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MONITORING FINE SEDIMENT GRANDE RONDE AND JOHN DAY RIVERS

Annual Report 2000

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MONITORING FINE SEDIMENT: GRANDE RONDE AND JOHN DAY RIVERS

Annual Report for 2000

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ABSTRACT

Fine sediment in spawning substrate has a major effect on salmon survival from egg to smolt. Basin-wide restoration plans have established targets for fine sediment levels in spawning habitat. The project was initiated to monitor surface fine sediment levels and overwinter intrusion of fine sediment in spring chinook salmon spawning habitat in the North Fork John Day (NFJDR) and Grande Ronde Rivers, for five years. The project is also investigating the potential relationship between surface fine levels and overwinter sedimentation. It will provide data to assess trends in substrate conditions in monitored reaches and whether trends are consistent with efforts to improve salmon habitat conditions. The data on the magnitude of overwinter sedimentation will also be used to estimate salmon survival from egg to emergence.

In Sept. 1998, 1999, and Aug. 2000, sites for monitoring overwinter sedimentation were established in salmon spawning habitat in the upper Grande Ronde River, Catherine Creek (a Grande Ronde tributary), the North Fork John Day River (NFJDR), and Granite Creek (a NFJDR tributary). Surface fine sediment levels were measured in these reaches via the grid method and visually estimated to test the relative accuracy of these two methods. In 1999 and 2000, surface fine sediment was also estimated via pebble counts at selected reaches to allow comparison of results among the methods. Overwintering substrate samples were collected in April 1999 and April - May 2000 to estimate the amount of overwinter sedimentation in clean gravels in spawning habitat. Monitoring methods and locations are described.

Results from 1998 - 2000 indicate that visual estimates provide an unbiased and accurate estimate of surface fine sediment levels as measured by the grid method, consistent with results from 1992 - 1995 (Rhodes and Purser, 1998). Therefore, we can recommend using visual estimates of surface fine sediment by trained observers in situations where extensive data is needed and time, effort, and expense are significant limitations. The grid method provides greater accuracy and is more amenable to statistical analysis than visual estimates, while not requiring substantially greater data collection efforts.

Our results indicate that the pebble count method is relatively insensitive to detecting differences in surface fine sediment levels among sites or over time. This result is consistent with other assessments of the accuracy of pebble counts to estimate fine sediment levels (Nelson et al., 1996; 1997). Pebble counts require much more time and effort for data collection and analysis than the other two methods evaluated. For these reasons, we recommend against using pebble counts for monitoring surface fine sediment levels as part of assessments of the effects of land management on substrate conditions and/or salmonid survival.

From 1998 - 2000, there was a statistically significant increasing trend in surface fine sediment levels in the NFJDR, in contrast to a statistically significant decreasing trend in the Grande Ronde and Granite Creek, and no trend in Catherine Creek during the same period. Based on the relationship between salmonid survival and fine sediment levels, it is likely that

salmonid survival from egg-to-emergence decreased in the NFJDR from 1998 - 2000, while it increased in the Grande Ronde and Granite Creek.

Mean surface fine sediment levels in 1998 in the monitored reaches of the Grande Ronde were higher than the <20% surface fine sediment goal set in CRITFC (1995) and NMFS (1995), although this is not statistically significant at $p < 0.10$. In 1998, it was also uncertain that the surface fine sediment goal was met in the NFJDR ($p < 0.10$). At this same level of statistical significance, it can be accepted that the substrate goals were met in the monitored reaches of the Grande Ronde, Catherine and Granite Creeks from 1999 - 2000 and not met in the NFJDR in 1999 and 2000. Surface fine sediment levels in Catherine Creek were the lowest among the four study streams in 1998 - 2000 ($p < 0.10$). The Grande Ronde had the highest surface fine sediment levels among the streams in 1998, while the NFJDR had the highest levels in 1999 and 2000 ($p < 0.10$).

Bulk samples of substrate collected in Sept. 1998 indicate that fine sediment levels (% by weight) at depth were generally higher than the amount of surface fine sediment, as is typical in many streams. Initial results indicate that surface fine sediment levels, both measured and visually estimated, are related to fine sediment conditions at depth in a statistically significant fashion. However, the apparent statistical significance may be an artifice of small sample numbers and/or inappropriately lumping samples from four streams into a single analysis population.

Samples collected in Dec. 1998 indicate that significant sedimentation occurs early in the incubation period for spring chinook salmon in the Grande Ronde and Catherine Creek. Although small sample numbers preclude a statistical assessment, the magnitude of overwinter sedimentation from Sept.-Dec. 1998 was higher in the Grande Ronde where surface fine sediment was higher than in Catherine Creek.

Samples collected in April 1999 indicate that overwinter sedimentation consistently occurs in clean gravels in environments mimicking salmon redds in all monitored reaches. Overwinter fine sediment levels were highest in the Grande Ronde for two of the three size fractions analyzed. Catherine Creek samples had the lowest level of overwinter fine sediment among the four streams for all three size fractions analyzed. There was a statistically significant ($p < 0.10$) relationship between mean surface fine sediment in monitored streams in Sept. 1998 and overwinter fine sediment in samples collected in April 1999, for all three size fractions. Preliminary results indicate that stream discharge is unlikely to explain the variation in overwinter fine sediment among streams. These results are consistent with those of Rhodes and Purser (1998).

Overwinter fine sediment levels in samples collected in April - May 2000 were not related to mean surface fine sediment levels. The departure from the pattern in results of the previous year may be due to higher streamflows, reduced recovery rate of samples from some streams, differential duration of exposure to high flows among samples in streams, and/or, that the previous year's results were an artifice of analysis of limited data.

INTRODUCTION

Fine sediment levels in spawning substrate have a major effect on salmon survival from egg to smolt (Bjornn and Reiser, 1991). Assessments have consistently concluded that fine sediment is a major problem for salmon in the Grande Ronde (Anderson et al., 1993; NMFS, 1993; Huntington, 1994; Mobrand et al., 1995) and, to a lesser extent, the John Day rivers (OWRD, 1986). It is likely that fine sediment levels in these rivers must be reduced if salmon survival from egg to smolt is to be increased. The NMFS Biological Opinion (NMFS, 1995) for the USFS Land and Resource Management Plans (LRMPs) and the salmon recovery plan of Columbia River basin Treaty Tribes (CRITFC, 1995) both set goals for surface fine sediment in spawning habitat at <20%. The NPPC (1994) recovery plan set a goal of <20% fine sediments in salmon redds. However, despite these goals for fine sediment and the documented sediment-related problems, baseline and trends in surface fine sediment had not been annually monitored in these rivers. This project was initiated, with funding from the Bonneville Power Administration in 1998, to monitor surface fine sediment levels and overwinter intrusion of fine sediment into cleaned gravels in artificially constructed redds in spawning habitat. The project is also investigating the potential relationship between surface fine levels and overwinter sedimentation in cleaned gravel, possibly resulting in a more cost-effective monitoring tool than coring or other extractive bulk substrate sampling methods.

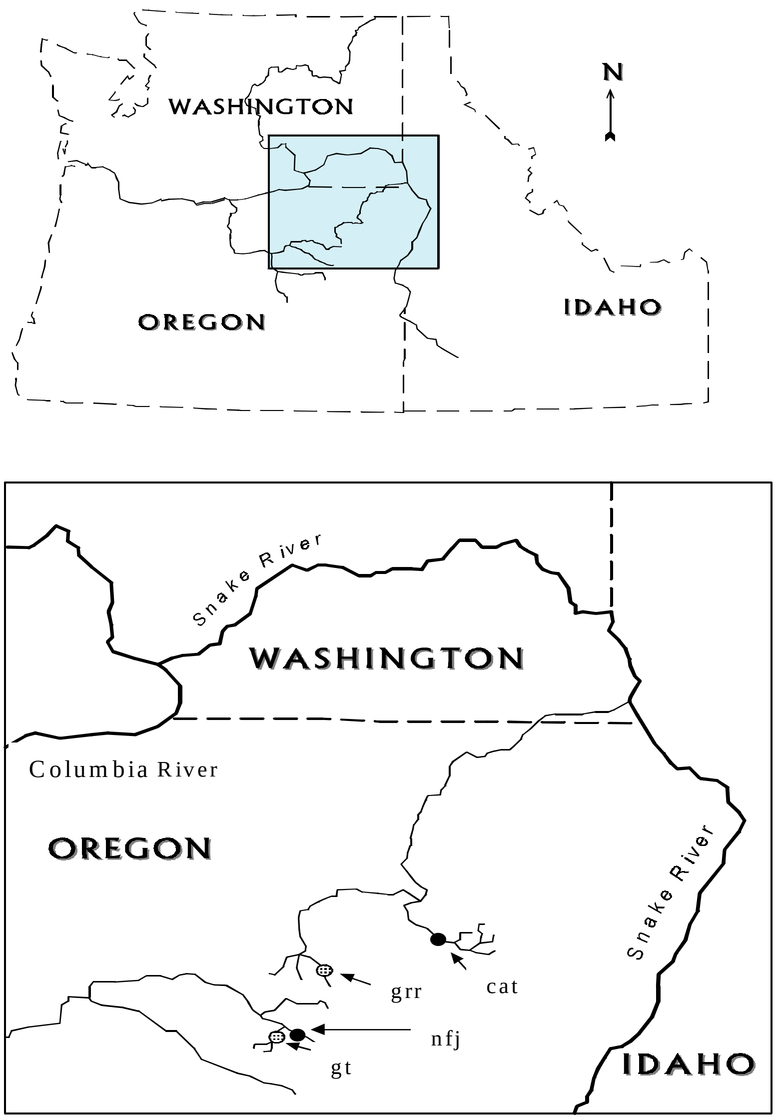
For five years, the project will annually measure surface fines and overwinter sedimentation during the incubation period in spawning gravels in the John Day and Grande Ronde Rivers. This will allow assessment of the following: 1) whether there is a trend in substrate conditions in spawning habitat in monitored reaches, and if so, whether it is consistent with efforts to reduce sedimentation and improve habitat conditions; 2) whether there is a relationship between levels of mobile surface fine sediment and the magnitude of fine sediment intrusion into cleaned spawning gravels; 3) whether substrate conditions and trends are in keeping with the quantitative substrate objectives of regional approaches to habitat restoration and protection (NPPC, 1994; NMFS; 1995; CRITFC, 1995).

The proposal will also test the following additional hypotheses: 1) the aggregate effectiveness of land management is adequate to meet fine sediment/substrate goals, prevent degradation of substrate conditions, and allow improvement in substrate conditions; 2) overwinter sedimentation in salmon redds is not occurring at magnitudes that reduce salmon survival; 3) watersheds with differing magnitudes of land disturbance, such as logging and road construction, do not have significantly different levels of surface fine sediment nor significantly different levels of overwinter sedimentation in cleaned gravels in spawning habitat; 4) temporal trends in surface fine sediment levels and the magnitude of overwinter sedimentation are not significantly different in watersheds with differing levels of land disturbance. Additionally, the project will also quantify the magnitude of overwinter sedimentation in cleaned gravels and use this data to estimate salmon survival from egg to emergence.

DESCRIPTION OF PROJECT AREA

The study reaches are in spawning habitat for spring chinook salmon in the Grande Ronde River, Catherine Creek (a Grande Ronde River tributary), the North Fork John Day River (NFJDR) and Granite Creek (tributary to the NFJDR). The general locations of the monitored streams and the study areas are shown in Figure 1.

Figure 1 General location of monitored reaches. Codes are as follows: grr = Grande Ronde River; cat = Catherine Cr.; nfj = NFJDR; gt = Granite Cr**.**



The area of Grande Ronde River watershed above the monitoring locations is about 90 km^2 and ranges in elevation from about 1200 m to 2400 m. The watershed is predominantly forested with mixed conifers. Soils are primarily derived from granitic parent materials. Snow is the dominant form of precipitation and spring snowmelt comprises the bulk of the annual hydrograph. The watershed of the upper Grande Ronde River has been extensively grazed, logged, and roaded over the past 30 years (Anderson et al., 1993; McIntosh et al., 1994). Portions of the floodplain and river were dredge-mined in the early 1900s (McIntosh et al., 1994). Parts of the watershed have been burned by wildfire over the past 10 years; flash floods from thunderstorms have also affected spawning and rearing areas. Most of the watershed above the sampling areas is on the Wallowa-Whitman National Forest (WWNF).

The monitoring sites for surface fine sediment and overwinter sedimentation in the Grande Ronde River are located upstream of the decommissioned Woodley Creek Campground to the west of USFS Road 5125 on the WWNF. The latitude and longitude, as measured using a global positioning system (gps) unit, of the 1998 and 1999 monitored transects within the study reaches in the upper Grande Ronde River are shown in Tables 1, 2, 3, and 4.

The watersheds of the other three streams monitored are broadly similar to the Grande Ronde with respect to vegetation, geology, and climate. However, the ownership patterns, watershed area, and intensity of land use vary among watersheds.

The watershed area of Catherine Creek, above the most downstream monitoring site, is about 240 km^2. Much of the Catherine Creek watershed is within wilderness. Most of the watershed is grazed. Outside of the wilderness, the watershed has been logged and roaded but to a lesser extent than the Grande Ronde River watershed. Most of the watershed is on the WWNF. The most downstream monitoring sites on Catherine Creek are located to the east of state highway 203 at a latitude of 45^o 7.92’ N and longitude of 117^o 42.49’ W, as measured with a gps unit in 1999. The most upstream monitoring sites are on the North Fork, upstream of the confluence of the South Fork of Catherine Creek, south of USFS Road 7785. The locations of the 1998 and 1999 monitoring sites are shown in Tables 1, 2, 3, and 4.

The watershed area of the NFJDR above the most downstream monitoring site is approximately 80 km^2. Most of this watershed area is on the WWNF. The watershed has been extensively logged. Most of the watershed is also grazed by livestock. Some sections of floodplains and the stream have been intensively altered by gravel spoils from historic dredge mining. Parts of the watershed have burned in wildfires; the most recent of which burned in 1996. The most downstream monitoring site is to the south of county road 73, on the WWNF, about 0.8 km east of the junction of county road 73 and county road 52. The most upstream sites are also on the WWNF, south of county road 73, about 1.5 km east of the junction of county road 73 and county road 52. The locations of the 1998 and 1999 monitoring sites are shown in Tables 1, 2, 3, and 4.

The watershed area of Granite Creek, above the most downstream monitoring site, is approximately 200 km^2. The watershed of Granite Creek has been extensively roaded and logged. Dredge mining has intensively altered significant portions of the floodplain and stream, including the areas flanking the monitoring sites. Most of the watershed is grazed. Ownership of the watershed is interspersed and includes private land, the WWNF, and the Umatilla National Forest (UNF). The most downstream monitoring site is on the UNF to the south of USFS Road 1035, approximately 1.2 km to the west of the junction with state highway 24. The most upstream monitoring sites are to the south of USFS Road 1035 approximately 0.8 km from the junction with state highway 24. The gps locations of the 1998, 1999 and 2000 monitoring sites are shown in Tables 1 - 6.

Table 1. Locations and site characteristics of areas excavated Sept. 5-6, 1998 to mimic redds for monitoring of overwinter sedimentation in clean gravels in containers. Site numbers with an asterisk (*) had 3 containers of cleaned gravels placed within the excavated redd site, with one bucket collected in Dec. 1998. Sites marked with a plus sign (+) had bulk substrate samples collected by shovel in Sept. 1998.

Stream	"Redd"	Latitude		Longitude		Wetted Channel Width	Water Column Depth	Visually estimated surface fine sediment	Notes/Site Description
	No.	Deg.	min.	Deg.	min.	(m)	(m)	(%)	
Grande Ronde	GR1	45	4.28	118	18.82	6.0	0.15	37	Glide tailout downstream of pool at river bend
Grande Ronde	GR2*+	45	4.18	118	18.83	10.2	0.13	40	Glide tailout below log weir ~200 m upstream of GR1
Grande Ronde	GR3	45	4.12	118	18.79	9.9	0.20	10	Tailout below pocket pool
Grande Ronde	GR4*+	45	4.06	118	18.79	6.5	0.10	35	Glide tailout
Grande Ronde	GR5	45	3.99	118	18.8	10.4	0.12	30	Shallow glide tailout.
Catherine Cr.	C1	45	7.92	117	42.55	7.7	0.05	5	Glide tailout downstream of exclosure fence
Catherine Cr.	C2*+	45	7.92	117	42.55	7.7	0.05	5	Glide tailout downstream of exclosure fence
Catherine Cr.	C3*+	45	7.44	117	41.99	13.3	0.12	2	Glide tailout
Catherine Cr.	C4	45	7.48	117	38.78	9.7	0.10	7	Shallow glide tailout
Catherine Cr.	C5	45	7.48	117	41.99	1.2	0.10	7	Shallow glide tailout, ~3 m upstream of C4
NFJDR	N1	44	54.81	118	23.39	10.6	0.14	25	Glide tailout below overhanging LWD
NFJDR	N2	44	54.69	118	23.31	8.05	0.10	20	Glide tailout
NFJDR	N3	44	54.63	118	23.27	11.3	0.10	15	Shallow glide tailout at riffle transition
NFJDR	N4+	44	54.73	118	23.25	10.3	0.10	30	Shallow glide tailout near N. bank
NFJDR	N5	44	54.68	118	23.23	10.1	0.07	30	Shallow glide tailout near N. bank
Granite Cr	GT1	44	49.75	118	27.43	7.7	0.15	6	Glide tailout
Granite Cr	GT2	44	49.49	118	27.3	10.0	0.10	10	Glide tailout
Granite Cr	GT3++	44	49.5	118	27.24	9.6	0.10	10	Glide tailout
Granite Cr	GT4	none taken				7.5	0.13	8	Shallow glide tailout at riffle transition
Granite Cr	GT5	44	49.36	118	27.13	7.5	0.13	8	Shallow glide tailout at riffle transition

Table 2. Locations and site characteristics of areas excavated Sept. 5-6, 1999 to mimic redds for monitoring of overwinter sedimentation in containers of clean gravels. Site numbers with an asterisk (*) had 3 containers of cleaned gravels placed within the excavated redd site, with one bucket collected in Dec. 1999. Sites marked with a plus sign (+) had bulk substrate samples collected by shovel in Sept. 1999.

Stream	"Redd"	Latitude		Longitude		Wetted Channel Width	Water Column Depth	Visually estimated surface fine sediment	Notes/Site Description
	No.	Deg.	min	Deg.	min.	(m)	(m)	(%)	
Grande Ronde	GR1	45	4.17	118	18.85	4.5	0.20	18	Low sand levels; redistributed onto point bars
Grande Ronde	GR2*	45	4.15	118	18.84	7.2	0.20	18	Pool tailout
Grande Ronde	GR3	45	4.12	118	18.81	5.7	0.20	21.5	Inboard of root wad, downstream of log weir
Grande Ronde	GR4*+	45	4.01	118	18.78	4.5	0.12	20	Green marker flag on downed log on W. bank, blue flag on downed log on E side
Grande Ronde	GR5+	45	4.04	118	18.78	6.9	0.27	32.5	Pool tailout
Catherine Cr.	C1*+	45	7.92	117	42.49	12.0	0.10	4.5	Pool tailout
Catherine Cr.	C2	45	7.92	117	42.49	12.0	0.21	4.5	Significant bank damage from grazing in Hall Ranch near buckets. Pool tailout
Catherine Cr.	C3*+	45	7.45	117	41.98	13.0	1.70	2	Pool/glide tailout
Catherine Cr.	C4	45	7.22	117	38.79	6.5	0.18	5	Pool tailout
Catherine Cr.	C5	45	7.22	117	38.79	6.5	0.17	2	Pool tailout
NFJDR	N1+	44	54.74	118	23.38	11.9	0.20	21	Pool tailout, cobble-size surface armor
NFJDR	N2+	44	54.71	118	23.33	10.6	0.20	30	Pool tailout
NFJDR	N3	44	54.67	118	23.23	12.1	0.12	30	Pool tailout
NFJDR	N4+	44	54.67	118	23.2	12.2	0.15	25	Pool tailout
NFJDR	N5	44	54.67	118	23.19	11.9	0.20	30	Pool tailout
Granite Cr	GT1	44	49.59	118	27.42	9.5	0.11	6	Glide tailout
Granite Cr	GT2+	44	49.59	118	27.42	10.0	0.10	6	Glide tailout
Granite Cr	GT3	44	49.55	118	27.34	9.5	0.15	10	Pool tailout
Granite Cr	GT4+	44	49.53	118	27.33	8.5	0.33	10	Pool tailout
Granite Cr	GT5	44	49.49	118	27.26	9.6	0.35	10	Pool tailout

Table 3. Locations and site characteristics of areas excavated Aug. 25-26, 2000 to mimic redds for monitoring of overwinter sedimentation in containers of clean gravels. Site numbers with an asterisk (*) had 3 containers of cleaned gravels placed within the excavated redd site, with one bucket collected in Dec. 2000. Sites marked with a plus sign (+) had bulk substrate samples collected by shovel in Aug. 2000.

Stream	"Redd"	Latitude		Longitude		Channel Width	Water Column Depth	Visually estimated surface fine sediment	Notes/Site Description
	No.	Deg.	min.	Deg.	min.	(m)	(m)	(%)	(all distances approximate)
Grande Ronde	GR1	45	4.18	118	18.84	5.6	0.12	10	Tailout at shallow glide/pool. Fines higher at depth - armored substrate. Much higher levels of fine sediment in pools/glides than in riffles. Differential levels higher than in past years. Signs of wood loss/ bank scouring from spring events
Grande Ronde	GR2*+	45	4.17	118	18.82	6.0	0.22	12	Tailout shallow glide/pool
Grande Ronde	GR3	45	4.14	118	18.8	4.4	0.24	9	Mid glide below log weir
Grande Ronde	GR4*+	45	4.05	118	18.77	6.5	0.07	22	Riffle site, but benchmarked to prev. yr.'s site
Grande Ronde	GR5	45	4.03	118	18.79	6.6	0.25	31	Pool tailout near rock bar
Catherine Cr.	C1	45	7.92	117	42.51	6.8	0.07	2.3	Glide tailout. At all sites, fines higher at depth - armored substrate. No signs of major channel change from spring flows. Reach in Hall Ranch site has had major bank loss (~1m) from livestock trampling upstream of C1 and C2. Significant trespass in "exclosures," fence down and not a livestock barrier.
Catherine Cr.	C2*+	45	7.92	117	42.51	6.8	0.09	2.3	Glide tailout
Catherine Cr.	C3*+	45	7.44	117	41.98	9.0	0.25	2.7	End of opening on E. bank, pool tailout
Catherine Cr.	C4	45	7.23	117	38.78	9.7	0.06	5	Glide tailout
Catherine Cr.	C5	45	7.23	117	38.77	7.5	0.18	5	Edge of tailout between glide and riffle
NFJDR	N1	44	54.77	118	23.4	9.8	0.12	29.5	Small glide tailout. Severe deposition over entire reach: bar deposits, duning sands behind rocks and in pools, and reduced complexity. Substrate highly bimodal: only large rocks protruding through a blanket of fines. Fines may be higher at depth, but substrate surface is sandy, not armored.
NFJDR	N2+	44	54.67	118	23.31	8	0.12	27	Glide tailout
NFJDR	N3+	44	54.67	118	23.22	12	0.05	24	Shallow glide tailout near 30 m high fir
NFJDR	N4	44	54.67	118	23.2	10.6	0.13	28	Glide tailout
NFJDR	N5	44	54.68	118	23.2	9.8	0.1	35	Small glide tailout
Granite Cr	GT1+	44	49.59	118	27.42	7.0	0.10	3	Glide tailout. At all sites, fine sediment much higher at depth; substrate armored. Significant bars and flood deposits on channel margins, from spring flows, mainly gravel/cobbles.
Granite Cr	GT2	44	49.59	118	27.42	7.0	0.12	3	Glide tailout
Granite Cr	GT3	44	49.56	118	27.38	8.3	0.10	10	Tail out - lg. Pool - 30% fines in pool
Granite Cr	GT4+	44	49.51	118	27.29	10.5	0.09	11	Side pool tailout next to flood deposit
Granite Cr	GT5	44	49.5	118	27.28	10.8	0.11	11	Glide tailout near collapsed bank

Table 4. Locations and results of monitoring of surface fine sediment in Sept. 1998. For locations of constructed "redds" in Sept. 1998, see Table 1.

Stream	Transect	Latitude		Longitude		Wetted Channel Width	Visually estimated surface fine sediment	Mean measured surface fine sediment	Location relative to "redds"
	No.	Deg.	min	Deg.	min	(m)	(%)	(%)	all distances approximate
Grande Ronde	**1**	45	4.17	118	18.81	7.2	37%	42%	7 m upstream of GR1
Grande Ronde	**2**	45	4.15	118	18.82	7.2	40%	34%	12 m upstream of GR2
Grande Ronde	**3**	45	4.14	118	18.81	7.2	19%	19%	43 m upstream of GR2
Grande Ronde	**4**	45	4.08	118	18.76	8.4	13%	27%	22 m upstream of GR3
Grande Ronde	**5**	45	4.09	118	18.76	6.0	21%	20%	44 m downstream of GR4
Grande Ronde	**6**	45	4.03	118	18.77	4.8	45%	30%	10 m upstream of GR4
Grande Ronde	**7**	45	4.02	118	18.77	7.2	23%	10%	36 m upstream of GR4
Grande Ronde	**8**	45	4.02	118	18.8	7.2	23%	14%	54 m upstream of GR4
Grande Ronde	**9**	45	3.98	118	18.79	8.4	46%	43%	25 m upstream of GR5
Grande Ronde	**10**	45	4.01	118	18.79	6.6	23%	16%	85 m upstream of GR5
Catherine Cr.	**1**	45	7.9	117	42.49	6.6	3%	1%	27 m upstream C2
Catherine Cr.	**2**	45	7.89	117	42.49	6.0	3%	1%	37 m upstream from C2
Catherine Cr.	**3**	45	7.45	117	41.99	9.6	3%	1%	75 m upstream from C2
Catherine Cr.	**4**	45	7.4	117	41.99	12.6	1%	2%	10 m upstream from C3
Catherine Cr.	**5**	45	7.4	117	41.99	8.4	2%	1%	63 m upstream from C3
Catherine Cr.	**6**	45	7.17	117	39.09	18.0	2%	2%	4.5 km upstream of C3; 200 m downstream of C4
Catherine Cr.	**7**	45	7.22	117	38.79	12.0	2%	3%	165m downstream of C4
Catherine Cr.	**8**	45	7.22	117	38.77	8.4	2%	5%	32m upstream of C4
Catherine Cr.	**9**	45	7.24	117	38.75	14.4	2%	1%	72m upstream of C5
Catherine Cr.	**10**	45	7.24	117	38.73	5.4	2%	2%	115m upstream of C5
NFJDR	**1**	gps battery down				10.8	20%	13%	5 m upstream of N1
NFJDR	**2**	gps battery down				11.4	17%	13%	25 m upstream of N1
NFJDR	**3**	gps battery down				7.8	15%	10%	20 m downstream of N2
NFJDR	**4**	gps battery down				8.4	20%	22%	14 m upstream of N2
NFJDR	**5**	gps battery down				9.6	15%	22%	75 m downstream of N3; pocket pool in transect
NFJDR	**6**	gps battery down				11.4	20%	17%	60 m downstream of N3
NFJDR	**7**	gps battery down				12	18%	21%	30 m downstream of N3
NFJDR	**8**	44	54.63	118	23.22	10.2	27%	31%	8 m downstream of N3
NFJDR	**9**	44	54.64	118	23.22	9.6	20%	16%	11 m downstream of N4
NFJDR	**10**	44	54.67	118	23.17	10.8	15%	4%	8 m upstream of N5
Granite Cr.	**1**	44	49.51	118	27.32	6.6	5%	6%	100 m upstream of GT1
Granite Cr.	**2**	44	49.5	118	27.31	4.8	25%	41%	210 m upstream of GT1; pocket pool in transect
Granite Cr.	**3**	44	49.49	118	27.3	9.0	17%	17%	2 m downstream of GT2; 240 m upstream of GT1
Granite Cr.	**4**	44	49.5	118	27.26	7.8	12%	9%	25 m downstream of GT3
Granite Cr.	**5**	44	49.5	118	27.26	9.6	8%	5%	3 m downstream of GT3
Granite Cr.	**6**	44	49.58	118	27.2	8.4	6%	1%	21 m upstream of GT3
Granite Cr.	**7**	44	49.42	118	27.19	11.4	8%	3%	150 m upstream of GT3
Granite Cr.	**8**	44	49.34	118	27.08	4.8	12%	17%	6 m upstream of GT4
Granite Cr.	**9**	44	49.34	118	27.08	8.4	8%	0%	3 m downstream of GT5
Granite Cr.	**10**	44	49.41	118	27.32	5.4	17%	13%	10 m upstream of GT5

Table 5. Locations and results of monitoring of surface fine sediment in Sept. 1999. Transect numbers marked with an asterisk (*) also had pebble counts performed. For locations of constructed "redds" in Sept. 1999, see Table 2.

Stream	Transect	Latitude		Longitude		Wetted Channel Width	Visually estimated surface fine sediment	Mean measured surface fine sediment	Location relative to "redds"
	No.	Deg.	min.	Deg.	min.	(m)	(%)	(%)	all distances approximate
Grande Ronde	**1**	45	4.16	118	18.84	7.2	10%	16%	10 m upstream of GR1
Grande Ronde	**2***	45	4.18	118	18.84	6.0	14%	11%	20 m upstream of GR1
Grande Ronde	**3**	45	4.14	118	18.81	4.8	11%	4%	60 m upstream of GR1, 25 m below GR3
Grande Ronde	**4***	45	4.15	118	18.77	10.8	26%	14%	2 m upstream of GR3
Grande Ronde	**5***	45	4.13	118	18.8	6.6	22%	5%	40 m upstream of GR3
Grande Ronde	**6**	45	4.11	118	18.79	9.0	21%	23%	50 m upstream of GR3
Grande Ronde	**7**	45	4.07	118	18.76	4.8	8%	7%	55 m upstream of GR3
Grande Ronde	**8***	45	4.07	118	18.77	4.2	9%	9%	60 m upstream of GR3, 10 m downstream of GR4
Grande Ronde	**9**	45	4.03	118	18.77	9.0	10%	6%	5m upstream of GR5
Grande Ronde	**10**	45	4.01	118	18.75	9.0	6%	6%	15 m upstream of GR5
Catherine Cr.	**1**	45	7.9	117	42.49	7.8	5%	9%	20 m upstream of C1
Catherine Cr.	**2**	45	7.89	117	42.49	6.0	1%	1%	30 m upstream of C1, 10 m upstream of SF1
Catherine Cr.	**3***	45	7.45	117	41.99	8.4	2%	1%	2 m upstream of C3
Catherine Cr.	**4**	45	7.4	117	41.99	7.2	2%	0%	20 m upstream of C3
Catherine Cr.	**5**	45	7.4	117	41.99	6.0	1%	0%	23 m upstream of C3
Catherine Cr.	**6**	45	7.17	117	39.09	12.6	3%	1%	200 m downstream of C4
Catherine Cr.	**7**	45	7.22	117	38.79	10.2	5%	1%	1 m downstream of C4
Catherine Cr.	**8**	45	7.22	117	38.77	5.4	2%	4%	25 m upstream of C5
Catherine Cr.	**9***	45	7.24	117	38.75	5.4	2%	0%	35 m upstream of C5
Catherine Cr.	**10***	45	7.24	117	38.73	8.4	1%	2%	40 m upstream of C5
NFJDR	**1**	44	54.73	118	23.39	10.8	25%	27%	5 m upstream of N1
NFJDR	**2**	44	54.4	118	23.4	11.4	25%	31%	10 m upstream of N1
NFJDR	**3**	44	54.68	118	23.23	7.8	22%	17%	30 m downstream of N3, 45 m upstream of N2
NFJDR	**4***	44	54.68	118	23.23	8.4	20%	14%	25 m downstream of N3
NFJDR	**5**	44	54.67	118	23.22	9.6	25%	32%	5 m downstream of N3
NFJDR	**6**	44	54.67	118	23.2	11.4	29%	27%	15 m downstream of N4, 10 m upstream of N3
NFJDR	**7**	44	54.67	118	23.19	12.0	34%	34%	5 m downstream of N 5, 5 m upstream of N4
NFJDR	**8***	44	54.67	118	23.17	11.4	30%	29%	15 m upstream of N5
NFJDR	**9**	44	54.68	118	23.15	11.4	35%	42%	25 m upstream of N5
NFJDR	**10***	44	54.68	118	23.15	10.8	19%	24%	30 m upstream of N5
Granite Cr.	**1**	44	49.59	118	27.42	8.4	8%	4%	2 m downstream of G1 & G2
Granite Cr.	**2**	44	49.59	118	27.41	9.6	6%	3%	6 m upstream of G1 & G2
Granite Cr.	**3**	44	49.55	118	27.34	7.2	5%	5%	6 m downstream of G3
Granite Cr.	**4**	44	49.55	118	27.34	7.2	9%	8%	3 m downstream of G3
Granite Cr.	**5***	44	49.54	118	27.33	7.2	9%	10%	4 m downstream of G4
Granite Cr.	**6**	44	49.53	118	27.34	7.8	8%	8%	5 m downstream of G4
Granite Cr.	**7***	44	49.52	118	27.31	7.2	15%	11%	10 m downstream of G5
Granite Cr.	**8***	44	49.5	118	27.27	11.4	22%	11%	5 m upstream of G5
Granite Cr.	**9**	44	49.5	118	27.26	9.0	16%	6%	25 m upstream of G5
Granite Cr.	**10**	44	49.6	118	27.26	7.8	17%	7%	30 m upstream of G5

Table 6. Locations and results of monitoring of surface fine sediment in Aug. 2000. Transect numbers marked with an asterisk (*) also had pebble counts performed. For locations of constructed "redds" in Aug. 2000, see Table 3.

Stream	Transect	Latitude		Longitude		Wetted Channel Width	Visually estimated surface fine sediment	Mean measured surface fine sediment	Location relative to "redds"
	No.	degrees	min	degrees	min	(m)	(%)	(%)	all distances approximate
Grande Ronde	**1**	45	4.17	118	18.83	6.9	10%	6%	15 m upstream from GR1
Grande Ronde	**2***	45	4.17	118	18.83	6.0	12%	12%	25 m upstream from GR1
Grande Ronde	**3**	45	4.15	118	18.8	5.4	9%	2%	30 m downstream from GR3
Grande Ronde	**4***	45	4.15	118	18.8	6.0	10%	9%	23 m downstream from GR3
Grande Ronde	**5**	45	4.09	118	18.79	7.2	9%	12%	45 m upstream from GR3, 18 m downstream from GR4
Grande Ronde	**6***	45	4.09	118	18.78	7.8	12%	10%	35 m upstream from GR4
Grande Ronde	**7**	45	4.09	118	18.78	7.8	8%	2%	40 m upstream from GR4
Grande Ronde	**8**	45	4.07	118	18.76	6.6	9%	11%	135 m upstream from GR4
Grande Ronde	**9***	45	4.02	118	18.79	9.6	11%	9%	4 m upstream from GR5
Grande Ronde	**10**	45	4.02	118	18.79	10.2	10%	3%	45 m upstream from GR5
Catherine Cr.	**1***	45	7.9	117	42.51	7.2	2%	0%	30 m upstream from C2
Catherine Cr.	**2**	45	7.89	117	42.51	6.0	1%	1%	45 m upstream from C2
Catherine Cr.	**3**	45	7.88	117	42.51	9.6	3%	3%	50 m upstream from C2
Catherine Cr.	**4**	45	7.41	117	41.97	6.6	2%	0%	40 m upstream from C3
Catherine Cr.	**5***	45	7.4	117	41.97	6.0	1%	1%	50 m upstream from C3
Catherine Cr.	**6**	45	7.39	117	41.96	8.4	1%	2%	55 m upstream from C3
Catherine Cr.	**7***	45	7.2	117	39.08	15.6	4%	3%	180 m downstream from C4
Catherine Cr.	**8**	45	7.22	117	38.78	7.8	3%	1%	30 m upstream from C5
Catherine Cr.	**9***	45	7.22	117	38.78	7.8	3%	2%	35 m upstream from C5
Catherine Cr.	**10**	45	7.26	117	38.72	5.4	2%	1%	55 m upstream from C5
NFJDR	**1**	44	54.75	118	23.38	11.4	29%	34%	7 m upstream from N1
NFJDR	**2**	44	54.75	118	23.38	12.6	32%	29%	15 m upstream from N1
NFJDR	**3***	44	54.68	118	23.25	9.6	22%	26%	30 m downstream from N3
NFJDR	**4**	44	54.68	118	23.25	11.4	28%	42%	25 m downstream from N3
NFJDR	**5***	44	54.67	118	23.23	10.8	31%	22%	10 m downstream from N3
NFJDR	**6**	44	54.67	118	23.22	11.4	27%	9%	2 m downstream from N3
NFJDR	**7***	44	54.68	118	23.19	10.2	44%	41%	5 m upstream from N4
NFJDR	**8***	44	54.68	118	23.18	8.4	38%	47%	25 m upstream from N5
NFJDR	**9**	44	54.68	118	23.17	10.2	33%	15%	37 m upstream from N5
NFJDR	**10**	44	54.69	118	23.17	11.4	38%	37%	40 m upstream from N5
Granite Cr.	**1**	44	49.59	118	27.42	6.6	6%	5%	1 m upstream from GR2, 2 m downstream from SF2
Granite Cr.	**2***	44	49.59	118	27.42	6.6	3%	4%	4 m upstream from GR2, 2 m upstream from SF1
Granite Cr.	**3**	44	49.56	118	27.38	6.0	3%	4%	5 m downstream from GR3
Granite Cr.	**4**	44	49.56	118	27.38	6.0	2%	4%	3 m downstream from GR3
Granite Cr.	**5**	44	49.56	118	27.35	6.0	4%	6%	10 m downstream from SF6, 40 m upstream from GR3
Granite Cr.	**6***	44	49.54	118	27.35	5.4	4%	5%	50 m upstream from GR3
Granite Cr.	**7***	44	49.51	118	27.29	7.2	5%	3%	2 m downstream from GR4
Granite Cr.	**8***	44	49.49	118	27.26	10.2	5%	4%	35 m upstream from GR5
Granite Cr.	**9**	44	49.49	118	27.25	8.4	4%	3%	40 m upstream from GR 5
Granite Cr.	**10**	44	49.48	118	27.24	9.6	3%	4%	70 m upstream from GR5, 2 riffles upstream from fence

METHODS AND MATERIALS

Previous monitoring: 1992-1995

Previous to the present funded project, we monitored overwinter sedimentation of fine sediment and surface fine sediment in the Grande Ronde River, Catherine Creek, and NFJDR, during the incubation periods of 1992-1993, 1993-1994, and 1994-1995. Samples were installed in artificial redds after salmon spawning in the fall, and collected after fry emergence. Overwinter sedimentation was monitored by placing cleaned gravels in solid-walled containers in spawning habitat in sites excavated to mimic the dimensions and attributes of salmon redds, based on the data in Bjornn and Reiser (1991). This method has been used successfully to monitor fine sediment accumulation in channel substrate in northern California (Lisle, 1989) and provides an indication of the ultimate sediment conditions in salmonid redds (Lisle and Eads, 1991). Lisle and Eads (1991) discuss the relative merits and precision of this method of sampling fine sediment accumulation. Solid-walled containers prohibit lateral infiltration of very fine sediment into cleaned gravels, and, therefore, the amount fine sediment collected in cleaned gravels solid-walled containers has been considered a minimum estimate of actual amounts (Lisle, 1989). Cleaned gravels typically have larger pores than ambient channel substrate, which tends to increase the depth and amount of infiltration by fine sediment (Lisle, 1989). Although Lisle and Eads (1991) suggested the method may approximate conditions in redds, it is not known to what extent the gravels placed in the containers deviate from those in actual redds in the monitored streams.

The solid-walled containers were tapered cylinders with an average diameter of 0.102 m and a height of 0.127 m. The "redds" were constructed in pool or glide tailouts in spawning habitat. The constructed redds had an average area of about 4 m^2 and were designed according to the dimensions described in Bjornn and Reiser (1991). Specialists trained in the identification of redds, provided additional advice on the location and construction of the artificial redds and confirmed that the geometry and size were within the range found in natural salmon redds in the Grande Ronde River (Jeff Zakel, Oregon Dept. of Fish and Wildlife, pers. comm.). Three to six artificial redds were constructed in each stream reach monitored. Gravels with diameters >6.3 mm were taken from the ambient substrate and randomly packed into the containers. Two solid-walled containers of cleaned gravels were placed in each constructed redds in the fall after the cessation of spawning and retrieved in the subsequent spring after salmon emergence. The tops of containers were placed about 30 mm below the channel bed surface with a surface layer of gravel over the containers; the containers were placed in locations within the constructed redd where egg centrums are typically encountered, according to Chapman (1988). However, the egg centrums of spring chinook are typically at depths ranging from 0.2-0.3 m (Chapman, 1988), while the deepest part of the containers was at a depth of about 0.16 m

Concurrent with placement of sample containers into substrate in the fall, the fraction of the streambed covered by fine sediment was visually estimated (Platts et al., 1983), in all monitored reaches during the placement and retrieval of samples. Bauer and Burton (1993) noted that ocular estimates of surface fine sediment are subject to significant observer bias. In the summer of 1995, we tested the accuracy and precision of the ocular estimates of the percent of the streambed covered by surface fine sediment against measurements of surface fine sediment by the "grid method" (Bauer and Burton 1993). The grid method entails placing a sample grid on the channel substrate at equidistant points along a transect across the stream reaches and counting the number of grid intersections that are directly over surface fine sediment and dividing by the total number of intersections to determine the fraction of the surface occupied by fine sediment. In each reach, where the grid method was employed, three to five transects were monitored and three to five measurements were taken across the stream at each transect. We found that visual estimates of the amount of the substrate surface occupied by fine sediment were relatively accurate and showed no consistent bias (Rhodes and Purser, 1998). The slope of the linear regression line through points of visually estimated versus measured surface fine sediment (%) by the grid method was 1.0 and the relationship was statistically significant using a *t* distribution to test for the significance of the regression slope ($R^2 = 0.92$; $p < 0.01$); the absolute standard error was 5.0% (Rhodes and Purser, 1998). Due to the accuracy and precision of the ocular estimates, we subsequently dropped measuring surface fine sediment in every monitored reach via the grid method. For the purpose of analysis, individual estimates of surface fine sediment (%) were combined and averaged for each stream reach monitored because the mean represents a more areally-integrated descriptor of fine sediment conditions within the reach than individual estimates at the subreach/transect scale.

The solid-walled containers, placed in the substrate in the fall, were collected from the monitoring sites in the following spring, after spring chinook emergence. We used a particle diameter of <6.35 mm to define the fine sediment fraction detrimental to salmon survival, after Stowell et al. (1983), although many descriptors of fine sediment sizes and distribution have been used to characterize substrate and effects on salmonid survival (Young et al., 1991). The percent by weight of overwinter sedimentation <6.35 mm in the collected containers was determined using standard particle size analysis methods.

In the Grande Ronde River, streamflow was continuously measured at a stream-gaging station near the sampling points for overwinter sedimentation near the decommissioned Woodley Campground. Stream width, stream gradient, and depth were measured using standard methods (Dunne and Leopold, 1978). All sampling locations were sketched into a schematic map of the monitored reaches.

Present Project: 1998-2000

The present project uses the same methods as in previous years, with minor modifications. To increase the accuracy and precision of measurements of overwinter sedimentation, we used larger containers than in previous years. The increased depth of the containers also ensured that the bottom of the containers were within the range of depths that egg centrums within natural redds are typically encountered, according to Chapman (1988) and Bjornn and Reiser (1991).

The solid-walled containers were tapered cylinders with a diameter of 0.18 m at the opening, a bottom diameter of 0.16 m, and a height of 0.185 m. The larger size container increases the individual sample volume by more than four times, relative to previous years.

Delays in project funding resulted in the project being initiated in Jan. 1998. This precluded sampling during the 1997-1998 incubation season for three reasons. First, sampling overwinter sedimentation could not be accurately measured by sampling over only a portion of the incubation period. Second, mid-winter sample placement in streams posed significant logistical problems and safety risks. Third, during higher winter flows, there was a risk of disturbing incubating eggs during sampling in the incubation season. For these reasons, the delays in project funding forced us to defer sampling until the fall of 1998.

To measure overwinter sedimentation, artificial “redds” were excavated Sept. 5-6, in 1998 and 1999, and Aug. 25-26, 2000. The tops of the sample containers were placed about 30 mm below the surface of the channel substrate, as in previous years. Five “redds” were excavated in each stream monitored. Two containers of cleaned gravel were buried in each “redd,” except for two “redds” each in the Grande Ronde River and Catherine Creek, which had three containers so that one could be collected during the winter to provide some indication of the rate of sedimentation during the incubation period. Catherine Creek and the Grande Ronde River are the only two streams among the four study streams that are reasonably accessible during the winter period. The four samples in these two streams were collected in December 1998, 1999, and 2000. The samples collected in Dec. 1998 were analyzed using standard particle size analysis methods. Analysis is on-going for samples collected in Dec. 1999 and 2000.

The latitude and longitude of the constructed “redds” were estimated using a hand-held gps unit. The gps unit is estimated to have an error in horizontal accuracy that rarely exceeds 100 m (Magellan Systems, 1997). Based on repeated measurements of benchmarked sites over two years, we found that gps coordinates of specific sites appear to vary by up to about 0.07 minutes, or about 90 m. We used gps coordinates, field benchmarks, and sketch maps to construct the "redds" in 1999 and 2000 in the same locations as in 1998, to the extent possible. In cases where inter-annual channel change (e.g. the loss of a pool tailout) had made a location fail to meet the location criteria (e.g., typical spawning habitats as in Bjornn and Reiser (1991)), the site was moved to the most proximate location meeting the site criteria. Other methods related to the monitoring of overwinter sedimentation remained the same as in prior years.

In April 1999, the containers of cleaned gravels placed in the substrate in 1998 were collected. The containers placed in the substrate in Sept. 1999 were collected in April and May 2000, because high flows from rain-and snow events in April 2000 prevented us from collecting samples in some of the streams until May 2000. Since some of the samples, most notably those in Catherine Creek, were in the stream for longer periods than samples in other streams, this may preclude valid comparison of overwinter sedimentation levels among streams.

The containers of cleaned gravels placed in the substrate in Aug. 2000 will be collected in April 2001. Sediment accumulations and the particle size of accumulated sediment within all of the containers of cleaned gravels were determined using standard particle size methods.

Salmon survival from egg to fry will be estimated from the fine sediment and overwinter sedimentation data via the methods of Stowell et al. (1983), the data of Scully and Petrosky (1991), and the data of Reiser and White (1988) and will be reported in a forthcoming report.

The results of the monitoring of overwinter sedimentation and surface fines were investigated using regression analysis and a *t*-distribution to test the hypothesis that surface fines and the magnitude of overwinter sedimentation are related in a statistically significant fashion. This potential relationship is being investigated for two reasons: 1) it can be performed without any additional collection effort; and 2) to investigate whether monitoring of surface fines can be a useful surrogate for monitoring of bulk bed composition to estimate the effects of fine sediment on salmon survival. Bulk sampling of substrate is time-consuming (Grost et al., 1991). In contrast, surface fines within a reach can be measured using the grid method in approximately one hour using five randomly spaced measurement points across 10 transects within a reach. Repeated sampling and subsequent analysis is required to estimate effects on redds during incubation via bulk sampling of substrate (Lisle and Eads, 1991). Therefore, if there is a valid relationship between surface fines and intrusion levels in some streams, measuring surface fines alone may be adequate to assess relative trends in habitat condition and salmon survival at a fraction of the expense and effort related to repeated bulk substrate sampling.

While the method for determining the particle sizes in samples of overwinter sedimentation is unchanged, we are analyzing all samples of overwinter sedimentation and bulk substrate for the percent composition in four particle size classes, rather than just the percent by weight < 6.35 mm in diameter, as in previous years. The four size classes are: 1) diameter >6.35 mm; 2) diameter <6.35 mm; 3) diameter <2.0 mm; 4) diameter <0.85 mm. These size fractions are being analyzed to provide greater detail on sedimentation and to use the data of Reiser and White (1988) to estimate the survival of salmon from egg-to-fry, as well as the methods of Stowell et al (1983) and the data of Scully and Petrosky (1991).

Surface fines in the study reaches were monitored concurrent with excavation and construction of artificial redds and placement of sample containers in Sept. 1998, Sept. 1999, and Aug. 2000. In each stream reach monitored, the grid method was used at 10 transects across riffles at locations upstream of the sites for monitoring overwinter sedimentation. At each transect, five measurements were taken at equidistant points across the channel width. Surface fines at each transect were visually estimated by two independent observers, prior to measurement by a third observer. To improve the accuracy of the grid counts, a below-water viewer was used for counting grid intersections. The latitude and longitude of transects where surface fines were measured, were recorded using a gps unit. All other methods for visually estimating and measuring surface fines via the grid method were as in previous years.

In Sept. 1999 and Aug. 2000, we also used the pebble count method of Wolman (1954) to assess particle sizes at the surface of the channel substrate, concurrent with placement of sample containers and visual estimates and grid measurements of surface fines. Pebble counts are often used to estimate the amount of surface fine sediment (e.g., Bauer and Burton, 1993; Clifton et al., 1999). The pebble counts were used to generate an additional measurement of the amount of surface fine sediment < 6.35 mm (Bauer and Burton, 1993) for comparison with the results of the other two methods.

In 1999, pebble counts were taken at 4 transects in the Grande Ronde River, where surface fine sediment was measured via the grid method and visually estimated, and at three transects in each of three other streams monitored. In 2000, pebble counts were taken at four transects where surface fine sediment was measured and estimated in each of the monitored streams. Table 5 and 6 provide the locations of the transects where pebble counts, grid measurements, and visual estimates of surface fines were made.

Bulk samples of substrate were collected in each stream concurrent with the placement of containers of cleaned gravels in artificial redds and monitoring of surface fine sediment. The bulk samples were collected to provide an indication of particle size distributions at depth, prior to the incubation period. Tables 1, 2, and 3 include the locations where bulk samples were collected. The bulk samples were collected using the shovel method (Grost et al., 1991). Sampling bulk substrate by shovel in small streams, such as the ones we monitored (3-20 m wide), can be as accurate as other methods, but far less difficult and time-consuming (Grost et al., 1991). The bulk samples were analyzed using standard particle size methods.

The results of surface fine measurements and visual estimates were analyzed via linear regression and *t*-distribution to test the hypothesis that they are related in a statistically significant fashion. Confidence intervals generated at given probability levels were used to test whether surface fine sediment goals of CRITFC (1994) and NMFS (1995) are met, based on the measurements of surface fines in the monitored streams via the grid method. Both of these tests were made treating transect means of measured surface fines as a single sample. The *t*-test was used to test the hypotheses that sample means for surface fine sediment in the four rivers were different from one another. The significance of temporal trends in surface fine sediment was tested via linear regression. The *F*-test, together with the *t*-test, were used to test the hypotheses that mean overwinter sedimentation by size fraction category differed among the rivers.

With one exception, all the statistical and regression analyses results reported in this report were derived using the statistical, regression, and mathematical functions and tools in Excel. We found that in one case, this software generated obviously incorrect results (e.g., a negative R^2 value in the linear regression of pebble count with visual estimates of surface fine sediment with the Y-intercept of the linear regression line forced through 0). For this case, the regression results were generated via SYSSTAT. We spot-checked other statistical and regression results generated from Excel functions with those from SYSSTAT and other spreadsheet software, and they were in agreement, and appear to be without error. In the future, the veracity of these results will be completely cross-checked with other computerized statistical packages.

Variability within and among sample sites will also be analyzed in the future using standard statistical methods. Initial estimates of variability will be used to estimate the number of samples needed in future investigations to generate a given level of statistical significance at given probabilities of "type I and II" errors using standard statistical methods (Benjamin and Cornell, 1970).

On the administrative end, a biological assessment (BA) of the project's effects was prepared for use in project consultation with NMFS under the Endangered Species Act (ESA) in 1998. The BA was prepared using the same format and approach as the BAs for Catherine Creek (La Grande Ranger District, 1994a) and the Upper Grande Ronde River (La Grande Ranger District, 1994b). The project BA tiered to La Grande Ranger District (1994a; b) and described potential project effects within the context of project actions, information on the study streams, and scientific literature related to possible effects. The project BA was submitted to BPA and NMFS in August 1998.

RESULTS AND DISCUSSION

Visual estimates and grid measurements of surface fine sediment: 1998-2000

The results of the grid measurements and visual estimates of surface fines from 1998 - 2000 are shown in Tables 7, 8, and 9 and in Figures 2, 3, and 4. Table 7 provides a comparison of the results of the linear regression analyses of measured and estimated surface fines in the fall of 1995 (Rhodes and Purser, 1998) and 1998 - 2000.

These results indicate that visual estimates of surface fine sediment were relatively accurate and unbiased compared to grid measurements. From 1998-2000, the slopes of the regression lines through data from individual and combined years ranged from 0.96 to 0.99. The differences between these derived slopes and a slope of 1.0 was not statistically significant at $p < 0.05$, indicating that visual estimates of surface fines exhibit no statistically significant bias (Table 7). The differences in the linear regression slopes among data from individual and combined years were also not statistically significant at $p < 0.05$. The standard error of the y-estimate ranged from 5.4 to 6.3% for data collected from 1998-2000 (Table 7). This indicates that the visual estimates are relatively accurate with respect to the measurements via the grid method.

Figure 2. Measured and visually estimated surface fines in the four study streams, Sept. 1998 and linear regression line through data (n = 40). Vertical lines show standard error of Y estimate.

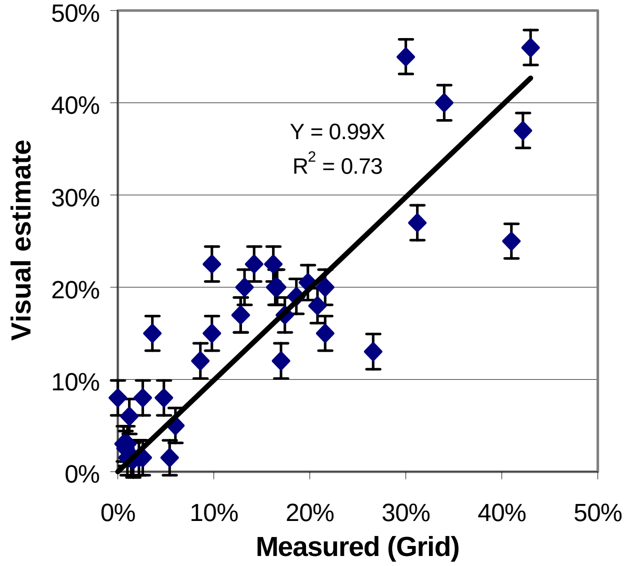


Figure 3. Measured and visually estimated surface fine sediment in the four study streams, Sept. 1999 and regression line through data (n = 40). Vertical lines through the data show standard error of Y estimate.

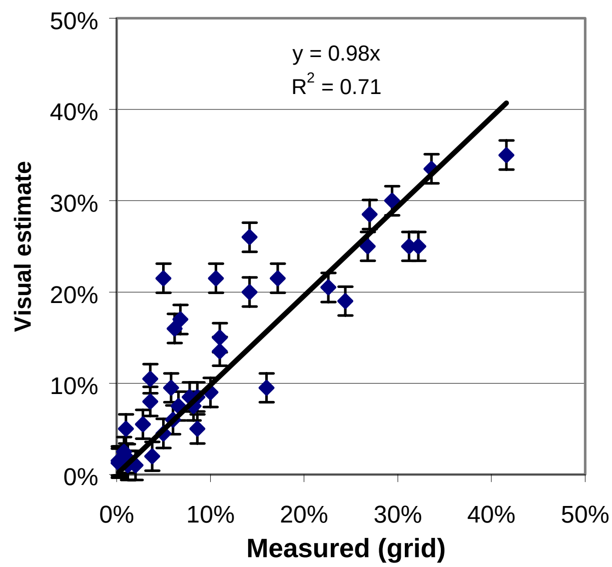


Figure 4. Measured and visually estimated surface fine sediment in the four study streams, Aug. 2000 with regression line through data (n = 40). Vertical lines through the data show standard error of Y estimate.

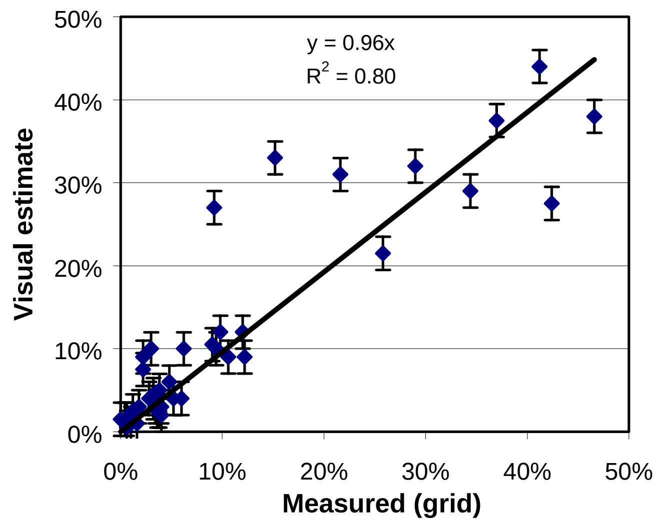


Figure 5. Measured and visually estimated surface fine sediment in the four study streams, Sept. 1998 and 1999 and Aug. 2000 with regression line (n = 120) through combined data.

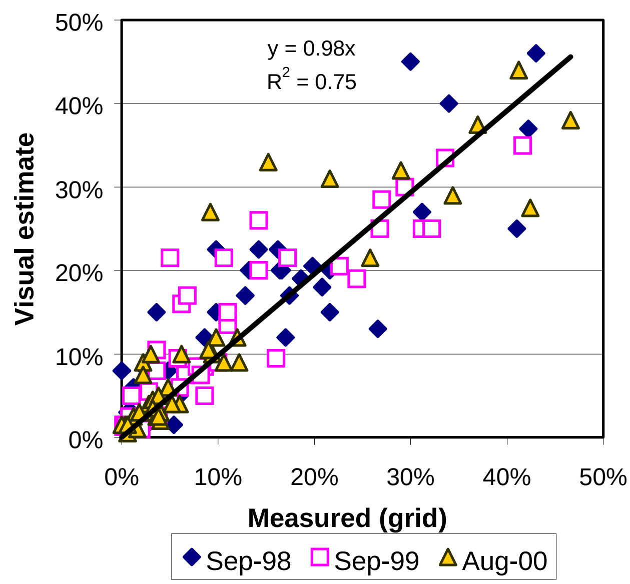


Table 7. Results of regression analysis of measured (grid method) and visually estimated percent surface fine sediment in Sept. 1995 (Rhodes and Purser, 1998) and 1998 - 2000 at all transects in all four study streams. Measured percent surface fine sediment was treated as the independent variable in the analyses in all years. See also Figures 2, 3, 4 and 5.

Attributes of analysis results	Year data collected				
	1995	1998	1999	2000	1998-2000 (combined)
n	14	40	40	40	120
Slope and relationship statistically significant?	Yes, $p < 0.01$	Yes, $p < 0.01$	Yes, $p < 0.01$	Yes, $p < 0.01$	Yes, $p < 0.01$
R^2 value from linear regression analysis	0.92	0.73	0.71	0.80	0.75
Slope of regression line	1.0	0.99	0.98	0.96	0.98
Statistically significant difference between linear regression slope and slope of 1.0 ($p < 0.05$)?	no	no	no	no	no
Y-intercept (forced)	0.0	0.0	0.0	0.0	0.0
Std. error of Y estimate	5.0%	6.3%	5.4%	5.7%	5.8%

The relationship between visual estimates and measured surface fines was statistically significant for data from all individual and combined years (Table 7). The R^2 values ranged from 0.73 to 0.80 for data collected 1998-2000 (Table 7).

The results of these analyses indicate that data collected in 1995 exhibited a tighter relationship between visually estimated and measured surface fine sediment levels (Table 7). We believe that this may be due to one, or a combination, of several factors affecting accuracy. Increased sample numbers in 1998-2000 are likely to have increased the accuracy of the results of both methods. The use of an underwater viewing scope from 1998 to 2000 also probably improved the accuracy of the grid method measurements. For these reasons, the data from 1998-2000 probably better reflect the relationship of visual estimates to measurements of surface fine sediment levels.

The results of the surface fine sediment measurements from the grid method in Sept. 1998 (Table 8 and Figure 6) indicate that the mean fine sediment levels in the monitored reaches of the Grande Ronde River were higher than the <20% surface fine sediment goal set in CRITFC (1995) and NMFS (1995). However, at $p = 0.10$, the calculated confidence interval (CI) around the mean overlaps with the <20% surface fine sediment goal. Therefore, the hypothesis that mean fine sediment levels in the Grande Ronde are higher than 20% is not statistically significant at $p < 0.10$, using transect means as independent sample points. However, at $p < 0.15$, the hypothesis that surface sediment levels in the Grande Ronde River are > 20% can be accepted as true. Results for the other sampled reaches in 1998 are shown in Table 8.

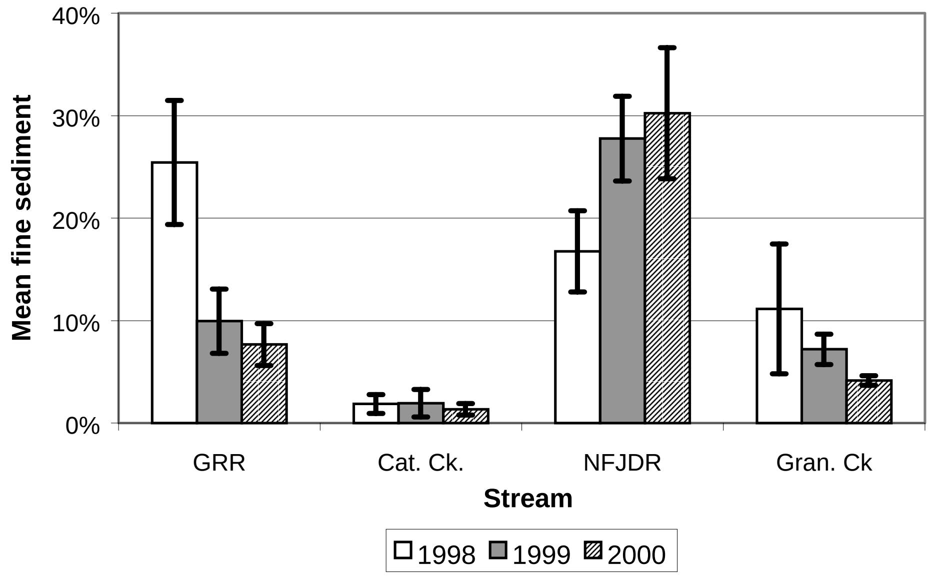
The results of the surface fine sediment measurements from the grid method in Sept. 1999 (Table 8 and Figure 6) indicate that the mean fine sediment levels in the monitored reaches of the NFJDR are higher than the <20% surface fine sediment goal ($p < 0.10$). Based on the grid measurements (Table 8) in Sept. 1999, the other three monitored stream reaches appear to meet the <20% surface fine sediment goal ($p < 0.10$).

In Aug. 2000, all reaches except the NFJDR had mean surface fine sediment levels that were < 20% (Table 8 and Fig. 6). Mean fine surface fine sediment levels in the NFJDR were > 20%; this can be accepted at $p < 0.10$ (Table 8 and Fig. 6)

Table 8. Summary statistics and results of the measured percent surface data collected by the grid method in 1998-2000 by stream. For all four monitored streams, n = 10, in each year.

Year data collected	Stream	Mean	Std. dev.	CI at p = 0.10	Mean < 20% (p < 0.10)	Mean > 20% (p < 0.10)
1998	Grande Ronde	25.4%	11.6%	6.0%	Possibly. No, at p < 0.15	Possibly. Yes, at p < 0.15
	Catherine Cr.	1.8%	1.4%	0.7%	Yes	No
	NFJDR	16.8%	7.6%	4.0%	Possibly. Yes, at p < 0.15	Possibly. No, at p < 0.15
	Granite Cr.	11.1%	12.2%	6.3%	Yes	No
1999	Grande Ronde	9.9%	6.0%	3.1%	Yes	No
	Catherine Cr.	1.9%	2.6%	1.3%	Yes	No
	NFJDR	27.8%	7.9%	4.1%	No	Yes
	Granite Cr.	7.2%	2.9%	1.5%	Yes	No
2000	Grande Ronde	7.7%	4.0%	2.1%	Yes	No
	Catherine Cr.	1.3%	1.1%	0.6%	Yes	No
	NFJDR	30.2%	12.3%	6.4%	No	Yes
	Granite Cr.	4.2%	0.9%	0.5%	Yes	No

Figure 6. Mean surface fine sediment (% < 6.35 mm) in each of the four monitored streams, as measured by the grid method in monitored reaches in 1998- 2000. Vertical lines through data show total size of confidence interval about the mean at p = 0.10.



There is a statistically significant difference in mean surface fine levels among some of the study streams in 1998 - 2000 and between years within some of the streams, as shown in Tables 9 - 11 and in Figures 6 - 14. In 1998, mean surface fine sediment levels in the Grande Ronde were higher than in Catherine and Granite Creeks with the difference statistically significant ($p < 0.10$), using data from either visual estimates or grid measurements. Catherine Creek had lower levels of mean surface fines than the NFJDR and Granite Creek in Sept. 1998; these differences were statistically significant at $p < 0.10$, using data from either visual estimates or grid measurements. The differences in mean surface fine sediment levels in the NFJDR and Grande Ronde River in 1998 were not statistically significant at $p < 0.10$, using data from either visual estimates or grid measurements. These and other results are summarized in Table 9.

In Sept. 1999, mean surface fines were higher in the NFJDR than in all three other study streams; these differences were statistically significant ($p < 0.10$). Catherine Creek had lower levels of mean surface fines than the other three streams in Sept. 1999; these differences were statistically significant at $p < 0.10$, using data from either visual estimates or grid measurements. These and other results are summarized in Table 9.

In Sept. 2000, we found the differences among streams in mean surface fines followed the same pattern as in 1999, with one exception. The mean in the Grande Ronde was greater than Granite Creek at $p < 0.10$ in 2000, using the data from either visual estimates or grid measurements. These and other results are summarized in Table 9.

Table 9. Results of statistical tests of differences in surface fine sediment among streams, 1998 - 2000, measured by grid and visual estimates (V.E.). One-tailed t-tests used to test if the mean in one stream were > or < the mean in the other; F-test used to test for differences in variability. In all years, in all streams, n = 10. Rows of data in bold font are test cases where measurements via the grid method led to the acceptance of a different hypothesis than visual estimates.

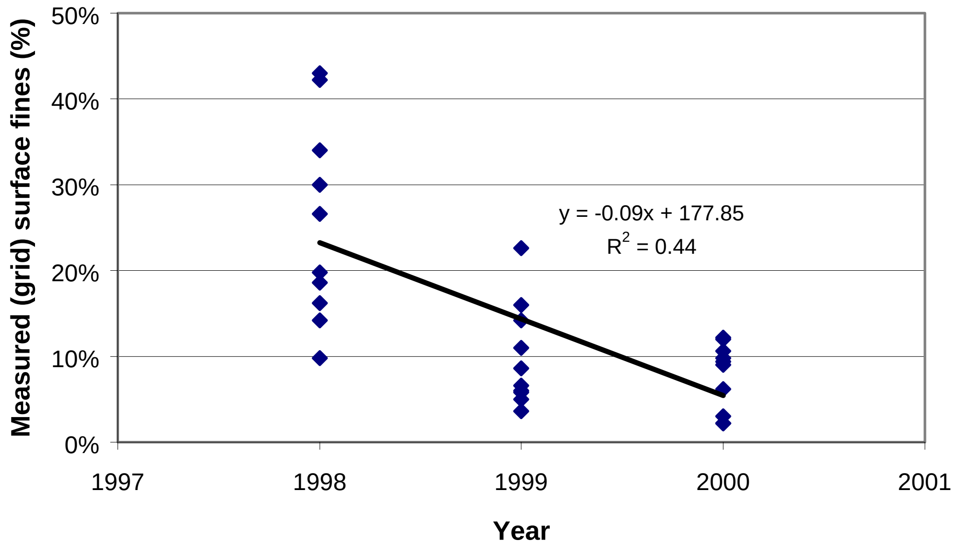
Year	Comparison		Mean		Method	F test p – value	*t*-test p - value	Hypothesis accepted at p < 0.10 (stream means)
	Stream A	Stream B	Stream A	Stream B				
1998	Cat Cr.	GRR	1.8%	25.4%	Grid	<0.001	<0.001	GRR > Cat. Cr.
1998	NFJDR	GRR	16.8%	25.4%	Grid	0.111	0.032	GRR > NFJDR
1998	NFJDR	Cat Cr.	16.8%	1.8%	Grid	<0.001	<0.001	NFJDR > Cat. Cr.
1998	**NFJDR**	**GT**	**16.8%**	**11.1%**	**Grid**	**0.089**	**0.118**	**NFJDR = GT**
1998	Cat Cr.	GT	1.8%	11.1%	Grid	<0.001	0.020	GT > Cat Cr.
1998	GRR	GT	25.4%	11.1%	Grid	0.447	0.008	GRR > GT
1999	Cat Cr.	GRR	1.9%	9.9%	Grid	0.009	0.001	GRR > Cat. Cr.
1999	NFJDR	GRR	27.8%	9.9%	Grid	0.211	<0.001	NFJDR > GRR
1999	NFJDR	Cat Cr.	27.8%	1.9%	Grid	0.001	<0.001	NFJDR > Cat. Cr.
1999	NFJDR	GT	27.8%	7.2%	Grid	0.003	<0.001	NFJDR > GT
1999	Cat Cr.	GT	1.9%	7.2%	Grid	0.379	<0.001	GT > Cat Cr.
1999	GRR	GT	9.9%	7.2%	Grid	0.018	0.108	GRR = GT
2000	Cat Cr.	GRR	1.3%	7.7%	Grid	<0.001	<0.001	GRR > Cat. Cr.
2000	NFJDR	GRR	30.2%	7.7%	Grid	0.001	<0.001	NFJDR > GRR
2000	NFJDR	Cat Cr.	30.2%	1.3%	Grid	<0.001	<0.001	NFJDR > Cat. Cr.
2000	NFJDR	GT	30.2%	4.2%	Grid	<0.001	<0.001	NFJDR > GT
2000	Cat Cr.	GT	1.3%	4.2%	Grid	0.298	<0.001	GT > Cat Cr.
2000	GRR	GT	7.7%	4.2%	Grid	<0.001	0.011	GRR > GT
1998	Cat Cr.	GRR	1.9%	28.8%	V. E.	<0.001	<0.001	GRR > Cat. Cr.
1998	NFJDR	GRR	18.7%	28.8%	V.E.	<0.001	0.013	GRR > NFJDR
1998	NFJDR	Cat Cr.	18.7%	1.9%	V.E.	<0.001	<0.001	NFJDR > Cat. Cr.
1998	**NFJDR**	**GT**	**18.7%**	**11.8%**	**V.E.**	**0.063**	**0.004**	**NFJDR > GT**
1998	Cat Cr.	GT	1.9%	11.8%	V.E.	<0.001	<0.001	GT > Cat Cr.
1998	GRR	GT	28.8%	11.8%	V.E.	0.034	<0.001	GRR > GT
1999	Cat Cr.	GRR	2.3%	13.3%	V.E.	<0.001	<0.001	GRR > Cat. Cr.
1999	NFJDR	GRR	26.3%	13.3%	V.E.	0.248	<0.001	NFJDR > GRR
1999	NFJDR	Cat Cr.	26.3%	2.3%	V.E.	<0.001	<0.001	NFJDR > Cat. Cr.
1999	NFJDR	GT	26.3%	11.3%	V.E.	0.451	<0.001	NFJDR > GT
1999	Cat Cr.	GT	2.3%	11.3%	V.E.	<0.001	<0.001	GT > Cat Cr.
1999	GRR	GT	13.3%	11.3%	V.E.	0.288	0.239	GRR = GT
2000	Cat Cr.	GRR	2.0%	9.9%	V.E.	0.262	<0.001	GRR > Cat. Cr.
2000	NFJDR	GRR	32.1%	9.9%	V.E.	<0.001	<0.001	NFJDR > GRR
2000	NFJDR	Cat Cr.	32.1%	2.0%	V.E.	<0.001	<0.001	NFJDR > Cat. Cr.
2000	NFJDR	GT	32.1%	3.7%	V.E.	<0.001	<0.001	NFJDR > GT
2000	Cat Cr.	GT	2.0%	3.7%	V.E.	0.370	0.002	GT > Cat Cr.
2000	GRR	GT	9.9%	3.7%	V.E.	0.380	<0.001	GRR > GT

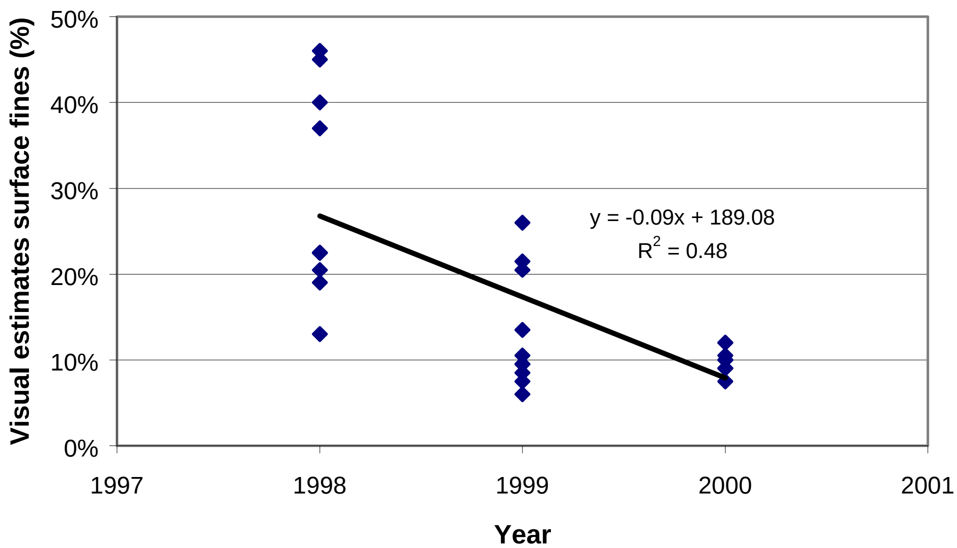
There were statistically significant differences in mean surface fine sediment levels between years in some of the streams based on data from the grid method and *t*-test results (Table 10). In the Grande Ronde, the decrease in mean surface fine sediment levels was statistically significant from 1998 - 1999 and 1998 - 2000. Catherine Creek had no statistically significant differences among years in mean surface fine sediment. In the NFJDR, the increase in mean surface fine sediment was statistically significant from 1998 - 1999 and 1998 - 2000. The decrease in mean surface fine sediment was statistically significant from 1999 - 2000 and 1998 - 2000 in Granite Creek. These results are summarized in Table 10.

Table 10. Results of statistical tests of differences in surface fine sediment levels in streams among years 1999 - 2000, as measured by the grid method. One-tailed t-tests used to test if mean in one year were > or < means in the other year in a stream; F-test used to test for differences in variability. In all years, in all streams, n = 10.

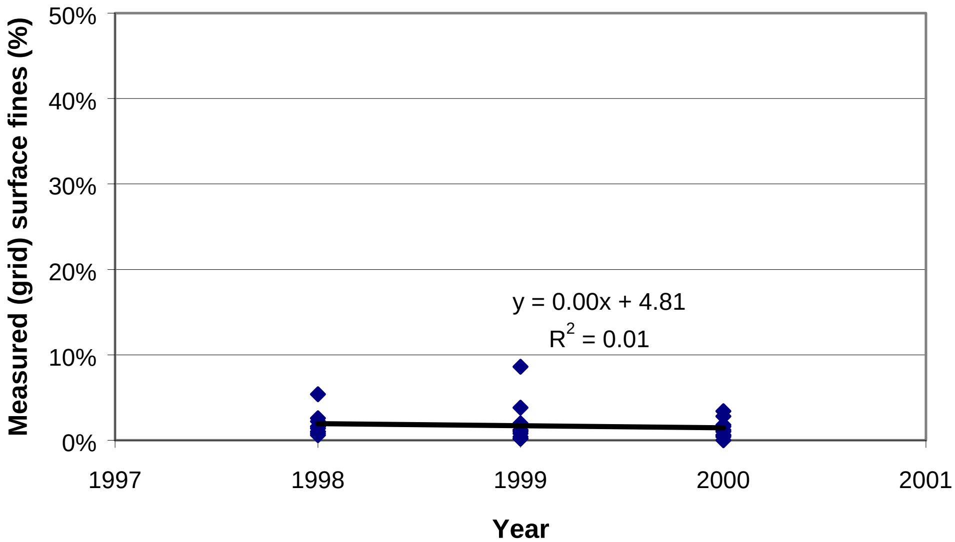
Stream	**Comparison**		**Mean**		**Method**	**F test p – value**	***t*-test p - value**	**Hypothesis accepted at p < 0.10 (between year means)**
	Year A	**Year B**	**Year A**	**Year B**				
GRR	1998	1999	25.4%	9.9%	Grid	0.031	0.001	1998 > 1999
GRR	1999	2000	9.9%	7.7%	Grid	0.113	0.165	1999 = 2000
GRR	1998	2000	25.4%	7.7%	Grid	0.002	<0.001	2000 < 1998
Cat. Cr.	1998	1999	1.8%	1.9%	Grid	0.043	0.449	1998 = 1999
Cat. Cr.	1999	2000	1.9%	1.3%	Grid	0.008	0.255	1999 = 2000
Cat. Cr.	1998	2000	1.8%	1.3%	Grid	0.227	0.202	2000 = 1998
NFJDR	1998	1999	16.8%	27.8%	Grid	0.451	0.003	1998 < 1999
NFJDR	1999	2000	27.8%	30.2%	Grid	0.104	0.299	1999 = 2000
NFJDR	1998	2000	16.8%	30.2%	Grid	0.084	0.005	2000 > 1998
GT	1998	1999	11.1%	7.2%	Grid	<0.001	0.172	1998 = 1999
GT	1999	2000	7.2%	4.2%	Grid	0.001	0.004	1999 > 2000
GT	1998	2000	11.1%	4.2%	Grid	<0.001	0.052	2000 < 1998

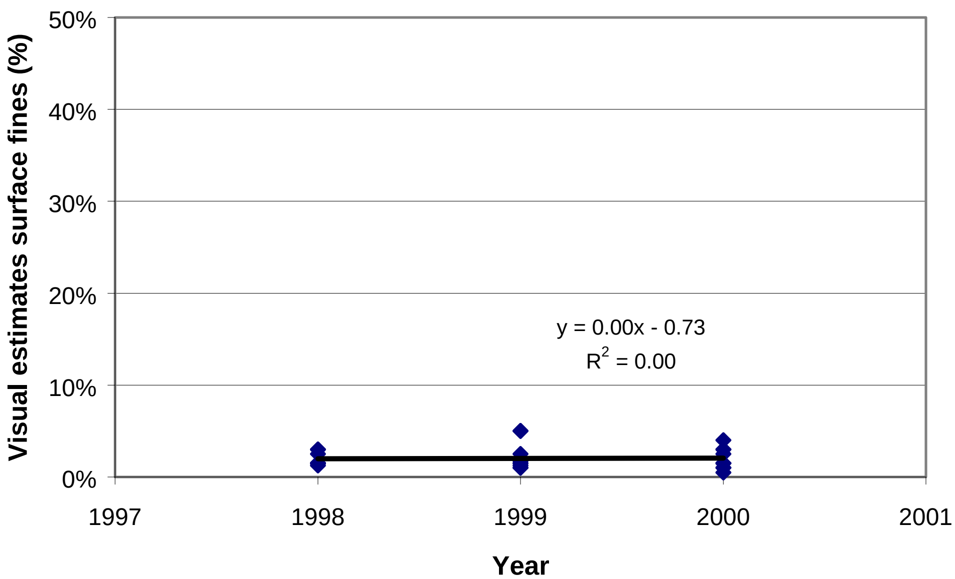
Figures 7 and 8. Mean surface fine sediment levels, from the grid method and visual estimates, in the Grande Ronde, 1998 - 2000, including regression lines through the data. For each year, n=10, for each method. The slopes of both regression lines are statistically significant ($p < 0.10$). See also: Table 11.



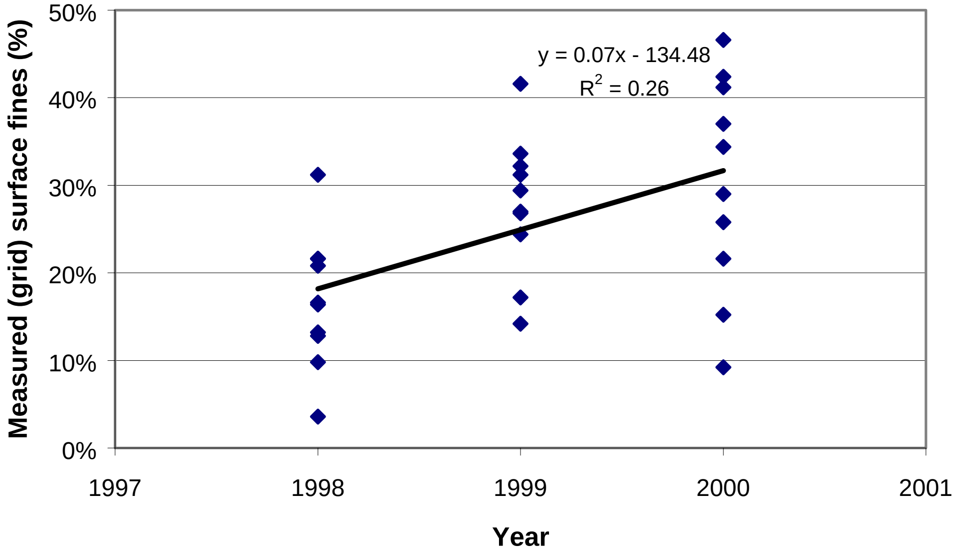


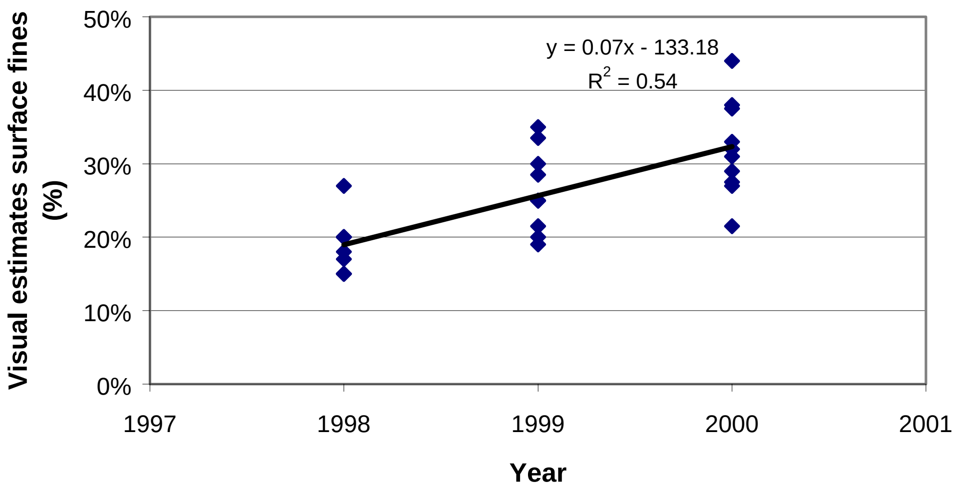
Figures 9 and 10. Mean surface fine sediment levels, from the grid method and visual estimates, in the Catherine Creek, 1998 - 2000, including regression lines through the data. For each year, n=10, for each method. The slopes of both regression lines are not statistically significant ($p < 0.10$). See also: Table 11.



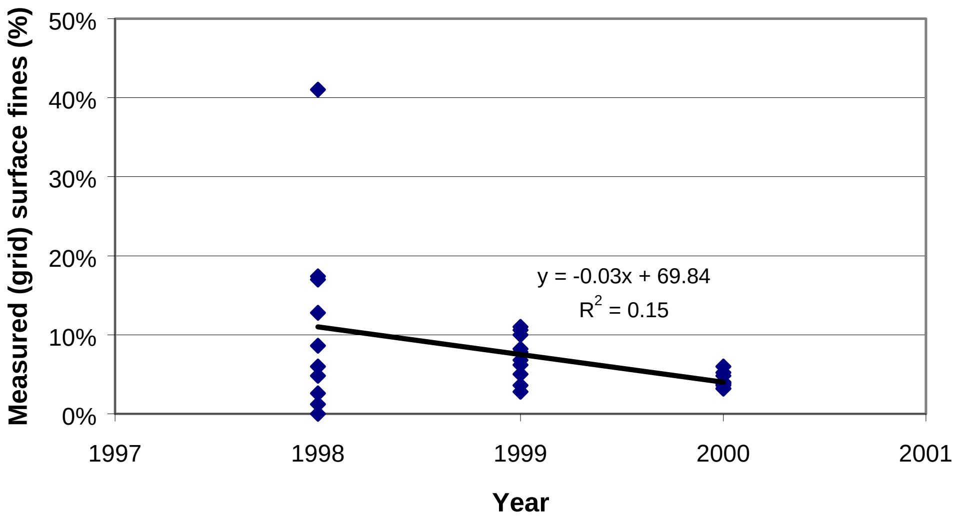


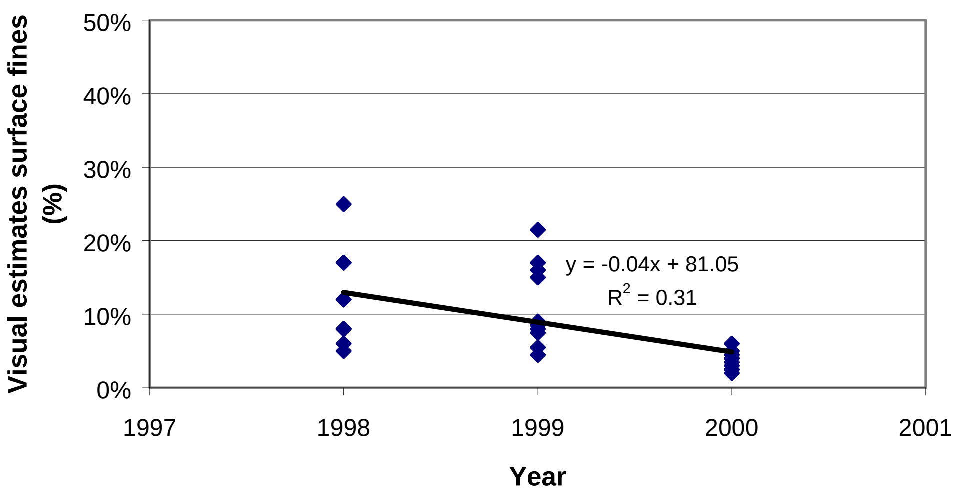
Figures 11 and 12. Mean surface fine sediment levels, from the grid method and visual estimates, in the NFJDR, 1998 - 2000, including regression lines through the data. For each year, n=10, for each method. The slopes of both regression lines are statistically significant ($p < 0.10$). See also: Table 11.





Figures 13 and 14. Surface fine sediment levels, from the grid method and visual estimates, in Granite Creek, 1998 - 2000, including regression lines through the data. For each year, n=10, for each method. The slopes of both regression lines are statistically significant ($p < 0.10$). See also: Table 11.





The results of regression analysis of fine sediment trends in the monitored streams corroborate the results of the analysis of differences among years in mean surface fine sediment levels in streams using the *t*-test. For both visual estimates and grid measurements of surface fine sediment, the 1998 - 2000 trend is statistically significant ($p < 0.10$) in the Grande Ronde, Granite Creek, and the NFJDR, while Catherine Creek exhibited no statistically significant trend (Table 11).

Table 11. Summary results of regression analyses of surface fine sediment levels (grid method and visual estimates (Ve) in the four monitored rivers from 1998-2000. Bold font indicates cases where linear regression relationship was statistically significant ($p < 0.10$).

Creek	Years	X-Value	Y-Value	n	R^2	Slope	Std. Error	p
Grande Ronde	**1998-2000**	**Year**	**Grid**	**30**	**0.44**	**-0.09**	**0.08**	**<0.001**
Grande Ronde	**1998-2000**	**Year**	**V.E.**	**30**	**0.69**	**-0.09**	**0.08**	**<0.001**
Catherine Cr.	1998-2000	Year	Grid	30	0.01	0.00	0.02	0.551
Catherine Cr.	1998-2000	Year	V.E.	30	0.00	0.00	0.01	0.885
NFJDR	**1998-2000**	**Year**	**Grid**	**30**	**0.26**	**0.07**	**0.10**	**0.004**
NFJDR	**1998-2000**	**Year**	**V.E.**	**30**	**0.54**	**0.07**	**0.05**	**<0.001**
Granite Cr.	**1998-2000**	**Year**	**Grid**	**30**	**0.15**	**-0.09**	**0.07**	**0.037**
Granite Cr.	**1998-2000**	**Year**	**V.E.**	**30**	**0.31**	**-0.04**	**0.05**	**0.001**

Based on these results, it is clear that there is a deteriorating trend in surface fine sediment conditions in the monitored reach in the NFJDR from 1998 to 2000. It is also clear that this trend in the NFJDR is anomalous, in comparison with the trends in the monitored reaches in the other three streams. During the same time period, there has been an improving trend in fine sediment conditions in the monitored reaches in the Grande Ronde and Granite Creeks, while there has been no significant trend in Catherine Creek. These same respective trends in the monitored streams are also corroborated by the data from pebble count method for 1999 - 2000. However, we did not statistically analyze the pebble count data for trends because we have only two years of data and relatively small sample numbers in each stream in each year (n = 2 to 4), rendering statistical analysis of questionable value.

Since all four streams are in watersheds that are broadly comparable with respect to vegetation and geology and have been subjected to similar climatic and hydrologic events during this period, it is probable that the differential trend in the NFJDR is due to land use conditions. Although it is outside of the scope of the current project, in the next year we will attempt to investigate and document the magnitude and trend of land-disturbing activities (e.g., roads, harvest, grazing, etc) in the four watersheds.

These trends have significant implications for likely trends in salmonid survival. Available literature consistently indicates that salmonid survival from egg to emergence is significantly reduced with increasing levels of fine sediment in substrate (See: review in Rhodes et al., 1994). Therefore, it is highly likely that rates of salmonid survival from egg to emergence have increased in the Grande Ronde and Granite Creek, due to decreases in surface fine sediment levels, while salmonid survival rates have decreased in the NFJDR from 1998 - 2000.

Comparisons of Results From Different Methods of Characterizing Surface Fines

The complete results of the pebble count measurements are displayed in Appendix A in Tables A-1 and A-2. The results of the pebble count, grid, and visual method for characterizing surface fines are shown in Table 12 for all surface fine sediment transects in all study streams where all three methods were used in 1999 and 2000. Table 13 summarizes the results of regression analysis of the relationship among the methods for determining the amount of surface fine sediment. The regression analyses were made using both regression-derived intercepts and an intercept forced through the origin to analyze bias in the methods. Figures 15, 16, and 17 graphically display the relationship of results among the three methods.

Table 12. Results of three methods for characterizing the amount (%) of surface fine sediment in channel substrate, in 1999 and 2000, at all transects where all three methods were used. In the table, GR = Grande Ronde; C = Catherine Cr.; N = NFJDR; GT = Granite Cr.; SF = surface fine sediment transect with numbers corresponding to the numbered transect locations in Table 5 and 6.

1999				**2000**			
Surface fine transect identifier	Surface fine sediment (%)			Surface fine transect Identifier			
	Mean measured (grid)	Visual estimate	Pebble count		Mean measured (grid)	Visual estimate	Pebble count
GRSF2	11.0%	13.5%	21.3%	GRSF2	12.0%	12.0%	14.1%
GRSF4	14.2%	26.0%	20.3%	GRSF4	9.4%	10.0%	10.8%
GRSF5	5.0%	21.5%	22.4%	GRSF6	9.8%	12.0%	13.2%
GRSF8	8.6%	8.5%	12.2%	GRSF9	9.0%	10.5%	8.3%
CSF3	1.2%	1.8%	3.0%	CSF1	0.4%	1.5%	4.1%
CSF9	0.4%	1.5%	2.0%	CSF5	0.6%	0.5%	0.0%
CSF10	2.0%	1.0%	6.1%	CSF7	2.8%	4.0%	6.2%
NSF4	14.2%	20.0%	13.1%	CSF9	1.8%	3.0%	3.1%
NSF8	29.4%	30.0%	21.1%	NSF3	25.8%	21.5%	13.1%
NSF10	24.4%	19.0%	22.1%	NSF5	21.6%	31.0%	28.2%
GTSF5	10.0%	9.0%	16.0%	NSF7	41.2%	44.0%	32.3%
GTSF7	11.0%	15.0%	20.3%	NSF8	46.6%	38.0%	34.1%
GTSF8	10.6%	21.5%	24.3%	GTSF2	4.0%	3.0%	7.9%
				GTSF6	5.2%	4.0%	7.9%
				GTSF7	3.2%	4.5%	16.2%
				GTSF8	3.8%	5.0%	12.3%

Based on these regression results, it appears that the visual estimates are more accurate than pebble count methods for estimating surface fines as measured by the grid method. In all but one case analyzed, regression analysis of visual estimates and grid method data resulted in generally higher R^2 values, slopes closer to a 1.0, and lower standard errors, than comparable analyses of the relationship between pebble count estimates and grid method data (Table 13, Figures 15 and 16). The sole exception to this pattern is found in the analysis results for the 1999 data for pebble counts vs. grid method, with the intercept forced through the origin. Although this single case had a higher R^2 value and a slope that is closer to 1.0, than for the comparable analysis of visual estimates vs. grid data, it increased the standard error to the highest value resulting from any of the regression analyses (Table 13). Further, the high R^2 value in this single case is an artifice of forcing the regression line through the origin, and consequently closer to a single outlying point, rather than an indication of a relatively tight fit through the data -- when the data from NSF 8 in Table 13 are omitted, the R^2 value is 0.14 for the regression analysis of pebble count vs. grid method data with a Y-intercept of zero.

There were only two cases analyzed that resulted in regression derived slopes that did not include a slope = 1.0 in the 95% confidence interval for slopes (Table 13). Both of these cases were for the relationship of data from pebble counts vs. the grid method, with a regression-derived intercept, in 1999 and with combined 1999 and 2000 data (Table 13). Because a 1:1 slope indicates a precise relationship without bias, it is apparent that pebble counts are not precise unbiased estimators of surface fine sediment levels as measured by the grid method.

In all cases where the Y-intercept was calculated via the regression, the Y-intercept of the regression lines through the visual estimates and grid data were closer to 0 than Y-intercepts calculated from analysis of pebble count vs. grid data (Table 13, Figures 15 and 16). In aggregate, these results indicate that visual estimates of surface fines are better correlated with grid data and more accurately estimate grid method results than do pebble counts. The data indicate that pebble counts tend to overestimate surface fines in locations where surface fines are low and underestimate surface fines where they are high. Based on these results, visual estimates are more likely to be able to detect differences in surface fine sediment conditions among streams or years than pebble counts.

In general, pebble count data for surface fines are more strongly correlated with visual estimates than to the grid method data (Table 13), although this varies somewhat among years. Regression analysis indicates that with comparable Y-intercepts, the visual estimates vs. pebble count data generally have higher R^2 values, slopes closer to 1.0, and lower standard errors, result from regression analyses of pebble counts vs. grid method data (Table 13). Regression-derived intercepts are generally closer to the origin for the visual estimates vs. pebble counts than from pebble counts vs. grid method. The sole exceptions are in 1999, where with comparable intercepts, the visual estimates and pebble count data are more highly correlated than either visual estimates vs. grid method or pebble count vs. grid method (Table 13). Although the pebble count data is better correlated with visual estimates than it is with the grid method, the visual estimates are generally better correlated with the grid method than pebble counts with the exception of the 1999 data (Table 13). These results indicate that visual estimates are also fairly well correlated with pebble counts and provide an reasonable accurate estimator of data derived from the pebble counts, although visual estimates provide an even better estimate of surface fines measured by the grid method.

All of the regression analyses summarized in Table 13 indicate that the slope of the regression lines are statistically significant at $p < 0.10$. Therefore, the null hypothesis (the data from the methods are unrelated and the slope of the regression line through the data = 0) can be rejected for all analyzed relationships among the data from the three methods.

Table 13. Results of regression analyses of 1999 and 2000 surface sediment data collected by visual, grid, and pebble count methods at transects in the four study streams. See Tables 5 and 6 for locations of transects. Asterisk (*) denotes regression data generated from SYSTAT. All analyzed relationships are statistically significant ($p < 0.10$). Intercepts of 0.0% result from forcing regression line through the origin; all other intercepts derived from regression analysis.

Year	Y-Value	X-Value	n	R^2	Slope	Intercept	Std. Error	p-value (slope = 0)	Slope = 1.0 included in 95% confidence interval?
1999	Pebble Count*	Mean Grid	13	0.79	1.13	0.0%	8.3%	<0.001	yes
1999	Visual Estimate	Mean Grid	13	0.50	1.16	0.0%	6.8%	0.006	yes
1999	Visual Estimate	Pebble Count	13	0.69	0.94	0.0%	5.4%	<0.001	yes
1999	Pebble Count	Mean Grid	13	0.42	0.59	9.3%	6.2%	0.017	yes
1999	Visual Estimate	Mean Grid	13	0.60	0.87	5.0%	6.3%	0.002	yes
1999	Visual Estimate	Pebble Count	13	0.69	1.03	-1.7%	5.5%	<0.001	yes
2000	Pebble Count	Mean Grid	16	0.62	0.83	0.0%	6.2%	<0.001	yes
2000	Visual Estimate	Mean Grid	16	0.93	0.97	0.0%	3.7%	<0.001	yes
2000	Visual Estimate	Pebble Count	16	0.83	1.07	0.0%	5.6%	<0.001	yes
2000	Pebble Count	Mean Grid	16	0.79	0.63	5.5%	4.8%	<0.001	**no**
2000	Visual Estimate	Mean Grid	16	0.93	0.92	1.4%	3.6%	<0.001	yes
2000	Visual Estimate	Pebble Count	16	0.86	1.25	-3.8%	5.2%	<0.001	yes
1999-2000	Pebble Count	Mean Grid	29	0.32	0.92	0.0%	7.5%	0.001	yes
1999-2000	Visual Estimate	Mean Grid	29	0.79	1.03	0.0%	5.4%	<0.001	yes
1999-2000	Visual Estimate	Pebble Count	29	0.78	1.01	0.0%	5.5%	<0.001	yes
1999-2000	Pebble Count	Mean Grid	29	0.64	0.61	7.2%	5.5%	<0.001	**no**
1999-2000	Visual Estimate	Mean Grid	29	0.82	0.90	3.0%	5.1%	<0.001	yes
1999-2000	Visual Estimate	Pebble Count	29	0.81	1.17	-3.3%	5.3%	<0.001	yes

Figure 15. Scattergram of surface fine sediment from pebble counts and grid measurements at all 29 transects where all three methods of quantifying of surface fines were used, in Sept. 1999 and Aug. 2000, with regression line through data. Vertical bars scaled to standard error of Y estimate. Regression is statistically significant ($p < 0.10$). See Table 13 for additional results and details.

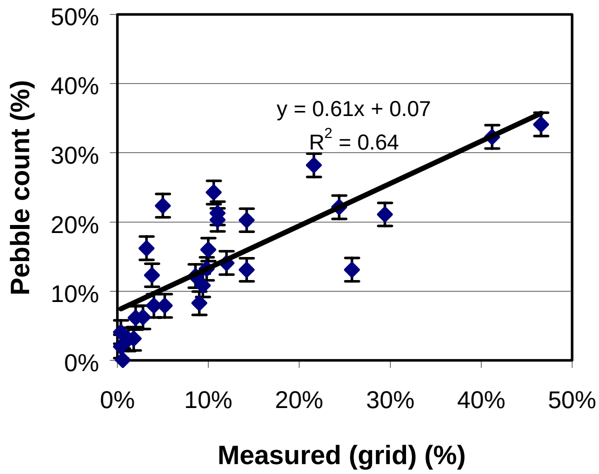


Figure 16. Scattergram of surface fine sediment from visual estimates and grid measurements at all 29 transects where all three methods of quantifying surface fines were used, in Sept. 1999 and Aug. 2000, with regression line through data. Vertical bars scaled to standard error of Y estimate. Regression is statistically significant ($p < 0.10$). See Table 13 for additional results and details.

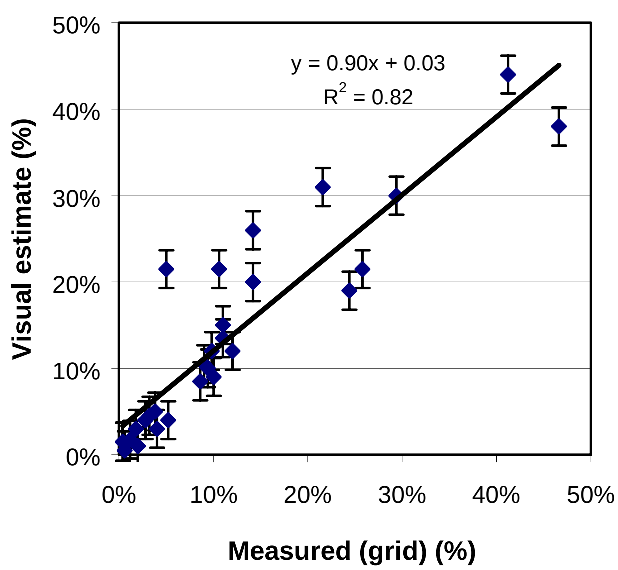
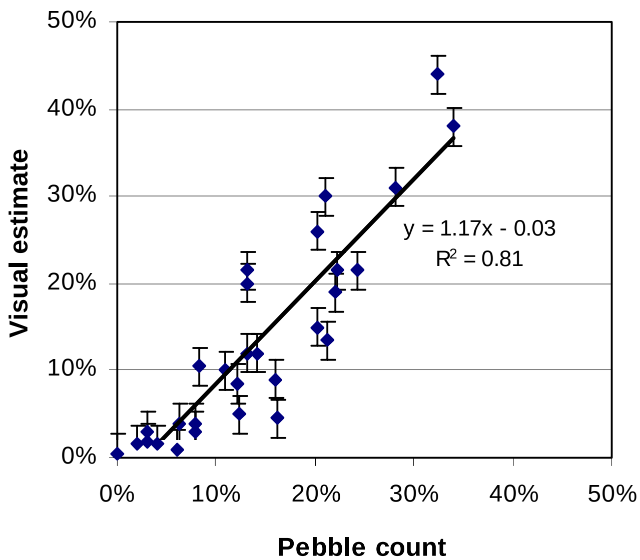


Figure 17. Scattergram of surface fine sediment from pebble counts and visual estimates at all 29 transects where all three methods of quantifying surface fines were used, in Sept. 1999 and Aug. 2000, with regression line through data. Vertical bars scaled to standard error of Y estimate. Regression is statistically significant (p < 0.10). See Table 13 for additional results and details.



Additional statistical analysis also indicates that mean levels of surface fine sediment by stream and year from visual estimates and the grid method yield comparable results. Table 14 contains the results of *F*- and *t*-tests (two-tailed) of the hypotheses that the variance and means are the same, respectively, between the visual estimates and grid method in each monitored stream by year. In the 12 cases analyzed (three years of data from reaches in four streams), there was only one case where surface fine sediment from visual estimates was statistically different from the mean via the grid method: in Granite Creek in 1999 (Table 14). In the same 12 cases, there was a statistically significant (p <0.10) difference variance between the two methods in 7 cases. We did not undertake similar statistical analyses of the differences between the pebble count and the other two methods, because of low numbers of samples from pebble counts in each case analyzed (n = 3 to 4).

As previously discussed, the data from the grid method and visual estimates at all 40 transects from 1998 - 2000 also indicate that visual estimates are a relatively accurate estimator of surface fines, as measured by the grid method (Tables 7, 9, and 11 and Figures 2-5 and 7-14). The use of visual estimates, instead of grid data, only lead to a different conclusion regarding the difference in means among streams in a given year in one case out of the 18 analyzed (Table 9). Data from visual estimates did not lead to significantly different conclusions regarding the direction, magnitude, and statistical significance of surface fine substrate trends in monitored reaches in each stream from 1998 - 2000 (Table 11 and Figures 7-14). Therefore, it appears that visual estimates provide a relatively accurate and unbiased estimator of surface fine sediment levels.

Table 14. Summary results of statistical test of hypotheses that grid method and visual estimate data for surface fine sediment have the same means and variances by stream and year. For each stream in each year, n=10, for each method.

Year	Stream	V. E. mean (%)	Grid method mean	F-test p - value	Hypothesis accepted at p < 0.10 (variances)	*t*-test (2-tailed) p - value	Hypothesis accepted at p < 0.10 (means)
1998	Catherine Cr.	1.9%	1.8%	0.021	V.E. ≠ Grid method	0.913	V.E. = Grid method
1998	Grande Ronde	28.8%	25.4%	0.470	V.E. = Grid method	0.532	V.E. = Grid method
1998	Granite Cr.	11.8%	11.1%	0.030	V.E. ≠ Grid method	0.881	V.E. = Grid method
1998	NFJDR	18.7%	16.8%	0.020	V.E. ≠ Grid method	0.480	V.E. = Grid method
1999	Catherine Cr.	2.3%	1.9%	0.066	V.E. ≠ Grid method	0.747	V.E. = Grid method
1999	Grande Ronde	13.3%	9.9%	0.348	V.E. = Grid method	0.261	V.E. = Grid method
1999	Granite Cr.	11.3%	7.2%	0.026	V.E. ≠ Grid method	0.065	V.E. ≠ Grid method
1999	NFJDR	26.3%	27.8%	0.138	V.E. = Grid method	0.626	V.E. = Grid method
2000	Catherine Cr.	2.0%	1.3%	0.465	V.E. = Grid method	0.231	V.E. = Grid method
2000	Grande Ronde	9.9%	7.7%	0.002	V.E. ≠ Grid method	0.119	V.E. = Grid method
2000	Granite Cr.	3.7%	4.2%	0.173	V.E. = Grid method	0.358	V.E. = Grid method
2000	NFJDR	32.1%	30.2%	0.034	V.E. ≠ Grid method	0.687	V.E. = Grid method

We have assumed that the grid method is the most accurate measure of surface fine sediment levels for several reasons. First, it is based on measurement rather than visual estimates. Second, unlike pebble counts, it explicitly measures fine sediments < 6.35 mm at the surface of the substrate. In contrast, the amount of fine sediment at the surface estimated by pebble counts is based on interpolation, rather than direct measurement, which can reduce accuracy (Nelson et al., 1996; 1997). Third, it is well-documented that pebble counts tend to underestimate the amount of surface fine sediment for several reasons, including that it is difficult to sample finer particles between the interstices of larger particles (Bauer and Burton, 1993; Nelson et al. 1996). Fourth, accuracy typically increases with sample number. The grid method, as employed in this study, uses 500 sample points at a transect while the pebble count method typically uses only 100. However, the sample points in the grid method are clustered, rather than widely distributed, across a transect and may be affected by heterogeneity at the sampling scale, which may affect accuracy.

Although the literature indicates that pebble counts tend to underestimate surface fine sediment, our results do not indicate this, uniformly. Based on our data, pebble counts tend to overestimate surface fine sediment at low values and underestimate it at high values, albeit with considerable scatter. This indicates that pebble counts may be the most insensitive of the three methods for detecting differences in fine sediment levels over time or between streams, which is a clearly undesirable trait in a monitoring technique.

Our results indicate that visual estimates also tend to overestimate surface fines at low levels and underestimate them at higher levels, relative to grid data, although to a lesser degree than pebble counts. Thus, it appears that visual estimates may be better able to detect differences among streams or over time than pebble counts.

The time required to evaluate surface fines varies considerably among the three methods. The field time required for measurement of surface fines at a transect via the grid method requires 10-20 minutes, while visual estimates by trained observers requires about 5 minutes (not including training and calibration), and pebble counts require 40-60 minutes depending on channel and stream conditions. The time needed for data entry and analysis also vary. For a single transect, visual estimates require no appreciable office time, while grid method data requires about 5 minutes and the pebble count data takes about 15 minutes to enter and evaluate, once spreadsheet algorithms for interpolation are in place.

Logistical considerations also vary among the methods. Visual estimates and the grid method require relatively high water clarity. The visual estimates also require relatively low surface turbulence. Both the grid method and pebble counts require traversing streams, which is unsafe at higher flows.

The methods also vary in potential outputs. Unlike the other two methods, the pebble count method can be used at the transect scale to estimate the median and geometric mean particle size of surface substrate, as well as the size of substrate at varying levels of the cumulative frequency distribution. Such information can be used to evaluate bed stability and channel sediment transport (Reid and Dunne, 1996). The pebble count can also be used to develop summary statistics on particle sizes, although it can not be used to develop variance estimates for smaller fractions, such as surface fine sediment. Notably, fine sediment fractions clearly have the greatest effect on salmonid survival (See review in Rhodes et al., 1994) and are the size fraction most sensitive to land management effects (Young et al., 1991).

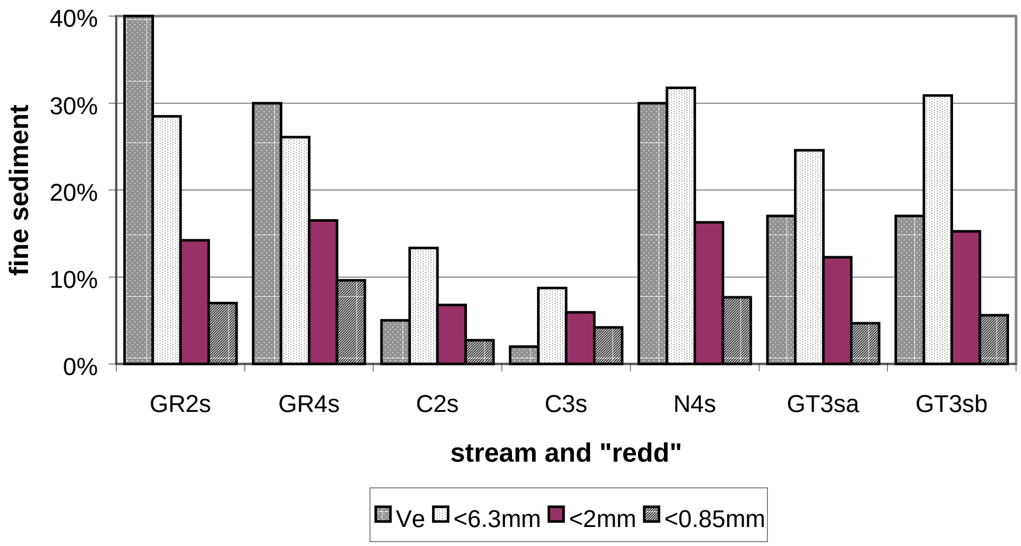
At the transect scale, the grid method data can be analyzed for estimates of central tendency and variance for surface fines, but not for other size fractions. It also provides an indication of how fine sediment levels vary across the channel at a transect, which the other two methods do not. Data from visual estimates cannot be used to generate estimates of central tendency or variance at the transect scale. Multiple observations by multiple observers can be used to examine observer bias and variation in estimation, but this does not provide an estimate of natural variation in surface fine sediment levels across the channel at the transect scale. However, visual estimates can be made at multiple transects within reaches or streams allowing analysis of the mean and variance at the reach or stream scale. Further, visual estimates by trained observers integrate conditions across a channel and may avoid errors associated with the point and clustered point sampling in pebble counts and the grid method.

Due to the pebble count method's apparent relative insensitivity to difference in surface fine sediment levels over time and space, lower relative accuracy, and relatively high time requirements for collection and analysis, it appears to be the least desirable method for monitoring surface fine sediments among the three used in this study. Visual estimates by trained observers correlate well with data generated by both other methods and require the least time to conduct. Where extensive measurements are needed in limited time and at limited expense, visual estimates of surface fines can be used where statistical variation at the transect scale is not the primary concern. However, we emphasize that if some degree of accuracy is to result from visual estimates, it must be done by trained observers with frequent calibration with measurements, as other experienced stream surveyors have repeatedly noted (C. Huntington, Principal Biologist, Clearwater BioStudies, Inc., pers. comm.) Where statistical analysis at the transect scale and accuracy are more important than logistical expediency, the grid method appears to be the preferred approach based on our data, especially since it does not require much greater field and analysis time than the visual estimates.

1998 Bulk Substrate Sampling and Mid-Winter Sedimentation Results

The results of the bulk substrate sampling in Sept. 1998 and the collection of containers of cleaned gravels in constructed "redds" in Dec. 1998 are shown in Table A-3 and Figures 18, 19, and 20. The amount of fine sediment by weight in bulk substrate samples from Sept. 1998 were generally higher than the levels of surface fine sediment as measured by the grid method or visually estimated (Figure 18). This result corroborated field notes from Catherine Creek, NFJDR, and Granite Creek, where it was observed that fine sediment levels at depth were higher than at the surface (Table A-3). Such gradation in sediment sizes with depth is common in streams where the supply of fine sediment does not exceed the capacity of a stream to transport fine sediment (Richards, 1982). In the Grande Ronde River, surface fine sediment levels exceeded the amount of fine sediment by weight at depth in bulk samples, possibly indicating a surfeit of fine sediment supply with respect to transport capacity.

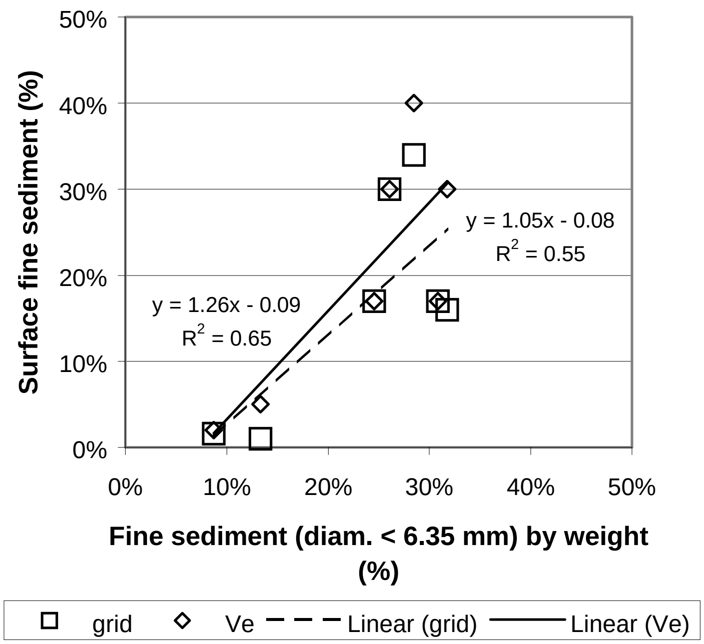
Figure 18. Visually estimated surface fine sediment levels and fine sediment by weight in bulk substrate samples collected at constructed "redds" in the four study streams in Sept. 1998. GR = Grande Ronde; C = Catherine Cr.; N = NFJDR; GT = Granite Creek. Numbers refer to enumerated "redds" (Table 1); "s" denotes samples collected by shovel; Ve = visual estimate of percent surface fine sediment at the location of the bulk sample. The three size fractions are all percent by weight.



Surface fine sediment levels measured both by the grid method and visually estimated were related, in a statistically significant fashion ($p < 0.10$), to the amount of fine sediment by weight with a diameter < 6.35 mm in the bulk samples collected by shovel. Visually estimated surface fine sediment exhibited greater correlation with the amount of fine sediment by weight < 6.35 mm in the bulk samples, than surface fines measured by the grid (Figure 19). However, this relationship is based on very few bulk samples collected in very few places in the four streams. The amount of fine sediment at depth typically exhibits considerable spatial variation (Everest et al., 1987). Increasing the sample number at a specific location probably would have increased the variability, although the two samples collected near "redd" GT3 in Granite Creek exhibited relatively little variation in the magnitude of the three size fractions (Table A-3 and Figures 18 and 19).

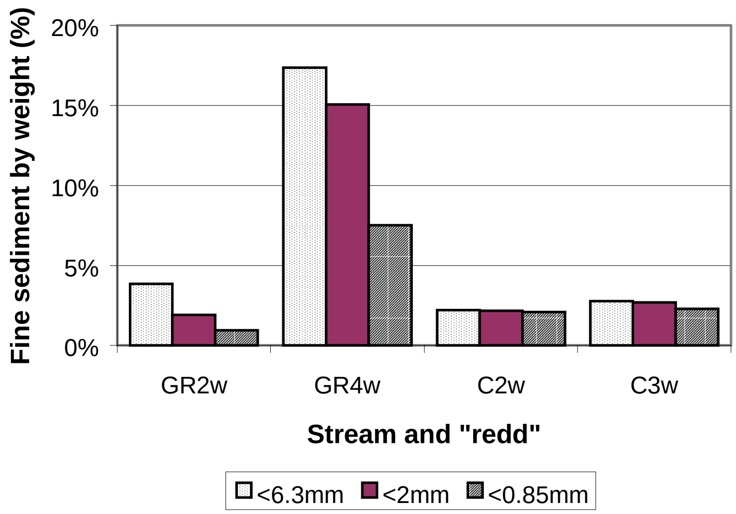
If there is a relationship between surface fine sediment and the amount of fine sediment at depth, it is likely to vary among streams (Nelson et al., 1996). The analysis in Figure 19 lumps all the data into a single population, which may not be merited. We will continue to analyze these potential relationships in the future, as more data is collected.

Figure 19. Scattergram of visually estimated (Ve) and measured (grid) surface fine sediment vs. percent fine sediment < 6.35 mm (% by weight) at locations where bulk substrate samples were collected by shovel in study streams in Sept. 1998 and regression lines through data. Measured surface fine sediment data is from site closest to the bulk sample collection point.



The results of the mid-winter monitoring of sedimentation in containers of cleaned gravels in constructed "redds" indicates that sedimentation occurs early in the incubation period for spring chinook salmon eggs (Figure 20). In at least one case, the sedimentation was significant. In "redd" 4 in the upper Grande Ronde River (Figure 20), the container collected in Dec. 1998 had ~17% fine sediments by weight for the fraction < 6.35mm. This was as high as any of the samples collected later in April 1999 (Table A-4), indicating that the sample was already at capacity for fine sediments in the container, as field notes also indicated (Table A-3). Although fine sediment accumulation from Sept.-Dec. 1998 was variable between the two reaches and at the two sites in the Grande Ronde (Figure 20), it is clear that measurable overwinter sedimentation is occurring during this period. It also appears, based on the limited sample numbers, that the amount of overwinter sedimentation for the < 6.35mm fraction was higher from Sept.-Dec. 1998 in the Grande Ronde than in Catherine Creek (Figure 20). This may be related to the amount of mobile fine sediment at the substrate surface which can be transported and re-deposited, even at low stream discharge levels (Leopold, 1992; Booth and Jackson, 1997). The mean surface fine sediment measured via the grid method was 25.4% in the Grande Ronde River study reach and 1.8% in Catherine Creek. However, the limited sample numbers make it impossible to analyze the statistical significance and the apparent result may be due solely to the small sample size.

Figure 20. Fine sediment by weight for three size fractions in constructed redds in containers of cleaned gravels collected in Dec. 1998. GR = Grande Ronde; C = Catherine Creek; numbers correspond to enumerated "redds" as in Table 1; "w" denotes sample collected in winter. In Sept. 1998, mean measured surface fine sediment was at 25.4% in the Grande Ronde and 1.8% in Catherine Creek.

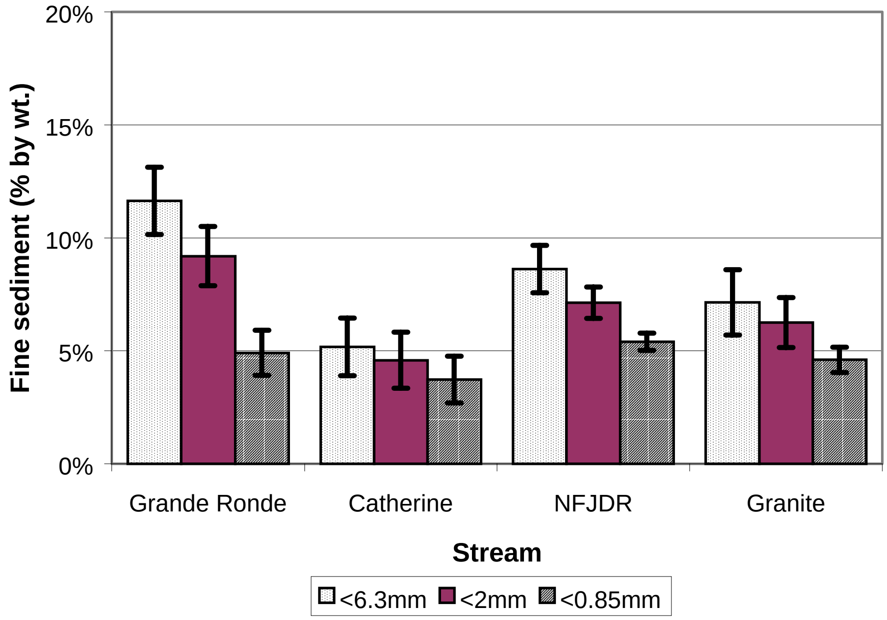


In Catherine Creek, sedimentation in containers in Dec. 1998 was almost solely comprised of fine sediment < 0.85 mm (Table A-3 and Figure 20). The fine sediments in the Grande Ronde samples were more evenly distributed among the three size classes, but were primarily comprised of sediment < 2.0 mm (Table A-3 and Figure 20). Collection notes indicated no bridging or surface sealing by fine sediment in the upper layers of the samples in Dec. 1998 (Table A-3). Other researchers have found that bridging or surface sealing from fine sediment occurs during the salmonid incubation period in northern California (Lisle, 1989) and Idaho (King et al., 1992; Maret et al., 1993).

<u>Overwinter sedimentation Sept. 1998-April 1999</u>

The results of overwinter sedimentation in the four study streams indicate that overwinter sedimentation occurred consistently in all sites where samples were recovered in April 1999. Table A-4 displays the complete results for all recovered samples, including field collection notes. Figure 21 shows the mean overwinter sedimentation for all four streams for three of the size fractions analyzed. In Granite Creek in April 1999, we were unable to recover samples at two constructed redd sites. Both areas exhibited significant signs of channel change due to the high spring runoff caused by a deep snowpack with a relatively long return period. One of the sites with unrecovered samples exhibited evidence of significant deposition, probably burying the samples deeply; the other site showed evidence of substantial scour, probably washing out the sample containers (Table A-4).

Figure 21. Mean overwinter fine sediment (% by weight) for three size fractions of fine sediment in containers collected in April 1999 in each of the four monitored streams. Vertical bars show magnitude of 90% confidence interval.



There were statistically differences in the level of overwinter sedimentation between some of the monitored streasms. Mean overwinter sedimentation by fine sediment was highest in the Grande Ronde for all but the < 0.85mm size fraction (Table 15). This difference between the Grande Ronde and the other three streams was statistically significant at $p < 0.10$ for the largest two size fractions (Table 15). For the <0.85mm size fraction, the mean for the Grande Ronde can be accepted as being equal to the means in the NFJDR and Granite Creek ($p < 0.10$). In Catherine Creek, mean overwinter fine sediment was lower than in the Grande Ronde and NFJDR (Table 15 and Figure 21) in a statistically significant fashion ($p < 0.10$).

For the < 6.35mm size fraction, the following can be accepted for the 1999 stream means, using statistical significance level of $p < 0.10$: Grande Ronde > NFJDR > Granite Cr. > Catherine Cr. For the < 2mm size fraction the following can be accepted for the 1999 stream means using statistical significance level of $p < 0.10$: Grande Ronde > NFJDR = Granite Cr. > Catherine Cr. The stream means for the < 0.85mm departed slightly from the pattern exhibited among streams by the other two size fractions, with the following accepted at $p < 0.10$: NFJDR = Grande Ronde > Catherine Cr., NFJDR > Granite Cr. = Catherine Cr., and Grande Ronde = Granite Cr. Additional detail and results are summarized in Table 15.

Table 15. Results *F*- and *t*-tests, summary of hypotheses accepted (p < 0.10), and mean overwinter fine sediment by size fraction category in containers collected April 1999. The hypotheses accepted in t-test p-value column are for stream means, based on the results of one-tailed *t*-test.

Year	streams	n	% <6.3mm			% <2.0mm			% < 0.85mm		
			Mean (% by wt.)	*F*-test *p-value*	*t*-test *p-value*	Mean (% by wt.)	*F*-test *p-value*	*t*-test *p-value*	Mean (% by wt.)	*F*-test *p-value*	*t*-test *p-value*
1999	Cat. Cr.	10	5.2	0.284	0.001	4.6	0.050	0.005	3.7	0.003	0.015
	NFJDR	10	8.6			7.1			5.4		
	Hypotheses accepted	--	--	Var. equal	NFJDR >Cat. Cr.	--	Var. not equal	NFJDR >Cat. Cr.	--	Var. not equal	NFJDR > Cat. Cr.
1999	Cat. Cr.	10	5.2	0.326	<0.001	4.6	0.436	<0.001	3.7	0.453	0.097
	GRR	10	11.6			9.2			4.9		
	Hypotheses accepted	--	--	Var. equal	GRR > Cat. Cr.	--	Var. equal	GRR > Cat. Cr.	--	Var. equal	GRR > Cat. Cr.
1999	Cat. Cr.	10	5.2	0.407	0.063	4.6	0.216	0.077	3.7	0.034	0.122
	GT	6	7.1			6.3			4.6		
	Hypotheses accepted	--	--	Var. equal	GT >Cat. Cr.	--	Var. equal	GT > Cat. Cr.	--	Var. not equal	GT = Cat. Cr.
1999	NFJDR	10	8.6	0.155	0.007	7.1	0.037	0.019	5.4	0.004	0.231
	GRR	10	11.6			9.2			4.9		
	Hypotheses accepted	--	--	Var. equal	GRR > NFJDR	--	Var. not equal	GRR > NFJDR	--	Var. not equal	GRR = NFJDR
1999	NFJDR	10	8.6	0.405	0.094	7.1	0.276	0.132	5.4	0.346	0.032
	GT	6	7.1			6.3			4.6		
	Hypotheses accepted	--	--	Var. equal	NFJDR > GT	--	Var. equal	NFJDR = GT		Var. equal	NFJDR > GT
1999	GRR	10	11.6	0.275	0.003	9.2	0.182	0.012	4.9	0.041	0.334
	GT	6	7.1			6.3			4.6		
	Hypotheses accepted	--	--	Var. equal	GRR > GT	--	Var. equal	GRR > GT	--	Var. not equal	GRR = GT

The patterns in overwinter sedimentation among streams from 1998 -1999 appear to be related to the amount of mobile fine sediment at the substrate surface. Surface fine sediment can be easily transported and re-distributed, even at low stream discharge levels (Leopold, 1992; Booth and Jackson, 1997). Regression analysis of overwinter sedimentation in samples collected in April 1999 and mean stream surface fine sediment levels measured in Sept. 1998, during sample placement, indicate that the overwinter sedimentation was correlated with surface fine sediment levels in a statistically significant fashion for all three size fractions (Table 16 and Figures 22-25).

Figure 22. Scattergram of fine sediment < 6.3mm in all containers recovered April 1999, in all four streams vs. mean grid-measured surface fine sediment in each stream Sept. 1998, with regression line through data.

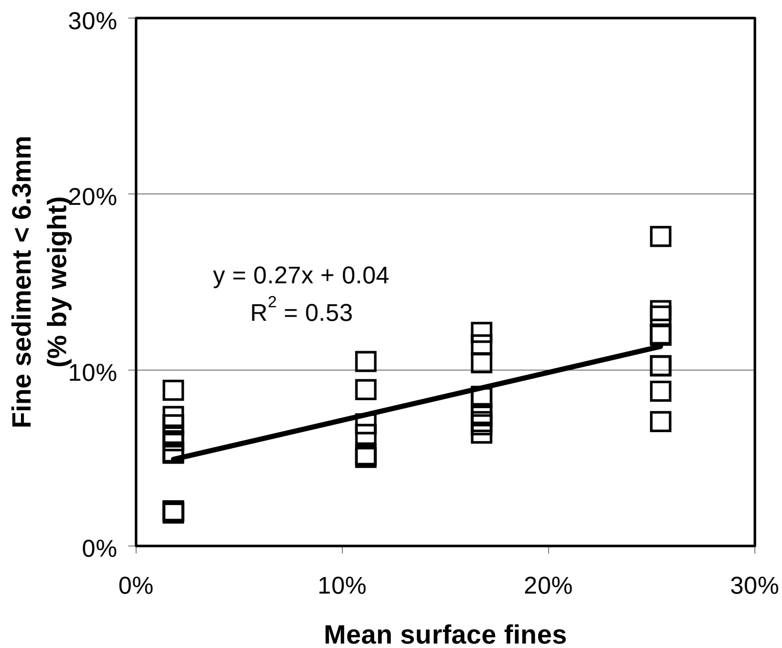


Figure 23. Scattergram of fine sediment < 2.0mm in all containers recovered April 1999, in all four streams vs. mean grid-measured surface fine sediment in each stream Sept. 1998, with regression line through data.

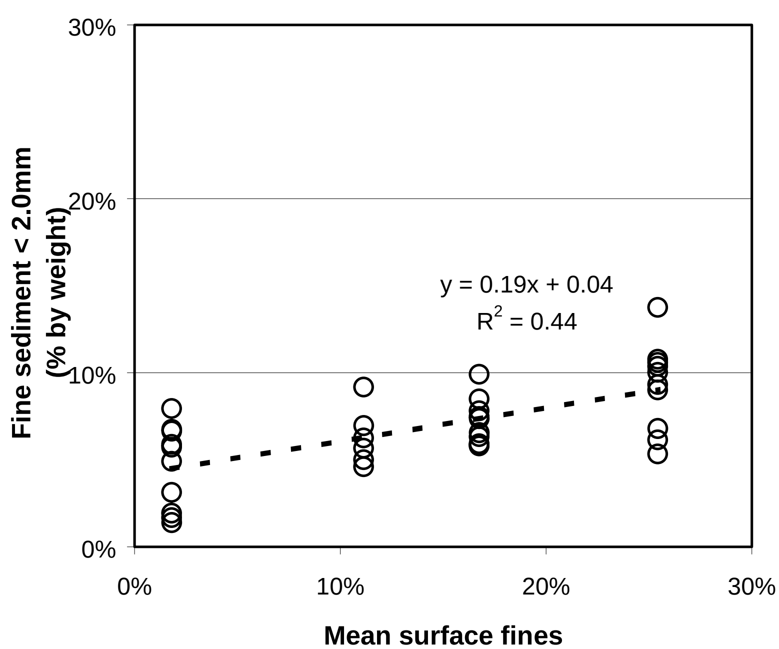


Figure 24. Scattergram of fine sediment < 0.85mm in all containers recovered April 1999, in all four streams vs. mean grid-measured surface fine sediment in each stream Sept. 1998, with regression line through data.

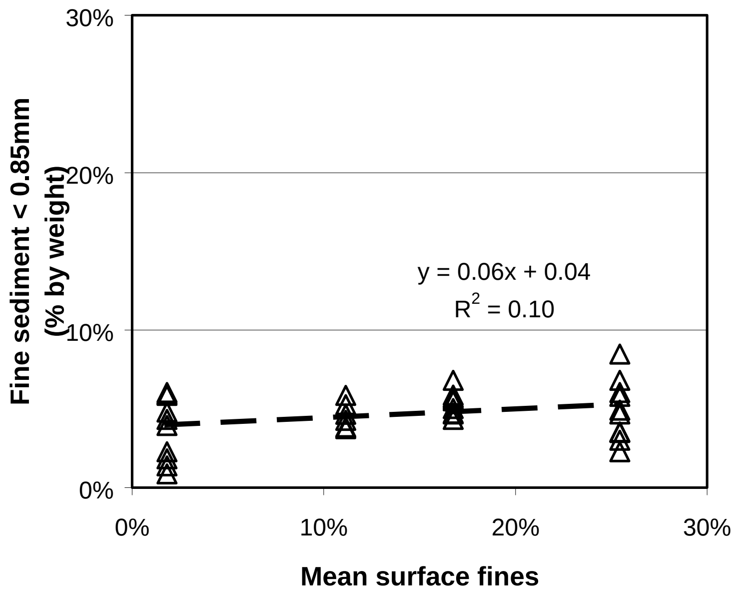


Table 16. Results of regression analysis of three size fractions of overwinter fine sediment in containers collected in April 1999 vs. mean surface fine sediment measured (grid) in each of the four monitored streams in Sept. 1998. The p - value is for the null hypotheses, e.g., that the three size fractions of overwinter fine sediment are not related to mean surface fine sediment (slope of the regression line = 0). These null hypotheses can be rejected at $p < 0.10$.

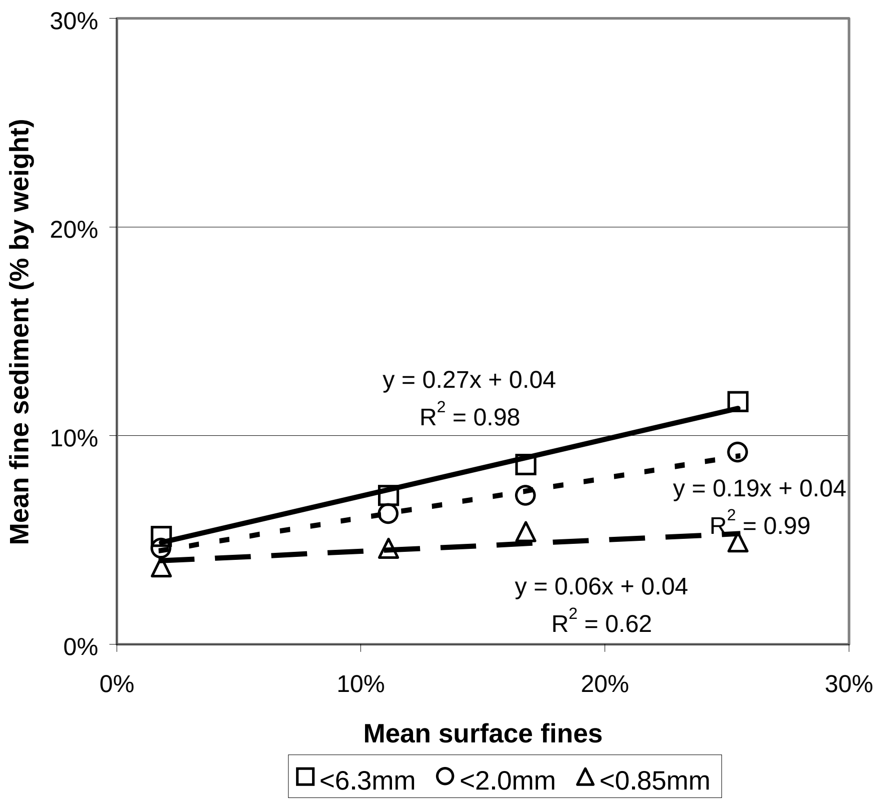
Year	Y - Value	X - Value	n	R2	Slope	Intercept	Std. Error	*p - value*
1999	Overwinter fine sediment < 6.3 mm (% by wt.)	Mean surface fine sediment (%)	36	0.53	0.27	4.4%	2.4%	< 0.001
1999	Overwinter fine sediment < 2.0mm (% by wt.)	Mean surface fine sediment (%)	36	0.44	0.19	4.1%	2.0%	< 0.001
1999	Overwinter fine sediment < 0.85mm (% by wt.)	Mean surface fine sediment (%)	36	0.10	0.06	3.9%	1.6%	0.061

Overwinter fine sediment and surface fine sediments may be linked for reasons other than the supply of mobile fine sediment at the substrate. Surface fine sediment may be an index of fine sediment at depth in the upper part of the substrate as found in Sept 1998 (Figure 19). Fine sediment in the upper substrate may be a source of overwinter fine sediment, released by winnowing during low flows, or via bed mobilization at higher flows. Surface fine sediment may also be an index of general fine sediment supply from all sources of overwinter sedimentation, including substrate, banks, overland flow, etc.

The regression analysis indicates that the < 6.35mm and < 2mm size fractions in overwinter sedimentation may be the most responsive to surface fine sediment levels. The slopes of the regression lines for these fractions were higher than the slope for the < 0.85mm fraction. These differences in slopes were statistically significant at the 95% confidence interval.

When overwinter fine sediment samples collected in 1999 are averaged on a stream basis for all three size fractions, the relationship becomes even clearer (Figure 25). Although the degree of correlation between mean overwinter fine sediment levels and mean surface fine sediment at the onset of spawning is partially due to the use of stream means of overwinter fine sediment (which reduces scatter and variability), the relationship is still compelling. Nonetheless, the apparent tightness of the relationship between overwinter fine sediment may be an artifice of the analysis of only one year's worth of data. Over the next year we will complete similar analysis of three years of overwinter fine sediment data.

Figure 25. Scattergram of mean overwinter fine sediment (% by weight) in each stream for all three size fractions April 1999 vs. mean grid-measured surface fine sediment in each stream Sept. 1998, with regression line through data.



It is extremely likely that many other variables influence overwinter sedimentation levels, besides the amount of mobile fine sediment at the substrate surface. One of the most obvious is discharge, which we will soon begin analyzing for its potential role in explaining variations in overwinter sedimentation levels. However, it is somewhat unlikely that discharge will explain the variation. Although we have not analyzed stream discharge, based on watershed area, stream widths, and field notes it is likely that
descending order of discharge magnitude is: Catherine Cr. > NFJDR > Granite Cr. > Grande Ronde. Since this does not correspond to the descending order of overwinter sedimentation levels by stream, discharge levels in the streams are unlikely to explain much of the variation in overwinter sedimentation. Additionally, investigations in previous years found no statistical relationship between overwinter sedimentation levels and several measures of discharge either among years or streams in a given year (Rhodes and Purser, 1998).

We found no clear evidence of bridging or surface sealing in the overwintering containers collected in April 1999 in the Grande Ronde, Catherine Creek, and Granite Creeks (See collection notes in Table A-4). Although samples from the NFJDR did not clearly exhibit bridging or surface sealing, fine sediment in the collected containers exhibited a clear gradation in particle size with depth, with finer fine sediment at the bottom of the containers that at the surface (Table A-4).

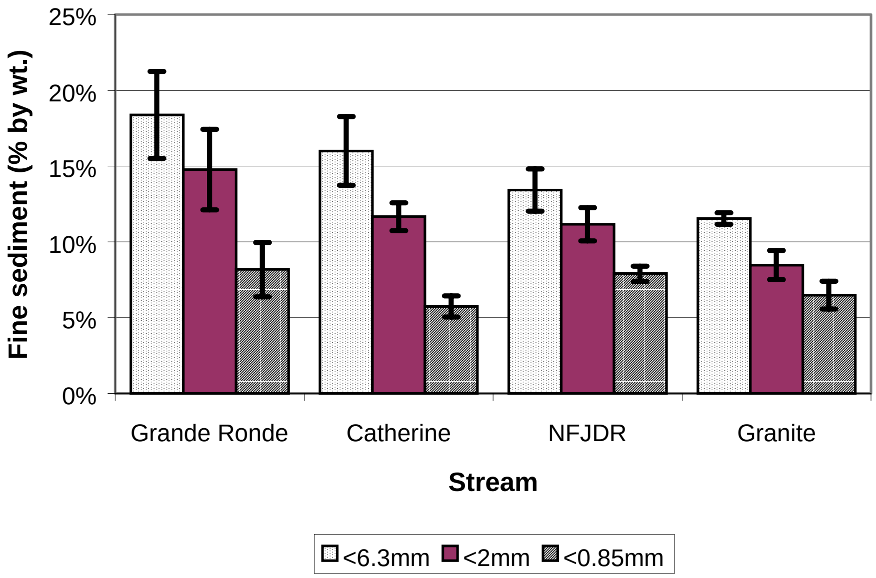
Any one, or combination, of the following phenomena could have caused the gradation in fine sediment size with depth in the NFJDR samples. First, fine sediment size fractions may be sequentially mobilized by flows of differing magnitude. Lower initial flows may transport silts and clays and deposit them at the base of the containers of cleaned gravels and higher flows later may transport sands with subsequent deposition above the finer deposited sediment. Second, differential settling of particle sizes within the containers may be occurring after initial deposition, causing a "sieving effect." Third, differential scour may be occurring in the upper layers of the containers, winnowing out the finest size fractions. Fourth, partial bridging may be occurring once larger sizes of fine sediment are deposited in the cleaned gravels under a sequential particle size transport regime.

Overwinter sedimentation Sept. 1999-April and May 2000

The results of overwinter sedimentation in the four study streams indicate that overwinter sedimentation occurred consistently in all sites where samples were recovered in April and May 2000. Table A-5 displays the complete results for all recovered samples, including notes from field collection. Figure 26 shows the mean overwinter sedimentation for all four streams for three of the size fractions analyzed, for samples that were recovered.

High flows from rain-on-snow during the peak snowmelt period prevented recovery of all samples, and recovering all samples at the same time. In April 2000, we were able to recover all samples in the Grande Ronde, but only 4 out of 10 samples in the NFJDR, apparently due to high levels of channel scour (See field notes in Table A-5). In early May in Granite Creek, we were unable to recover samples at one constructed redd site, due to high flows from rain-on-snow. We were able to recover 8 of the 10 samples in Catherine Creek, but six of these could not be recovered until mid-May, due to high flows from rain-on-snow.

Figure 26. Mean overwinter fine sediment (% by weight) for three size fractions of fine sediment in containers collected in April and May 2000 in each of the four monitored streams. Vertical bars show magnitude of 90% confidence interval.



In samples recovered in 2000, overwinter fine sediment levels in all streams were considerably higher than in samples recovered in 1999. In the near future, we will analyze the data to determine the statistical significance of differences in overwinter sedimentation, for all three size fractions, among streams in samples collected in 2000, and within streams between 1999 and 2000.

In contrast to the 1999 results, overwinter fine sediment levels in samples collected in 2000 was not related, in a statistically significant fashion, to surface fine sediment levels at the onset of incubation (Table 17). There are several possible reasons for these departures from the 1999 results. First, most of the samples were in the streams for longer than in 1998-1999. It is likely that overwinter sedimentation increases with increased time in-channel, other factors remaining equal.

Second, field notes indicate that high flows in April and May 2000 were considerably higher than during the same period in 1999, although we have not verified this with gaging records. Other factors remaining equal, it is likely that overwinter sedimentation increases with increased discharge.

Table 17. Results of regression analysis of three size fractions overwinter fine sediment in containers collected in April and May 2000 vs. mean surface fine sediment measured (grid) in each of the four monitored streams in Sept. 1999. The p - value is for the null hypotheses, e.g., that the three size fractions of overwinter fine sediment are not related to mean surface fine sediment (slope of the regression line = 0). The null hypotheses can be accepted for all three size fractions.

Year	Y - Value	X - Value	n	R2	Slope	Intercept	Std. Error	*p - value*
2000	Overwinter fine sediment < 6.3mm (% by wt.)	Mean surface fines (%)	30	0.01	-0.05	15.8%	4.8%	0.643
2000	Overwinter fine sediment < 2.0mm (% by wt.)	Mean surface fines (%)	30	0.00	0.02	11.6%	4.1%	0.842
2000	Overwinter fine sediment < 0.85mm (% by wt.)	Mean surface fines (%)	30	0.08	0.08	6.2%	2.4%	0.143

Third, samples in some of the streams remained instream for considerably longer than other streams. In Catherine Creek, 75% of the recovered samples were subjected to high flows for about 27 days longer than samples from the NFJDR and the Grande Ronde and about 15 days longer than Granite Creek (Table A-5). This likely resulted in increased sedimentation in Catherine Creek relative to samples from other streams, especially due to the relatively high flows in April-May 2000. This effect, alone, is likely to have significantly swamped any potential relationship between surface fine sediments and overwinter sedimentation, because Catherine Creek had the lowest surface fine sediment levels measured in Sept. 1999.

Fourth, the results may have been biased due to recovery of only some of the samples in some of the streams. The highest potential for such bias is in the NFJDR, where only 40% of the samples were recovered.

Fifth, it appears that the spring 2000 flow events had effects on samples that differed among streams. Observations and field notes (Table A-5) indicate that the Grande Ronde samples exhibited no signs of scour, while all recovered samples in the NFJDR and Granite Creek exhibited signs of scour of fines in the upper 3-4 cm (~ 17-22% of total sample depth) of the containers. In Catherine Creek, three of the eight (37.5%) recovered samples exhibited scour of both fine and coarse sediments in the upper 3-8cm.

Sixth, the relationship between surface fine sediment levels and overwinter fine sediment found in 1999 may be an artifice of the analysis of one year's worth of data. Nonetheless, it is possible that the same relationship may have held in 2000 until high flows in spring scoured fines from the NFJDR samples and continued to deposit fine sediments in Catherine Creek from the time the other samples were collected in April, until the majority of the Catherine Creek samples were collected in May.

Streamflow is also a likely control on overwinter fine sediment levels. As mentioned, we will investigate this over the next year. However, it is unlikely that streamflow levels, alone, explain the variation in overwinter fine sediment levels found in 2000, because watershed areas, stream widths, and field notes all indicate that the likely descending order in high flows in the spring of 2000 was: Catherine Cr. > NFJDR > Granite Cr. > Grande Ronde. This order is considerably different than the descending order of overwinter fine sediment levels by stream (Figure 26). In the near future, we will obtain gage records, estimate flows in monitored reaches, and analyze their potential relationship with overwinter fine sediment levels.

In 2000, we found only one sample that had clear indications of bridging or surface sealing by fine sediments in the upper levels of the samples. However, many of the samples exhibited pronounced gradation in the particle size of overwinter fine sediment with depth, with the finest overwinter sediment at depth, based on field observations and sampling notes (Tables A-5 and 18).

Table 18. Number and percentage of samples recovered that exhibited bridging/surface sealing and/or fining of overwinter fine sediment with depth.

Stream	Samples recovered		Samples with overwinter fine sediment grading finer with depth		Samples with clear signs of bridging or surface sealing	
	n	(%)	n	(%)	n	(%)
Grande Ronde	10	100	6	60	0	0
Catherine Cr.	6	60	3	50	1	16.7
NFJDR	4	40	3	75	0	0
Granite Cr.	8	80	8	100	0	0
Total	30	75	20	67	1	3.3

The gradation in sediment sizes in the samples may be due one, or a combination, of the following: 1) sequential mobilization and deposition of clays, silts, and sands; 2) differential settling of particle sizes within the containers after initial deposition; 3) winnowing of finer size fractions in the upper layers of the containers via differential scour; or 4) partial bridging after larger sizes of fine sediment are deposited in the cleaned gravels under a sequential particle size transport regime.

Other Results

Consultation with NMFS on the projects potential effects on spring chinook salmon and their habitats was completed in Sept. 1998. NMFS concluded that the project was not likely to adversely affect the salmon or their habitats.

The summary of the findings from monitoring from 1992-1995 was published in a peer-reviewed conference proceeding (Rhodes and Purser, 1998). Results include the following. Fine sediment accumulation was highly variable, but occurred consistently, indicating that fine sediment is transported invariably during the winter incubation period for spring chinook salmon. The magnitude of sedimentation was related to surface fine sediment in a statistically significant fashion when data from all streams in all years were analyzed ($p < 0.01$); this was not the case in a single year among streams nor in the upper Grande Ronde River among all sampling years. Sedimentation was the highest in the upper Grande Ronde River where surface fine sediment levels were highest. The winnowing of fine sediment from redds by salmon is a transient condition in the monitored streams, especially where surface sediment is high. The magnitude of overwinter sedimentation collected in containers in constructed redds in the upper Grande Ronde River, was not related, in a statistically significant fashion, to stream discharge. In the upper Grande Ronde River, it appears that stream discharge or the availability of mobile fine sediment does not limit the magnitude of sedimentation during the incubation period. This may be because surface fine sediment levels are high and stream discharge regularly occurs at magnitudes that are adequate to transport fine sediment. It appears that overwinter sedimentation is reducing salmon survival-to-emergence in the study area and especially in the upper Grande Ronde River. Surface fine sediment appears to provide a statistically significant index of the susceptibility of redds to overwinter sedimentation in streams.

CONCLUSIONS

Analysis of surface fine sediment data from 1998 to 2000 indicate that visual estimates of surface fine sediment by trained observers provide a rapid, but fairly accurate means of estimating surface fine sediment levels. Visual estimates show no significant bias when compared to measurements of surface fine sediment via the grid method. The grid method has distinct advantages in situations where accuracy and a greater degree of flexibility to perform statistical analysis are of more concern than limitations in time and effort.

As others have noted (Nelson et al., 1996; 1997), estimates of surface fine sediment by pebble counts appear to have less accuracy than other methods. Our results indicate that pebble counts are relatively insensitive to detecting differences in surface fine sediment levels among sites or over time. Pebble counts also require significantly more time and effort for both data collection and analysis than the other two methods. The insensitivity of the pebble count method, together with the time and effort requirements, make it a poor choice for monitoring surface fine sediment conditions. For these reasons, we recommend that other methods for monitoring fine sediment should be used instead of the pebble counts, as others have recommended in evaluating the utility of various methods of monitoring fine sediment conditions in substrate (Nelson et al., 1996; 1997). This is especially important because fine sediments have consistently been shown to be the size fraction most deleterious to salmonid survival (Rhodes et al., 1994) and most affected by land management (Young et al., 1991). Notably, the pebble count method was not originally developed as a tool for monitoring fine sediments, but rather for characterizing the size of coarse bed, as the title of Wolman's (1954) paper attests.

In the Grande Ronde, it was uncertain if the surface fine sediment (< 20%) goals of CRITFC (1995) and NMFS (1995) were met in 1998, using a statistical significance level of $p < 0.10$. At $p < 0.15$, the hypotheses can be accepted that the fine sediment substrate goal were not met in the monitored reach of the Grande Ronde in 1998. In 1999 and 2000, the monitored reach in the Grande Ronde met the CRITFC and NMFS substrate goals at $p < 0.10$. The decreasing trend in surface fine sediment in the Grande Ronde from 1998 - 2000 was statistically significant ($p < 0.10$), indicating that it is likely salmonid survival from egg to emergence improved in this reach during this time period.

The monitored reach in Catherine Creek met the substrate goal from 1999-2000. Mean surface fine sediment levels in Catherine Creek were lower than in the other three streams, in a statistically significant fashion, from 1999 - 2000. Surface fine sediment levels in Catherine Creek exhibited no statistically significant trend from 1999 - 2000.

In the NFJDR in 1998, it is uncertain that the monitored reach met the < 20% surface fine sediment goal ($p < 0.10$), but at $p < 0.15$, it can be accepted that it met the substrate goal. In 1999 and 2000, the NFJDR monitored reach did not meet the substrate goal ($p <0.10$). In 1999 and 2000, mean surface fines were higher in the NFJDR than in all three other study streams and these differences were statistically significant ($p < 0.10$). The increasing trend in surface fine sediment in the NFJDR from 1998 - 2000 was statistically significant ($p < 0.10$), indicating salmonid survival from egg to emergence likely declined in this reach from 1999 - 2000. This trend in surface fine sediment in the NFJDR is anomalous in comparison with trends in the other three streams.

The monitored reach in the Granite Creek met the substrate goal of CRITFC (1995) and NMFS (1995) from 1998 - 2000. There was also a statistically significant decreasing trend in surface fine sediment levels in Granite Creek from 1998 -2000, indicating that salmonid survival from egg to emergence likely increased in this reach during that time period.

Bulk samples of substrate in 1998 by shovel indicate that fine sediment levels at depth (% by weight) were generally higher than the amount of surface fine sediment, as is typical in many streams. Initial results indicate that surface fine sediment levels, both measured (grid) and visually estimated, are related to fine sediment conditions at depth in a statistically significant fashion. This statistically significant relationship may be an artifice of small sample numbers and/or inappropriately lumping the samples from all four study streams into a single population for statistical analysis.

Samples collected in Dec. 1998 indicate that significant sedimentation occurs early in the incubation period in the Grande Ronde River and Catherine Creek. Although small sample numbers preclude a statistical assessment, the magnitude of overwinter sedimentation from Sept.-Dec. 1998 increased with increasing levels of surface fine sediment. The highest amount of sedimentation by fine sediment during this period occurred in the Grande Ronde where mean surface fine sediment measured by the grid method was 25.4%, in comparison to 1.8% mean surface fine sediment in Catherine Creek.

Samples collected in April 1999 and April - May 2000 indicate that overwinter sedimentation consistently occurs in clean gravels in environments mimicking salmon redds in all four monitored streams. In samples collected in 1999, mean overwinter fine sediment was higher in the Grande Ronde than in the other three streams for all but the < 0.85mm size fraction, at p <0.10. In Catherine Creek, mean overwinter fine sediment was lower than in the other three streams for all three size fractions ($p < 0.10$). The regression relationship between mean surface fine sediment and mean overwinter fine sediment was statistically significant for all three size fractions in samples collected in 1999. Preliminary information indicates that stream discharge is unlikely to explain the variation among streams in overwinter fine sediment levels in samples collected in 1999. These results are consistent with those previously documented by Rhodes and Purser (1998) in the study streams from 1992-1995.

In contrast to the 1998 - 1999 results, overwinter fine sediment levels in samples collected in April - May 2000 were not related to mean surface sediment levels in a statistically significant fashion, for any size fraction. This may be due to a number of factors including higher streamflows, reduced rate of recovery of samples from some streams, and differential duration of exposure to high flows among samples in streams. It may also be a reflection that the pattern found in the previous year's results were an artifice of limited data.

Consistent with statistical considerations and the results of most studies, increased sample numbers would have improved the resolution of the results. Although we will attempt to increase the number of sampling points for surface fine sediment levels in the forthcoming year, this attempt will have to be tempered by budgetary considerations. Collection of pebble count data together with the increased expense of analyzing larger volumes of overwinter sediment samples have seriously stressed the annual project budget. We may not be able to increase sampling effort in any aspect of the project without significantly increasing the annual budget. In the near future, we will use the results of the project to date to provide estimates of the increases in budget required to increase sampling efforts.

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Appendix A

Data from 1999 - 2000 Pebble Counts, 1998 Bulk Substrate Samples, 1998 Midwinter Sedimentation Samples, and 1998-1999 and 1999 - 2000 Overwinter Sedimentation Samples

Table A-1. Results of pebble counts at all transects where all three methods of characterizing surface fine sediment were used, Sept. 1999. SF = surface fine transect; numbers correspond to transect numbers by stream in Table 5.

Particle size (mm)	Grande Ronde Transects -- 9/5/99 (Cum. % < particle size)					Catherine Creek Transects -- 9/5/99 (Cum. % < particle size)				NFJDR Transects -- 9/5/99 (Cum. % < particle size)				Granite Creek Transects -- 9/5/99 (Cum. % < particle size)			
	GRSF2	GRSF4	GRSF5	GRSF8	Mean	CSF3	CSF9	CSF10	Mean	NSF4	NSF8	NSF10	Mean	GTSF5	GTSF7	GTSF8	Mean
1.2	4%	5%	4%	2%	3.8%	0%	0%	2%	0.7%	1%	2%	1%	1.3%	0%	2%	6%	2.7%
2.5	8%	7%	6%	6%	6.8%	1%	1%	3%	1.7%	12%	20%	15%	15.7%	16%	20%	24%	20.0%
6.0	21%	20%	22%	12%	18.8%	3%	2%	6%	3.7%	13%	21%	22%	18.7%	16%	20%	24%	20.0%
15.0	27%	26%	30%	16%	24.8%	4%	2%	9%	5.0%	15%	23%	25%	21.0%	16%	27%	30%	24.3%
31.0	35%	33%	35%	23%	31.5%	10%	7%	18%	11.7%	22%	25%	28%	25.0%	21%	46%	40%	35.7%
64.0	47%	43%	46%	30%	41.5%	24%	21%	26%	23.7%	29%	38%	38%	35.0%	33%	81%	71%	61.7%
128.0	83%	68%	69%	63%	70.8%	57%	64%	55%	58.7%	64%	59%	70%	64.3%	59%	99%	97%	85.0%
256.0	100%	96%	100%	97%	98.3%	97%	97%	94%	96.0%	89%	82%	92%	87.7%	90%	100%	100%	96.7%
512.0	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%	95%	97%	96.7%	98%	100%	100%	99.3%
1024.0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Results (linear interp.)																	
% < 6.35mm	21.3%	20.3%	22.4%	12.2%	19.0%	3.0%	2.0%	6.1%	3.7%	13.1%	21.1%	22.1%	18.8%	16.0%	20.3%	24.3%	20.2%
d16 (mm)	4.7	4.9	4.7	15.0	5.2	45.1	52.2	27.4	42.9	17.3	2.2	3.0	2.9	2.5	2.2	1.9	2.2
d50 (mm)	69.3	81.9	75.1	102.8	82.6	114.4	107.2	117.0	112.2	102.4	100.6	88.0	96.7	105.8	34.8	41.6	49.2
d84 (mm)	135.5	201.1	189.9	207.1	189.7	214.4	205.6	223.2	214.9	230.4	267.1	209.5	235.9	231.2	74.7	96.0	125.3

Table A-2. Results of pebble counts at all transects where all three methods of characterizing surface fine sediment were used, Aug. 2000. SF = surface fine transect; numbers correspond to transect numbers by stream in Table 5.

Particle size (mm)	Grande Ronde Transects -- 8/25/2000 (Cum. % < particle size)					Catherine Creek Transects -- 8/25/2000 (Cum. % < particle size)					NFJDR Transects -- 8/26/2000 (Cum. % < particle size)					Granite Creek Transects -- 8/26/2000 (Cum. % < particle size)				
	GRSF2	GRSF4	GRSF6	GRSF9	Mean	CSF1	CSF5	CSF7	CSF9	Mean	NSF3	NSF5	NSF7	NSF8	Mean	GTSF2	GTSF6	GTSF7	GTSF8	Mean
1.2	2%	0%	0%	0%	0.5%	0%	0%	0%	0%	0.0%	1%	0%	1%	1%	0.7%	0%	0%	4%	0%	1.0%
2.5	9%	5%	3%	4%	5.2%	4%	0%	4%	3%	2.8%	12%	19%	15%	18%	15.9%	3%	2%	6%	5%	3.9%
6.0	14%	11%	13%	8%	11.4%	4%	0%	6%	3%	3.3%	13%	28%	32%	34%	26.8%	8%	8%	13%	12%	10.0%
15.0	19%	16%	18%	14%	16.8%	5%	1%	11%	6%	5.8%	15%	33%	36%	37%	30.1%	12%	12%	21%	25%	17.1%
31.0	38%	22%	26%	28%	28.4%	12%	3%	19%	15%	12.3%	22%	36%	39%	41%	34.5%	21%	19%	37%	34%	27.9%
64.0	60%	40%	46%	44%	47.7%	32%	9%	30%	42%	28.3%	29%	42%	52%	47%	42.6%	35%	27%	66%	60%	47.0%
128.0	87%	78%	76%	79%	80.0%	70%	49%	69%	72%	64.9%	64%	62%	70%	66%	65.4%	62%	45%	89%	79%	69.0%
256.0	100%	98%	98%	100%	99.0%	100%	86%	96%	96%	94.5%	89%	88%	92%	94%	90.8%	91%	90%	99%	100%	95.2%
512.0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100.0%	98%	96%	100%	100%	98.5%	100%	100%	100%	100%	100%
1024.0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Results (linear interp.)																				
% < 6.35mm	14.1%	10.8%	13.2%	8.3%	11.6%	4.1%	0.0%	6.2%	3.1%	3.4%	13.1%	28.2%	32.3%	34.1%	26.9%	7.9%	7.9%	13.2%	12.3%	10.3%
d16 (mm)	9.9	14.5	11.4	17.3	13.7	37.3	75.2	25.0	32.2	38.6	17.3	2.3	2.8	2.4	2.5	22.2	25.4	9.6	9.0	13.6
d50 (mm)	48.9	80.4	72.5	75.0	68.6	94.3	131.5	96.8	81.1	101.9	102.4	89.6	58.1	73.6	84.7	99.4	141.6	45.9	51.3	72.7
d84 (mm)	120.5	166.8	174.5	158.5	154.9	188.4	249.1	199.1	192.0	210.6	230.4	236.3	211.0	209.2	221.8	224.1	237.9	113.6	156.5	201.5

Table A-3. Collection notes and percent by weight of fine sediment fractions in bulk samples collected by shovel (Sept. 1998) and sample containers collected midwinter (Dec. 1998) . Sample ID codes are as follows: GR = Grande Ronde; C = Catherine Creek; N = NFJDR; GT = Granite Creek; numbers reference “redd numbers” where samples were collected (see Table 2); s = collection by shovel; w = containers of cleaned gravels in “redds” collected in Dec. 1998.

Collection date	Sample ID	< 6.3 mm	Mean < 6.3 mm	< 2mm	Mean < 2mm	<0.85 mm	Mean <0.85 mm	Visually estimated (Ve) surface fines at collection time	Collection notes	mean surface fines for stream (n=10) in 9/98 (grid method)
(mo/d/yr)		(%)	(%)	(%)	(%)	(%)	(%)	(%)		(%)
09/05/98	GR2s	28.5%	27.3%	14.2%	15.4%	7.0%	8.3%	40.0%	--	25.44%
09/05/98	GR4s	26.1%		16.5%		9.6%		30.0%	--	
09/05/98	C2s	13.3%	11.0%	6.8%	6.4%	2.7%	3.5%	5.0%	Fine sediment levels higher at depth than at surface (armored)	1.82%
09/05/98	C3s	8.7%		5.9%		4.2%		2.0%	Fine sediment levels higher at depth than at surface (armored)	
09/05/98	N4s	31.8%		16.3%		7.7%		30.0%	--	16.76%
09/05/98	GT3sa	24.6%	27.7%	12.3%	13.8%	4.7%	5.1%	17.0%	Fine sediment levels higher at depth than at surface (armored)	11.14%
09/05/98	GT3sb	30.8%		15.2%		5.6%		17.0%	Fine sediment levels higher at depth than at surface (armored)	
12/05/98	GR2w	3.9%	10.6%	1.9%	8.5%	1.0%	4.2%	18.0%	Signs of fine sediment fill: duned/drifted sands, buckets not filled to capacity, fine sediment mainly sand, no bridging, filling from bottom up. Log sill upstream may be trapping fines in transport. Surface fines measured by grid as in 9/98 (n=5)=19.8%.	25.44%
12/05/98	GR4w	17.4%		15.1%		7.5%		30.0%	Duned/drifted sands, all buckets filled to capacity, fine sediment mainly sand, no bridging. Surface fines measured by grid as in 9/98 (n=5)=28.6%. GR1-5 all show infilling, but GT4 the most.	
12/05/98	C2w	2.2%	2.5%	2.2%	2.4%	2.1%	2.2%	3.0%	No signs of scour/fill, buckets not filled to capacity, fine sediment mainly silt, no bridging, filling from bottom up.	1.82%
12/05/98	C3w	2.8%		2.7%		2.3%		3.0%	No signs of scour/fill, buckets not filled to capacity, fine sediment mainly silt, no bridging, filling from bottom up.	

Table A-4. Collection notes and overwinter fine sediment in samples recovered in April 1999. Sample ID codes are as follows: GR = Grande Ronde; C = Catherine Creek; numbers reference "redd numbers" where samples were collected (see Table 2).

Collection date	sample ID	< 6.3mm Samples	< 6.3mm Mean for stream	< 6.3mm 90% CI	< 6.3mm Std. dev.	< 2 mm Samples	< 2 mm Mean for stream	< 2 mm 90% CI	< 2 mm Std. dev.	< 0.85 mm Samples	< 0.85 mm Mean for stream	< 0.85 mm 90% CI	< 0.85 mm Std. dev.	Visually estimated surface fines 4/99	Collection notes	Mean surface fines (grid) for stream (n=10) 9/98
(mo/d/yr)		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)		(%)
04/12/99	GR1A	12.0%	11.6%	1.5%	2.9%	9.3%	9.2%	1.3%	2.5%	3.0%	4.9%	1.0%	1.9%	27%	No major signs scour or deposition at site. Fines to capacity in bucket, no bridging.	25.44%
04/12/99	GR1B	8.8%				6.8%				2.3%						
04/12/99	GR2A	10.2%				9.0%				4.7%				50%	In pool 5m upstream, Ve=70-80%. Duned/drifted fines at site. Fines to capacity in buckets, no bridging in 2a. Bridging in 2b.	
04/12/99	GR2B	12.0%				10.6%				4.9%						
04/12/99	GR3A	12.0%				10.0%				5.8%				35%	No major signs of scour/fill, fines to capacity in bucket, no bridging.	
04/12/99	GR3B	13.1%				10.8%				6.0%						
04/12/99	GR4A	13.4%				10.4%				6.8%				40%	Duned/drifted fines, also on N. bank outside of channel. Fines to capacity in bucket, no bridging.	
04/12/99	GR4B	17.6%				13.7%				8.5%						
04/12/99	GR5A	7.1%				5.3%				3.5%				45%	Duned/drifted fines, also on N. bank outside of channel. Fines to capacity in bucket, no bridging.	
04/12/99	GR5B	10.2%				6.1%				3.5%						
04/12/99	C1A	6.0%	5.2%	1.3%	2.5%	5.7%	4.6%	1.2%	2.4%	4.3%	3.7%	1.0%	2.0%	7%	Signs of scour: bucket tops now 2-5cm above bed. Fines mainly silt and not to capacity in bucket, no bridging.	1.8%
04/12/99	C1B	5.3%				4.9%				3.9%						
04/12/99	C2A	6.2%				5.9%				4.8%				5%	Signs of scour: bucket tops now 2-5cm above bed. Fines mainly silt and not to capacity in bucket, no bridging.	
04/12/99	C2B	8.9%				7.9%				6.0%						
04/12/99	C3A	6.9%				6.6%				5.9%				5%	No signs of scour/fill, buckets not to capacity, fines mainly silt, no bridging, 3a has higher levels of fines than all other samples in Cat. Ck.	
04/12/99	C3B	7.4%				6.7%				5.9%						
04/12/99	C4A	2.0%				1.6%				1.4%				3%	No signs of scour/fill. Fines mainly silt and not to capacity in bucket, no bridging.	
04/12/99	C4B	2.0%				1.9%				1.8%						
04/12/99	C5A	5.3%				3.1%				2.3%				3%	No signs of scour/fill. Fines mainly silt and not to capacity in bucket, no bridging.	
04/12/99	C5B	1.9%				1.4%				0.9%						

Table A-4 (cont'd). Collection notes and overwinter fine sediment in samples recovered in April 1999. Sample ID codes are as follows: N = NFJDR; GT = Granite Creek; numbers reference "redd numbers" where samples were collected (see Table 2).

Collection date	sample ID	< 6.3mm				< 2 mm				< 0.85 mm				Visually estimated surface fines 4/99	Collection notes	Mean surface fines (grid) for stream (n=10) 9/98
		Samples	Mean for stream	90% CI	Std. dev.	Samples	Mean for stream	90% CI	Std. dev.	Samples	Mean for stream	90% CI	Std. dev.			
(mo/d/yr)		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)		(%)
04/25/99	N1A	6.9%	8.6%	1.0%	2.0%	5.8%	7.1%	0.7%	1.3%	4.7%	5.4%	0.4%	0.7%	37%	No major signs of scour/fill, fines to capacity in bucket. Fines in bucket grade from sands at top to silt at bottom, possibly from bridging. Ve is poor, based on margins, flow highly turbid.	16.8%
04/25/99	N1B	11.4%				8.5%				5.9%						
04/25/99	N2A	6.4%				5.8%				4.7%				37%	No major signs of scour/fill, fines to capacity in bucket. Fines in bucket grade from sands at top to silt at bottom, possibly from bridging. Ve is poor, based on margins, flow highly turbid.	
04/25/99	N2B	7.4%				6.5%				5.7%						
04/25/99	N3A	8.4%				7.4%				5.6%				37%	No major signs of scour/fill, fines to capacity in bucket. Fines in bucket grade from sands at top to silt at bottom, possibly from bridging. Ve is poor, based on margins, flow highly turbid.	
04/25/99	N3B	12.1%				9.9%				6.8%						
04/25/99	N4A	7.1%				6.3%				5.0%				37%	No major signs of scour/fill, fines to capacity in bucket. Fines in bucket grade from sands at top to silt at bottom, possibly from bridging. Ve is poor, based on margins, flow highly turbid.	
04/25/99	N4B	8.5%				7.5%				5.7%						
04/25/99	N5A	10.4%				7.8%				5.5%				37%	No major signs of scour/fill, fines to capacity in bucket. Fines in bucket grade from sands at top to silt at bottom, possibly from bridging. Ve is poor, based on margins, flow highly turbid.	
04/25/99	N5B	7.5%				5.9%				4.3%						
04/13/99	GT1A	8.9%	7.1%	1.4%	2.2%	6.9%	6.3%	1.1%	1.7%	3.7%	4.6%	0.6%	0.8%	15%	Minor signs of variable scour/fill. Fines not to capacity in bucket, but at highest levels of GT samples, no bridging.	11.1%
04/13/99	GT1B	10.5%				9.1%				5.3%						
04/13/99	GT2A&B	nd				nd				nd				15%	Major signs of scour/fill, bed reworked, buckets not found, probably due to scour	
04/13/99	GT3A	6.9%				5.6%				4.3%				15%	Signs of variable scour/fill. Fines not to capacity in bucket, fines mainly silt, no bridging.	
04/13/99	GT3B	5.2%				4.6%				3.8%						
04/13/99	GT4A&B	nd				nd				nd				15%	Major signs of scour/fill, bed reworked, buckets not found, probably due to fill.	
04/13/99	GT5A	5.0%				5.0%				4.7%				15%	Signs of variable scour/fill. Fines not to capacity in bucket, fines mainly silt, no bridging.	
04/13/99	GT5B	6.3%				6.2%				5.9%						

Table A-5. Collection notes and overwinter fine sediment in samples recovered in April - May 2000. Sample ID codes are as follows: GR = Grande Ronde; C = Catherine Creek; numbers reference "redd numbers" where samples were collected (see Table 3).

Collection date	sample ID	< 6.3mm Samples	< 6.3mm Mean for stream	< 6.3mm 90% CI	< 6.3mm Std. dev.	< 2 mm Samples	< 2 mm Mean for stream	< 2 mm 90% CI	< 2 mm Std. dev.	< 0.85 mm Samples	< 0.85 mm Mean for stream	< 0.85 mm 90% CI	< 0.85 mm Std. dev.	Visually estimated surface fines 4/99	Collection notes	Mean surface fines (grid) for stream (n=10) 9/98
(mo/d/yr)		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)		(%)
04/21/00	GR1A	12.6%	18.4%	2.9%	5.5%	10.1%	14.8%	2.7%	5.1%	5.7%	8.2%	1.8%	3.4%	30%	Stringing sand in channel. Fines to capacity in bucket, grading finer with depth. Upper 6-10 cm in bucket is sand w/some silt, below this is primarily < silt w/some sand	9.9%
04/21/00	GR1B	20.8%				15.6%				8.2%						
04/21/00	GR2A	30.5%				27.5%				14.8%				30%	Lateral sand bars/deposition. Fines to capacity in buckets, fines grade finer with depth. Upper 6-10 cm in bucket is sand w/some silt, below this is primarily < silt w/some sand	
04/21/00	GR2B	15.9%				13.9%				8.0%						
04/21/00	GR3A	19.8%				11.8%				3.7%				30%	No major signs of scour/fill. Fines to capacity in bucket, fines do not grade finer with depth. Upper 6-10 cm is sand w/some silt, below is primarily < silt w/some sand	
04/21/00	GR3B	18.0%				11.3%				2.9%						
04/21/00	GR4A	14.8%				13.9%				9.2%				30%	Stringing sand in channel and lateral bars at margins. Fines to capacity in bucket, grading finer with depth. Upper 6-10 cm is sand w/some silt, below is primarily silt w/some sand	
04/21/00	GR4B	22.8%				18.2%				10.0%						
04/21/00	GR5A	17.3%				14.9%				10.4%				30%	No major signs of scour/fill. Fines to capacity in bucket, fines grade finer with depth. Upper 6-10 cm is sand w/some silt, below this is primarily < silt w/some sand.	
04/21/00	GR5B	11.4%				10.6%				8.8%						
05/18/00	C1A	18.2%	16.0%	2.5%	4.4%	11.3%	11.7%	1.0%	1.8%	4.6%	5.8%	0.8%	1.3%	5%	CC1A buried under about 0.1 m of cobble. Primarily silts filled in from bottom without bridging. Not to capacity. Unable to sample earlier due to high water. Late sampling may have increased deposition.	1.9%
05/18/00	C1B	16.6%				10.6%				4.4%						
05/18/00	C2A	19.9%				12.2%				4.3%				5%	CC2A has upper 5 cm scoured out. Signs of bridging about 10 cm into bucket. Primarily silts, midsection and below filled to capacity. Unable to sample earlier due to high water. Late sampling may have increased deposition.	
05/18/00	C2B	22.7%				14.2%				5.6%						
05/18/00	C3A	8.5%				8.2%				6.1%				5%	CC3A has top 5-8 cm scoured out. Primarily silts filled in from bottom. No sign of bridging. Not to capacity. Unable to sample earlier due to high water. Late sampling may have increased deposition.	
05/18/00	C3B	13.1%				11.8%				8.1%						
05/01/00	C4A	14.8%				12.2%				6.3%				5%	No major signs of scour/fill. Only CC4A found, due to scour/burial or high water. Fines primarily silts filling in from bottom. Not to capacity, no sign of bridging.	
05/01/00	C4B	nd				nd				nd						
04/21/00	C5A	14.2%				12.8%				6.7%				5%	No signs of scour/fill only CC5A found, due to scour/burial. Fines primarily silts filling in from bottom. Not to capacity, no sign of bridging.	
04/21/00	C5B	nd				nd				nd						

Table A-5 (cont'd) . Collection notes and overwinter fine sediment in samples recovered in April - May 2000. Sample ID codes are as follows: N = NFJDR; GT = Granite Creek; numbers reference "redd numbers" where samples were collected (see Table 3).

Collection date	sample ID	< 6.3mm Samples	< 6.3mm Mean for stream	< 6.3mm 90% CI	< 6.3mm Std. dev.	< 2 mm Samples	< 2 mm Mean for stream	< 2 mm 90% CI	< 2 mm Std. dev.	< 0.85 mm Samples	< 0.85 mm Mean for stream	< 0.85 mm 90% CI	< 0.85 mm Std. dev.	Visually estimated surface fines 4/99	Collection notes	Mean surface fines (grid) for stream (n=10) 9/98
(mo/d/yr)		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)		(%)
04/22/00	N1A	13.3%	13.4%	2.2%	2.7%	12.2%	11.2%	1.7%	2.1%	9.0%	7.9%	0.8%	1.0%	30%	Large scale sand deposits: lateral bars at channel margins, duning behind rocks, sample surface indicates scour of fines in upper 3-4 cm. Below that fines to capacity, with some fining with depth: 6-10 cm thick layer of sand and silt, remainder mainly silt. Possibly due to bridging, scour, or settling.	27.8%
04/22/00	N1B	16.4%				13.5%				8.3%						
04/22/00	N2A	14.1%				10.3%				6.9%				35%	Deposition on channel margins and behind rocks, but also scour, N2A protrudes ~ 8 cm above bed, tipped over and out of bed, from scour. N2A contents exhibit same pattern as N1: 1st 3-4 cm scoured of fines, remainder at capacity with 2nd 6-10cm layer at capacity, mainly sand, remainder at capacity with mainly silts	
04/22/00	N2B	nd				nd				nd						
04/22/00	N3A&B	nd				nd				nd				35%	Unable to find, either buried or scoured out.	
04/22/00	N4A&B	nd				nd				nd				35%	Both scoured out of bed, attached to twine. No collection.	
04/22/00	N5A	9.9%				8.6%				7.3%				35%	Signs of significant scour. Only N5A found, N5B probably scoured out. N5A contents exhibit same pattern as N1: 1st 3-4 cm scoured of fines, remainder at capacity with 2nd 6-10cm layer mainly sand, and remainder at capacity with mainly silt.	
04/22/00	N5B	nd				nd				nd						
05/04/00	GT1A	12.4%	11.5%	0.4%	0.7%	10.3%	8.5%	1.1%	1.9%	7.4%	6.5%	1.0%	1.8%	27%	Some fill behind rocks and channel margin. Upper 4 cm of sample has been scoured, remainder at capacity with a 5-8 cm layer sand, remainder mainly silt.	7.2%
05/04/00	GT1B	10.2%				9.1%				7.4%						
05/04/00	GT2A	10.9%				8.4%				6.4%				27%	Some fill behind rocks and channel margin. Upper 4 cm of sample has been scoured, remainder at capacity with a 5-8 cm layer mainly sand, remainder mainly silt.	
05/04/00	GT2B	11.1%				9.4%				7.4%						
05/04/00	GT3A	11.9%				9.4%				7.5%				40%	Some fill behind rocks and channel margin. Upper 4 cm of sample has been scoured, remainder at capacity with a 5-8 cm layer mainly sand, remainder mainly fine silt.	
05/04/00	GT3B	11.7%				9.8%				8.1%						
05/04/00	GT4&B	nd				nd				nd				25%	Not recovered, high flows to deep to reach.	
05/04/00	GT5A	12.4%				4.7%				2.9%				20%	Some fill behind rocks and channel margin. Upper 4 cm of sample has been scoured, remainder at capacity with a 5-8 cm layer primarily sand, remainder mainly fine silt.	
05/04/00	GT5B	11.7%				6.7%				4.8%						