal, Normal
Cinder Default
Crushed rock
Native
Paved
herbaceous veg
brush
trees > 4 in dia

Percent surface cov. Menu, Normal, Normal
> 75 % Default
> 50
> 25
> 10
0

Surface Condition Menu, Normal, Normal
Good Default
rilled/eroded
washboard
rutted
rocky
Road Type Menu, Normal, Normal
System road Default
High clearance

C. S. Ht. 1 Menu, Normal, Normal
Fill
0' no ditch
0 - 6' Default
6 - 18'
> 18'

C. S. Ht. 2 Menu, Normal, Normal
Fill
0' no ditch Default
0 - 6'
6 - 18'
> 18'

C. S. Veg. 1 Menu, Normal, Normal, 110% is no cutslope

110%
> 75 %
> 50 %
> 25 %
> 10
> 0 % Default

C. S. Veg. 2 Menu, Normal, Normal, 110% is no cutslope

110% Default
> 75
> 50 %
> 25 %
> 10 %
> 0

C. S. Cond. 1 Menu, Normal, Normal

No problem Default
Badly rilled
Badly ravelling
Badly slumping
Bedrock

C. S. Cond. 2 Menu, Normal, Normal

No problem Default
Badly rilled
Badly ravelling
Badly slumping
Bedrock

Flow Path 1 Menu, Normal, Normal

Base of Cut Default
Wheel Tracks
Berm
Diffuse

Flow Path 2 Menu, Normal, Normal

Diffuse
No secondary Default
Wheel Tracks
Base of Cut
Berm

Ditch Veg 1 Menu, Normal, Normal

110%
> 75 %
> 50 %
> 25 %
> 10
> 0 % Default

Ditch Veg 2 Menu, Normal, Normal, 110% = N/A

- 110% Default
- > 75 %
- > 50 %
- > 25
- > 10 %
- > 0 %

Ditch Cond 1 Menu, Normal, Normal

- No Problem Default
- Gullied
- Buried
- Rutted
- Blocked
- Stream course
- Woody veg

Ditch Cond 2 Menu, Normal, Normal

- No Problem Default N/A
- Gullied
- Buried
- Rutted
- Blocked
- Stream course
- Woody veg.

Ditch Relief Culvert Point Feature, Label 1 = Drain ID, Label 2 = Size Drain

ID Numeric, Decimal Places = 2, Minimum = 0, Maximum = 123199999.99, Default Value = 0 Required, Required

Size Menu, Required, Required

- < 12"
- 12"
- 15"
- 18' Default
- 24"
- > 24"

Pipe Length Menu, Normal, Normal

- 20'
- 30' Default
- 40'
- 50'
- 60'
- 70'
- >70'

Type Menu, Required, Required

Steel Default
Concrete
Aluminum
Plastic
Log

Condition Menu, Required, Required

0 Default
1-20%
20-80%
80-100%
Partially Crushed
Totally Crushed
Rusted significantly
Flows around pipe

Slope Shape Menu, Required, Required

Concave
Planar Default
Convex

Discharge to Menu, Required, Required

Forest Floor Default
Gully
Ditch
Landslide
Wetland
Stream

Stream Connection Menu, Required, Required

No Default
Yes
Unknown

Fill Erosion Menu, Normal, Normal

No Default
Yes

Flow Diversion Menu, Normal, Normal

No Default
Yes
Previous

Stream Crossing Point Feature, Label 1 = Drain ID, Label 2 = Type,

Drain ID Numeric, Decimal Places = 2
Minimum = 0, maximum = 123199999.99, Default Value = 0 Required, Required

Type Menu, Normal, Normal

Steel culvert round Default
Steel culvert D shap
Steel culvert arched
Plastic culvert
Baffled culvert
Concrete culvert
Log culvert
Concrete ford
Natural ford
Aluminum culvert
Bridge

Round Pipe Dia. Menu, Normal, Normal

N/A
12"
15"
18"
24" Default
36"
48"
60"
> 60"

Oval Pipe size Menu, Normal, Normal

N/A Default
13"x17"
15"x21"
20 "x28 "
24"x35"
29"x42"
33 "x49"
38 "x57 "

Channel width Numeric, Decimal Places = 0, feet, Minimum = 1, Maximum = 100, Default Value = 4 Normal, Normal

Number of pipes Menu, Normal, Normal

N/A
1 Default
2
3
>3

Pipe length Menu, Normal, Normal

N/A
20'
30'
40' Default
50'
60'
70'
>70'

Fill Depth Numeric, Decimal Places = 0, Units of feet minimum = 1, maximum = 100, Default Value = 10
Normal, Normal

Condition Menu, Normal, Normal
Open and sound Default
Partially blocked
Totally blocked
Partially Crushed
Totally Crushed
Rusted significantly
Flows around pipe
Scoured under bridge

Angle to Channel Menu, Normal, Normal, Angle between pipe and channel
<25 degrees Default
<45 degrees
45-75 degrees
> 75 degrees

Evidence of Blockage Menu, Normal, Normal
no Default
Sediment plume
Scoured road W
ashed out road
organic debris pile

Outlet drop Menu, Normal, Normal
< 1' Default
< 2'
< 3'
> 3'

Outlet pool Menu, Normal, Normal, Depth and Length
no water Default
> 2 ' and 6
1 -2' and 4 -6'
< 1' and < 4'

Channel grade Menu, Normal, Normal, upstream of road
0-2% Default
2-4%
4-10%
> 10%

Crossing Substrate Menu, Normal, Normal
Culvert Material Default
Sand
Gravel
Boulders
Bedrock

Debris Flow? Menu, Normal, Normal
No Default
Yes

Fill Erosion Menu, Normal, Normal
No Default
Yes

Lead Off Point Feature, Label 1 = Drain ID, Label 2 = Slope Shape

Drain ID Numeric, Decimal Places = 2, Minimum = 0, Maximum = 123199999.99, Default Value = 0
Required, Required

Slope Shape Menu, Required, Required
Concave
Planar Default
Convex

Discharge to Menu, Required, Required
Forest Floor Default
Gully
Ditch
Landslide
Wetland
Stream

Stream Connection Menu, Required, Required
No Default
Yes
Unknown

Condition Menu, Normal, Normal
No Problem Default
Gullied
Not functional
Excess deposition

Water Bar Point Feature, Label 1 = Drain ID, Label 2 = Slope Shape

Drain ID Numeric, Decimal Places = 2
Minimum = 0, Maximum = 123199999.99, Default Value = 0 Required, Required

Slope Shape Menu, Required, Required
Concave
Planar Default
Convex

Discharge to Menu, Required, Required
Forest Floor Default
Gully
Ditch
Landslide
Wetland
Stream

Stream Connection Menu, Required, Required
No Default
Yes
Unknown

Fill Erosion Menu, Normal, Normal
No Default
Yes

Flow Diversion Menu, Normal, Normal
No Default
Yes
Previous

Type Menu, Normal, Normal
Road Material Default
Fabricated Material

Condition Menu, Normal, Normal
No Problem Default Damaged
Too Small
Drains Inboard Ditch

Broadbase Dip Point Feature, Label 1 = Drain ID, Label 2 = Slope Shape

Drain ID Numeric, Decimal Places = 2, Minimum = 0, Maximum = 123199999.99, Default Value = 0
Required, Required

Slope Shape Menu, Required, Required
Concave
Planar Default
Convex

Discharge to Menu, Required, Required
Forest Floor Default
Gully
Ditch
Landslide
Wetland
Stream

Stream Connection Menu, Required, Required
No Default
Yes
Unknown

Fill Erosion Menu, Normal, Normal
No Default
Yes

Type Menu, Normal, Normal
Grade Reversal Default
Flat Ditch
Constructed

Condition Menu, Normal, Normal
No problem Default
Puddles on road
Wetland in ditch
Saturated fill

Material Menu, Normal, Normal
Crushed rock
Native
Soil Default
Vegetated
Paved
Cinder

Comment Text, Maximum Length = 100 Normal, Normal

Non-engineered Point Feature, Label 1 = Drain ID, Label 2 = Slope Shape

Drain ID Numeric, Decimal Places = 2, Minimum = 0, Maximum = 123199999.99, Default Value = 0
Required, Required

Slope Shape Menu, Required, Required
Concave
Planar Default
Convex

Discharge to Menu, Required, Required
Forest Floor Default
Gully
Ditch
Landslide
Wetland
Stream

Stream Connection Menu, Required, Required
No Default
Yes
Unknown

Fill Erosion Menu, Normal, Normal
No Default
Yes

Condition Menu, Normal, Normal
Blocked Ditch Default
Diverted Wheel Track
Broken Berm
Gully Crosses Road
Outsloped

Comment Text, Maximum Length = 100 Normal, Normal

Sump Point Feature, Label 1 = Drain ID, Label 2 = Condition

Drain ID Numeric, Decimal Places = 2, Minimum = 0, maximum = 123199999.99, Default Value = 0 Required, Required

Condition Menu, Normal, Normal
No Problem Default
Fill Saturation
Puddles on Road

Comment Text, Maximum Length = 100 Normal, Normal

Diffuse Drainage Point Feature, Label 1 = Drain ID, Label 2 = Slope Shape minimum of 150'

Drain ID Numeric, Decimal Places = 2, Minimum = 0, maximum = 123199999.99, Default Value = 0 Required, Required

Slope Shape Menu, Required, Required
Concave
Planar Default
Convex

Discharge to Menu, Normal, Normal
Forest Floor Default
Gulley
Ditch
Landslide
Wetland

Stream Connection Menu, Normal, Normal
No Default
Yes
Unknown

Fill Erosion Menu, Normal, Normal
No Default
Yes

IntersectionPoint Feature, Label 1 = Comment

Comment Text, Maximum Length = 100 Normal, Normal

Closed Road **Point Feature, Label 1 = Closure Description, Label 2 = Closure efficiency**

Closure Description Menu, Normal, Normal
Log and soil Default
Down trees
Overgrown
Planted
Ripped or subsoiled
Trenched
Boulders
Guard rail
Cable
Fencing

Closure efficiency Menu, Normal, Normal
Fully effective Default
Driven around
Damaged Missing

Gated Road **Point Feature, Label 1 = Description, Label 2 = Condition**

Description Text, Maximum Length = 100 Normal, Normal

Condition Menu, Normal, Normal
Functional Default
Damaged

Access **Menu, Normal, Normal**
Unlocked Gate
Default Locked gate

Road Hazard **Point Feature, Label 1 = Type** Type Text, Maximum Length = 100 Normal, Normal

End of road **Point Feature, Label 1 = Description** Description Text, Maximum Length = 100 Normal, Normal

Revisit **Point Feature, Label 1 = Description describes an area to come back to** Description Text, Maximum Length = 100 Normal, Normal

Appendix B: Field Procedure for Sediment Mass Determination

Updated 6/1/00

The goal of this technique is to obtain the mass of an unknown quantity of sediment. We determine this number by measuring the mass of the weighing container full of water to a known volume (M_{tw}). Next we measure the mass of the unknown sediment, submerged in water (M_{ts}). This can be converted to dry mass of sediment (M_s) using the particle density of the material (D_s) and the density of water (D_w). The calculation is as follows:

$$M_s = (M_{ts} - M_{tw})Ds/(D_s - D_w)$$

I. Method

The sediment is collected in the field in a large settling basin. Observations are made at the end of the precipitation season at each basin. This includes weighing the sediment, sampling the sediment and observing the texture and color of the sample along with any observations on the condition and function of the field plot from which it came.

The excess water from the 300-gallon tanks is carefully siphoned down to near the level of the sediment, avoiding any loss of sample. The tank is shoveled out, then scraped with a plastic trowel and or brush to remove any adhering material. When the tank is as clean as a trowel will allow, the tank is tipped on its side and water is either sprayed with a hose from the tank or splashed with a bucket to collect all the mud into a corner. It may then be scooped up and sampled. The goal is to leave less sediment in the tank than is detectable by the scale. This may be about one ounce of dry sediment. This will be significant number for the samples that collect only a few pounds each season. The sediment is transferred to plastic buckets and carried to the road where the measurements are taken.

Before disturbing the sample, a measurement of the depth of the sample is taken. This number should reflect an average depth and if all of the mass is in a pile below the inlet pipe, an approximation should be made. The color of the sample should be recorded using descriptors such as reddish brown or grayish red. The texture of the sediment should be noted as well using a soil textural description such as silty sand.

The weighing is done with a digital load cell hanging from a tripod. The tripod is set up on the road above the tank. The hook is installed and the load cell hangs from the hook at a height so that the suspended weighing bucket clears the ground by several inches. The load cell is turned on and zeroed before installation.

The weighing bucket has three turnbuckles used to level the bucket. The bucket is filled with water to obtain the weight of water and the container (M_{tw}). The bucket is filled until water begins to spill and then the turnbuckles are adjusted until water spills out in equal volumes from between each of the tree quadrants defined by the attachment points. Once the bucket is close to level, a half turn of adjustment is sufficient to make an appreciable difference in height. It is generally easier to raise the lowest of the three sides (the one with the most flow) rather than lowering the two that have the least flow.

To check the level pour about 100 ml of water in to the bucket slowly using a cup and observe where it spills over. When it is spilling evenly within the three quadrants it is deemed level. Then take an additional 100 ml of water and carefully add it. Count to five after it is added and then read the load cell (in pounds) to the hundredths of pounds and record the measurement in the field book. This is the M_{tw} number that is entered as the mass of water and bucket on the field form. This number is typically around 48.15 pounds. This measurement should be taken at the start of each sampling day to check the scale and the precision of the system.

The weighing of sediment is done in the same fashion except that the weighing bucket is filled with the sediment to a level close to full and then clean water is added to reach the full level as defined above. After a five count record the reading and enter it under the bucket #1 entry in the field form.

The weighed sediment is sub-sampled and a one kilogram sample is placed in a one gallon Ziploc bag. This bag is labeled with the plot number and the date and placed into a five-gallon bucket for transport and containment. Within a day the sample will settle and excess water may be poured off before sealing the bag.

II. Equipment list

Battery operated load cell 100-pound capacity (and spare)
Survey tripod
Load cell hanger hook
Steel leveling bucket
Plastic buckets (a couple of small and a 5, 5 gallon size)
Plastic scoops 2
Cup measure
Squirt bottle, 1 Liter
Shovel, short handle flat blade
Brush to clean inside of tank
Water supply (55 gallon drum)
Pump, Shindawa portable gasoline
Hoses for pump, suction and discharge
Hose for water supply container
Pump fuel container
Tool box (everything breaks unless you have one)
Tape measure
Field book with data sheets
Sample bags, gallon size
Sharpies
Pencils
Gloves
Rubber boots

III. Field Data Collection Form

Tripod Weighing of Sediment

Field Area:

Plot #: Date:

Plot Letter: Crew:

Depth of Sediment (in):

Texture of Sediment (in):

Color of sediment:

Tare of bucket+water (lbs):

Weight of sediment + bucket (lbs)

#1	#2	#3	#4	#5
#6	#7	#8	#9	#10

Plot Condition:

Sample taken ?

Appendix C: Instructions for Calculating Road Sediment Production and Delivery from GPS Data in ArcView

(Developed by USFS RMRS: ROADINV9; 12/18/2002)

(Revised to describe methods used on 12/15 and 12/16/2003 for editing and analyzing Spencer Creek watershed road inventory data. Comments specific to the Spencer Creek project are highlighted in bold)

NOTES:
-Before beginning, load ArcView and the ArcView extension, Spatial Analyst.
-In ArcView, turn on the Spatial Analyst, Sinmap, and Geoprocessing extensions. (File/Extensions).
-You will need a DEM that extends at least a few hundred meters beyond the watershed boundaries.
-The formulas shown for populating fields using the Field Calculator can be copied into the Calculator using CNTL C to copy and CNTL V to paste.
-Accumulating sediment along a drainage requires a program called Tardem. This can be downloaded free from Dr. David Tarboton's website at: http://www.ece.usu.edu/dtarb/tardem.html
-Note that names of the fields in attribute tables may vary from those shown here, depending on the data dictionary version used to GPS the features.
-When instructions call for "populating" a new field, use Field/Calculator. (The table must be in Edit mode to calculate.)

FILE PREPARATION:
-GPS files can be exported from Pathfinder Office as ArcView shapefiles, ready to load into ArcView. (View/AddTheme to load.)
-Prepare a road file of the watershed that is clipped to 100 or 200 meters of the watershed boundary. To clip the watershed from a larger map, you will need a polygon shapefile of watershed boundaries. Then:

View/Geoprocessing/Clip one theme based on another

ERROR-CHECKING ROAD ARCVIEW DATA

1. Check the road theme attribute table for roads that don't have drains assigned to them. (All road sections must have at least one drain assigned.) An easy way to check for empty drain fields is by using Query. Data could be missing because either it was not collected, or because it was not copied correctly when files were merged. Improper merging usually happens because field names do not match. If field names do not match, copy the data into a new, properly named field; alias field names won't work.

   The results of "joins" between each type of drain and the road coverage indicated that 281 road segments were not linked to any drainage feature. Common causes included incorrect or omitted dates or odometer mileages in one of the Drain-id fields. If this type of error was not apparent, topography and the flow paths and drains of adjacent road segments were used to link the road segment(s) to one or more drains.

2. Scan the display of roads for "spaghetti" roads and use the Vertex Edit tool to delete scattered points. (Incorrect road lengths result from connecting the scattered points.) **(Spatial data in the roads coverage was edited in 12/2001)**
   a. Intersections are often problems. Zoom in to check them.
3. Scan the map of roads for missing sections of road.
   a. Check the end of road segments for a drain or end-of-road marker.
   b. Check for gaps between road segments.

   c. **Four road segments were manually added to the coverage (this was noted in the "comment" field). Attributes were populated based on observations by the KFRA hydrologist and the characteristics of adjacent road segments.**
4. Scan the map of roads for sections that were surveyed twice, and where sections overlap. Use the Identify tool to find hidden overlaps. **(On 12/15/2003, GIS staff at the RMRS lab used the topology validation tool in ArcMap8.3 to remove overlapping road segments and road segments less than 4 meters in length)**
5. Before beginning the analysis, be sure that each field in the roads attribute table has a unique name. Field names may have been truncated during data processing.
6. **The values of the "surfacing" field were revised as follows:**
   a. **"brush" and "herbaceous veg" were changed to "vegetated"**
   b. **"crushed rock" was changed to "gravel"**

CALCULATING SEDIMENT DELIVERY:

1. From the View window, select the clipped Road theme and start editing (Theme/Start editing).
2. Open the attribute table for the Road shapefile, and update the length field. (Length is in meters.)
   a. Select Length field
   b. In Field Calculator type: [shape].ReturnLength

3. Resample the existing DEM (assuming you have a 30 meter DEM. A 10 m re-sampling should be sufficient.
4. Find the elevation range for each road segment (i.e. the change in elevation in meters)
   a. create a field of unique IDs for each record:
      Edit/Add Field, called Road_seg (as number, decimal places=0)
      and then populate it in Field Calc. Type:
      rec+1
   b. From the view window, load a DEM for the area (load as a grid, not an image)
   c. select the road theme, then (requires Spatial Analyst)
      i. Analysis/Summarize Zones
      ii. The field=the new unique ID field
      iii. Theme=the DEM
      iv. This creates a table "Stats of…" which includes elev range
      v. Join "Stats of…" table into Road table using the ID field to join on, and turn off all "Stats of…" fields except Range (turn off fields using Tables/Properties)
5. Edit add field called "slope", number with 3 decimals. In field calculator
   slope = range / length
6. Copy the drain numbers from Z1_drain into any blank records in Z2_drain (or records containing 0). (This works because if Z2_drain is blank or 0, then both halves of the road drains to Z1_drain).
   a. Create Boolean field Drain2flag and populate with: ([Z2_drain_i]=0) (ie, missing ditch data=true)
   b. Make new field with 2 decimal places (2nd_Drain) and populate with:
(("False True").asList.FindByValue(([ditch2flag]).AsString)) * [Z1_drain_i]) + [Z2_drain_i]
   c. For clarity, drag 2nd_Drain back next to Z2_drain and create an alias for Z1_drain called 1st_Drain.
   d. Note that the formula first converts true to 1 and false to 0, then multiplies by the drain number in Drain1 and adds it to the drain number in Drain 2. This will copy Z1_drain into any blanks.

7. Base Rate
   a. In Road table, create field BaseRate (number, 0 decimal places) Populate in Field Calc with
      79*Range
   b. Note that 79=constant (in kg/m) for sed. production in the Oregon Coast Range area, and range represents the slope*length. Use the appropriate constant for your area.

c. **For this analysis, a constant of 2.7 kg/m was used for sediment producton. This was based on 3 years of monitoring at 15 plots in the Spencer Creek watershed.**

8. **Create a new field “surface-mod” to re-categorize the “surfacing” data in the roads coverage as follows:**

“surfacing” value (from roads coverage)	“percent-surfacing” value (from roads coverage)	“surface-mod” value (new field)
Paved		Paved
Native		Native
Vegetated	<50%	Native
Cinder		Surfaced
Gravel		Surfaced
Vegetated	>50%	Surfaced

9. Create a new field as a number with 1 decimal place called SurfMult for a surface type multiply to modify base rate, and populate manually with the following values (using queries of “surface-mod” and the field calculator):

Paved: 0.2
Surfaced: 1.0
Native: 3.0

These values are based on monitoring results from the Spencer Creek sediment traps and the more comprehensive analysis done in the Oregon Coast Range (Eugene District BLM). The Spencer Creek native surface plots had sediment production that was twenty times higher than that of cinder and gravel plots (from which sediment production was essentially equal). Higher production from native plots resulted from (1) the surface type and (2) the fact that the flow paths on the native roads were disturbed during plot installation while the flow paths (ditches) on the cinder and gravel roads were not. Analysis of Eugene data indicates that sediment production from roads with recently disturbed flow paths is seven times higher than the long-term “base rate” of production from roads with armored, undisturbed ditches. Therefore, it was assumed that the native surfacing causes sediment production to increase by a factor of 3.

10. Create 2 fields called “FP1-mod” and “FP2-mod” (flowpath modifiers) for the purpose of re-categorizing the condition of the various flow paths encountered in the Spencer Creek road inventory. Populate these fields as follows (using queries of relevant fields and the field calculator). These changes were necessary to classify the cases when there was no data for the vegetation on the flow path, such as when the flow path was Bern or Wheel Tracks. Additionally the value of 110% was misused by the field crew in some cases when they should have recorded an observation of ditch vegetation cover. :

“FLOWPATH_x” value (from road coverage)	Other Factors (from road coverage)	“FPx-mod” value (new field)
Base of Cut	If “ditchveg_1” ≠ “110%”	“ditchveg_1” value
	If “ditchveg_1” = “110%”	“> 75%”
Berm or Wheel Tracks	If “surfacing” = vegetated	“percent_surfacing”
	If “surfacing” = native or cinder or gravel	“> 10%”
No Ditch	If “surface_condition” = good or washboard or rocky	“> 75%”
	If “surface_condition” = rilled or rutted	“< 10%”

Diffuse		**“> 75%”**
No Secondary Ditch (“Flowpath_2” only)		**“FP1-mod” value**

11. Create 2 fields with 2 decimal places, called FP1-mult and FP2-mult, for modifying base rate based on flowpath vegetation and surface condition. Populate FP1-mult and FP1-mult manually as follows:
    If FPx-mod equals 0% or <10% or >10%, **FPx-mult = 1.0**
    If FPx-mod equals >25%, >50%, or >75%, **FPx-mult = 0.14**

12. Create two new fields with 2 decimal places (SedProd1 and SedProd2) for the sediment production (kg/m), modified by ditch vegetation and surface type, for each side of each section of road. Populate each new field with:
    [Baserate] * [SurfMult] * [FP1-mult]
    [Baserate] * [SurfMult] * [FP2-mult]
13. Create a new field with 2 decimal places (SedProd) for the sum of the sediment produced from each half of each section of road. Populate with:
    ([SedProd1] / 2) + ([SedProd2] / 2)
14. Create a new field with 4 decimal places (Sed/m) for the total sediment per meter of road produced for each section of road. Populate:
    [SedProd] / [Length]
15. Table/SaveEdits

[Analysis on 12/16/2003 did not proceed beyond this point.]

16. Determine which drains deliver sediment to a stream
    a. Open the Ditch Relief table, and select the field, Drain_id. Then, in the Road table, select the first drain id field and join the tables. Using Table/Properties, create an alias for the Stream_con field, calling it Ditch_con1.
    b. In the Ditch Relief table, select the field, Drain_id again. Then select the second drain id field in the Road table, and join the tables. Create an alias for this Stream_con field called Ditch_con2. This will distinguish the connectivity for each drain.
    c. You can hide all the newly joined in fields except the Ditch_con* fields using Theme/Properties.
17. Start editing the stream crossing table. Add a string field named Stream_con. Populate the field with “Yes”. Stop editing. Join into the Road table following instructions in Step 12.
18. Repeat the procedure in Step 12 for joining for each of the remaining drain types.
19. Code each side of each road segment for delivery to stream
    a. Add a Boolean field (Con_1) to road table and populate:
       ([ditch_con1] = "Yes") Or ([wbar_con1] = "Yes") Or ([Leadoff_con1] = "Yes") Or ([stream_con1] = "Yes") Or ([Broadbas_con1] = "Yes")

    b. Add Con_2 field to road table and populate:
       ([ditch_con2] = "Yes") Or ([wbar_con2] = "Yes") Or ([Leadoff_con2] = "Yes") Or ([stream_con2] = "Yes") Or ([Broadbas_con2] = "Yes")
20. Create 2 new fields with 4 decimal places (SedDeliv1 and SedDeliv2) for sediment delivered to a stream from each side of each section of road:

((((“False True").asList.FindByValue([con_1].AsString)) * [SedProd1]) / 2)

((((“False True").asList.FindByValue([con_2].AsString))*[SedProd2])/2)

20.Create a new field with 4 decimal places (SedDelivery) for total sediment deliveried to the stream from each section of road:
    [SedDeliv1] + [SedDeliv2]

21. Remove the Joins with Table/Remove All Joins. The fields that were created to hold the results of the calculations will stay in the table. Stop editing the Road table and Save.

[Completed this task on 4/17/2004]

ANALYZING SEDIMENT BY DRAIN (see potential alternative below as a potential starting place if analysis by drain type is not needed).

1. Summarize sediment and contributing road length for each drain:
    a. In Road table, select the Z1_drain field and push Summarize button
    b. Name= Sedbydrain1.dbf
    c. Field=Length Summarize By=Sum Add
    d. Field=Sed_Prod1 Summarize By=Sum Add
    e. Field=Sed_Deliv1 Summarize By=Sum Add
    f. In Road table, select the Ditch2 field and push Summarize button
    g. Name= Sedbydrain2.dbf
    h. Field=Length Summarize By=Sum Add
    i. Field=Sed_Prod2 Summarize By=Sum Add
    j. Field=Sed_Deliv2 Summarize By=Sum Add
    k. Note that both sedbydrain1 and sedbydrain2 should have an exhaustive list of the drains. If no secondary drainage comes to a drain, 0 should be entered for sum of length, sedprod, and seddelivery.
2. Join Sedbydrain1.dbf and Sedbydrain2.dbf back into each Drain table
    a. Select Z1_drain field in Sedbydrain1.dbf
    b. In each Drain table, select the Drain_id field, and then Join
    c. Select Drain2 field in Sedbydrain2.dbf
    d. In each Drain table, select the Drain_id field, and then Join
    e. This lets you access the sediment and contributing length for each drain from inside the drain tables.
3. Sum the sediment production and sediment delivered by each Drain
    a. Start editing the DitchRelief table, and create a new field with 4 decimal places called *SedProd, where the * represents the type of drain. (For example, "ditSedProd".) Populate with:
       ([Sum_SedProd1] + [Sum_SedProd2])/2
       Note that the division by two is similar to what was done in the per segment sediment production (instruction 9 of previous section)
    b. Create a new field with 4 decimal places called *SedDel, using the same naming convention as for *SedProd. Populate with:
       [Sum_SedDeliv1] + [Sum_SedDeliv2]
    c. Give Sum_length2 alias of Sumlen2 in table properties
    d. Create a new field with 4 decimal places called RoadLen. This will hold the contributing road lengths after the joins are removed. Populate by making it equal to:
       ([Sum_Length]+[Sumlen2])/2
    e. Table/RemoveAllJoins and Table/StopEditing/Save.
    f. Repeat steps 3a – 3d for the rest of the drain type tables.
    g. The total sediment (kg/m) and the contributing road length (meters) for each drain is now stored in the Drain tables.

ALTERNATIVE INITIALIZATION FOR ANALYSIS BY DRAINS

This alternative can be used if one does not need the drain type ID in front of sed delivery and sediment production. Some data is lost in the transfer, but it can be much quicker.

1. Turn on Geoprocessing wizard extension in ArcView
2. Merge the drain points into one table called Alldrains

a. Open Geoprocessing wizard
b. Select all of the themes together
c. Use fields from the largest most complete table – e.g. ditchrelief culvert
d. Save as shape file named "alldrains"
e. Put output into the work folder
f. Proceed as above to summarize Seddel and Sedprod, but only for the one drain type, note that this effectively leaves you with just the one drain table. Instruction 1 in the previous section is unchanged, and the only change starts with instruction 2 where only this one amalgamated drain table is used.

[Chose to analyze for all drains combined (alternative analysis described above). Task complete on 4/29/2004.]

Appendix D: GIS Metadata

All coverages have a projection of UTM Zone10 NAD27 Spheroid Clarke1866.

A. Sediment Plots

Path to coverages: gis/hydro/

Coverage Name: SPENCERSEDPLOTS
Comments: GPS Point data for the location of sediment plots

B. Road Inventory Field Data

Path to coverages: /gis/engineering/rdinv01/spencer/

Coverage Name: ALLDRAINS
Comments: Was merged in ArcView using 2000 and 2001 drainage feature data; this coverage does not have the correct Drain ID numbers.

Coverage Name: ALLPOINTS
Comments: Was merged in ArcView using 2000 and 2001 drainage feature data; this coverage does not have the correct Drain ID numbers.

Coverage Name: ALLPOINTS_00
Comments: All of the points data was appended from /gis/spencer/combined/fs00/ and copied into /gis/engineering/rdinv01/spencer/. Used as backup.

Coverage Name: ALLPOINTS_00W
Comments: Working coverage for ALLPOINTS_00. ALLPOINTS_00 is a backup.

Coverage Name: ALLPOINTS_01
Comments: GPS data from 2001 points coverages was merged together in ArcView. The drainage ID's were not correct after the merge function. Used as backup.

Coverage Name: ALLPOINTS_01W
Comments: Working coverage for ALLPOINTS_00. ALLPOINTS_01 is a backup.

Coverage Name: ALLROADS_00
Comments: All of the roads GPS'd in 2000. Copied Roads_0606 from /gis/spencer/ and renamed it ALLROADS_00. Used as backup.

Coverage Name: ALLROADS_00W
Comments: Working coverage for ALLROADS_00. ALLROADS_00 is a backup.

Coverage Name: ALLROADS_01
Comments: Roads GPS'd in 2001 were appended in ARCINFO. Used as backup.

Coverage Name: ALLROADS_01W
Comments: Working coverage for ALLROADS_01. ALLROADS_01 is a backup.

Coverage Name: ALLROADS
Comments: Append ALLROADS_01 and ALLROADS_00.

Coverage Name: ALLROADSW
Comments: Working coverage for ALLROADS. ALLROADS is a backup.

The following coverages were created from appending the 2000 and 2001 points coverages in ARCINFO. The 2000 points coverages are located at /gis/spencer/combined/fs00/; the 2001 points coverages are located at /gis/engineering/rdinv01/spencer/pastwork/ :

BBDIP; CLOSED_RD; CULVERT; DIFFUSE; END_OF_RD; GATED_RD; GENERIC_PT; INTERSECTION; L_O_DITCH; NON_ENG; RD_HAZ; REVISIT; STREAM_CROSS; SUMP; WATER_BAR

The PASTWORK work directory was created to place interim items. Some items may or may not be applicable.

C. Sediment Production and Delivery Analysis

Path to coverages: /public/hydrology/road inventories/spencer_road_seds/interim_results/

Coverage Name: ALLDRAINS040429
Comments: Merged all drains, used for analysis of sediment delivery by subwatershed

Coverage Name: SPENCER_ROAD_SEDIMENT_PRODUCTION
Comments: Road inventory data that has been corrected to rectify drain errors and attributed with slope, surface and flow path modifiers, and calculations of sediment production and delivery

Coverage Name: SEDIMENT_REDUCTION
Comments: Data from SPENCER_ROAD_SEDIMENT_PRODUCTION attributed with recent and planned road treatments