APPENDIX I
ROAD SURFACE SEDIMENT ANALYSIS METHODS AND RESULTS

I.1. Methods

Sediment delivery from roads to main stem Grave Creek is a potential source contributing to water quality impairment. Appendices B and C provided detailed results of general roads analysis measures including road density, road lengths, roads in the rain-on-snow zone and roads on sensitive land types. Table I-1 provides a summary of the primary results from Appendices B and C.

The Kootenai National Forest analyzed road source contributions in the Grave Creek drainage using the WEPP: Road interface (Elliot et al. 1999) of the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston 1995). WEPP: Road estimates road bed erosion and resulting sediment delivery. WEPP: Road allows users to easily describe numerous road erosion conditions. Variables used in the WEPP: Road model include climate, soil and gravel addition, local topography, drain spacing, road design and surface condition, and ditch condition. Road fill slope and vegetative buffer conditions may also be described. Additional physical variables including road gradient, road width and surface type, road design (insloped vs. outsloped), and traffic volume were used to predict sediment production

Climatic information included mean annual precipitation (46.6 inches) and 123 wet days per year. Topography data included elevation (5,081 ft). Road design was represented by a contributing road surface distance of 800 ft, and road gradients measured from USGS topographic maps. Road design was further categorized according to outsloped, insloped, and crowned roadbeds. Road surfaces included paved, gravel, and native material. The same values for the fill and buffer parameters were used for all runs. The fill gradient was set at 50 percent, fill length was set at 15 ft; buffer gradient was set at 25 percent, and buffer length was set at 33 ft. Unlike other road sediment modeling approaches which focus solely on sediment contribution from roads at stream crossings (XDRAIN, Washington Method, and others), WEPP: Road attempts to account for sediment production and delivery along the entire road length within sediment contributing distance to streams. Therefore measures of fill and buffer lengths and gradients are required input parameters.

Table I-1 provides a general description of the roads evaluated in this analysis. The road network was evaluated based on characteristics of primary and secondary roads. Primary roads are classified as main arterial roads within the watershed. Secondary roads included other forest roads that comprised the rest of the network not including the main arterial roads. The analysis focused on surface erosion from roads including cut slopes, fill slopes, and the roadbed. Composition of particles from these sources is mostly likely fine sediment. The analysis does not cover impacts from culvert failure, water routing, increased flows, or increased potential for mass wasting associated with roads. Analyses of other factors affecting road-associated sediment contributions (not sediment from road surface erosion) are presented in Appendices B and C (road density, roads in rain-on-snow zone, and roads on sensitive landtypes) and Appendix J (mass wasting and bank erosion from road encroachment).

Table I-1: Road Network Statistics.				
Stream	Miles of Road	Road Density (mi/mi^2)	Miles of Road in ROS* Zone	Miles of Road in RHCA
Williams	16.6	1.8	3.5	4.1
Clarence-Stahl	36.6	2.0	19.7	9.2
Blue Sky	25.6	2.1	16.8	8.8
Upper Grave-Foundation-Lewis	19.4	1.4	11.8	n/a
Lower Grave Creek Main stem	71.8	3.3	0	6.2

Sediment modeling results from WEPP: Road include the projected amount of sediment produced as well as projected amount of sediment delivered. Delivered sediment is usually lower than produced sediment as a result of buffer characteristics.

At the time of road building there was an initial pulse of sediment over several years from road construction and from the presence of the new roads. Over time, this sediment input has likely diminished to a relatively steady state, as modeled in this analysis. Much of this recovery would be due to re-vegetation of cut and fill slopes. Current levels of sediment from roads are relatively low when compared to the sediment load from bank erosion in the lower portion of the watershed. Current levels of sediment from roads in the upper watershed areas are probably also relatively low when compared to 1) historic road sediment loading levels when the roads were in greater use for timber harvest purposes prior to the implementation of BMPs; 2) relatively high sediment pulses when mass wasting linked to historic riparian harvest first occurred and 3) the initial road building discussed above. In several cases, field observations document continued sediment loading from roads as a result of road maintenance practices (snow plowing into ditches and culvert inlets and outlets and ditch and culvert clean-out) and lack of road BMPs. BMP upgrades implemented since sediment modeling occurred, or which were otherwise not accounted for in the sediment modeling process, have likely further reduced the sediment loading from roads.

Table I-2: Miles of Road and Road Conditions in the Main Stem Grave Creek Watershed and Tributary Sub-watersheds. Road Miles Measured From GIS Dataset.						
Drainage	Total Road Length (mi)	Paved/ Chipsealed Roads	Total Paved Road (mi)	Main Road Numbers	Main Road Length (mi)	Other Road Length (mi)
Foundation	6.4	None	0.0	None	0.0*	6.4
Lewis	4.5	None	0.0	114	2.1	2.4
Blue Sky	25.6	None	0.0	7020	25.6	0.0
Clarence	13.0	None	0.0	114, 7021, 7022	5.8	7.2
Stahl	19.9	None	0.0	7021, 7022	5.1	14.8

Table I-2: Miles of Road and Road Conditions in the Main Stem Grave Creek Watershed and Tributary Sub-watersheds. Road Miles Measured From GIS Dataset.						
Drainage	Total Road Length (mi)	Paved/ Chipsealed Roads	Total Paved Road (mi)	Main Road Numbers	Main Road Length (mi)	Other Road Length (mi)
Williams	16.4	None	0.0	7019 (in HUC 0203)	4.5	11.9
Upper Main Stem Grave	8.5	None	0.0	114, 319	4.7	3.8
Upper Middle Main Stem Grave	3.8	114	2.6	7021	0.1	1.1
Lower Middle Main Stem Grave	24.3	114	4.4	7019, 7061, 7066	7.2	12.7
Lower Main Stem Grave	47.3	93, 114	6.2	7019, 7061, 7066	2.7	38.4

I.2. Results

I.2.1 Grave Creek Watershed

WEPP: Road modeling results indicate that for the Grave Creek watershed, 203 tons of sediment from road surface erosion is delivered to the stream network (Table I-3). Of the total sediment delivery related to the road network, 98 tons per year are delivered to tributaries, and 105 tons per year are delivered to main stem Grave Creek. Primary and secondary roads yielded an average of 1.2 and 1.1 tons of sediment per mile, respectively. Primary roads in the Stahl Creek drainage had the highest loading per road mile (3.97 tons/mi). Loading per mile of road is compared in Tables I-4 and I-5).

Table I-3: Summary of Annual Sediment Delivery From Roads in the Grave Creek Drainage.			
Drainage	Sediment from Primary Roads (tons)	Sediment from Secondary Roads (tons)	Total Sediment Delivery (tons)
Foundation	0.0	2.8	2.8
Lewis	8.3	3.7	12.0
Blue Sky	0.0	17.6	17.6
Clarence	17.1	6.4	23.5
Stahl	20.2	6.4	26.7
Williams	4.2	10.6	14.9
Upper Main Stem Grave	7.7	5.9	13.6
Upper Middle Main Stem Grave	0.3	1.7	2.0
Lower Middle Main Stem Grave	21.2	19.6	40.8
Lower Main Stem Grave*	2.2	46.5	48.8
Total	81.3	121.3	202.7

*Most of these roads are private.

Roads in lower Grave Creek contribute 24% (49 tons) of the sediment load from road surface erosion. The road networks along middle Grave Creek contribute 21% (43 tons) of the total road surface sediment load. The tributaries each deliver between 5% and 15% of the sediment load from road surface erosion to the channel network. A summary of road surface erosion assessment results is presented in Section 6.0. Sediment load from In-stream sources associated with road encroachment is described in Appendix J.

Road density provides an indication of sediment loading, with location or distance from a stream and road condition influencing the amount of sediment load likely to reach a stream network. Figure I-1 demonstrates that for secondary roads in the Grave Creek watershed (which generally lack BMPs) road surface sediment load increases more rapidly with increasing road density than for primary roads. Most of the sediment is contributed from secondary roads, which generally lack adequate BMPs such as cross drains and graveled, paved, or chip-sealed surface. BMP implementation, which is more common on primary roads, partially offsets sediment load increase from increasing road density.

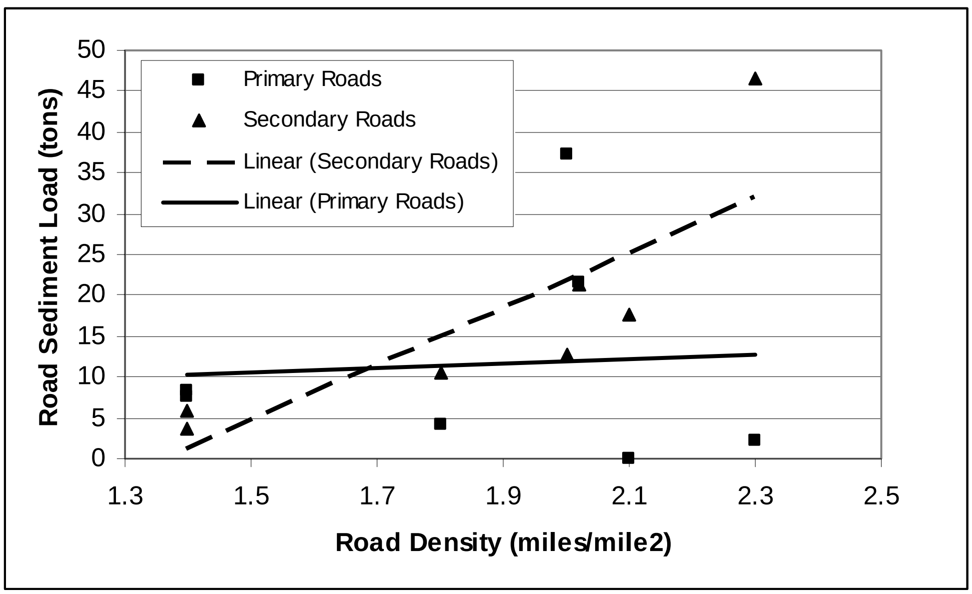

Figure I-1: Relationship between road density and sediment load from road surface erosion.

I.2.2 Williams Creek

The road surface erosion contribution to Williams Creek is estimated to be 14.9 tons per year (Table I-3). The road transportation network consists of 16.6 miles of closed roads, with an average road density of 1.8 miles per square mile (Table I-1). Twenty-five percent of the network is within the Riparian Habitat Conservation Area (RHCA), or within 300 ft of surface water and over 21 percent within the rain-on-snow zone (Table I-1).

I.2.3 Clarence Creek

An estimated 17.1 tons and 6.4 tons per year of sediment are delivered annually from primary and secondary roads in Clarence Creek (Table I-3). The total road sediment load for the Clarence Creek drainage was estimated to be 23.5 tons per year.

Clarence Creek road density analysis incorporated roads within the Stahl Creek sub-watershed. There are over 36.6 miles of road in the Clarence-Stahl sub-watershed, with approximately 53.8 percent of the road mileage located in the rain-on-snow zone. Approximately 25 percent of the road system is within 300 ft of surface water (Table I-1).

I.2.4 Stahl Creek

An estimated 20.2 tons and 6.4 tons per year of sediment are delivered annually from the surface of primary and secondary roads in Stahl Creek watershed (Table I-3). The total road sediment load for the Stahl Creek drainage was estimated to be 26.7 tons per year (Table I-3).

I.2.5 Lewis Creek

Road surface erosion contributes an estimated 12 tons of sediment per year to surface water in Lewis Creek (Table I-3). The road transportation network in Lewis Creek consists of 19.4 miles of road, with an average road density of 1.4 miles per square mile (Table I-1).

I.2.6 Blue Sky Creek

An estimated 17.6 tons of sediment are delivered annually to Blue Sky Creek from secondary roads in the sub-watershed (Table I-3). The road transportation network consists of 25.6 miles of secondary road, with an average road density of 2.1 miles per square mile (Table I-1). Sixty-five percent of the system is constructed within the rain-on-snow zone in the watershed. Thirty-four percent of the system is within 300 ft of surface water.

I.2.7 Foundation Creek

Road tread erosion contributes an estimated 2.8 tons per year to surface water in Foundation Creek (Table I-3). Sediment delivery occurs from closed, secondary roads that were decommissioned in the 1980s following logging activities. Roads in Foundation Creek were grouped with roads from the upper main stem and Lewis creek to generate road network statistics (Table I-1).

Table I-4: Characteristics of Primary Roads and Estimated Sediment Contributions From Road Surface Erosion.

Drainage	Total Road Length (mi)	Road Gradient	Road Width (ft)	Road Surface	Road Design	Traffic Level	Per Segment Erosion Rate (lbs/yr)	Per Segment Sediment Delivery (tons/mi)	Total Sediment Delivery (tons)
Foundation	0	-	-	-	-	-	0.0	0.00	0.0
Lewis	2.1	8%	12	Gravel	Insloped	High	1202.5	3.97	8.3
Blue Sky	0	-	-	-	-	-	0.0	0.00	0.0
Clarence	5.8	6%	16	Gravel	Insloped	High	892.1	2.94	17.1
Stahl	5.1	8%	16	Gravel	Insloped	High	1202.5	3.97	20.2
Williams *	4.5	4%	16	Gravel	Insloped	Low	285.7	0.94	4.2
Upper Main Stem Grave	4.7	6%	16	Gravel	Crowned	High	499.4	1.65	7.7
Upper Middle Main Stem Grave	0.1	6%	16	Gravel	Insloped	High	892.1	2.94	0.3
Upper Middle Main Stem Grave	2.6	2%	16	Paved	Outsloped	High	22.1	0.07	0.2
Lower Middle Main Stem Grave	7.2	6%	16	Gravel	Insloped	High	892.1	2.94	21.2
Lower Middle Main Stem Grave	4.4	2%	16	Paved	Outsloped	High	22.1	0.07	0.3
Lower Main Stem Grave	2.7	2%	16	Gravel	Insloped	High	249.8	0.82	2.2
Lower Main Stem Grave	6.2	2%	16	Paved	Outsloped	High	22.1	0.07	0.5
Total	45.4						6182.4	20.4	82.3

* Includes recently closed portion of 7019 that actually has no traffic; assumed that road is not yet vegetated.

Table I-5: Characteristics of Secondary Roads and Estimated Sediment Contributions From Road Surface Erosion.

Drainage	Total Road Length (mi)	Road Gradient	Road Width (ft)	Road Surface	Road Design	Traffic Level	Per Segment Erosion Rate (lbs/yr)	Per Segment Sediment Delivery (tons/mi)	Total Sediment Delivery (tons)
Foundation	6.4	4%	10	Native	Insloped	None	131.6	0.43	2.8
Lewis	2.4	8%	10	Native	Insloped	None	468.4	1.55	3.7
Blue Sky	19.7	6%	10	Native	Insloped	None	270.6	0.89	17.6
Clarence	7.2	6%	10	Native	Insloped	None	270.6	0.89	6.4
Stahl	14.8	4%	10	Native	Insloped	None	131.6	0.43	6.4
Williams	11.9	6%	10	Native	Insloped	None	270.6	0.89	10.6
Upper Main Stem Grave	3.8	8%	10	Native	Insloped	None	468.4	1.55	5.9
Upper Middle Main Stem Grave	1.1	8%	10	Native	Insloped	None	468.4	1.55	1.7
Lower Middle Main Stem Grave	12.7	8%	10	Native	Insloped	None	468.4	1.55	19.6
Lower Main Stem Grave	38.4	4%	10	Native	Insloped	Low	367.2	1.21	46.5
Total	118.4						3316.0	10.9	121.3