#### COMPLETION REPORT

Monitoring Spawning Bed Material Used By
Bull Trout On the Glacier View District
Flathead National Forest

Prepared by

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Montana Department of Fish, Wildlife and Parks
Region 1, Kalispell, Montana
August 1982

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#### INTRODUCTION

Bull trout production in the upper Flathead Basin depends on limited spawning areas in tributary streams to the North and Middle Forks of the Flathead River. Spawning site (redd) inventories conducted by the Montana Department of Fish, Wildlife and Parks (MDFWP) during 1979, 1980 and 1981 located important spawning areas which were easily identified, limited in distribution and apparently site specific. The importance of these spawning areas cannot be over emphasized. The entire Flathead Lake - Flathead River bull trout fishery depends on the continued health of these spawning areas.

The Flathead National Forest manages the majority of land adjacent to these limited bull trout spawning areas. It is imperative that consideration be given to this valuable spawning habitat resource when Forest Service management activities are planned in drainages used by adult bull trout for spawning. Forest management activities can impact these spawning areas by increasing the amount of sediment delivered to the stream channel (Gibbons and Salo 1973). Sediment can affect spawning success by restricting intragravel flow of water resulting in reduced transport of oxygen to, and metabolic wastes from, the embryos (Gangmark and Bakkala 1960, Cordone and Kelly 1961, Coble 1961, McNeil and Ahnell 1964, Cooper 1965, Hall and Lantz 1968), and, in some instances, sediment can form a physical barrier entrapping fry attempting to emerge (Koski 1966, Phillips et al. 1975, Hausle and Coble 1976).

This study was initiated to design a substrate monitoring program of known bull trout spawning areas in four streams on the Glacier View District, Flathead National Forest. The objectives of the study were:

- Design a substrate monitoring program for the Glacier View District.
- Evaluate analysis by wet versus dry sieving of stream bed materials and recommend a preferred method.
- Determine the difference between reporting results as percent by weight versus percent by volume.
- 4) Calculate factors to convert wet volume to dry volume and determine the average density of the stream bed material for conversion from wet volume to dry weight.
- 5) Evaluate a visual method of identifying substrate composition.

#### STUDY AREA DESCRIPTION

Trail, Whale, Coal and Big creeks all drain the Whitefish Range on the west side of the North Fork of the Flathead River. The North Fork originates in the Rocky Mountains of British Columbia, Canada and flows

south, crossing the United States - Canada boundary into Montana, before joining the Middle and South Forks to form the Flathead River which flows into Flathead Lake.

Most streams draining the west side flow through glacial till material containing fine silts and clays. Trail Creek is 23.3 km long with a gradient of 3.7 percent. The area sampled had a channel gradient of 1.7 percent. The geology underlying the drainage is Goup I (Table 1).

Whale Creek is 18.0 km long with a channel gradient of 1.2 percent. The geology underlying the drainage are of Groups A and C.

Coal Creek is 25.5 km long with a channel gradient of 2.3 percent. The two areas sampled had channel gradients of one to two percent. The underlying parent material consists of Groups A, B and C.

Big Creek is 17.0 km long with a channel gradient of 3.4 percent. The channel gradient in the area sampled was one to two percent. The underlying materials are of Groups A, C and I.

# FIELD SAMPLING

Sample sites were located in high density bull trout spawning areas (Table 2). During October, 1981, 12 sites in Big Creek, 20 sites in Coal Creek, 13 sites in Whale Creek and 20 sites in Trail Creek were sampled. During March and April, 1982, nine sites in Big Creek, 30 sites in Coal Creek. 12 sites in Whale Creek, and 11 sites in Trail Creek were sampled. Three sites in Big Creek and one site in Trail Creek could not be sampled during March and April, 1982 due to excessive water depths. Nine additional samples were collected in Coal Creek upstream from the South Fork Coal Creek Road bridge during March and April, 1982, as part of the "spruce" beetle salvage sale study' in Coal Creek. Seven core samples from Big Creek may be inaccurate due to excessive water depths. In four of these seven samples, the Imhoff cone measurements of the fine suspended sediments were known to be inaccurate since water was flowing over the corer. The labels identifying eight core samples taken during March and April, 1982, were destroyed and unidentifiable for laboratory analysis. These eight samples, including four from Big Creek, two from Coal Creek, and two from Trail Creek, were not used in the final analysis.

Four sites were sampled per transect, two redds (either natural or artificial) and two undisturbed sites (Table 3). Artificial redds were constructed at each transect if fewer than two natural redds were present. Artificial redds were constructed by kicking down into the gravel to form a depression and tail spill similar to natural redds.

Substrate samples were collected across sampling transects identified by rebar stakes driven into the stream bank on each side of the stream. A measuring tape was stretched across the stream from rebar to rebar perpendicular to the stream flow. Undisturbed and artificial redd sample sites

Table 1. Geologic bedrock types in the Flathead National Forest. Physical and chemical characteristics are mean values derived from samples of typical unwatered soil materials. (Martinson et al. 1982).

1010 43 151 54 145			ogic bedroc		
Parameter	Α	В	NT C1 91	D	Trail (Icealc
Bedrock nature	Limestone	Calcareous Argillite		Quartzi te	Shales, Sand- stone and Limestones
Permeability rating	10	6	£ 45I	4	(1-9)
1 - 10 low high					
Wil HEL Sec. Hq	7.8	7.0	6.7	5.7	7.8
Base ion ex- change (meq/100g soil)	9.2	5.7	9.8	4.5	20 00 0
Ca <sup>++</sup> (meq/100g soil)	6.2	2.2	4.9	2.5	18.0
Mg <sup>++</sup> (meq/100g soil)	0.9	1.0	1.5 9973 [603 n	1.1	3.0 W Zeros del
P (mg/1)	1.0	2.0	0.4	1.0	3.0
Soil texture	silty	silty	silty	sandy	sand and clay
% Gravel (% total by weight)	46	39	40	60	30

Table 2. Location of substrate coring transects sampled for the Flathead National Forest during 1981-82.

Creek	Transect numbers (4 cores per transect)			Legal description		
Trail Creek	12, 13, 14		NW⅓,	NW¼, SW¼, Sec. T37N, R22W	29	
	15, 16		SW⅓.	SE <sup>1</sup> 4. NE <sup>1</sup> 4, Sec. T37N, R22W	30	
Whale Creek	1, 2, 3	a	SE¼,	NW¼, SE¼, Sec. T36N, R22W		
Coal Creek	4, 5, 6		SW¼.	NE¼, SW¼, Sec. T34N, R21W	28	
	7,8		SE¼,	NW¼, NE¼, Sec. T34N, R21W	34	
Big Creek_/	9, 10, 11		NE¼,	SE¼, NE¼, Sec. T33N, R21W	33	

Whale Creek, transect 2 had one additional natural redd site sampled during the fall of 1981.

Ten cores were taken in Coal Creek above the South Fork Coal Creek Road bridge as part of the "spruce salvage sale' monitoring.

Table 3. Description of areas cored by hollow core sampler for Flathead National Forest by stream and transect. Nat. Redd = Natural Redd; Undist. = Undisturbed substrate; Art. Redd = Artificial Redd.

eferfed	estimates of su	ENSTY ONT	Core Number			
Stream	Transect No.	rose 11 ses	11193/19/2 9/11	3-31-4	4	
Trail m	12 13 14 15 16	Nat. Redd Undist. Art. Redd Nat. Redd Nat. Redd	Undist. Nat. Redd Undist. Undist. Undist.	Art. Redd Undist. ½/ Art. Redd Art. Redd Art. Redd	Undist. Art. Redd Undist. Undist. Undist.	
Whale	1 22/ 20/14/19 3	Nat. Redd Undist. Nat. Redd	Undist. Art. Redd Undist.	Art. Redd Undist. art. Redd	Undist. Nat. Redd Undist.	
Coal and	4 5 6 7 8	Undist. Nat. Redd Undist. Undist. Art. Redd	Art. Redd Undist. Art. Redd Art. Redd Undist.	Undist. Art. Redd Undist. Undist. Nat. Redd	Art. Redd Undist. Art. Redd Art. Redd Undist.	
	mples @ollected e the Of weigh er depff in the total volume	Undist. Art. Redd Art. Redd		Undist. 1/ Art. Redd Nat. Redd	Nat. Redd¹/ Undist. Undist.	
tness	the stream adj	collected in	cone samples	ttonmi .(c su	ir water (lab	

 $<sup>^{1}</sup>$ / Cores 13-3, 9-2, 9-3, and 9-4 could not be sampled during the spring of 1982 due to high stream flows.

the nearest gram. After weighing, volumes of sediment retained on e sieve were determined to the nearest mililiter by water displacement. Wet volumes were determined for a subsample of 30 core samples collecteduring October, 1981.

e less than .063 mm) was multiplied by the total water volume within he corer to determine total volume of suspended sediment. This

 $<sup>^2/</sup>$  An extra natural redd (2-5) was sampled during the fall of 1981.

were randomly selected across each transect. To facilitate relocation of sample sites, all measurements were taken from the rebar on the left bank looking downstream. All sample sites were assigned an identification number recorded as the transect number - core number (i.e. 5-1).

Prior to the removal of the sample, two visual estimates of substrate composition were conducted. The percentage of each substrate size class (Graham et al. 1980), was recorded for each site (Table 4). Bed material was also ranked by dominant and subdominant particle sizes and channel embeddedness (Nielson 1974).

To remove the sample, the hollow corer was worked into the stream bed to a depth of 15 cm. The depth of core samples was similar to the depth eggs were deposited. Several of our core samples taken from natural redds encountered eggs at the bottom of the sample (15cm).

Fine material disturbed by the coring procedure often remains suspended in water within the corer and is usually not included in hollow core samples. To improve the estimate of fine particles in the sample, turbid water within the corer was sampled with a one liter Imhoff cone. This water sample was allowed to stand for 20 to 25 minutes in the field before the amount of sediment was recorded as milliliters of sediment per liter of water.

During the spring of 1982, 11 one liter water samples collected from the corer were returned to the laboratory to determine the dry weight of sediment per liter of water within the corer. Water depth in the corer was measured to the nearest centimeter in calculating total volume of water (Table 5). Imhoff cone samples collected in the stream adjacent to the corer produced undetectable amounts of fine sediments.

Core samples were then placed in heavy duty plastic bags along with their transect-core numbers and transported to the Flathead National Forest's Soils Laboratory for analysis. Maps were drawn of each sampling area identifying transect locations (Appendix A).

#### LABORATORY ANALYSIS

Samples were oven dried and shaken through 50.8, 16, 6.35, 2, and .063 mm sieves. A 19.1 mm sieve was included when samples collected during October 1981 were analyzed and a 76.2 mm sieve was included when analyzing samples collected during March and April, 1982. The material retained on each sieve and passing through the .063 mm sieve was weighed to the nearest gram. After weighing, volumes of sediment retained on each sieve were determined to the nearest milliliter by water displacement. Wet volumes were determined for a subsample of 30 core samples collected during October, 1981.

The volume of sediment which settled in the Imhoff cone (assumed to be less than .063 mm) was multiplied by the total water volume within the corer to determine total volume of suspended sediment. This

Table 4. Sieve sizes used to seperate and classify bed material. This is a standard system.

Material	Depth of	Volume of	Size Class
Fines Small Gravel Gravel Cobble Boulder-Bedrock	43 44 45 45 45 46 47 47 47 48 48 48	7.88 8.48 9.43 10.48 11.58 12.48	less than 2 mm 2mm to 16mm 16mm to 64mm 64mm to 256mm greater than 256mm
31 58	69	86.43	32

Table 5. Volume of water (liters) related to depth of water (cm) within the McNeil-Ahnell hollow core sampler.

	Volume of	Depth of	Volume of
Water (cm)	Water (1)	Water (cm)	Water (1)
25.5	7.88	43	25. 18
26	8.48	44	26.18
27	9.43	45	27.08
28	10.48	46	28.03
29	11.58	47	28.88
30	12.48	48	29.73
31	13.58	49	30.63
32	14.38	50	31 58
33	15.38	51	32.53
34	16.38	52	33.38
35	17.38	53	34.38
36	18.38	54	35.38
37	19.38	55	36.33
38	20.33	56	37.33
39	21.33	57	38.33
40	22.28	58	39.43
41	23. 38	59 <sub>1</sub> ,	40.43
42	24.38	60_/	41.13

Top of corer

result was included when determing the total volume of material less than .063 mm.

One liter water samples collected from inside the corer were filtered through a 0.45 micron millipore filter and oven dried. Dry weight of the fine sediment retained on the filter was measured and expressed as mg/l.

#### DATA ANALYSIS

All transect-core identification numbers, dry weights by size class, dry volumes by size class and wet volumes by size class were entered into data files on the CP6 computer located at Montana State University, Bozeman, Montana. Interactive Data Base Processor (IDP) data location dictionaries and data analysis programs were created to analyze the data.

Percent composition by sieve size class was calculated for each sample. Comparisons were made between percent by dry weight and percent by dry volume for material larger than 0.063 mm.

Wet to dry volume conversion factors were computed for the 30 randomly selected core samples collected during October, 1981. Average gravel density was calculated for 31 randomly selected core samples collected during October, 1981 according to methods described by Shirazi and Seim (1979). We compared our wet to dry volume conversion factors to Shirazi and Seim's wet volume to dry weight conversion factors. Regression analysis was also used to determine the relationship between the wet volume and dry weight of the material sampled using the Imhoff cone.

A conversion factor of 0.44 was used to convert wet volume of sediment sampled using the Imhoff cone to dry volume (Shirazi and Seim 1979). Bar graphs were drawn of the substrate composition by dry volume for each sample and for each type of site (natural redd, artificial redd, and undisturbed) by creek and season.

#### RELATING SUBSTRATE COMPOSITION TO BULL TROUT SPAWNING SUCCESS

No quantitative data is available on the effects of sediment on bull trout spawning success. Therefore, we used results from research done with other species, primarily chinook salmon and steelhead trout to predict impacts on bull trout.

Although an effort is being made to standardized methods to analyze and report substrate composition of salmonid spawning areas, use of "percent fines" in past research relating substrate composition to embryo survival ranged from percent smaller than 1 mm to percent smaller than 6.35 mm (Bjornn 1969, Phillips et al. 1975, Hansle and Coble 1976, McCuddin 1977). Recently, several new methods have been proposed

including geometric mean (dg) by Platts et al. (1979) and Shirazi and Seim (1979), "fredle index" by Lospeich and Everest (1980) and a method described by Tappel (1981).

Tapple (1981) listed simplicity and ease of applicability as major attributes of his method. His method incorporates the fact that stream gravels have log-normal distributions (Shen 1971). This means that gravel samples are represented by a straight line when plotted on log-probability paper (Figure 1. For the rationale and methodology for transforming gravel compositions to log-normal distributions using cummulative percent (inverse probability transformation) and sieve size (natural log transformation) see Appendix B. We calculated regression lines for 65 samples collected during October, 1981 and 14 samples collected during March and April, 1982 and obtained an average r² value of 0.92 (range = 0.75 to 1.00). These regression equations were used to predict geometric means (particle size which 50 percent of material is smaller than), fredle indices, percent of material smaller than 9.5 mm and percent of material smaller than 0.85 mm for each sample collected during October, 1981.

#### RESULTS

#### COMPARING COMPOSITION BY DRY WEIGHT VERSUS DRY VOLUME

Substrate compositions can be analyzed and reported either by percent by dry weight or dry volume as little difference was found betwen these two methods when they were compared (values of 1.00 indicated no difference) (Table 6).

# Wet Volume to Dry Volume Conversion Factors

Conversion factors were calculated from 30 samples analyzed both by dry volume and wet volume. To compare our conversion factors to those calculated by Shirazi and Seim (1979), we determined the average density of gravels from North Fork tributaries to be 2.27 gm/cm³ (Table 7). Our conversion factors were similar to those calculated by Shirazi and Seim (Table 8).

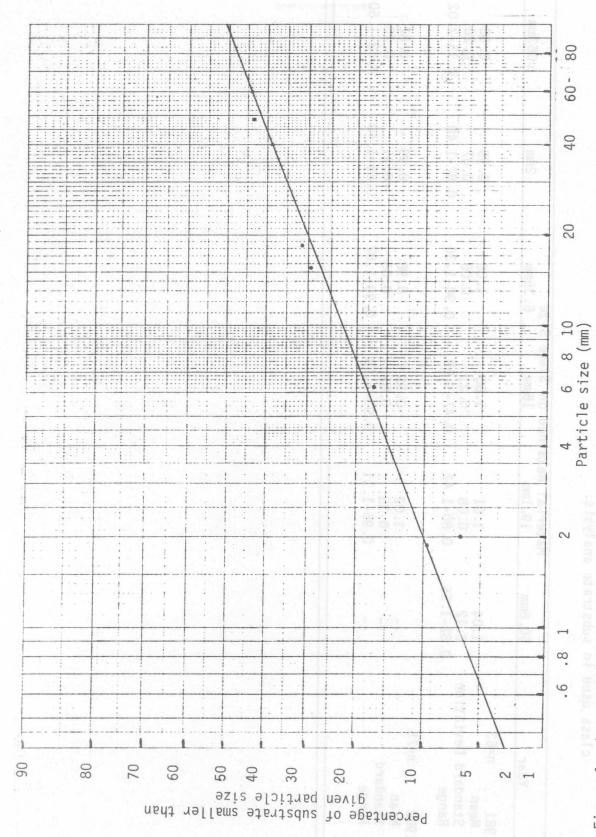
# Relationship Between Dry Weight versus Wet Volume of Material Sampled in Imhoff Cone

Factors were calculated to convert wet volume to dry weight for material sampled using the Imhoff cone. The conversion factors ranged from .23 to .33.

Regression analysis was also used to relate wet volume to dry weight for material sampled with the Imhoff cone (Figure 2). The predictive equations developed was:

Dry Weight = -.048 + (.279)(Wet Volume)

 $r^2 = .942$ .



particle size distribution close to gravel sample with a Log-probability plot of spawning log-normal. Figure 1.

Ratio of percent by dry weight to percent by dry volume (Dry Weight/Dry Volume) for each size class used in substrate analysis. Table 6.

Year	50.8mm	19.1mm	19.1mm 16mm 6.	6.35mm	2mm	.063mm
1981 n=63 Mean	1.04	1.01		1.00	0.99	0.98
Standard Deviation Range	0.12	0.08	0.21 0.47-1.69	0.06	0.07	0.20
.982 n=75 Mean	1	1.02	0.99	0.98	0.99	0.82
Standard Range	l i	0.35	0.03	0.03	0.11	0.20

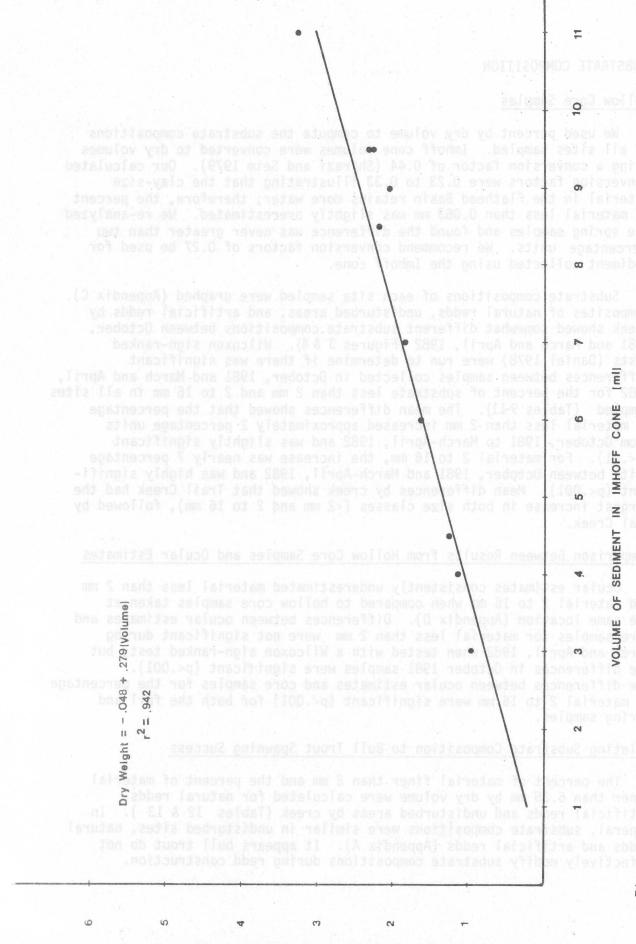
Table 7. Average gravel densities calculated for 31 cored sites using the dry weight divided by wet volume ( $cm^3$ ) of material 2 to 6.35 mm.

Average Gravel Density				
Transect	Dry Weight(g)	Wet Volume (ml)	Densi ty	
11 te of 39	721	230	3.13	
12	20/1	370	2. 39	
13		1220	2.34	
14		6 90	1.96	
21		660	2.33	
22	1284	540	2.38	
23	1729	880	1.96	
24	2301	1120	2.05	
31	1111	490	2: 27	
32	1526	710	2.15	
33	908	410	2.21	
34	373	140	2.66	
42	1780	710	2.51	
44	1353	590	2.29	
52	2205	920	2.39	
54	1383	610	2.27	
62	1489	670	2.22	
63	1253	520	2.41	
83	1029	460	2.24	
91	1749	890	1.97	
92	1756	7 90	2.22	
93	933	410	2.27	
94	1324	645	2.05	
101	2616	1190	2.20	
102	1185	530	2.23	
103	1820	820	2.22	
104	1035	485	2.13	
111	536	210	2.55	
112	556	220	2.53	
113	824	440	1. 87	
114	1260	600	2. 10	

Mean Density	Standard Error	Range
2.27	0.04	1.87 to 3.13
(n=31)		

Table 8. Factors calculated during this study to convert wet to dry volume compared to conversion factors calculated by Shirazi and Seim (1979) for material with an average gravel density of 2.2.

Sieve Size (mm)	Calculated Conversion Factor	Shirazi and Seim's Conversion Factor
50.8 16 6.35 2 .063	0.98 0.99 0.91 0.89 0.74	.96 to .97 .93 to .96 .89 to .93 .83 to .87 .46 to .83
		23 1729
		1111
		32 1526 33 908 34 373
		809
	096	62 2205 54 1383 62 1489
		E8E1 058
03.3		
		1035



to the cone an Imhoff in Regression line and equation relating volume of sediment measured weight of that sediment. Figure

#### SUBSTRATE COMPOSITION

### Hollow Core Samples

We used percent by dry volume to compute the substrate compositions of all sites sampled. Imhoff cone volumes were converted to dry volumes using a conversion factor of 0.44 (Shirazi and Seim 1979). Our calculated conversion factors were 0.23 to 0.33 illustrating that the clay-size material in the Flathead Basin retains more water; therefore, the percent of material less than 0.063 mm was slightly overestimated. We re-analyzed the spring samples and found the difference was never greater than two percentage units. We recommend conversion factors of 0.27 be used for sediment collected using the Imhoff cone.

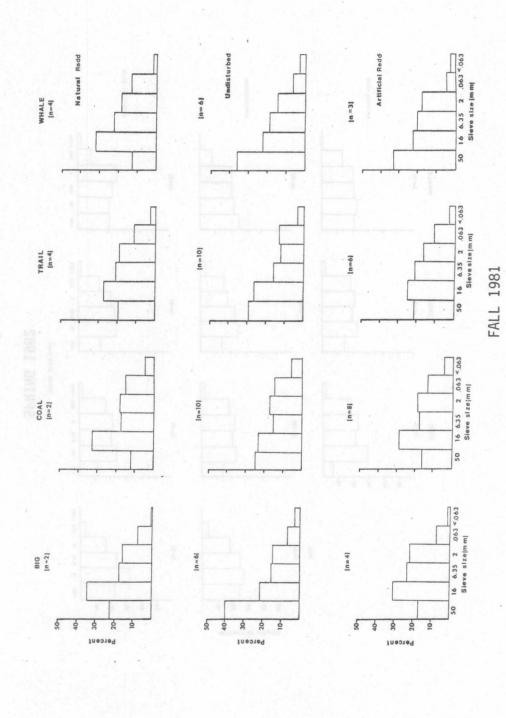
Substrate compositions of each site sampled were graphed (Appendix C). Composites of natural redds, undisturbed areas, and artificial redds by creek showed somewhat different substrate compositions between October, 1981 and March and April, 1982 (Figures 3 & 4). Wilcoxon sign-ranked tests (Daniel 1978) were run to determine if there was significant differences between samples collected in October, 1981 and March and April, 1982 for the percent of substrate less than 2 mm and 2 to 16 mm in all sites sampled (Tables 9-11). The mean differences showed that the percentage of material less than 2 mm increased approximately 2 percentage units from October, 1981 to March-April, 1982 and was slightly significant (p<.01). For material 2 to 16 mm, the increase was nearly 7 percentage units between October, 1981 and March-April, 1982 and was highly significant (p<.001). Mean differences by creek showed that Trail Creek had the largest increase in both size classes (<2 mm and 2 to 16 mm), followed by Coal Creek.

# Comparison Between Results from Hollow Core Samples and Ocular Estimates

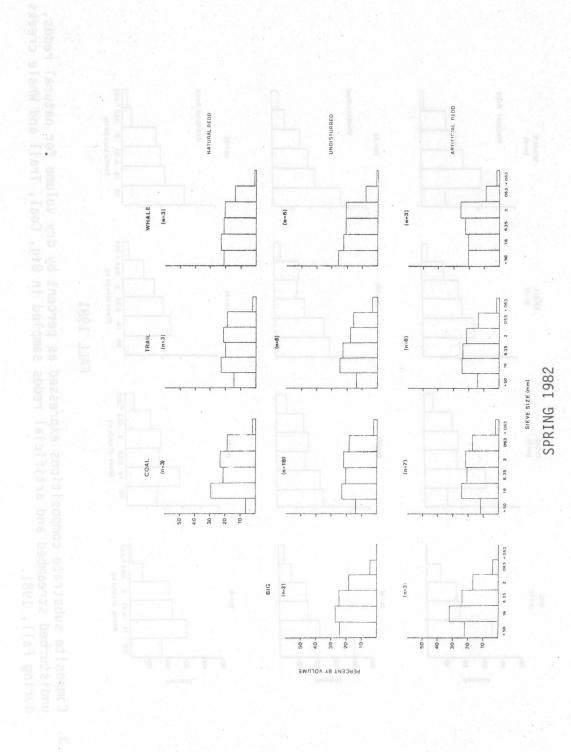
Ocular estimates consistently underestimated material less than 2 mm and material 2 to 16 mm when compared to hollow core samples taken at the same location (Appendix D). Differences between ocular estimates and core samples for material less than 2 mm were not significant during March and April, 1982 when tested with a Wilcoxon sign-ranked test, but the differences in October 1981 samples were significant (p<.001). The differences between ocular estimates and core samples for the percentage of material 2 to 16 mm were significant (p<.001) for both the fall and spring samples.

# Relating Substrate Composition to Bull Trout Spawning Success

The percent of material finer than 2 mm and the percent of material finer than 6.35 mm by dry volume were calculated for natural redds, artificial redds and undisturbed areas by creek (Tables 12 & 13 ). In general, substrate compositions were similar in undisturbed sites, natural redds and artificial redds (Appendix A). It appears bull trout do not effectively modify substrate compositions during redd construction.



Composite substrate compositions expressed as percent by dry volume for natural redds, undisturbed streambed and artificial redds sampled in Big, Coal, Trail and Whale creeks during Fall, 1981. Figure 3.



Composite substrate compositions expressed as percent by dry volume for natural redds, undisturbed streambed and artificial redds sampled in Big, Coal, Trail and Whale creeks during Spring, 1982. Figure 4.

Comparison between Fall, 1981 and Spring, 1982 core sampling for <2mm and 2 to 16 mm sizes in Coal Creek. Table 9.

Transect S Dead Horse Bridge 41 42 43	Chrina 100					
Horse 41 42 43	1	Fall '81	Dì FF.	Spring '82	Fall '81	Diff.
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						
422 43		19	2	44	30	14
43	20	14	9	49	45	4
44	15	11	4	40	28	12
	18	12	9	52	36	16
	24	27	6-1	41	35	9
52	22	20	2	38	38	0
	-	1	1	- 56	-	1
	12	14	-2	33	24	6
	19	26	-7	34	34	0
	16	19	61	38	34	4
63	21	15	9	42	23	19
64	27	17	10	40	34	9
Mean		97	1.9			8.2
	4					
Cyclone Road Cutoff						
71	24	24	0	41	37	4
72	21	24	-3	40	37	3
	10	1	1	1-100	44	1
	14	19	-5	39	33	9
81	25	25	0	43	42	100
	25	27	-2	37	32	2
	14	12	2	39	36	c
84	15	21	9-	39 88	36	c
			-2.0			3.6

Comparison between Fall, 1981 and Spring, 1982 core sampling for <2mm and 2-16mm sizes in Trail Creek. Table 10.

		<2mm			2-16mm	
Transect	Spring '82	Fall '81	Diff.	Spring '82	Fall '81	Diff.
	23	14	6	46	39	7
	15	00	7	38	18	20
	16	10	9	32	28	4
124	29	30	-	35	22	13
131	21	21	0	37	31	9
132			011	T	1	1
133		1	1	1 1	1 1	1
	16	10	9	20	46	4
	13	16	6-1	44	42	2
	17	7	10	38	34	4
	10	12	-2	38	32	9
144	23	10	13	34	25	6
	22	13	6	33	45	
	111	7	4	54	24	30
	8	21	6-	26	47	6
	16	14	2	55	32	13
161	18	9	12	44	34	10
162		1	1	1941	1	!
163		14	6	20	36	14
164	20	21	-10	44	37	7
Mean		40	4.5			8.6

Comparison between Fall, 1981 and Spring, 1982 core sampling for <2mm and 2-16mm sizes in Whale Creek. Table 11.

Diff.	1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-	Table 12. Summary of percent substrate from fall
181	fean percentage Mea of material less than 2.00mm	(31)
6mm Fa11	322 322 336 344 466 336 330 330 330 330	Whale Creek
2-1	8.61 6.51 13.99	Undisturbed (6) Artificial redd (3) Natural redd (3)
1 182		Coal Creek (Bead Horse)
Spring	044   1 4 6 8 6 8 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	Undisturbed (5) Artificial redd (5) Natural redd (1)
	24, 17 23, 17 12, 42	Undisturbed (4)
Diff.	2011-1-202-1-21	Natural redd (Combined)
٥	18.86	Undisturbed (10) Artificial redd (2) Natural redd (2)
31		Big Creek
<2mm     Fall   81	3 6 10 10 10 13 13 7	Undisturbed ( f) Artificial redd ( A) Natural redd ( 2)
		Trail Greek
1 '82	15.94 13.85 12.86	Undisturbed Artificial Redd (6 Natural redd (4
Spring	10 10 10 10 10 10 10 10	
ct	111 121 13 14 223 223 33 33 34	
Transect	Mean Whale Creek	

Table 12. Summary of percent of dry volume for smaller size classes of substrate from fall coring in 1981.

	(N)	Mean percentage of material less than 2.00mm	Mean pecentage of material less than 6.35mm
Whale Creek			187 3
Undisturbed Artificial redd Natural redd	(6) (3) (3)	8.61 6.51 13.99	22. 86 24. 45 33. 29
Coal Creek (Dead Horse)			
Undisturbed Artificial redd Natural redd (Cyclone)	(6) (5) (1)	17.57 14.60 27.23	33. 24 33. 46 45. 21
Undisturbed Artificial redd Natural redd	(4) (3) (1)	24. 17 23. 17 12. 42	42.64 42.27 30.22
(Combined) Undisturbed Artificial redd Natural redd	(10) (8) (2)	20.87 18.88 19.82	37.94 37.86 37.72
Big Creek			
Undisturbed Artificial redd Natural redd	( 6) ( 4) ( 2)	8.76 8.31 7.78	23.44 30.07 23.84
Trail Creek			
Undisturbed Artificial Redd Natural redd	(10) (6) (4)	15.94 13.86 12.86	28.44 30.83 31.79

Table 13. Summary of percent of dry volume for smaller size classes of substrate from spring coring in 1982.

edds, but is applicable 20 percent in Coal lie Creek to 21 percent in redds were sampled	Big Creek 1	Mean percentage of material less than 2.00mm	Mean percentage of material less than 6.35mm
Whale Creek_	highest par	ing areas contain the	Coal Creek spawn
Undisturbed Artificial redd Natural redd	(6)	9.24 7.11 14.92	30.12 36.44 35.38
Coal Creek - (Dead H			
Undisturbed Artificial redd Natural redd	(6) (4)	(Minus Bullet Ref)	37.32 43.44 44.23
(Cyclon	e)		Geometric means a
Undisturbed Artificial redd Natural redd	(3) (3) (1)	21.12 15.80 13.74	40.66 40.60 35.37
Coal Creek - (Combin	ed)		
Undisturbed Artificial redd Natural redd	(9) (7) (2)	19.78 18.04 18.98	38.99
Coal Creek - (Snoose	e can)		sorting coefficient mples collected dur
Undisturbed Natural redd	(9) (1)	22.07 23.14	50.75
Big Creek			
Undisturbed Artificial redd Natural redd	(0)	4.47 4.10	22.78 30.22 22.78
Trail Creek		ion equations for each	
Undisturbed Artificial redd Natural redd	(8) (6) (3)	19.05 15.97 21.26	37.70 37.26 42.51

ercent of material less than 0.85 mm

The remaining discussion will focus on natural redds, but is applicable to all three types of sites. Natural redds had mean values of material finer than 2 mm ranging from 8 percent in Big Creek to 20 percent in Coal Creek during October 1981, and from 15 percent in Whale Creek to 21 percent in Trail Creek during March and April, 1982 (no natural redds were sampled in Big Creek during the spring of 1982.).

Coal Creek spawning areas contain the highest percent of material finer than 2 mm during time of egg deposition. Trail Creek bull trout redds had a large quantity of fine sediment deposited in them during the winter months, increasing from 13 percent of material finer than 2 mm in the fall to 21 percent in the spring.

The trend in materials finer than 6.35 mm ranged from 23 percent in Big Creek to 38 percent in Coal Creek during fall, 1981; and from 35 percent in Whale Creek to 43 percent in Trail Creek during spring, 1982. Materials between 2 and 6.35 mm can form a barrier preventing the emergence of swimming sac fry (Imawoto et al 1978, Cordone and Kelly 1961, Koski 1966).

Geometric means and fredle indices were computed for all samples collected during October, 1981 (Appendix D). Mean geometric means and fredle indices by type of site (natural redd, artificial redd and undisturbed) and creek showed Coal Creek had the lowest geometric means and fredle indices (Table 14).

Tappel (1981) developed curves to predict spawning survival for chinook salmon and steelhead trout from gravels of known compositions using fredle indices and geometric means (Figures 5 and 6). Lotspeich and Everest (1980) stated that fredle indices are more useful for describing substrate composition than geometric means since fredle indices include a sorting coefficient term. We related fredle indices computed for samples collected during October, 1981 in North Fork tributaries to Tappel's curve and found that embryo survival would be the lowest in Coal Creek.

Because stream gravels had log-normal distributions, especially those less than 25.4 mm, Tappel (1981) determined that the entire composition of substrate less than 25.4 mm could be described by using only cummulative values for the percent of material finer than 9.5 mm and finer than 0.85 mm. He then developed "survival bands" predicting embryo survival for chinook salmon and steelhead trout (Figure 7). We determined the percent of material less than 9.5 mm and percent of material less than 0.85 from the log-normal regression equations for each sample collected during October, 1981. We then computed potential embryo survival using Tappel's best equation relating chinook salmon embryo survival to gravel size composition:

Percent Survival =  $93.4 - 0.171(S_{9.5})(S_{0.85}) = 3.871(S_{0.85})$ 

Where:  $S_{9.5}$  = Percent of material less than 9.5 mm  $S_{0.85}$  = Percent of material less than 0.85 mm

Table 14. Mean values for geometric mean particle sizes and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds and undisturbed sites in Big, Coal, Whale and Trail creeks during October, 1981.

Creek and Type of Site	n	Geometric Mean (dg)	Fredle Index
Big Creek Natural redd Artificial redd Undisturbed Mean	2 4 <u>6</u> 12	28.8 26.6 73.6 50.5	6.7 5.6 9.5 7.7
Coal Creek - Dead Horse Natural redd Artificial redd Undisturbed Mean	e Road Bridge 1 5 6 12	6.1 14.1 24.7 18.7	0.9 2.2 2.7 2.3
Coal Creek - Cyclone L Natural redd Artificial redd Undisturbed Mean	ake Road Cutoff  1 3 4 8	11.7 6.0 6.1 6.8	2.9 1.1 1.0 1.3
Whale Creek Natural redd Artificial redd Undisturbed Mean	4 3 6 13	11.3 35.9 135.2 74.2	2. 9 6. 0 8. 4 6. 1
Trail Creek - Junk Car Natural redd Artificial redd Undisturbed Mean	Si te 2 4 6 12	11.2 21.1 29.2 23.5	2.4 3.5 4.2 3.7
Trail Creek - Rock Sli Natural redd Artificial redd Undisturbed Mean	de Site 2 2 4 8	19.4 11.3 31.1 23.2	4.2 1.9 4.5 3.8

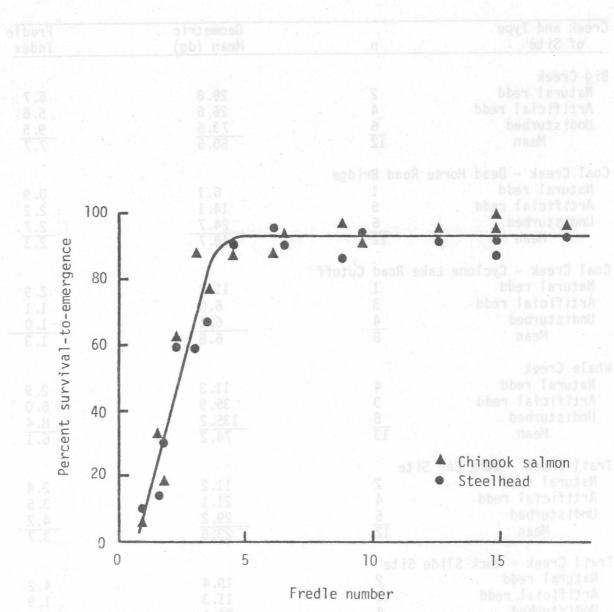


Figure 5. Relationship between fredle numbers and embryo survivalto-emergence. Curve fitted by eye to data from laboratory experiments (Tappel, 1981).

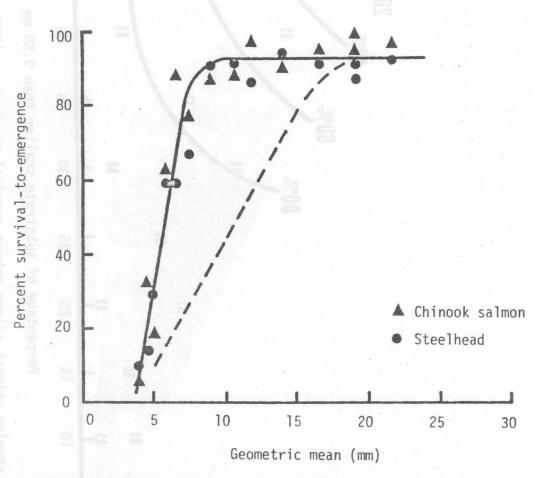
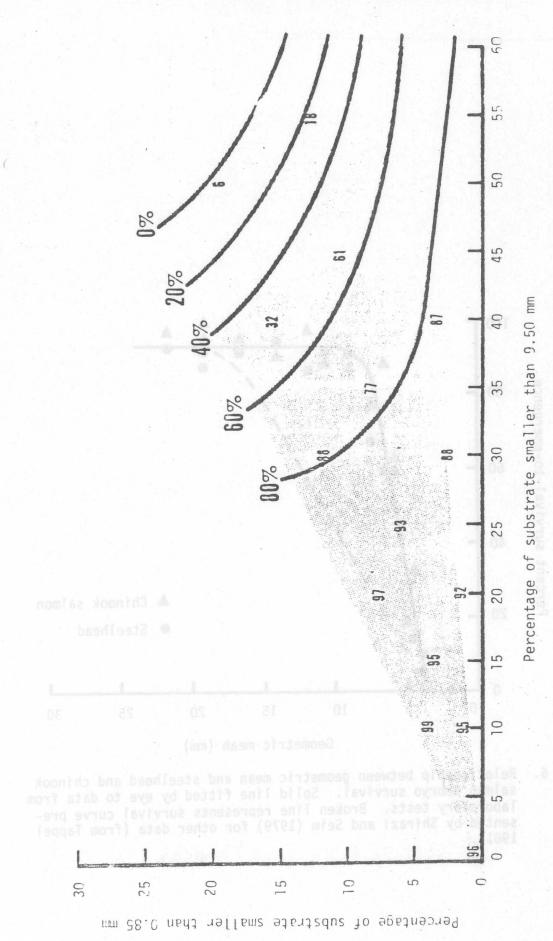


Figure 6. Relationship between geometric mean and steelhead and chinook salmon embryo survival. Solid line fitted by eye to data from laboratory tests. Broken line represents survival curve presented by Shirazi and Seim (1979) for other data (from Tappel 1981).



gure 7. Bands showing chinook salmon embryo survival predictions (80%, 60%, 40%, 20%, 0%) overlving range of natural spawning gravel. Scattered numbers are percent survival values from laboratory incubation tests. (from lappel 1981). Figure

The  $R^2$  value was 0.93.

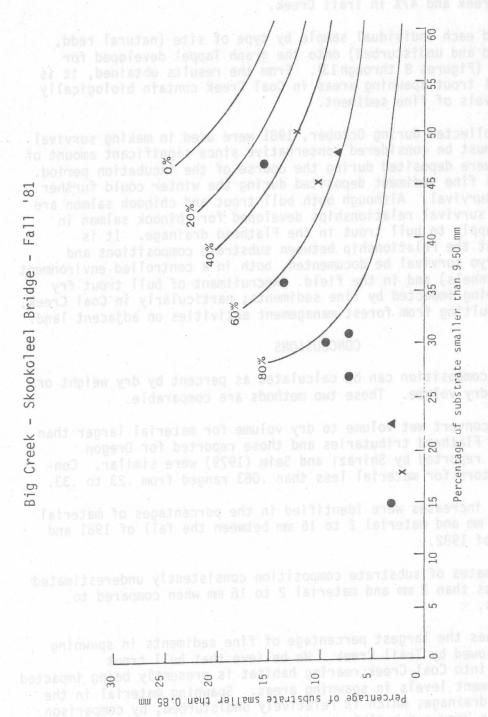
The average percent survivals were 64% in Big Creek, 6% in Coal Creek, 60% in Whale Creek and 47% in Trail Creek.

We plotted each individual sample by type of site (natural redd, artificial redd and undisturbed) onto the graph Tappel developed for chinook salmon (Figures 8 through 13). From the results obtained, it is clear that bull trout spawning areas in Coal Creek contain biologically significant levels of fine sediment.

Samples collected during October, 1981 were used in making survival estimates and must be considered conservative since significant amount of fine sediment were deposited during the course of the incubation period. This additional fine sediment deposited during the winter could further reduce embryo survival. Although both bull trout and chinook salmon are full spawners, survival relationships developed for chinook salmon in Idaho may not apply to bull trout in the Flathead drainage. It is recommended that the relationship between substrate compositions and bull trout embryo survival be documented, both in a controlled environment (laboratory channels) and in the field. Recruitment of bull trout fry is presently being impacted by fine sediments; particularly in Coal Creek, most likely resulting from forest management activities on adjacent land.

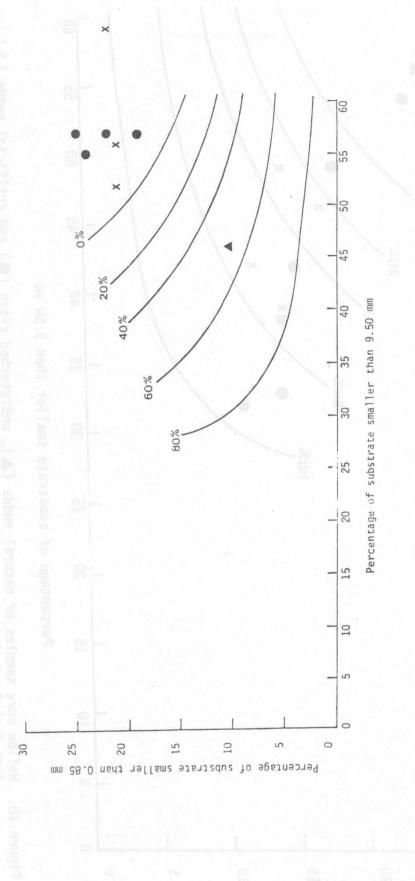
#### CONCLUSIONS

- 1. Substrate composition can be calculated as percent by dry weight or percent by dry volume. These two methods are comparable.
- 2. Factors to convert wet volume to dry volume for material larger than .063 mm for Flathead tributaries and those reported for Oregon tributaries reported by Shirazi and Seim (1979) were similar. Conversion factors for material less than .063 ranged from .23 to .33.
- 3. Significant increases were identified in the percentages of material less than 2 mm and material 2 to 16 mm between the fall of 1981 and the spring of 1982.
- 4. Visual estimates of substrate composition consistently underestimated material less than 2 mm and material 2 to 16 mm when compared to core samples.
- 5. Coal Creek has the largest percentage of fine sediments in spawning gravels followed by Trail Creek. We believe that bull trout recruitment into Coal Creek rearing habitat is presently being impacted by fine sediment levels in spawning areas. Spawning material in the Trail Creek drainage, which is relatively undisturbed, by comparison appears to be very susceptible to disturbance which alter sediment imput and water yield in the drainage.

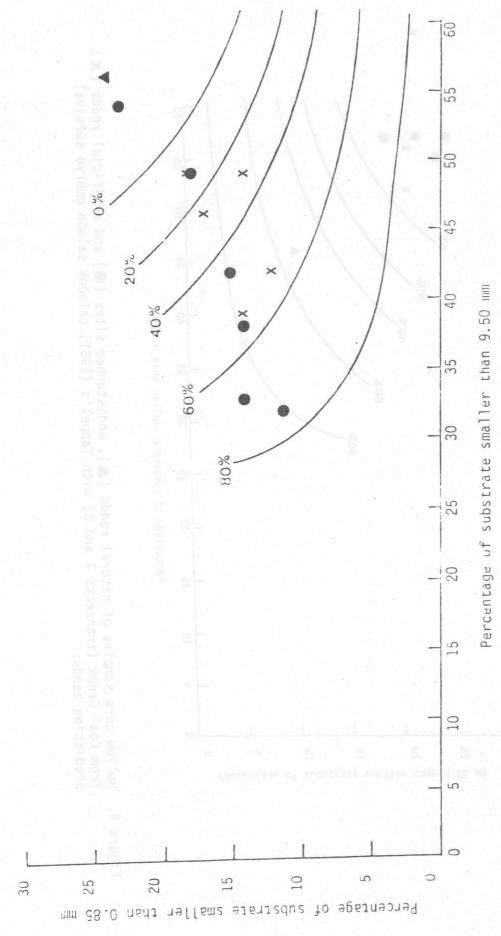


The avexue percent survivals were 64% in 84g Creek, 6% in Coal Creek, 60% In Whate C ) and artificial redds non embryo survival s (▲), undisturbed sites (●) and Tappel's (1981) chinook salmon Hollow core samples of natural redds from Big Creek (transects 9-11) with prediction bands. Figure

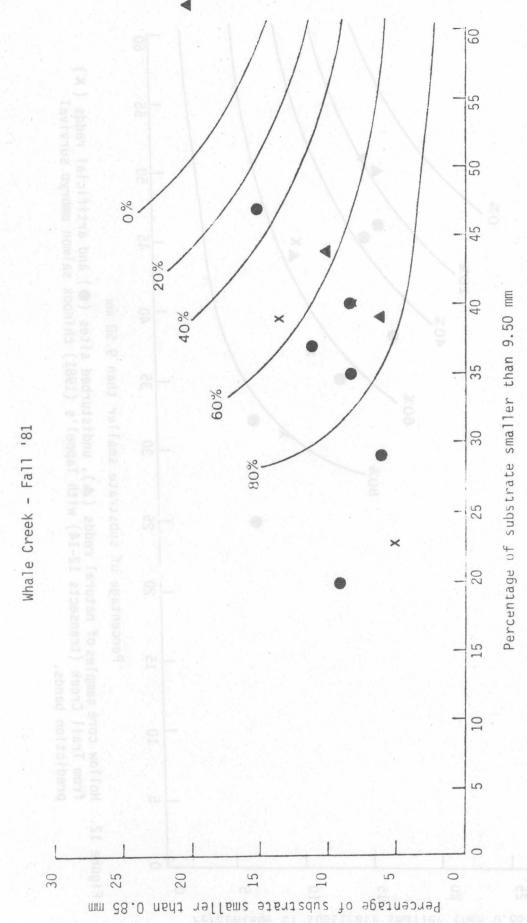




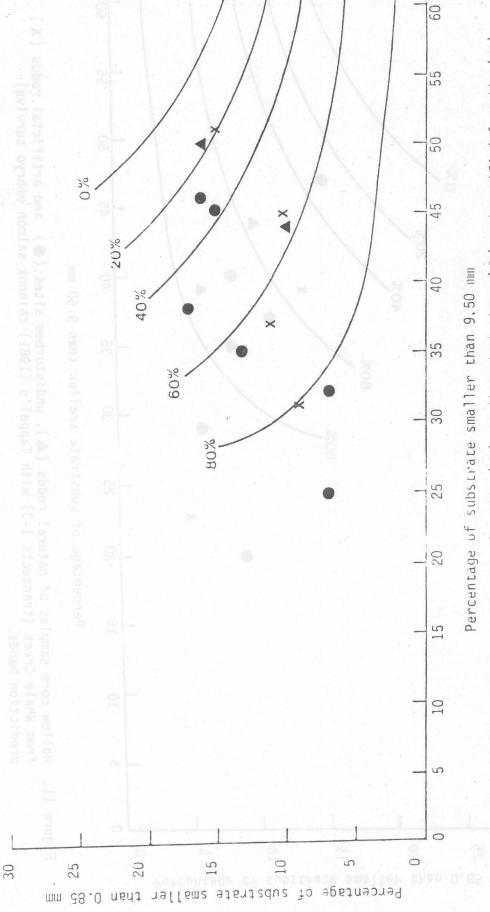
Hollow core samples of natural redds ( $\blacktriangle$ ), undisturbed sites ( $\blacktriangledown$ ) and artificial redds (x) from Coal Creek (transects 7 and 8) with Tappel's (1981) chinook salmon embryo survival prediction bands. Figure 9.



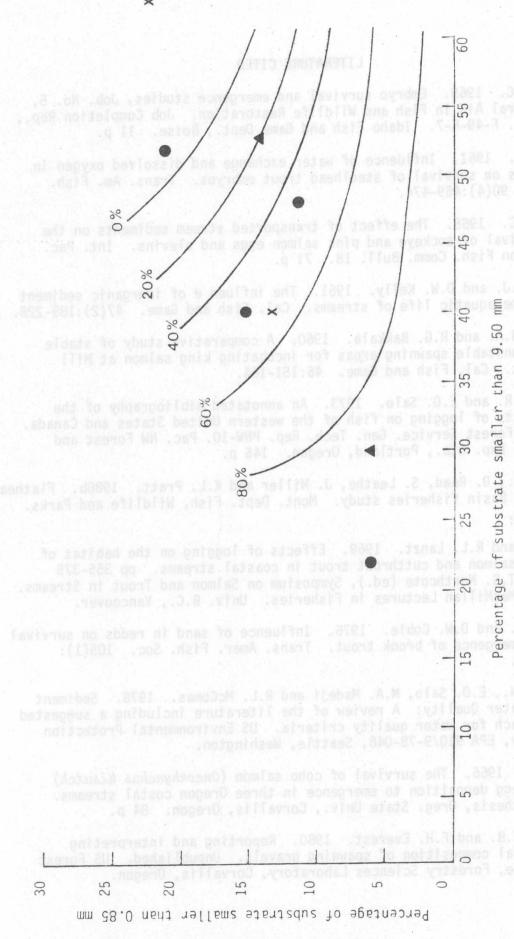
Hollow core samples of natural redds ( $\blacktriangle$ ), undisturbed sites ( $\blacktriangledown$ ) and artificial redds (x) from Coal Creek (transects 4-6) with Tappel's (1981) chinook salmon embryo survival prediction bands. Figure 10.



Hollow core samples of natural redds ( $\blacktriangle$ ), undisturbed sites ( $\blacktriangledown$ ) and artificial redds (x) from Whale Creek (transects 1-3) with Tappel's (1981) chinook salmon embryo survival prediction bands. Figure 11.



Hollow core samples of natural redds ( $\triangle$ ), undisturbed sites ( $\bigcirc$ ) and artificial redds ( $\times$ ) from Trail Creek (transects 12-14) with Tappel's (1981) chinook salmon embryo survival prediction bands. Figure 12.



Hollow core samples of natural redds (♠), undisturbed sites (♠) and artificial redds (x) from Trail Creek (transects 15 and 16) with Tappel's (1981) chinook salmon embryo survival prediction bands.

## LITERATURE CITED

- Bjornn, T.C. 1969. Embryo survival and emergence studies, Job. No. 5, Federal Aid in Fish and Wildlife Restoration. Job Completion Rep., Proj. F-49-R-7. Idaho Fish and Game Dept., Boise. 11 p.
- Coble, D.W. 1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead trout embryos. Trans. Am. Fish. Soc. 90(4):469-474.
- Cooper, A.C. 1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevins. Int. Pac. Salmon Fish. Comm. Bull. 18. 71 p.
- Cordone, A.J. and D.W. Kelly. 1961. The influen e of inorganic sediment on the aquatic life of streams. Cal. Fish and Game. 47(2):189-228.
- Gangmark, H.A. and R.G. Bakkala. 1960. A comparative study of stable and unstable spawning areas for incubating king salmon at Mill Creek. Cal. Fish and Game. 46:151-164.
- Gibbons, D.R. and E.O. Salo. 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. USDA Forest Service. Gen. Tech. Rep. PNW-10. Pac. NW Forest and Range Exp. Sta., Portland, Oregon. 145 p.
- Graham, P.J., D. Read, S. Leathe, J. Miller and K.L. Pratt. 1980b. Flathead River Basin fisheries study. Mont. Dept. Fish, Wildlife and Parks. 166 p.
- Hall, J.D. and R.L. Lanzt. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. pp 355-375
   In: T.G. Northcote (ed.), Symposium on Salmon and Trout in Streams.
   H.R. MacMillan Lectures in Fisheries. Univ. B.C., Vancouver.
- Housle, D.A. and D.W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout. Trans. Amer. Fish. Soc. 105(1): 57-63.
- Iwamoto, R.N., E.O. Salo, M.A. Madeji and R.L. McComas. 1978. Sediment and Water Quality: A review of the literature including a suggested approach for water quality criteria. US Environmental Protection Agency, EPA 910/9-78-048, Seattle, Washington.
- Koski, K.V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon costal streams. M.S. thesis, Oreg. State Univ., Corvallis, Oregon. 84 p.
- Lotspeich, F.B. and F.H. Everest. 1980. Reporting and interpreting textural composition of spawning gravels. Unpublished. US Forest Service, Forestry Sciences Laboratory, Corvallis, Oregon.

- Martinson, A.H., W.J. Baska and D.A. Sirucek. 1982. Soil inventory of the Flathead National Forest and the Swan, Stillwater and Coal Creek State Forests. National Coop Soil Survey Public. USDA, SCS.
- McCuddin, M.E. 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. M.S. thesis, Univ. of Idaho, Moscow. 30 p.
- McNeil, W.J. and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. US Fish and Wildl. Serv. Spec. Sci. Rep. Fish. No. 459. 15 p.
- Neilson, D.R. 1974. Sediment transport through mountain streams of the Idaho Batholith. MS thesis. Agricultural Engineering, Univ. of Idaho, Moscow.
- Phillips, R.W., R.L. Lantz, E.W. Claire, and J.R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steel-head trout fry. Trans. Amer. Fish. Soc. 104(3):461466.
- Platts, W.S., M.A. Shirazi and D.H. Lewis. 1979. Sediment particle sizes used by salmon for spawning, and methods for evaluation. US Environmental Protection Agency, EPA-600/3-79-043, Corvallis Environmental Research Laboratory, Corvallis, Oregon.
- Shirazi, M.A. and W.K. Seim. 1979. A stream systems evaluation with emphasis on spawning habitat for salmonids. Corvallis Environmental Branch Laboratory. Environmental Protection Agency. E.P.A. 600/3-79-109. 37 p.
- Tappel, Paul D. 1981. A new method of relating spawning gravel size composition to salmonid embryo survival. Master of Science thesis. University of Idaho, Moscow, Idaho, USA.

- Martinson, A.H., W.J. Baska and D.A. Sirucek. 1982. Soil inventory of the Flathead National Forest and the Swan, Stillwater and Coel Creek State Forests. National Coop Soil Survey Public. USDA, SCS.
  - McCuddin, M.E. 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. M.S. thesis, Univ. of Idaho, Moscow, 30 p.
    - McMeil, W.J. and W.H. Ahnell. 1954. Success of pink salmon spawning relative to size of spawning bed materials. US Fish and Wildl. Serv. Spec. Sci. Rep. Fish. No. 459. 15 n.
  - Hellson, D.R. 1974. Sediment transport through mountain streams of the Idano Bathelith. MS thesis. Agricultural Engineering, Univ. of Idano, Moscow.
  - Phillips, R.W., R.L. Lentz, E.W. Claire, and J.R. Moring. 1975. Some affects of gravel mixtures on emergence of coho salmon and steel-head trout fry. Trans. Amer. Fish. Soc. 104(3):461466.
  - Piatts, W.S., M.A. Shinazi and D.H. Lewis. 1979. Sediment particle sizes used by salmon for spanning, and methods for evaluation. US finvironmental Protection Agency. EPA-800/3-79-043. Corvellis Environmental Research Lab

## Maps and table to core sample site locations.

800/3-79-109. 37 p. appel, Paul D. 1981. A new method of relation counseler.

University of Idaho, Moscow, Idaho, USA.

Table 1. Core sample site locations on each transect sampled during October, 1981. Distance in meters from the left rebar (looking downstream).

Creek	Transect Number	1	2	3	4
Whale	1	4.8	5.8	8. 1	11.1
	2 3	5.2	16.8	11.9	13.5
		3.7	6.3	7.7	8.8
	4	9.4	10.6	11.7	13.1
	5	9.0	10.9	12.4	13 3
	6	8.4	9.3	10.8	12.4
	7	6.2	8.2	10.8	12.6
	6 7 8 9	6.4	7.9	10.1	11.5
	9	9.2	10.2	11.2	12.1
	10	5.5	6.4	7.3	8.4
	11	4.2	6.3	8.5	10.5
	12	5.1	7.4	8.3	13.6
	13	5.8	7.1	9.8	12.1
	14	7.5	9.7	11.8	15.6
	15	2.3	3 /	9 0	10.7
	16	2.0	3.5	9. 2	10.1

Section Dates and Particulars

Figure 1. Map of Skookoleel Creek Road Bridge Sampling Area of Big Creek

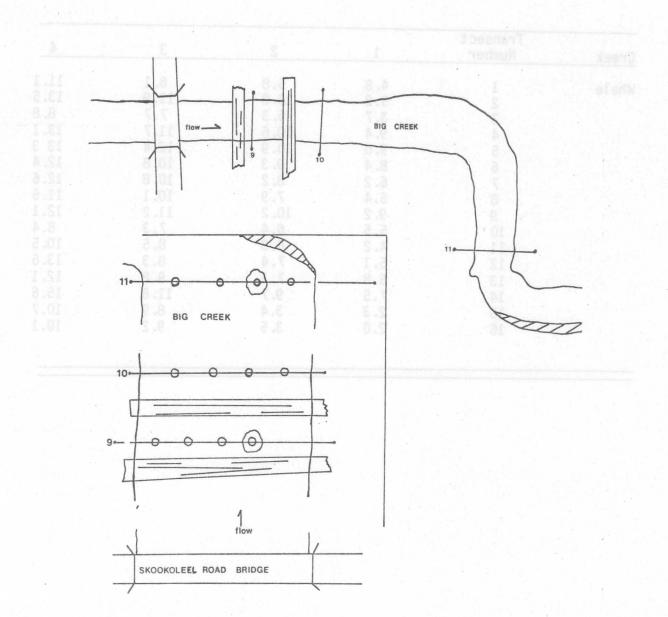


Figure 1. Map of Skookoleel Creek Road Bridge Sampling Area of Big Creek

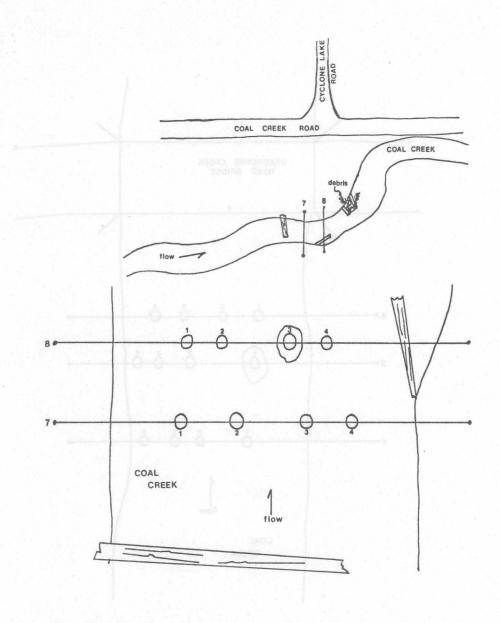


Figure 2. Map Of Cyclone Lake Road Cutoff Sampling Area Of Coal Creek .

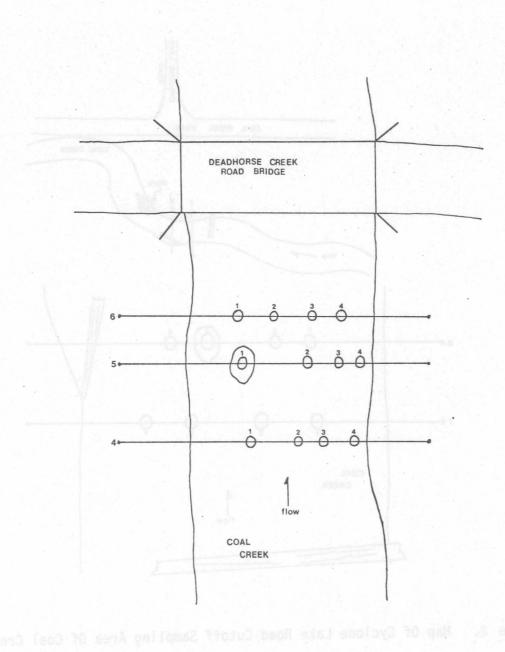


Figure 3. Map of Dead Horse Creek Road Bridge Sampling Area of Coal Creek

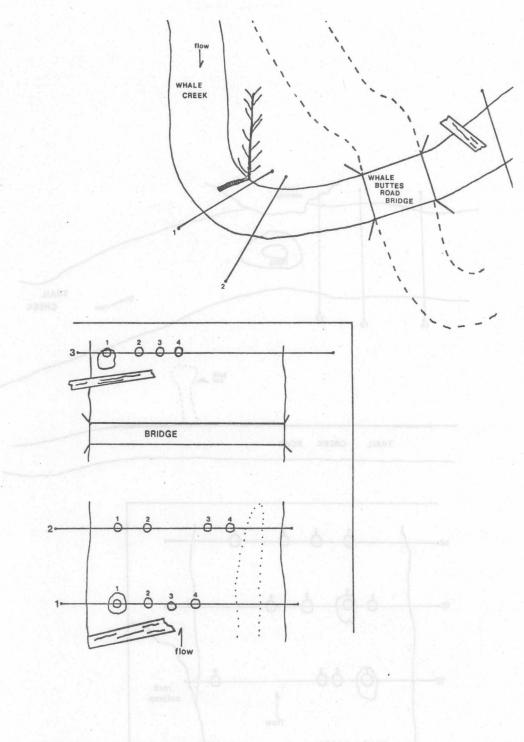


Figure 4. Map of Whale Buttes Road Bridge Sampling Area of Whale Creek

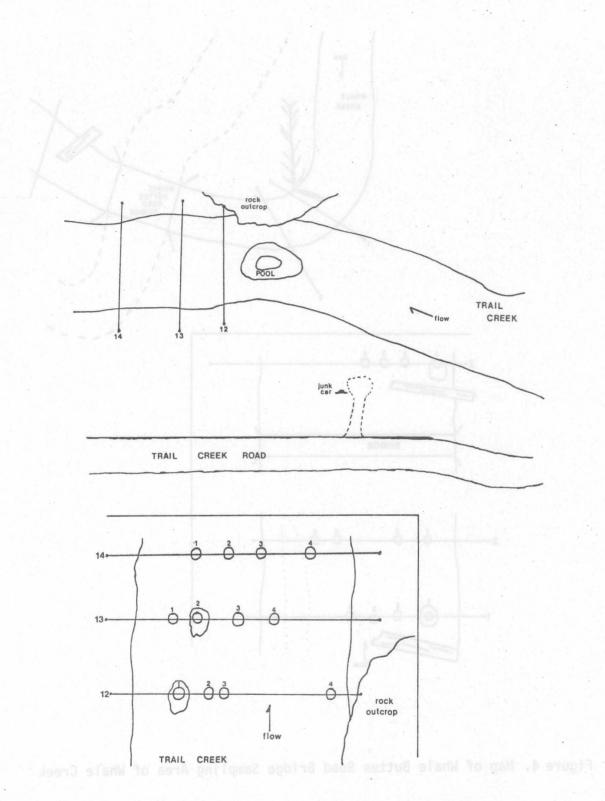


Figure 5. Map of "Junk Car" Sampling Area of Trail Creek

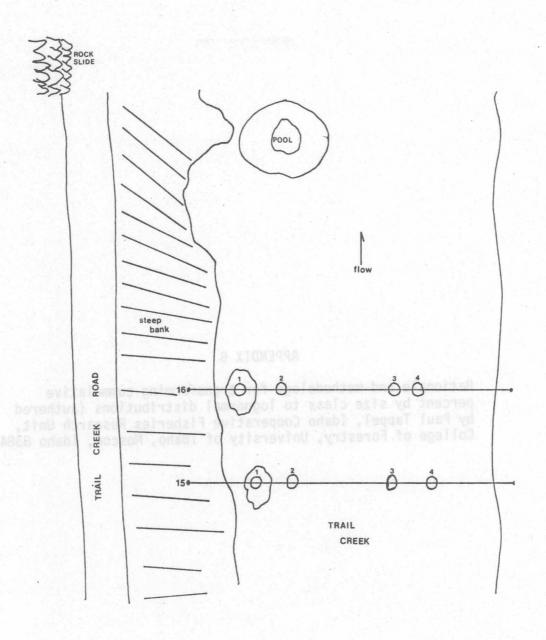


Figure 6. Map of Rock Slide Sampling Area of Trail Creek.

APPENDIX B

Rationale and methodology for transforming cummulative percent by size class to lognormal distributions (authored by Paul Tappel, Idaho Cooperative Fisheries Research Unit, College of Forestry, University of Idaho, Moscow, Idaho 83843)

## LOGNORMAL DISTRIBUTION OF SPAWNING GRAVEL

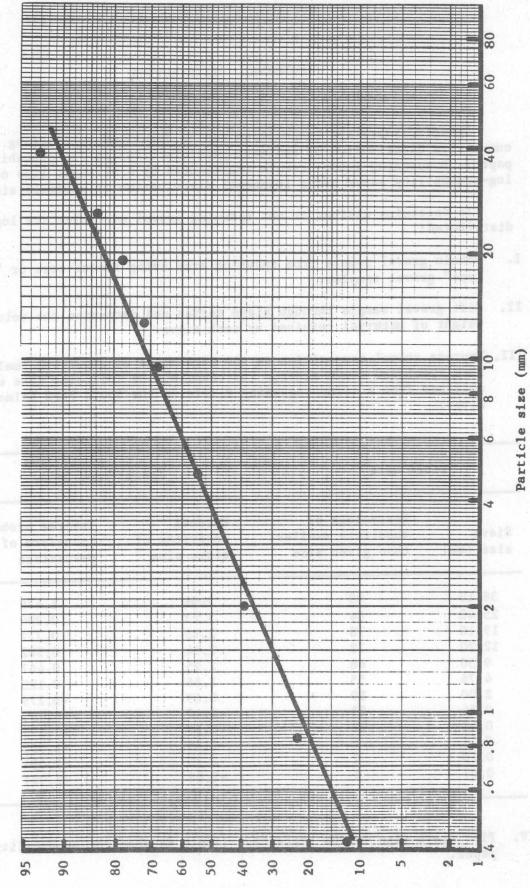
Spawning substrate composition can be described by plotting the cumulative distribution of sediment particle sizes on log-probability paper. A spawning gravel sample represented by a straight line on log-probability paper has a lognormal distribution of particle sizes.

To determine whether or not spawning gravel particles are lognormally distributed:

- I. Obtain gravel sample from spawning area using freeze-core or "McNeil type" gravel sampler.
- II. Sift gravel sample through sieve series and determine the volume or weight of material retained by each sieve.
- III. Express gravel composition as the percentage of substrate smaller than specified sieve sizes. For example, the following data were obtained from a salmon spawning riffle in the South Fork Salmon River:

Field data		Transformed data		
Sieve size (mm)	Percentage of substrate smaller than given size	Natural logarithm of sieve size	Inverse probability transform of percentage	
38.10	93	3.64	1.476	
25.40	84	3.23	0.994	
19.10	78	2.95	0.772	
12.70	72	2.54	0.582	
9.50	68	2.25	0.467	
4.76	55	1.56	0.125	
2.00	39	0.69	-0.279	
0.84	23	-0.17	-0.739	
0.42	12	-0.87	-1.175	
0.25	6	-1.39	-1.555	
0.10	2	-2.30	-2.054	
0.07	1	-2.66	-2.327	

IV. Plot sieve size versus percentage (field data) on log-probability paper.



Log-probability plot of spawning gravel sample with a particle distribution close to lognormal.

Percentage of substrate smaller than given particle size

V. If field data plotted on log-probability paper resembles a straight line, transform data and calculate least squares regression line through data. Transform sieve size by taking natural logarithm of sieve size. Transform percentage data using inverse probability transform values listed on last page of handout. Because the inverse probability transforms of 0 and 100 percent are undefined, these data are omitted from the analysis.

Treating the natural logarithm of sieve size as the independent variable, do a linear regression for transformed data. Regression equations will be of the form:

PERCENT = C + Klog SIZE

where

PERCENT = inverse probability transform of percentage smaller than a given size

C = intercept of regression line
K = slope of regression line

SIZE = sieve size in mm

The coefficient of determination (r<sup>2</sup>) for this regression will be close to 1.0 if gravel particles are lognormally distributed.

Using transformed data from the South Fork Salmon River (page 1), the following regression equation was obtained:

PERCENT = 
$$-0.74 + 0.55\log_{e}$$
SIZE  
r<sup>2</sup> = 0.99

VI. If the r<sup>2</sup> value is close to 1.0, the regression equation provides a relationship between particle size and percentages smaller than given sizes. An r<sup>2</sup> value close to 1.0 means that the slope and intercept of the regression line could be used to describe the entire range of particles in spawning gravels.

For the spawning gravel sample shown on page 1, suppose you needed to know what percentage of the substrate was smaller than 6.35 mm in diameter:

PERCENT = -0.74 + 0.55log<sub>e</sub>SIZE " = -0.74 + 0.55log<sub>e</sub>6.35 PERCENT = 0.277

Using table on last page of handout, if inverse probability transform equals 0.277, the percentage of the substrate smaller than 6.35 mm is about 61 percent.

Suppose you needed to know the geometric mean particle size. If gravel particles are lognormally distributed, the geometric mean is equal to the particle size that 50 percent of the substrate is smaller than. Inverse probability transform of 50 percent = 0. Therefore:

0 = -0.74 + 0.55log<sub>e</sub>SIZE 1.34 = log<sub>e</sub>SIZE 3.8 = SIZE

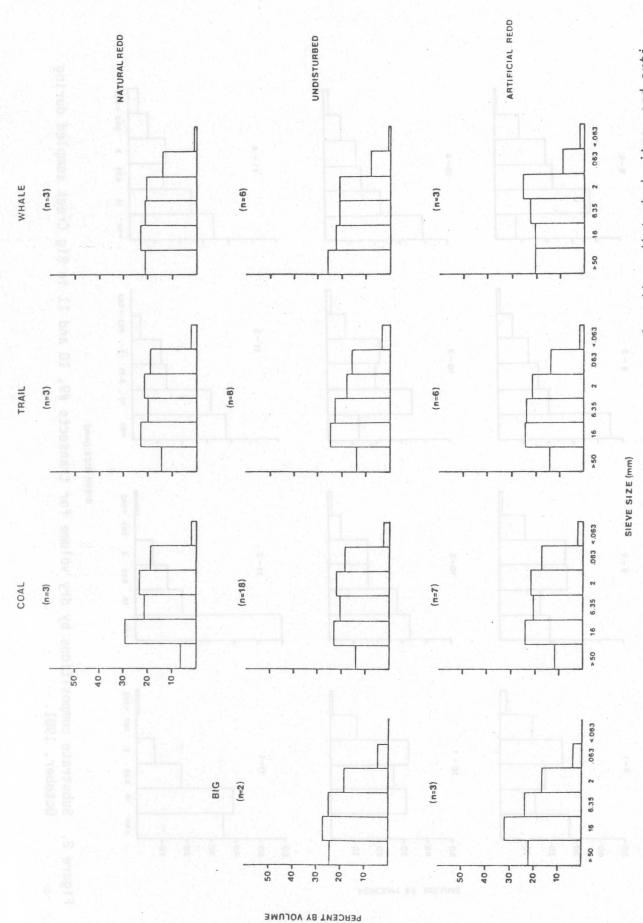
The geometric mean is 3.8 mm.

Inverse probability transform values for percentages ranging from 1 to 99

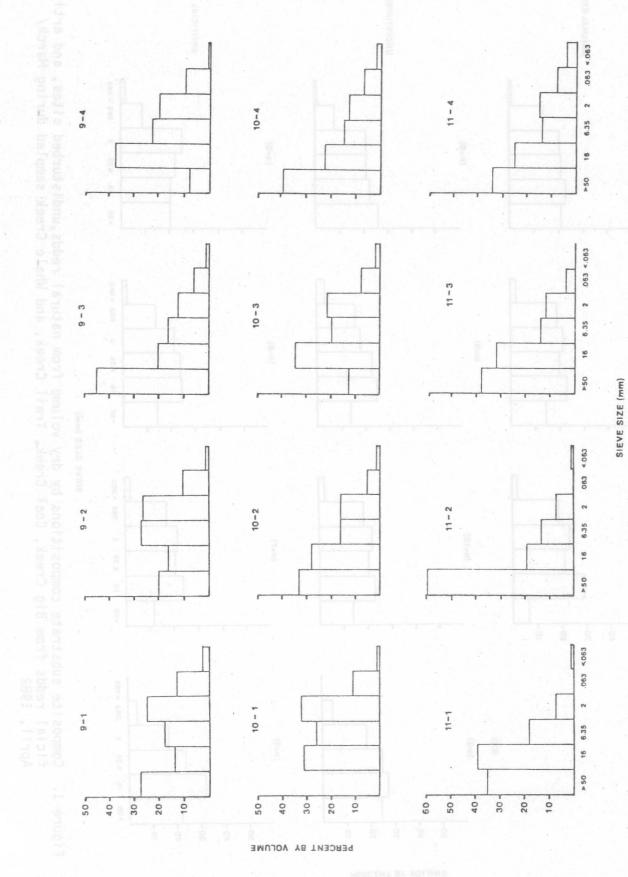
Percentage value	Inverse probability transform	Percentage value	Inverse probability transform	Percentage value	Inverse probabilit transform
insha	-2.327	41	-0.227	81	0.878
2	-2.054	42	-0.202	82	0.915
3	-1.881	43	-0.176	83	0.954
4	-1.751	44	-0.151	84	0.994
5	-1.645	45	-0.125	85	1.036
6	-1.555	46	-0.100	86	1.080
7	-1.476	47	-0.075	87	1.126
8	-1.405	48	-0.050	88	1.175
9	-1.341	49	-0.025	89	1.227
10	-1.282	50	-0.000	90	1.282
11	-1.227	51	0.025	91	1.341
12	-1.175	52	0.050	92	1.405
13	-1.126	53	0.075	93	1.476
14	-1.080	54	0.100	94	1.555
15	-1.036	55	0.125	95	1.645
16	-0.994	56	0.151	96	1.751
17	-0.954	57	0.176	97	1.881
18	-0.915	58	0.202	98	2.054
19	-0.878	59	0.227	99	2.327
20	-0.842	60	0.253	77	2.321
21	-0.806	61	0.279		
22	-0.772	62	0.305		
23	-0.739	63	0.331		
24	-0.706	64	0.358		
25	-0.674	65	0.385		
26	-0.643	66	0.412		
	-0.612	67	0.439		
27			0.467		
28	-0.582	68	0.495		
29	-0.553	69	0.524		
30	-0.524	70			
31	-0.495	71	0.553		
32	-0.467	72	0.582		
33	-0.440	73	0.612		
34	-0.412	274 mob			
35	-0.385	75	0 70/		
36	-0.358	76	0.706		
37	-0.331	77	0.739		
38	-0.305	78			
39	-0.279	79	0.806		
40	-0.253	80	0.842		

## APPENDIX C

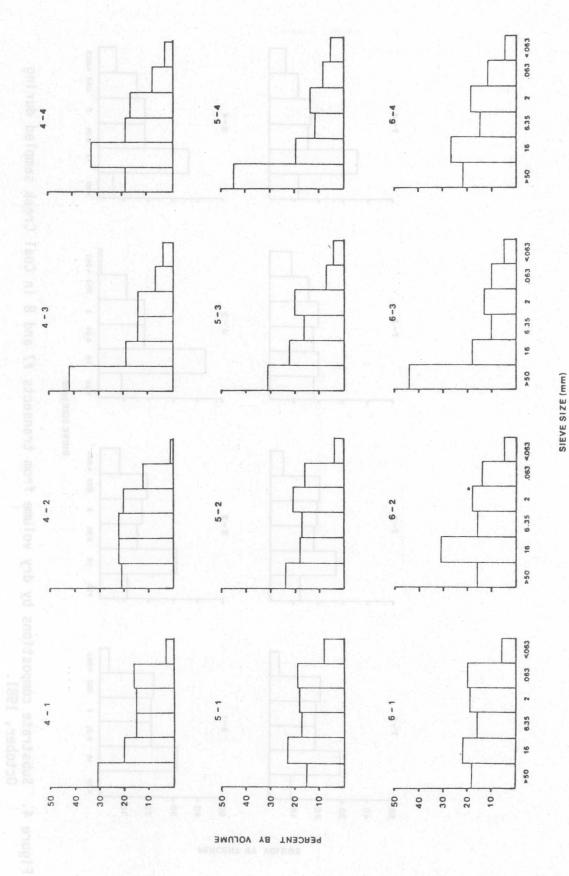
Bar graphs of substrate compositions for each site sampled during October, 1981 and March and April, 1981 presented as percent by dry volume versus sieve size.



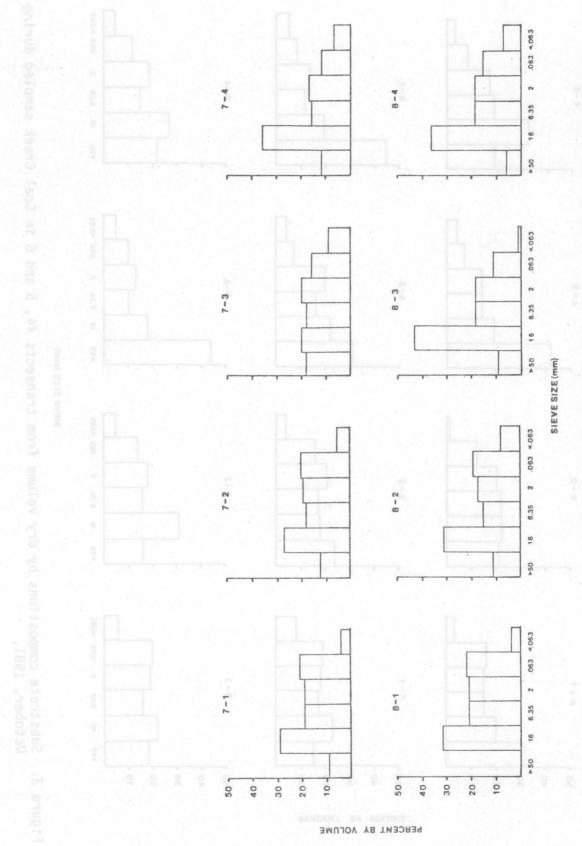
Composite substrate compositions by dry volume from natural redds,undisturbed sites, and arti-ficial redds from Big Creek, Coal Creek, Trail Creek, and Whale Creek sampled during March/ April, 1982 Figure 1.



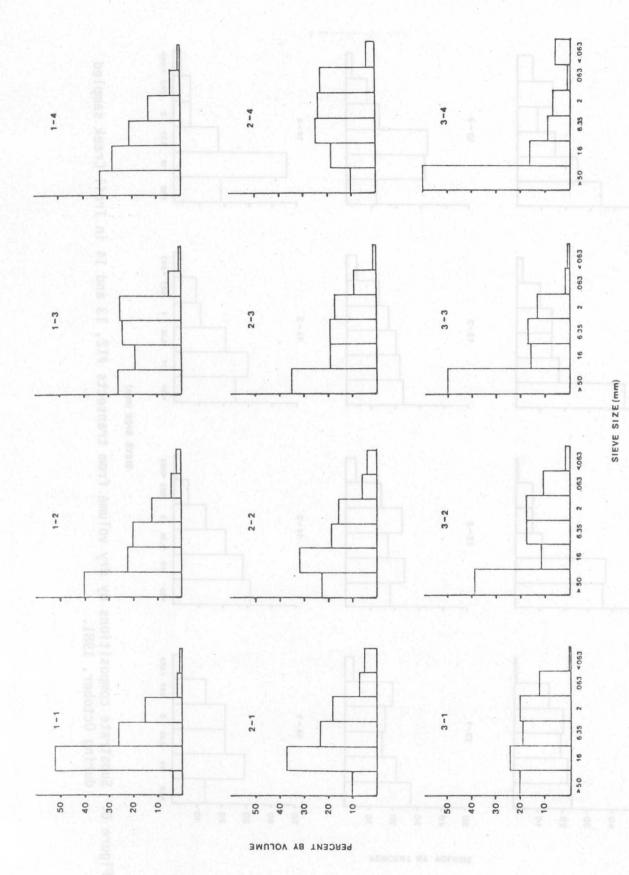
Substrate compositions by dry volume for transects #9, 10 and 11 in Big Creek sampled during October, 1981. Figure 2.



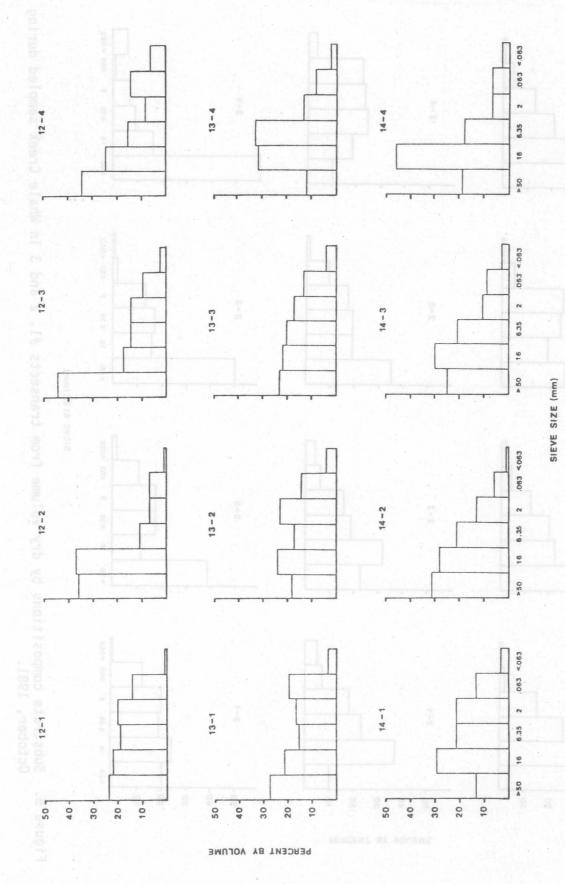
5 and 6 in Coal Creek sampled during Substrate compostions by dry volume from transects #4, October, 1981. Figure 3.



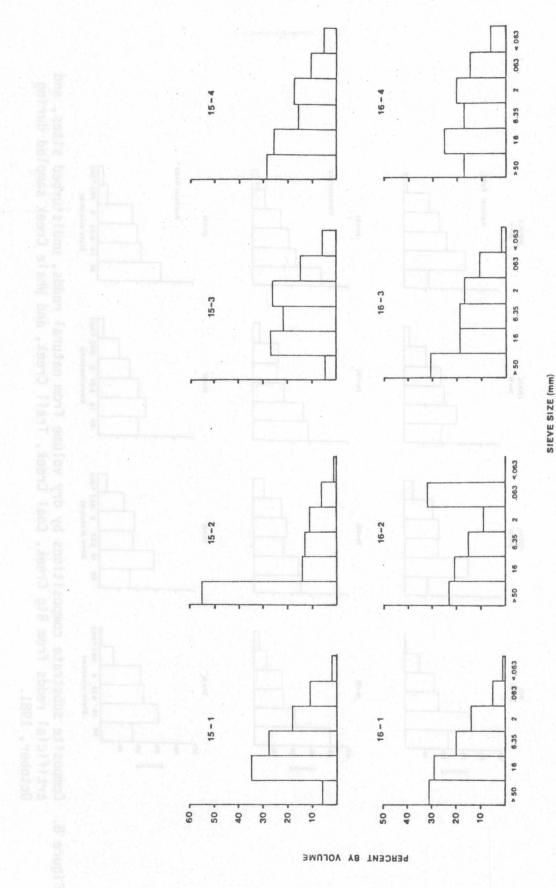
Substrate compostions by dry volume from transects #7 and 8 in Coal Creek sampled during October, 1981. Figure 4.



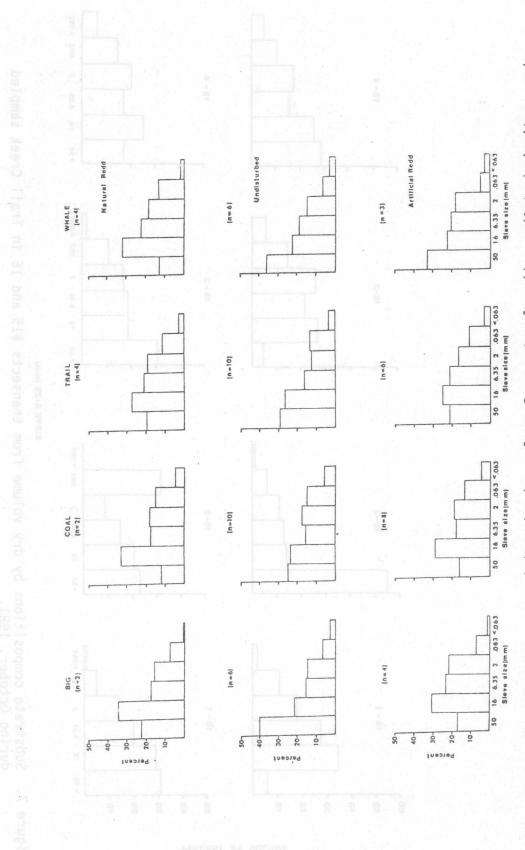
Substrate compositions by dry volume from transects #1, 2 and 3 in Whale Creek sampled during October, 1981. Figure 5.



Substrate compositions by dry volume from transects #12, 13 and 14 in Trail Creek sampled during October, 1981. Figure 6.



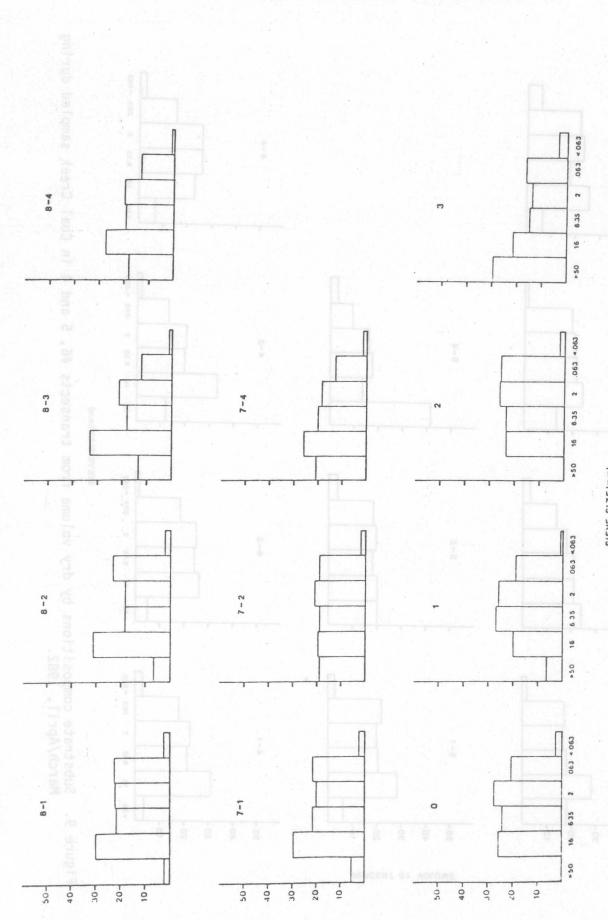
Substrate compositions by dry volume from transects #15 and 16 in Trail Creek sampled during October, 1981. Figure 7.



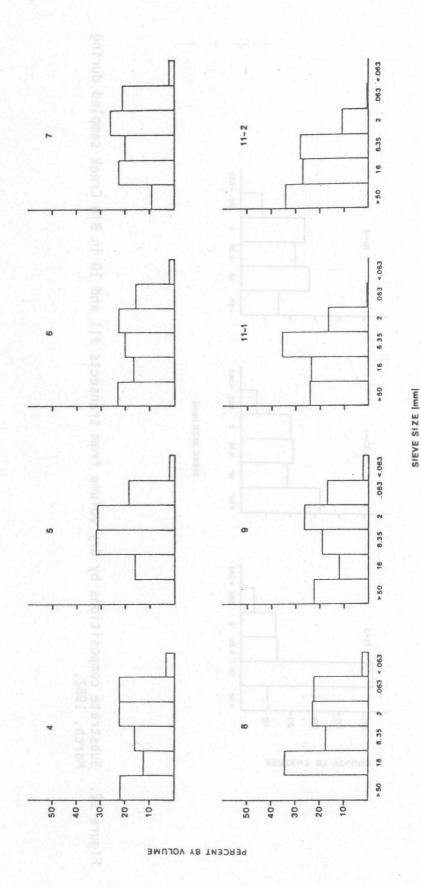
Composite substrate compositions by dry volume from natural redds, undisturbed sites, and artificial redds from Big Creek, Coal Creek, Trail Creek, and Whale Creek sampled during October, 1981. Figure 8.



Substrate compositions by dry volume from transects #6, 5 and 4 in Coal Creek sampled during March/April, 1982. Figure 9.



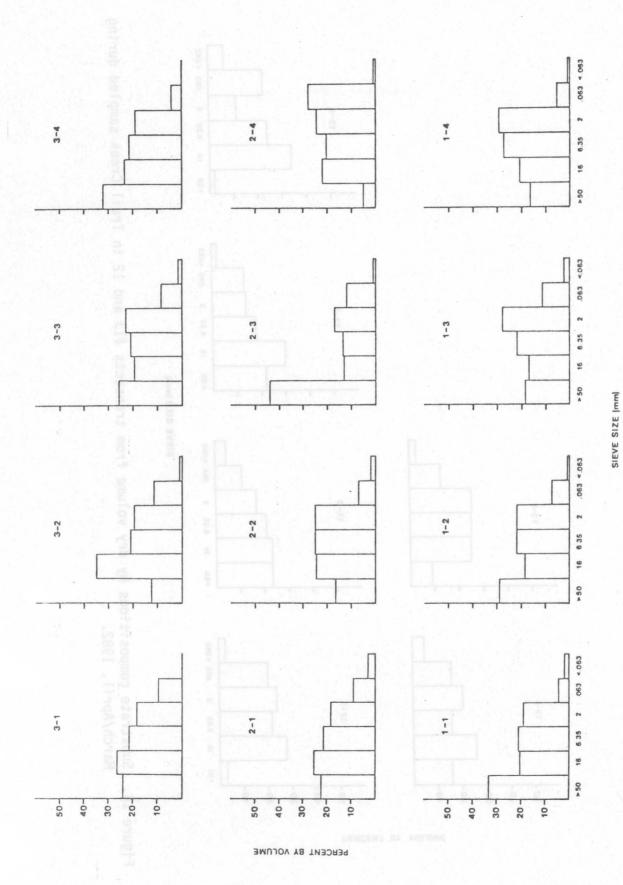
Substrate compositions by dry volume from transects #8 and 7 and cores #0-3 in Coal Creek sampled during March/April, 1982. Figure 10.



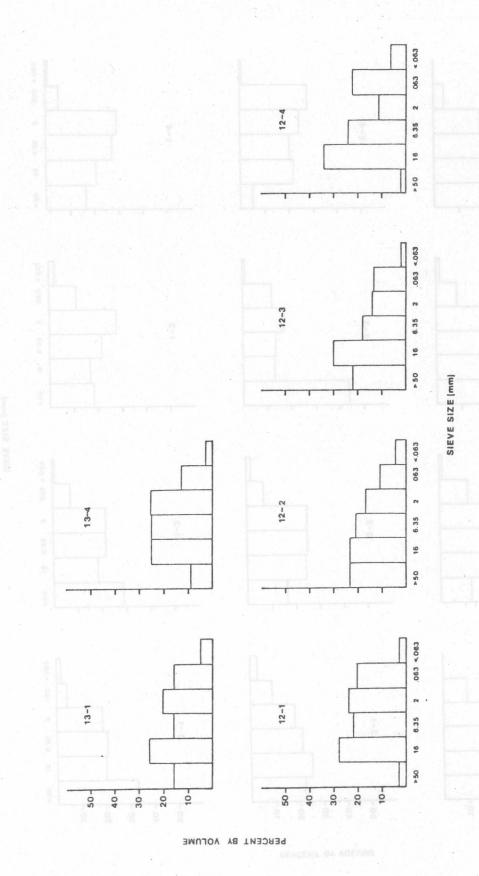
Substrate compositions by dry volume from cores #4-9 in Coal Creek and transect #11 in Big Creek sampled during March/April, 1982. Figure 11.



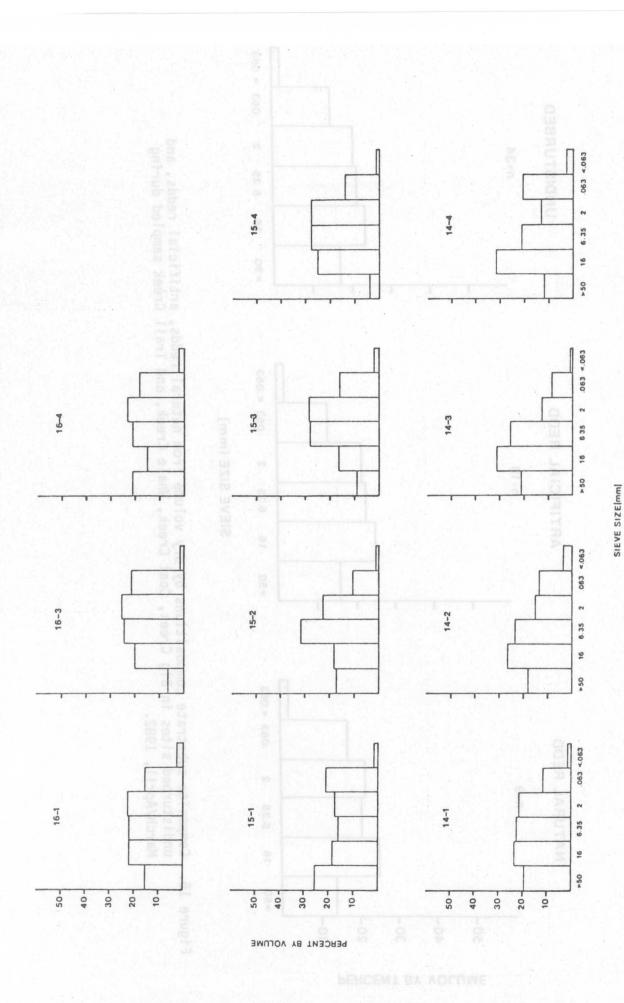
Substrate compositions by dry volume from transects #11 and 10 in Big Creek sampled during March, 1982. Figure 12.



Substrate compositions by dry volume from transects #3,2 and 1 in Whale Creek sampled during April, 1982. Figure 13.



Substrate compositions by dry volume from transects #13 and 12 in Trail Creek sampled during March/April, 1982. Figure 14.



Substrate compositions by dry volume from transects #16, 15 and 14 in Trail Creek sampled during March/April, 1982. Figure 15.



Composite substrate compositions by dry volume from natural redds, artificial redds, and undisturbed sites in Big Creek, Coal Creek, Whale Creek, and Trail Creek sampled during March/April, 1982. Figure 16.

## APPENDIX D

Comparison of ocular estimates of substrate composition and hollow core samples.

APPENDIX D

Comparison of ocular estimates of substrate composition and hollow core samples.

Table 1. Comparison of ocular versus cored substrate compositions sampled during Fall 1981.

			ım		2-16 n	nm
Transect	Core	Ocular	Difference	Core	Ocular	Difference
11	3	10	s - 7 0	41	20	21
12	6	10	- 4 08		20	12
13		10	E - 4	49	25	24
14			- 5 51	34	20	14
21			- 4	42	30	12
22			0 8	36	20	16
23			0	36	20	16
24			16	46	35	11 541
31			3	41	15 51	26
32			3 0	36	25	11
33	3		- 7 8	30	30	0
34	3 7		2	16	20	- 4
41			4 11	30	20 18	10
42			SE 4 4	45	30	15
43			i i	28	01 20	8
44		10	2	36	30	6
51	27	10	17	35	35	0 801
52	20	10	10	38	25	13
53	11	10	1	36	30	
54	14	10	4	24	20	6
61	26	15	11 5.8	34	25	9
62	19	10	9	34	25	9
63	15	15	0 10	23	15	8
64	17	10	7	34	30	0
71	24	15	9	37	30	visniftcantly
72	24	15	9	37	30	7
73	24	15	9	37	30	7
74	19	15	4	33	35	2
81	25	5	20	42	25	- 2 17
82	27	10	17	32	30	2
83	12	10	2	36	30	6
84	21	10	11	36	25	6 11
91	16	10	6	42		11
92	11	10	1	53	30 20	12
93	11 7	10		53 28	15	33 13
94	11	10	- 3 1	43	20	13
101	12	15	- 3	58	30	23
102	12 6	10	- 4	32	20	28
103	9	10	- 1	44	35	12
104	9 10	10	0	27	35	9 17
111	1	10		25	10	1/
112	1	10	- 9	25	15	10
113	5	10	- 5	20	25	- 5
114	1 5 12	10	- 9 - 9 - 5 2	25	20	10 - 5 5 15
221	17	10	4	30	15	15

Table 1. (Continued).

balance analyteograph at a result of the companion of the companion

			ım	2-16 mm		
Transect	Core	Ocular	Difference	Core	Ocular	Difference
121	14	150 15 gr	- 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1	39	30 30	1
122	8	10	- 2	18	20	- 2
123	10	10	A 0 1	28	20	8
124	30	10	20	22	15	7
131	21	10	11	31	20	11
132	17	5	12	41	35	6
133	17	10	7	37	15	22
134	10	5	5 0	46	20	26
141	16	10	6 0	42	25 01	17
142	7	5	2 21	34	01 15 89	19
143	12		7 8	32	15	17
144	10	10	0 8	25	10 81	15
151	13	5	8	45	20	25
152	7	10	- 3	24	25	- 1
153	21	10	11	47	30	17
154	14	10	4	32	15	17
161	6	10	- 4	34	20	14
162	32	10	22	24	15	9
163	14	10	88 4 VI	36	25	11
164	21	5	85 16 OI	37	25	12
Mean diffe	rence (a	bsolute				
value)			6.2			11.9
(n=64) Standard e	rror		0.7			0.9
Significan	tlv diff	erent (p<.	001)	Signif	icantly dif	ferent (p<.00

74 81 82

Table 2. Comparison of ocular versus cored substrate compositions sampled during Spring 1982.

		<2	mm		2-16 r	nm
Transect	Core	Ocular	Difference	Core	Ocular	Difference
11	6	20	-14	40	55	-15
12	8	10		44	20	24
21	12	5	- 2 7	40	30	10
22	9	25	-26	50	20	30
23	13	10	3 8.0	30	15	15
24	29	15	14	45	30	15
31	10	15		40	30	10
32	12	15 15	- 5	40	25	15
33	10	10	0	44	35	9
34	4	0	4	40	10	30
41	21	20	1	44	20	24
42	20	20	0	49	30	19
43	15	15	0	40	15	25
44	18	30	-12	52	25	27
51	24	25	- 1	41	20	21
52	22	15	7	38	15	23
54	12	10	2	33	10	23
61	19	30	-11	34	15	19
62	16	30	-14	38	20	18
63	21	20	1	42	20	22
64	27	25	2	40	25	15 16
71	24	20	4	41	25	16
72	21	15	6	40	30	10 - 1 18
74	14	20	- 6	39	40	- 1
81	25	15	10	43	25	18
82	25	25	0	37	25	12
83	14	15	- 1	39	20	19
84	15	15	0	39	20	19
121	23	25	- 2	46	35	11
122	15	15	0	38	20	18
123	16	10	6	32	20	12
124	29	30	- 1	35	25	10
131	21	25	- 4	37	25	12
134	16	10	6	50	25	25
141	13	. 10	6 3 7	44	20	24
142	17	10		38	25	13
143	10	15	- 5	38	30	8
144	23	15 25 15 10	- 5 - 2 7	34	25	13 8 9 3 34
151	22	15	7	33	30	3
152	11	10	1	54	20	34
153	18	25	- 7	56	30	26
154	16	30	1 - 7 -14 - 7	55	20	35
161	18	25	- 7	44	25	19

Table 2. (Continued).

		<2 mm			2-16 mm			
Transect	Core	Ocular	Difference	Core	Ocular	Difference		
163	23	25	- 20nerel	50	25	25		
164	20	30	-10	44	30	14		
Mean diffe	erence (a	bsolute						
value)			5.3			17.8		
(n=45) Standard e	error		0.8			1.1		
Not signif	ficantly	different	5 4	Signific	cantly diff	erent (p<.001		

## APPENDIX E

Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds and undisturbed areas in Big, Coal, Whale and Trail creeks during October, 1981.

## APPENDIX E

Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds and undisturbed areas in Big, Coal, Whale and Trail creeks during October, 1981.

Table 1. Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds, and undisturbed areas in Big Creek during October, 1981.

Transect	Site Description	Geometric Mean (dg)	Sorting Coefficient(so)	Fredle Index
9-1	Undist.	11.5	5.7	2.0
9-2	Art. redd	10.0	4.1	2.4
9-3	Undist.	53.2	6.8	7.8
9-4	Nat. redd	10.5	3. 5	3.0
10-1	Art. redd	4.3	2.6	1.6
10-2	Undist.	34.4	5.8	6.0
10-3	Art. redd	12.2	4.3	2.9
10-4	Undist.	44.0	7.7	5.7
11-1	Art. redd	79.9	5.1	15.6
11-2	Undist.	269.2	8.5	31.8
11-3	Nat. Redd	47.1	4.5	10.5
11-4	Undist.	29. 4	8.5	3.5
Mean .				
Nat.	redd (2)	28.8		6.7
Art.		26.6		5.6
Undis		73.6		
	11	50.5		7.7

Table 2. Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds and undisturbed areas in Coal Creek during October, 1981.

Area and Transect	Site Description	Geometric Mean (dg)	Sorting Coefficient(so)	Fredle Index
Dead Horse Road Bri	dge			
4-1 4-2 4-3 4-4 5-1 5-2 5-3 5-4 6-1 6-2 6-3 6-4	Undist. Art. redd Undist. Art. redd Nat. redd Undist. Art. redd Undist. Undist. Art. redd Undist. Art. redd Undist. Art. redd	17.1 10.1 44.6 15.7 6.1 10.1 21.5 22.6 6.8 10.3 46.8 12.8	7.2 4.7 9.5 5.7 6.9 6.4 7.5 8.0 6.7 6.5 12.0 7.0	2.4 2.1 4.7 2.8 0.9 1.6 2.8 2.8 1.0 1.6 3.9 1.8
Mean for: Nat. Art. Undis	redd (5)	6.1 a 88 14.1 24.7	dd (2) dd (4)	
Overa		18.7		2.3
Road Cut		6.1	4.6	1.3
7 - 2 7 - 3 7 - 4 8 - 1 8 - 2 8 - 3 8 - 4	Art. redd Undist. Art. redd Art. redd Undist. Nat. redd Undist	6.5 6.5 8.3 3.1 5.8 11.7 6.0	5.4 7.5 6.7 3.1 6.7 4.0 5.4	1.2 0.9 1.2 1.0 0.9 2.9 1.1

Table 2. Continued to Table 2. To Continue to Table 2. To Continue

Area and Transect	Site Description	Geometric Mean (dg)	Sorting Coefficient(so)	Fredle Index
Mean for: Nat. Art. Undis	redd (3)	11.7 6.0 6.1		2.9 1.1 1.0
Overa	11 8.4	6.8		1.3
Overall Me Nat. Art. Undis	redd (2) redd (8)			1.9 1.8 2.0
Mean		14.0		1.9

Table 3. Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds, and undisturbed areas in Whale Creek during October, 1981.

Transect	Site Description	Geometric Mean (dg)	Sorting Coefficient(so)	Fredle Index
1-1	Nat. Redd	15.7	3.4 (E) bbs	4.5
1-2	Undist.	15.6	4.0	3.9
1-3	Art. redd	16.4	4.3	3.8
1-4	Undist.	34.6	4.9	7.1
2-1	Undist.	11.0	5.3	2.1
2-2	Art. redd	20.6	6.7	3.1
2-3	Undist.	23.5	4.9	4.8
2-4	Nat. redd	4.9	4.3	1.1
2-5	Nat. redd	11.8	4.1	2.9
3-1	Nat. redd	12.7	4.1	3.1
3-2	Undist.	23.1	2.2	10.7
3-3	Art. redd	70.7	6.3	11.1
3-4	Undist.	703.6	32.1	21.9
Mean for:				
Nat. 1	redd (4)	11.3		2.9
Art.		35.9		6.0
Undist		135.2		8.4
0vera	11	74.2		6.1

Table 4. Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds and undisturbed areas in Trail Creek during October, 1981.

Area and	Site	Geometric	Sorting	Fredle
Transect	Description	Mean (dg)	Coefficient	Index
Junk Car Si				
12-1	Nat. redd	13.1	4.3	3.0
12-2 12-3	Undist.	66.2 40.7	7.2	9.1
12-3	Art. redd Undist.	26.4	7.1 11.4	5.7 2.3
13-1	Undist.	13.0	6.2	2. 1
13-2	Nat. redd	9.4	5.3	1.8
13-3	Undist.	12.2	6.3	1.9
13-4	Art. redd	12.2	4.2	2.9
14-1 14-2	Art. redd Undist.	9.0 30.4	4.7	1.9
14-3	Art. redd	22.5	5.3 6.3	5.7 3.5
14-4	Undist.	27.1	6.4	4.2
Means for:				
	redd (2)	11.2		2.4
	redd (4)	21.1		3.5
Undi	st. (6)	29.2		4.2
Over	a11	23.5		3.7
Rock Slide				
15-1 15-2	Nat. redd	7.9	4.0	2.0
15-2	Undist. Art. redd	86.9 4.5	7.4 4.4	11.8
15-4	Undist.	19.3	7.6	2.5
16-1	Nat. redd	30.9	4.7	6.5
16-2	Undist.	10.2	4.0	2.6
16-3 16-4	Art. redd Undist.	18. 2 8. 0	6.4	2.8
	ond is c.	0.0	6.7	1.2
Means for:	nodd (2)	10.4		
	redd (2)	19.4 11.3		4. 2 1. 9
Undis		31.1		4.5
Overa				
		23.2		3.8
Overall Mea	ns redd (4)	15 2		
	redd (6)	15.3 17.8		3.3 3.0
Undis		30.0		4.3
ME/	AN	23.4		3.7

able 4. Geometric means and "fredle indices" for substrate samples collected from natural bull trout redds, artificial redds and undisturbed areas in Trail Creek during October, 1981.