APPENDIX C
RAIN-ON-SNOW, WATER YIELD, EQUIVALENT CLEARCUT ACREAGE AND PEAK FLOW INCREASES ANALYSIS SUMMARY

This section includes the results of spatial analysis conducted for the Grave Creek watershed to analyze timber harvest and road building activities that could potentially affect the hydrology and runoff regime of the watershed. Two sets of analyses are included: road and harvest activity within the rain on snow zone conducted by River Design Group (2003-2004), and water yield analysis conducted by the USFS (2004). The water yield analysis includes equivalent clearcut area (ECA) and peak flow increase (PFI) modeling.

Like roads, skid trails and jammer roads constructed in the rain-on-snow zone in the watershed (4,500 ft to 5,500 ft) can potentially modify the routing efficiency of managed sub-basins, shifting the timing of the peak flow to earlier in the snowmelt season, and increasing the magnitude of channel forming discharges. However, skid trails and jammer roads are not considered in these analyses because neither a map nor GIS layers of their extent and location have been compiled. These trails and jammer roads still have the potential to intercept and route flows, although the level of impact under normal conditions has been mitigated since many of these skid trails and jammer roads will have revegetated over time.

C.1 Rain on Snow Analysis

The rain-on-snow analysis is an extension of the harvest analysis and the road analyses provided in Appendix A and B, respectively. Summary statistics provided below were generated using the same input data and the same methods as those described in Appendix A and B. This rain-on-snow analysis includes summary statistics for road building and harvest activity within the rain-on-snow zone only. The rain-on-snow zone is defined as the area within the elevation band between 4500 and 5500 feet. This band was delineated using a 30m digital elevation model (USGS) provided by the Kootenai National Forest.

Table C-1: Area Harvested at Least Once within Rain-on-Snow Zone by Sub-Watershed.

Sub-watershed	Meters^2	KM^2	Miles^2	Acres	%Sub-Water-shed	% Water-shed	%North	%South
Blue Sky	3180772	3.2	1.2	786	9.9	1.6	97	3
Clarence-Stahl	3720606	3.7	1.4	919	8.0	1.9	50	50
Lower Grave Creek	0	0.0	0.0	0	0.0	0.0	0	0
Upper Grave-Foundation-Lewis	1052185	1.1	0.4	260	3.0	0.5	68	32
Williams Creek	690617	0.7	0.3	171	2.8	0.4	39	61
Total	**8644181**	**8.6**	**3.3**	**2136**		**4.4**	**69**	**31**

Table C-2: Harvest Area within Rain-on-Snow zone by LTA by Sub-Watershed.										
Landtype	Meters2	KM2	Miles2	Acres	% Sub-Watershed	% Grave Watershed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky										
351	180657	0.2	0.1	45	0.6	0.1	moderate	moderate	high	severe
404	357828	0.4	0.1	88	1.1	0.2	moderate	moderate	low	moderate
406	128528	0.1	0.0	32	0.4	0.1	moderate	slight	low	moderate
407	813882	0.8	0.3	201	2.5	0.4	moderate	moderate	high	severe
408	1699878	1.7	0.7	420	5.3	0.9	moderate	slight	high	severe
	3180773	**3.2**	**1.2**	**786**	**9.9**	**1.6**				
Clarence-Stahl										
351	618643	0.6	0.2	153	1.3	0.3	moderate	moderate	high	severe
401	135230	0.1	0.1	33	0.3	0.1	moderate	slight	high	severe
404	1746107	1.7	0.7	431	3.8	0.9	moderate	moderate	low	moderate
405	14497	0.0	0.0	4	0.0	0.0	moderate	slight	low	moderate
406	27486	0.0	0.0	7	0.1	0.0	moderate	slight	low	moderate
407	1177511	1.2	0.5	291	2.5	0.6	moderate	moderate	high	severe
408	1133	0.0	0.0	0	0.0	0.0	moderate	slight	high	severe
	3720606	**3.7**	**1.4**	**919**	**8.0**	**1.9**				
Lower Grave Creek										
Upper Grave-Foundation-Lewis										
108	47740	0.0	0.0	12	0.1	0.0	severe	severe	low	moderate
351	164775	0.2	0.1	41	0.5	0.1	moderate	moderate	high	severe
401	97177	0.1	0.0	24	0.3	0.0	moderate	slight	high	severe
404	374374	0.4	0.1	93	1.1	0.2	moderate	moderate	low	moderate
405	501	0.0	0.0	0	0.0	0.0	moderate	slight	low	moderate
406	37826	0.0	0.0	9	0.1	0.0	moderate	slight	low	moderate
407	283609	0.3	0.1	70	0.8	0.1	moderate	moderate	high	severe
408	46182	0.0	0.0	11	0.1	0.0	moderate	slight	high	severe
	1052185	**1.1**	**0.4**	**260**	**3.0**	**0.5**				
Williams										
401	18702	0.0	0.0	5	0.1	0.0	moderate	slight	high	severe
406	194648	0.2	0.1	48	0.8	0.1	moderate	slight	low	moderate
407	477267	0.5	0.2	118	1.9	0.2	moderate	moderate	high	severe
	690617	**0.7**	**0.3**	**171**	**2.8**	**0.4**				
Grave Creek Watershed										
108	47740	0.0	0.0	12		0.0	severe	severe	low	moderate
351	964075	1.0	0.4	238		0.5	moderate	moderate	high	severe
401	251109	0.3	0.1	62		0.1	moderate	slight	high	severe
404	2478309	2.5	1.0	612		1.3	moderate	moderate	low	moderate
405	14998	0.0	0.0	4		0.0	moderate	slight	low	moderate
406	388488	0.4	0.1	96		0.2	moderate	slight	low	moderate
407	2752269	2.8	1.1	680		1.4	moderate	moderate	high	severe
408	1747193	1.7	0.7	432		0.9	moderate	slight	high	severe
	8644181	**8.6**	**3.3**	**2136**		**4.4**				

Table C-3: Area of Riparian-Linked Stands Harvested at Least Once Within the 4500-5500' Elevation Band by Sub-Watershed.

Sub-watershed	Meters^2	KM^2	Miles^2	Acres	%Sub-Water-shed	%Water-shed	%North	%South
Blue Sky	2851921	2.9	1.1	705	8.8	1.5	97	3
Clarence-Stahl	2347276	2.3	0.9	580	5.1	1.2	47	53
Lower Grave Creek	0	0.0	0.0	0	0.0	0.0	0	0
Upper Grave-Foundation-Lewis	886333	0.9	0.3	219	2.5	0.5	67	33
Williams Creek	651565	0.7	0.3	161	2.7	0.3	41	59
Total	**6737095**	**6.7**	**2.6**	**1665**		**3.5**	**70**	**30**

Table C-4: Harvest Area in Riparian Related Stands within Rain-on-Snow Zone by LTA by Sub-Watershed.

Landtype	Meters2	KM2	Miles2	Acres	%Sub-Water-shed	%Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky										
351	180657	0.2	0.1	45	0.6	0.1	moderate	moderate	high	severe
404	214213	0.2	0.1	53	0.7	0.1	moderate	moderate	low	moderate
406	128528	0.1	0.0	32	0.4	0.1	moderate	slight	low	moderate
407	813882	0.8	0.3	201	2.5	0.4	moderate	moderate	high	severe
408	1514642	1.5	0.6	374	4.7	0.8	moderate	slight	high	severe
	2851921	**2.9**	**1.1**	**705**	**8.8**	**1.5**				
Clarence-Stahl										
351	618643	0.6	0.2	153	1.3	0.3	moderate	moderate	high	severe
401	135230	0.1	0.1	33	0.3	0.1	moderate	slight	high	severe
404	569993	0.6	0.2	141	1.2	0.3	moderate	moderate	low	moderate
405	14497	0.0	0.0	4	0.0	0.0	moderate	slight	low	moderate
406	5129	0.0	0.0	1	0.0	0.0	moderate	slight	low	moderate
407	1003784	1.0	0.4	248	2.2	0.5	moderate	moderate	high	severe
	2347276	**2.3**	**0.9**	**580**	**5.1**	**1.2**				
Lower Grave Creek										
Upper Grave-Foundation-Lewis										
108	47740	0.0	0.0	12	0.1	0.0	severe	severe	low	moderate
351	164775	0.2	0.1	41	0.5	0.1	moderate	moderate	high	severe
401	97177	0.1	0.0	24	0.3	0.0	moderate	slight	high	severe
404	246544	0.2	0.1	61	0.7	0.1	moderate	moderate	low	moderate
406	3807	0.0	0.0	1	0.0	0.0	moderate	slight	low	moderate
407	280108	0.3	0.1	69	0.8	0.1	moderate	moderate	high	severe
408	46182	0.0	0.0	11	0.1	0.0	moderate	slight	high	severe
	886333	**0.9**	**0.3**	**219**	**2.5**	**0.5**				
Williams										
401	18702	0.0	0.0	5	0.1	0.0	moderate	slight	high	severe
406	163173	0.2	0.1	40	0.7	0.1	moderate	slight	low	moderate

Table C-4: Harvest Area in Riparian Related Stands within Rain-on-Snow Zone by LTA by Sub-Watershed.										
Landtype	Meters2	KM2	Miles2	Acres	%Sub-Water-shed	%Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
407	469690	0.5	0.2	116	1.9	0.2	moderate	moderate	high	severe
	651565	**0.7**	**0.3**	**161**	**2.7**	**0.3**				
Grave Creek Watershed										
108	47740	0.0	0.0	12		0.0	severe	severe	low	moderate
351	964075	1.0	0.4	238		0.5	moderate	moderate	high	severe
401	251109	0.3	0.1	62		0.1	moderate	slight	high	severe
404	1030749	1.0	0.4	255		0.5	moderate	moderate	low	moderate
405	14497	0.0	0.0	4		0.0	moderate	slight	low	moderate
406	300638	0.3	0.1	74		0.2	moderate	slight	low	moderate
407	2567463	2.6	1.0	634		1.3	moderate	moderate	high	severe
408	1560824	1.6	0.6	386		0.8	moderate	slight	high	severe
	6737095	**6.7**	**2.6**	**1665**		**3.5**				

Table C-5: Road Length Within the 4500-5500' Elevation Band by Sub-Watershed.								
Sub-watershed	% Total Road Length in HUC 6.5 within ROS band	Meters	Feet	Miles	% Sub-Water-shed	% Water-shed	%North	%South
Blue Sky	66	27122	88959	16.8	65.8	9.9	79	21
Clarence-Stahl	54	31701	103979	19.7	53.8	11.6	50	50
Lower Grave Creek	0	0	0	0.0	0.0	0.0	0	0
Upper Grave-Foundation-Lewis	61	19022	62392	11.8	61.0	22.8	45	55
Williams Creek	21	5578	18295	3.5	20.9	2.0	69	31
Total	**53**	**83422**	**273625**	**51.8**		**30.5**	**59**	**41**

Table C-6: Road Length in Rain-on-Snow band by LTA by Sub-Watershed.								
Landtype	Meters	Miles	% Sub-Water-shed	% Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky								
351	1639	1.0	4.0	0.6	moderate	moderate	high	severe
401	186	0.1	0.5	0.1	moderate	slight	high	severe
404	3473	2.2	8.4	1.3	moderate	moderate	low	moderate
406	1705	1.1	4.1	0.6	moderate	slight	low	moderate
407	14396	8.9	34.9	5.3	moderate	moderate	high	severe
408	5723	3.6	13.9	2.1	moderate	slight	high	severe
	27122	**16.9**	**65.8**	**9.9**				
Clarence-Stahl								
351	2441	1.5	4.1	0.9	moderate	moderate	high	severe
401	1225	0.8	2.1	0.4	moderate	slight	high	severe
404	15422	9.6	26.2	5.6	moderate	moderate	low	moderate

Table C-6: Road Length in Rain-on-Snow band by LTA by Sub-Watershed.								
Landtype	Meters	Miles	% Sub-Water-shed	% Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
406	219	0.1	0.4	0.1	moderate	slight	low	moderate
407	12394	7.7	21.0	4.5	moderate	moderate	high	severe
	31701	**19.7**	**53.8**	**11.6**				
Lower Grave Creek								
Upper Grave-Foundation-Lewis								
108	886	0.6	2.8	1.1	severe	severe	low	moderate
351	1753	1.1	5.6	2.1	moderate	moderate	high	severe
401	1513	0.9	4.9	1.8	moderate	slight	high	severe
404	6770	4.2	21.7	8.1	moderate	moderate	low	moderate
406	1096	0.7	3.5	1.3	moderate	slight	low	moderate
407	7003	4.4	22.5	8.4	moderate	moderate	high	severe
	19022	**11.8**	**61.0**	**22.8**				
Williams								
401	364	0.2	1.4	0.1	moderate	slight	high	severe
406	1700	1.1	6.4	0.6	moderate	slight	low	moderate
407	3316	2.1	12.4	1.2	moderate	moderate	high	severe
408	197	0.1	0.7	0.1	moderate	slight	high	severe
	5578	**3.5**	**20.9**	**2.0**				
Grave Creek Watershed								
108	886	0.6		0.3	severe	severe	low	moderate
351	5833	3.6		2.1	moderate	moderate	high	severe
401	3289	2.0		1.2	moderate	slight	high	severe
404	25665	15.9		9.4	moderate	moderate	low	moderate
406	4720	2.9		1.7	moderate	slight	low	moderate
407	37109	23.1		13.6	moderate	moderate	high	severe
408	5920	3.7		2.2	moderate	slight	high	severe
	83422	**51.8**		**30.5**				

C.2. Water Yield, Equivalent Clearcut Acreage and Peak Flow Increases Analysis

The impact of increased water yield on sediment transport depends on both the sediment availability as well as the temporal distribution of the additional water on the flow hydrograph. Data derived from closely monitored, harvested watersheds characterized by spring snowmelt runoff have shown that the flow augmentation tends to be concentrated on the rising limb and peak of that spring snowmelt runoff event (Troendle et al., 2001).

An increase in stream flow during the snowmelt period can result in a significant increase in sediment transport capacity, as spring runoff conditions commonly constitute the channel forming discharge characterized by active sediment transport and channel

adjustment (Andrews and Nankervis, 1995). In an analysis of sediment transport from Deadhorse Creek (Troendle and Olsen, 1994) it was concluded that documented increases in sediment production following timber harvest were derived from channel bank or bed scour due to increased duration of higher flows.

ECA, water yield, and peak flow increase estimates may also be used as a potential indicator of increased sediment production from other soil disturbing activities related to vegetation removal, for example skid trails. If sediment is conveyed to the stream network, the increased sediment transport capacity caused by an increase in peak flows will result in an increased delivery of sediment to Grave Creek. Alternatively, if sediment is not available for transport, increased transport energy will result in sediment sourcing downstream from the channel perimeter due to bank and bed scour (Troendle et al., 2001). Therefore, the most effective means of preventing increased water yield and associated sediment delivery is to increase or maintain vegetative cover.

Analysis of the effects of vegetation removal from road building and timber harvest on water yield included modeling of Equivalent Clearcut Areas (ECA) and associated projected Peak Flow Increases (PFI). This analysis was conducted by the USFS. The analysis included harvest activity recorded in the USFS TSMRS (Timber Stand Management Record System) as well as consideration of vegetation removed for roads and from the Kopsi Fire. The period of analysis was 1915 through 1998. Harvest and other activity on private land and National Forest harvest activity not recorded in TSMRS were not included. The TSMRS activity codes considered in this analysis are included in Table C-7.

Below is a summary of the parameters used by the USFS to run these analyses.

- Road ECAs are computed (4 acres per mile of road).
- HIR (historic roads) roads are included.
- Calculated PFI uses Forest Plan formula in Vol. II, Pp A 18-6, with maximum percent increase constants of .77 per road ECA and .45 per harvest ECA.
- WATSED PFI uses relationship between 217 %ECA and %PFI points (R^2 = .8971).

Table C-7: ECA Analysis Included the Following TSMRS Activity Codes.

TSMRS Activity Code	TSMRS Activity Description
4111	Clearcut – Patch
4113	Clearcut – Stand
4114	Clearcut - with Reserves
4131	Shelterwood Seed Cut
4132	Seed Tree Seed Cut
4146	Shelterwood Final Cut
4147	Seed Tree Final Cut
4148	Shelterwood Final Cut with Reserves
4149	Seed Tree Final Cut with Reserves
4152	Group Selection Cut
4211	Liberation Cutting

Table C-7: ECA Analysis Included the Following TSMRS Activity Codes.	
TSMRS Activity Code	TSMRS Activity Description
4220	Thinning
4230	Sanitation Salvage
4250*	Natural Changes (Blue Sky/Kopsi Fire)
4270*	Permanent Land Clearing

* Not included in the timber harvest analysis described in Appendix A. Timber harvest analysis in Appendix A also included 4521 (pre-commercial thinning) and 4987 (fire line construction).

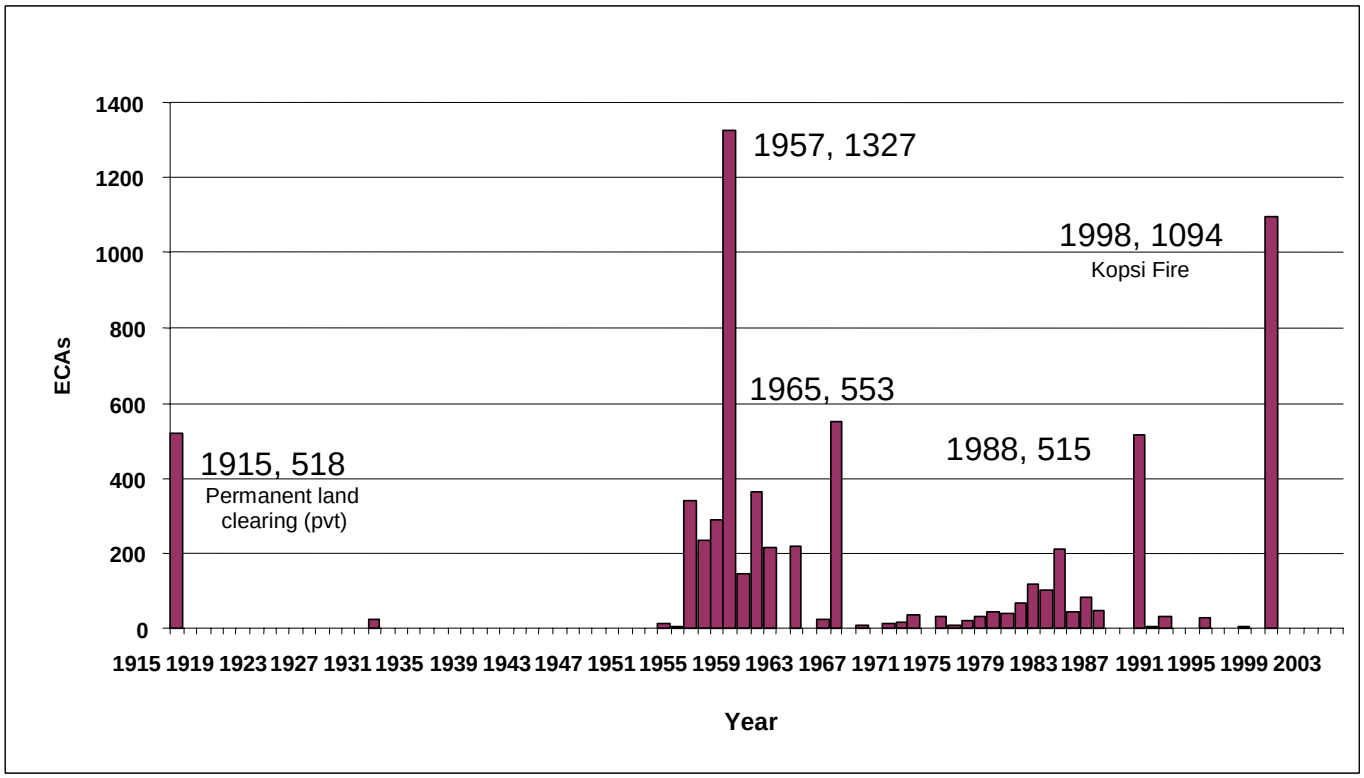

Figure C.3: Summary of ECA in Grave Creek Watershed.
Does not include timber harvest on privately owned land or land clearing on privately owned land after early twentieth-century development.

Figure C-3 provides a historical context for the equivalent clearcut acreage. Table C-8 summarizes the results of the equivalent clearcut area (ECA) and peak flow increase (PFI) analyses for tributary watersheds and all of the Grave Creek Watershed. The road modeling portion of the ECA is based on 2003 conditions. Watershed ECA from road and vegetation changes, either from historic harvest or the more recent Kopsi Fire, was modeled at 5 percent, with vegetation change constituting 72 percent of the cumulative ECA. Total watershed PFI was 2.5 percent. These existing PFI values linked to timber harvest activities in all watersheds are not considered very high and are likely not of significant concern. When the Kopsi Fire ECA results are removed, the harvest related PFI in the Blue Sky drainage would be within the range of the other watersheds (personal communication with Julie Gott, February 2005).

Historical values in all drainages and for the whole watershed would have been higher in the late 1950s through 1960s period based on the PFI calculation methodology and the Figure C.3 data. These elevated historical PFI values, in combination with a lack of BMPs during the 1950s and 1960s, including operations within the riparian areas, would likely have contributed to fine and coarse sediment loading based on the above discussions and references.

Table C-8. Equivalent Clearcut Area (ECA) and Peak Flow Increase (PFI) Results for the Grave Creek Watershed.

					Forest Plan Calculations			
	Road	Vegetation Change	Wtrsh	Percent	Roads	Vegetation Change	Total	WATSED
Watershed	ECAs	ECAs	Acres	ECA	PFI	PFI	PFI	PFI
Blue Sky	104	1326	7972	18%	1.0%	7.5%	8.5%	9.3%
Lewis	18	41	2458	2%	0.6%	0.8%	1.3%	1.9%
Foundation	29	76	1760	6%	1.3%	2.0%	3.2%	3.6%
Upper Grave	71	83	4507	3%	1.2%	0.8%	2.0%	2.4%
Clarence	63	175	4207	6%	1.2%	1.9%	3.0%	3.4%
Stahl	102	251	4351	8%	1.8%	2.6%	4.4%	4.6%
Upper Middle Grave	33	14	2925	2%	0.9%	0.2%	1.1%	1.5%
Williams	78	198	6048	5%	1.0%	1.5%	2.5%	2.9%
Lower Middle Grave	133	162	8571	3%	1.2%	0.9%	2.0%	2.4%
Lower Grave	285	309	5359	11%	4.1%	2.6%	6.7%	6.0%
Grave CE	916	2634	48158	7%	1.5%	2.5%	3.9%	4.3%