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EMBEDDEDNESS OF SALMONID HABITAT OF SELECTED STREAMS ON THE PAYETTE NATIONAL FOREST

by
David C. Burns
and
Richard E. Edwards

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PAYETTE NATIONAL FOREST

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INTRODUCTION

Comparison of fish habitat condition among various locations within the Payette National Forest is necessary in order to facilitate development of future management objectives for aquatic ecosystems. The single most significant element of fish habitat management during recent history has been development of objectives for limiting deposition of fine sediment. Three environmental impact statements within Forest during the past decade (Anon., 1977; Anon., 1979; Anon., 1981) have all dealt with the impact of sediment on fish habitat as a major issue. The development of another environmental impact statement pursuant to the implementation of the National Forest Management Act of 1976 (36 CFR 1950) is presently underway.

Embeddedness is generically defined as the amount of fine sediment which is deposited in the interstices between larger stream substrate particles. This fish habitat characteristic has been demonstrated by research (Klamt, 1976, Kelly and Dettman, 1980) to negatively influence the ability of a stream to rear fish. Increasing the amount of deposition, embeddedness, decreases the number of fish a stream can rear.

Stowell, Espinosa, Bjornn, Platts, Burns and Irving(1984) related increased embeddedness to man-caused sedimentation, as did Burns(1984).

This inventory of embeddedness of fish habitat was conducted in order to empirically answer five questions.

1) Are there detectable sources of man-caused sediment, which could be detrimental to fish habitat, associated with the Thunder Mountain mining area ?

2) Are there detectable sources of man-caused sediment, which could be detrimental to fish habitat, associated with the Stibnite mining area ?

3) What is the condition of the mainstem South Fork Salmon River relative to its major tributaries, the East Fork and the Secesh? This granitic wateshed has been described by various authors (Anon., 1969; Anon., 1970; Thompson, Skabelund and Kulesza, 1973).

4) Are there detectable sources of man-caused sediment, which could be detrimental to fish habitat, in the Little Salmon River? The metamorphic nature of the watershed has been described in a National Forest report (Thompson, Skabelund, Kulesza and Dean, 1973).

5) Are there detectable sources of man-caused sediment, which could be detrimental to fish habitat, in the Weiser River drainage or other basalt watersheds (Knight, Thompson and Kulesza, 1973; Larson, Paulson, Thompson and Skabelund, 1973)?

STUDY AREA

Thunder Mountain Mining Area

Fifteen locations were identified surrounding the Thunder Mountain mining area (Table 1). Two locations were established in Marble Creek, both upstream and downstream of Cottonwood Creek. Cottonwood Creek was established as a control, undisturbed by recent mining. Two locations were established in Big Creek, both upstream and downstream of Monumental Creek, in order to identify any influence in Big Creek. Control areas for Monumental Creek included Snowslide Creek, the West Fork of Monumental Creek, and Monumental Creek downstream from Annie Creek but upstream of most road reconstruction. Seven locations were established in Monumental Creek at various locations to establish the upstream and downstream extent of measurable increases in sediment deposition related to mining activities.

Stibnite Mining Area

Five locations were identified surrounding the Stibnite mining area (Table 2). These were in the same areas as those sampled by Burns(1984) in 1983. Two control areas were sampled, one in Tamarack Creek and one in Sugar Creek upstream of the mine in West End Creek. Three locations were sampled to determine the downstream extent of possible sediment deposition resulting from the West End mine.

South Fork Salmon River Drainage

Seven locations were identified in the mainstem South Fork Salmon River and its tributaries (Table 3). These locations were selected in an attempt to determine the extent of downstream deposition resulting from heavily embeddeded streams described by Burns(1984). Two relatively unembeddeded streams were selected from those sampled in 1983, Blackmare Creek and Lick Creek, in order to facilitate comparison between years. The mainstem of the South Fork, the East Fork South Fork, and Secesh were sampled near their confluence in order to make comparisons of their relative condition. In addition, the Secesh was sampled upstream of major areas of historic development in Zena and Cow/ Maverick Creeks. Finally, the mainstem South Fork was sampled near the Frank Church-River of No Return Wilderness boundary at Knob Creek in order to determine the condition of the river at the most downstream extent of possible future development.

Little Salmon River Drainage

Ten locations were identified in the Little Salmon River drainage (Table 4). Four controls were established in Rapid River, because it has remained relatively undisturbed by recent development. A control was also established in Boulder Creek upstream from recent roading and logging. Boulder Creek was sampled immediately downstream from recent roading and logging in the Pollock Creek drainage and at the Forest boundary to determine the possible downstream extent of any logging related sediment deposition. Three locations, Hard Creek, Hazard Creek and Elk Creek, were

TABLE 1. Embeddedness samples were taken from Big Creek and its tributaries, Monumental Creek and Marble Creek. These locations were picked to surround mining activity on Thunder Mountain. Samples above and below Mule Creek in Monumental Creek are similar locations to those sampled by Burns (1983). Legal descriptions are approximate. Burns took all measurements in 1984.

Location	Township	Section	Range	Description
Marble Creek Upstream from Cottonwood Creek	18N	11NW1/4	11E	Pool tailouts approximately 200m upstream from the mouth of Cottonwood Creek
Cottonwood Creek	18N	11NW1/4	11E	Run approximately 100m upstream from the confluence with Marble Creek.
Marble Creek downstream from Cottonwood Creek	18N	11	11E	Run approximately 100m downstream from Cottonwood Creek.
Big Creek upstream from Monumental Creek	21N	17NE1/4	11E	Pool tailout about 100m upstream from the mouth of Monumental Creek.
Big Creek downstream from Monumental Creek	21N	16	11E	Run about 200m downstream from the mouth of Monumental Creek.
Monumental Creek downstream from Snowslide Creek	20N	6	11E	Pool tailout about 100m downstream from the mouth of Snowslide Creek.
Snowslide Creek	20N	6	11E	Pool tailout 10m upstream from Monumental Creek.
Monumental Creek downstream from Holy Terror Creek	20N	33	11E	Run about 400m downstream from the mouth of Holy Terror Creek; at trail crossing.
Monumental Creek downstream from the West Fork of Monumental Creek	19N	5NE1/4	11E	Run about 400m downstream from the West Fork; at trail crossing
West Fork of Monumental Creek	19N	8NW1/4	11E	Pool tailout about 100m upstream from Monumental Creek; at trail crossing.
Monumental Creek downstream from Mule Creek	19N	24NE1/4	10E	Pool tailout sampled by Burns (1983) about 200m downstream from Mule Creek.

Table 1.Cont'd.

Monumental Creek upstream from Mule Creek	19N	24NE1/4	10E	Run about 100m upstream from Mule Creek.
Monumental Creek upstream from Roosevelt Lake	19N	24SE1/4	10E	Run about 100m upstream from Roosevelt Lake.
Monumental Creek downstream from Coon Creek	19N	25	10E	Pool tailout downstream from Coon Creek.
Monumental Creek downstream from Annie Creek	18N	10NE1/4	10E	Run 100m downstream from Annie Creek.

Table 2. Embeddedness samples were taken from the East Fork South Fork Salmon River (EF) vicinity. These locations were picked to "bracket" sediment input from an active open-pit mine near Stibnite, Idaho, in West End Creek (WE), and were sampled by Burns (1984). Legal descriptions are approximate. Burns took all measurements in 1984.

Location	Township	Section	Range	Description
EF downstream from Sugar Creek	19N	34	9E	Pool tailout in EF 200m downstream from Sugar Creek.
EF upstream from Vibika Creek	19N	27NW1/4	8E	In EF 10m upstream from Vibika Creek.
Sugar Creek downstream from WE	19N	34SE1/4	9E	In Sugar Creek upstream for FS road 48 bridge.
Sugar Creek upstream from WE	19N	35SE1/4	9E	In Sugar Creek 30m upstream from WE.
Tamarack Creek	19N	29NW1/4	9E	In Tamarack Creek upstream from FS road 48 bridge.

Table 3. Embeddedness sampling locations in the mainstem South Fork Salmon River and tributaries were selected in order to determine their relative condition. Two areas sampled by Burns (1984) were selected for comparison. Legal descriptions are approximate. Burns took all measurements in 1984.

Location	Township	Section	Range	Description
Blackmare Creek	17N	10SE1/4	6E	Upstream from old road crossing sampled by Burns(1984).
Lower East Fork	19N	30NW1/4	7E	Pool tailout at base of avalanche path 3.7Km upstream from Forest highway 48 bridge.
Glory Hole Area	19N	16NE1/4	6E	In South Fork in a run 100m downstream from Glory Hole.
Lick Creek	20N	18SE1/4	6E	Upstream from old bridge location sampled by Burns(1984)
Secesh River upstream from Lick Creek	20N	17	6E	Run about 0.6Km upstream from Forest highway 48 bridge.
Secesh River downstream from Zena Creek	20N	33NE1/4	6E	Pool tailout at dispersed camp site 2Km downstream from Forest highway 48 bridge.
South Fork upstream from Knob Creek	22N	17NE1/4	8E	Pool tailout on east side of river about 100m upstream from mouth of Knob Creek.

Table 4. Embeddedness samples were taken from Little Salmon River tributaries in order to determine whether man caused sediment resulted in detectable deposition in fish habitat. Legal descriptions are approximate. Burns took measurements in 1984, except in Upper Boulder Creek and Elk Creek which were measured by Edwards.

Location	Township	Section	Range	Description
Upper Boulder Creek	20N	8NE1/4	1W	Upstream of bridge on Forest road 662; north of Railroad Saddle.
Boulder Creek downstream from Pollock Creek	21N	7SE1/4	1E	Pool tailout about 200m downstream from Pollock Creek.
Lower Boulder Creek	21N	4	1E	Run at Payette National Forest boundary.
Hard Creek	21N	1SW1/4	1E	Pool tailout 10m upstream from confluence with Hazard Creek.
Hazard Creek	21N	1	1E	Pool tailouts about 300m upstream from confluence with Hazard Creek.
Elk Creek	22N	26NW1/4	1E	Pool tailouts upstream from second bridge upstream from Little Salmon River.
West Fork of Rapid River	23N	26NE1/4	1W	Pool tailout 20m upstream from Rapid River.
Rapid River upstream from the West Fork of Rapid River	23N	26	1W	Run about 100m upstream from the West Fork.
Rapid River downstream from Castle Creek	22N	11NW1/4	1W	Run about 200m upstream from Payette National Forest boundary
Rapid River upstream from Castle Creek	22N	11SW1/4	1W	Run about 200m upstream from Upstream from Castle Creek.

sampled in order to determine the possible effects of [illegible] levels of development in these watersheds.

Basalt Drainages

Twenty-one locations were sampled in order to begin developing a data base for use in characterizing embeddedness conditions in watersheds of primarily basalt origins (Table 5). Multiple sample sites were selected in some drainages in order to identify any localized effects of sedimentation or to document baseline trends at the Forest boundary.

The development history of most of these study watersheds is much more extensive than that of the granitic and meta-granitic drainages discussed above. Most of the basalt drainages have received moderate to heavy development over a long period of time. The only control site in this set of drainages is Deep Creek. The control sites identified for the Little Salmon River drainages are also applicable to this group, due to the predominance of basalt materials in those areas.

Table 5. Embeddedness samples were taken from drainages of primarily basalt origin in order to determine whether man caused sediment resulted in detectable deposition in fish habitat. Legal descriptions are approximate. Edwards took all measurements in 1984.

Location	Township	Section	Range	Description
Deep Creek downstream from Lake Creek	21N	6SE1/4	2W	Runs and pool tailouts immediately downstream from Lake Creek confluence
Deep Creek downstream from Trail Creek	22N	36NW1/4	3W	Pool tailouts just upstream of channel gradient break-approximately 0.4 km downstream of Trail Creek confluence
Lost Creek at mouth	18N	7SE1/4	1W	Runs and pool tailouts immediately upstream of confluence with West Fork Weiser River
West Fork Weiser River	18N	18SE1/4	1W	Runs at Payette National Forest boundary-approximately 2.6 km downstream of Lost Creek confluence
East Fork of Brownlee Creek	16N	9SW1/4	4W	Runs and pool tailouts in reach immediately adjacent to lower end of Brownlee Guard Station
West Pine Creek	15N	20NW1/4	4W	Runs and pool tailouts immediately downstream of confluence with Blue Springs Creek
Crooked River	19N	26SE1/4	3W	Runs just downstream from junction of Roads 070 and 002
Bear Creek at mouth	19N	29NE1/4	3W	Runs immediately upstream of confluence with Crooked River
Lick Creek	20N	28NE1/4	2W	Runs at Payette National Forest boundary approximately 1.0 km upstream of Butterfield Gulch bridge
Mud Creek	20N	32NE1/4	1E	Runs in reach due west of Middle Mud Creek crossing on Road #100
East Branch Weiser River	20N	26SW1/4	1W	Runs and pool tailouts approximately 0.5 km upstream of East Branch bridge on Road #074

TABLE 5. (Continued)

Little Weiser River	14N	35NW1/4	1E	Runs and pool tailouts at Payette National Forest boundary, approximately 0.4 km upstream of Grouse Creek
Anderson Creek	14N	29NW1/4	2E	Runs immediately upstream from confluence with the Little Weiser River
East Fork of Lost Creek	19N	8NE1/4	1W	Runs upstream of crossing on Road # 139
Lost Creek (Upper)	20N	36NE1/4	2W	Runs immediately upstream of crossing on Road #138
Bear Creek (Upper)	20N	7SE1/4	2W	Runs approximately 100 meters downstream of bridge crossing on Road #130
Indian Creek above Landore	21N	30SE1/4	2W	Runs and pool tailouts approximately 0.8 km upstream of Indian Creek bridge at Landore
Indian Creek above Cuprum	20N	2SW1/4	3W	Runs approximately 35m downstream of the Mann Creek confluence
Mica Creek	15N	7SE1/4	2E	Runs immediately upstream from confluence with Middle Fork Weiser River
Middle Fork Weiser River (Lower)	15N	9NW1/4	1E	Runs immediately upstream of projection of Payette National Forest boundary along Sec. 8/9
Middle Fork Weiser River (Upper)	16N	16NW1/4	2E	Runs immediately upstream of crossing on Road #186

METHODS

Methods for this inventory were adapted from Kelly and Dettman (1980) and Burns (1984). Data acquired could be entered into the General Aquatic Wildlife System (GAWS) of Region Four of the USDA-FS.

Embeddedness was earlier defined in generic terminology. For the remainder of this report embeddedness refers specifically to the proportion of a matrix particle (4.5 - 30.0 cm greatest diameter) surrounded by fine sediment (< 6.3 mm dia.). The proportion is calculated from the formula (Fig. 1):

$$E = \frac{d_2}{d_1} (100),$$

Where; E = (percent) embeddedness,

d_1 = the total diameter of a matrix particle (4.5 - 30.0 cm greatest diameter) at right angles to the plane of deposition of fine particles (<6.3mm dia.), and,

d_2 = the distance along d_1 covered by fine sediment (<6.3 mm dia.) or "embedded" in the stream bottom.

Note that this measurement is different than described by Burns (1984). He measured the longest diameter perpendicular to the plane of deposition, which was continuous on the rock. The "total diameter" described here is not necessarily continuous on the rock (Fig. 1). This difference might lead to increased mean embeddedness estimates from sampled populations. Comparisons between data collected by Burns (1984) and this inventory should be conducted with appropriate care.

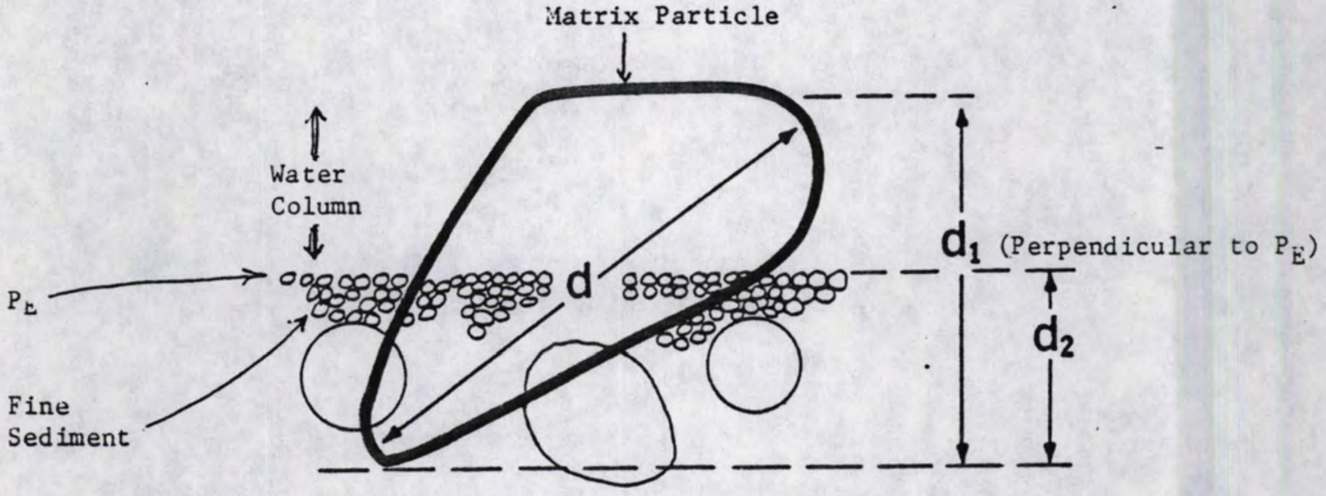
Embeddedness is the proportion of a single matrix particle as measured. A population of single matrix particles must be sampled in order to characterize fish habitat conditions in a quantitatively precise manner.

The standard of measurement for d_1 and d_2 was established as the closest millimeter. A sample size of 100 was selected as a minimum number of measurements for each population or location sampled. These standards were developed based on Burns'(1984) work.

Sampling required use of several tools. A 60 cm steel hoop (Kelly and Dettman, 1980) was used to isolate particles to be measured. A 30 cm transparent ruler graduated in millimeters was used to measure greatest particle diameter, d_1, d_2, and water depth. A float and stop watch were used to measure water velocity. A steel pry bar (45 cm long) was necessary to dislodge stream bottom particles. Chest waders and shoulder length rubber gloves were used to keep dry and avoid hypothermia. Data and observations were recorded on a field form made of waterproof paper.

The transparent ruler was affixed to a plexiglass frame hinged at right angles (Fig. 2). This facilitated more precise measurement.

Samples were taken systematically at each location in order to minimize the number of variables influencing measurement. Fish habitat was defined



$$E = \frac{d_2}{d_1}(100)$$

Figure 1. Embeddedness ($E = \frac{d_2}{d_1}(100)$)is defined in this 1984 survey as the percentage derived from the total diameter (d_1) of a matrix particle which is perpendicular to the plane of embeddedness (P_E) divided into the portion (d_2) of the length which is below the plane of embeddedness. A matrix particle is a rock which has its greatest diameter (d) between 4.5cm and 30.0 cm. The plane of embeddedness is formed by fine sediment ($<$ 6.3 mm diameter) surrounding some portion of the matrix particle.

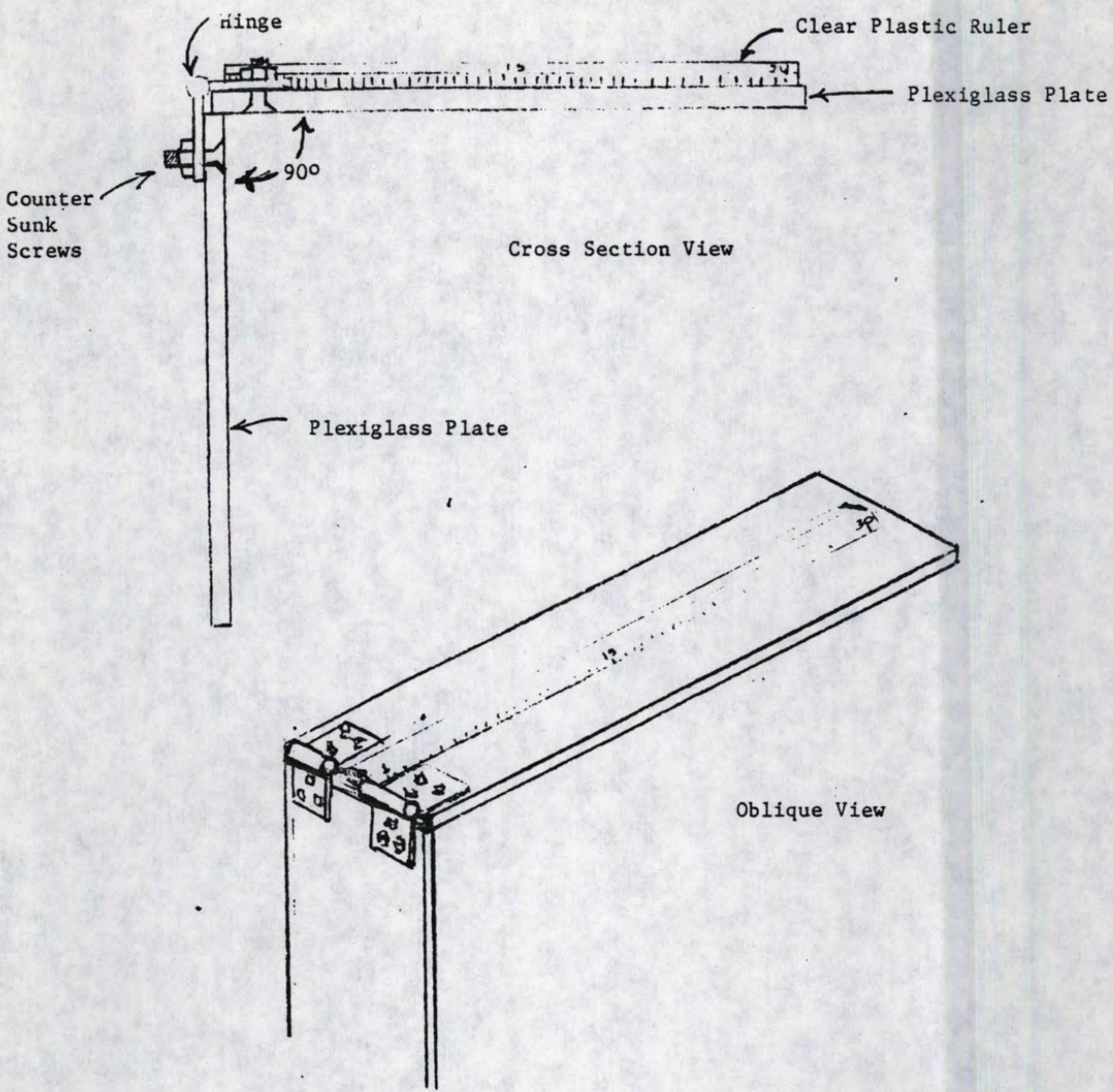


Figure 2. Embeddedness of each matrix particle was calculated from measurements taken with a clear plastic ruler glued to hinged plexiglass plates. The plates were hinged at right angles. The rules was marked in millimeters from 0 to 300.

consistently among locations which would la[illegible] pared. All locations were sampled during baseflow conditions. Criteri[illegible] ed to define fish habitat were developed from Bovee (1978) and further refined for this study.

Upon arriving at each location (Tables 1 to 5) the 60 cm steel hoop was randomly thrown into an area which had generally laminar flow across at least the hoop diameter. Samples were not taken if:

1) Float time across the hoop diameter was less than 0.9 seconds or greater than 2.5 seconds or,

2) water depth was less than 15 cm or, greater than 45 cm or,

3) the hoop or part of the hoop was in an eddy caused by a pool or large boulder or,

4) particles in the hoop were all less than 4.5 cm or greater than 30 cm. These criteria eliminated sites that did not approximate rearing habitat for juvenile trout.

Beginning at one side of the hoop and working across it, each free matrix particle (4.5 to 30.0 cm greatest diameter), which had no fine particles (<6.3 mm diameter) surrounding it was lifted from the hoop, cursorily measured for d_1 and discarded. Measurement could be cursory for these particles because they show up as zeros in the data.

Starting back across the ring, matrix particles were then removed as systematically as possible. A matrix particle was generally picked up with the right hand (for a right-handed person) by grasping it with the thumb and index finger at the plane of embeddedness. The particle was rotated so that the embedded portion was to the left. An index finger was placed on the side of the rock away from the eye used to read the ruler. By aligning an index finger with a point on the rock at the plane of embeddedness closest to the observers eye, the plane of embeddedness was identified. The embedded portion of the rock was held against one plate of the plexiglass frame (Fig. 3). Measurements were taken from this alignment.

We considered misalignment and parallax to be sources of error in the measurement of d_1 and d_2. Misalignment should yield random error and parallax should be a source of systematic error. Neither should be significant sources of bias for comparison of relative values. Changes of hand position were occasionally made in order to move large rocks. Every particle exposed to the water column and meeting the criteria was measured until the hoop contained only a plane of particles greater than 30 cm and/or less than 4.5 cm diameter.

We then repeated throwing the hoop and taking measurements until 100 measurements had been taken. After taking 100 measurements we finished measuring all matrix particles in the last hoop in order to avoid bias against the most heavily embedded particles.

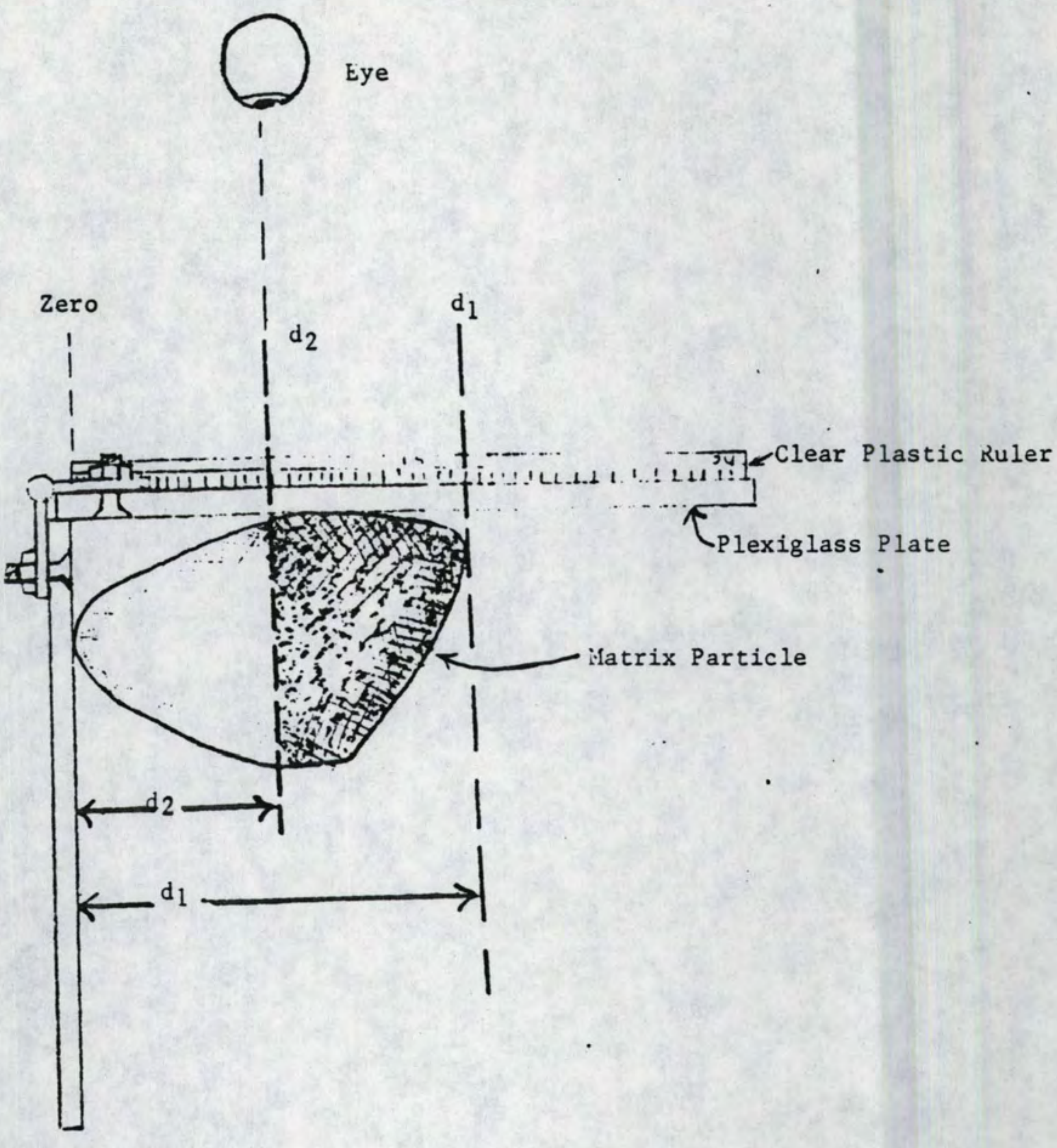


Figure 3. This sketch shows how measurements of matrix particles were taken in a 1984 survey of embeddedness on the Payette National Forest.

RESULTS

Thunder Mountain Mining Area

Mean embeddedness ranged from a low of 5% in Monumental Creek upstream from Mule Creek, immediately downstream from Roosevelt Lake, to a high of 51% in Monumental Creek downstream from Mule Creek (Table 6). Means in the remainder of the area were generally 30% or less, with the exception of the Marble Creek drainage. Locations in that drainage ranged from 30% to 37% mean embeddedness. The probability that all sample means are equal is less than or equal to 9 in 100,000 (F=16.543 with 14 and 1618 degrees of freedom).

No location was significantly less embedded than Monumental Creek upstream from Mule Creek and all other locations were significantly less embedded than Monumental Creek downstream from Mule Creek (Table 7). No differences could be found amoung the three locations sampled in the Marble Creek drainage. Similarly, no differences could be described between the two locations sampled in Big Creek. Six locations sampled in the Monumental Creek drainage, excluding those mentioned above, could not be distinguished from one another and two locations, Snowslide Creek and Monumental Creek downstream from Holy Terror Creek, were significantly less embedded than those six locations. Significance statements for all pairwise comparisons on sample means by location in RESULTS are for a probability of 0.05.

Stibnite Mining Area

Mean embeddedness in the Stibnite area ranged from a low of 16% in Tamarack Creek to a high of 48% in Sugar Creek downstream from West End Creek (Table 8). The probability that all sample means are equal is less than or equal to 9 in 100,000 (F=18.169 with 4 and 535 deegrees of freedom).

No locations were significantly less embedded than Tamarack Creek and the East Fork upstream from Vibika Creek (Table 9). Those two locations were both significantly less embedded than the East Fork downstream from Sugar Creek. All locations were significantly less embedded than Sugar Creek downstream from West End Creek.

South Fork Salmon River Drainage

Mean embeddedness ranged from lows of 19% and 20% in Lick Creek and Blackmare Creek, respectively, to a high of 63% in the Glory Hole area of the South Fork (Table 10). The probability that the sample means are equal is less than or equal to 9 in 100,000 (F=35.62 with 6 and 766 degrees of freedom).

No location was significantly less embedded than Lick Creek or Blackmare Creek (Table 11). The Secesh River upstream from Lick Creek was significantly less embedded than the Secesh River downstream from Zena Creek. No difference could be found between the Secesh upstream from Lick Creek and the Lower East Fork. These latter two locations were both significantly less embedded than either the Secesh River downstream from Zena Creek or the South Fork upstream from Knob Creek. All locations were

Table 6. Mean embeddedness ranged from a low of 5% [illegible]tal Creek immediately downstream of Roosevelt Lake to a high of 51% immediately downstream of Mule Creek. Means in the rest of the Thunder Mountain mining area were generally less than 30% in undisturbed areas, with the exception of the Marble Creek drainage where means ranged up to 37%. The probability that all tabled means are equal is equal to or less than 9 in 100,000 (F=16.543 with 14 and 1618 degrees of freedom).

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
Marble Creek upstream from Cottonwood Creek	120	37	32 - 42
Marble Creek downstream from Cottonwood Creek	102	36	29 - 42
Cottonwood Creek	102	30	24 - 36
Big Creek upstream from Monumental Creek	101	16	12 - 21
Big Creek downstream from Monumental Creek	102	19	13 - 24
Monumental Creek downstream from Snowslide Creek	112	29	23 - 34
Snowslide Creek	115	13	9 - 18
Monumental Creek downstream from Holy Terror Creek	104	15	10 - 20
Monumental Creek downstream from the West Fork of Monumental Creek	104	30	24 - 35
West Fork of Monumental Creek	122	24	18 - 29
Monumental Creek downstream from Mule Creek	103	51	46 - 56
Monumental Creek upstream from Mule Creek	101	5	2 - 8

Table 6. Mean embeddedness ranged from a low of 5% in Monumental Creek immediately downstream of Roosevelt Lake to a high of 51% immediately downstream of Mule Creek. Means in the rest of the Thunder Mountain mining area were generally less than 30% in undisturbed areas, with the exception of the Marble Creek drainage where means ranged up to 37%. The probability that all tabled means are equal is equal to or less than 9 in 100,000 (F=16.543 with 14 and 1618 degrees of freedom).

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
Marble Creek upstream from Cottonwood Creek	120	37	32 - 42
Marble Creek downstream from Cottonwood Creek	102	36	29 - 42
Cottonwood Creek	102	30	24 - 36
Big Creek upstream from Monumental Creek	101	16	12 - 21
Big Creek downstream from Monumental Creek	102	19	13 - 24
Monumental Creek downstream from Snowslide Creek	112	29	23 - 34
Snowslide Creek	115	13	9 - 18
Monumental Creek downstream from Holy Terror Creek	104	15	10 - 20
Monumental Creek downstream from the West Fork of Monumental Creek	104	30	24 - 35
West Fork of Monumental Creek	122	24	18 - 29
Monumental Creek downstream from Mule Creek	103	51	46 - 56
Monumental Creek upstream from Mule Creek	101	5	2 - 8

Table 6. Con't.

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
Monumental Creek upstream from Roosevelt Lake	141	29	24 - 35
Monumental Creek downstream from Coon Creek	103	26	20 - 32
Monumental Creek downstream from Annie Creek	101	27	22 - 33

Table 7. Significant differences between mean embeddedness [illegible] for various locations in the Thunder Mountain mining area were ident[illegible]d using a Least Significant Difference test.

LOCATION	MEAN EMBEDDEDNESS	LOCATIONS SIGNIFICANTLY LESS EMBEDDED (P=0.05)
1.Monumental Creek upstream from Mule Creek	5	
2.Snowslide Creek	13	1.
3.Monumental Creek downstream from Holy Terror Creek	15	1.
4.Big Creek upstream from Monumental Creek	16	1.
5.Big Creek downstream from Monumental Creek	19	1.
6.West Fork of Monumental Creek	24	1.,2.,3.,4.
7.Monumental Creek downstream from Coon Creek	26	1.,2.,3.,4.
8.Monumental Creek downstream from Annie Creek	27	1.,2.,3.,4:,5.
9.Monumental Creek downstream from Snowslide Creek	29	1.,2.,3.,4.,5.
10.Monumental Creek upstream from Roosevelt Lake	29	1.,2.,3.,4.,5.
11.Monumental Creek downstream from the West Fork of Monumental Creek	30	1.,2.,3.,4.,5.

Table 7. Cont'd.

LOCATION	MEAN EMBEDDEDNESS	LOCATIONS SIGNIFICANTLY LESS EMBEDDED (P=0.05)
12.Cottonwood Creek	30	1.,2.,3.,4.,5.
13.Marble Creek downstream from Cottonwood Creek	36	1.,2.,3.,4.,5.,6.,7.,8.
14.Marble Creek upstream from Cottonwood Creek	37	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.
15.Monumental Creek downstream from Mule Creek	51	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14

Table 8. Mean embeddedness in the Stibnite mining a[illegible] from 16% in Tamarack Creek to 48% in Sugar Creek below West End Creek. The probability that tabled means are equal is equal to or less than 9 in 100,[illegible]0 (F=18.169 with 4 and 535 degrees of freedom).

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
East Fork downstream from Sugar Creek	100	31	24 - 38
East Fork upstream from Vibika Creek	104	23	16 - 30
Sugar Creek downstream from West End Creek	108	48	43 - 53
Sugar Creek upstream from West End Creek	123	26	21 - 30
Tamarack Creek	105	16	10 - 21

Table 9. Significant differences between estimates of mean embeddedness at various locations in the Stibnite mining area were determined using a least Significant Difference test.

LOCATION	MEAN EMBEDDEDNESS	LOCATIONS SIGNIFICANTLY LESS EMBEDDED (P=0.05)
1. Tamarack Creek	16	
2. East Fork upstream from Vibika Creek	23	
3. Sugar Creek upstream from West End Creek	26	1.
4. East Fork downstream from Sugar Creek	31	1., 2.
5. Sugar Creek downstream from West End Creek	48	1., 2., 3., 4.

Table 10. Mean embeddedness in the South Fork Salmon River ranges from lows of 19% & 20% in Lick Creek and Blackmare Creek, respectively, to highs of 45% & 63% in the mainstem South Fork upstream from Knob Creek and at Glory, respectively. The probability that tabled means are equal is equal to or less than 9 in 100,000 (F=35.62 with 6 and 766 degrees of freedom).

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
Blackmare Creek	111	20	16 - 25
Lower East Fork	127	29	24 - 35
Glory Hole area	102	63	58 - 67
Lick Creek	108	19	14 - 24
Secesh River upstream from Lick Creek	101	28	23 - 33
Secesh River downstream from Zena Creek	103	39	34 - 44
South Fork upstream from Knob Creek	121	45	40 - 50

(67) part II

Table 11. Significant differences between mean embeddedness [illegible] for various locations in the South Fork Salmon River drainage were [illegible]ntified using a Least Significant Difference test.

LOCATION	MEAN EMBEDDEDNESS	LOCATIONS SIGNIFICANTLY LESS EMBEDDED (P=0.05)
1.Lick Creek	19	
2.Blackmare Creek	20	
3.Secesh River upstream from Lick Creek	28	1.,2.
4.Lower East Fork	29	1.,2.
5.Secesh River downstream from Zena Creek	39	1.,2.,3.,4.
6.South Fork upstream from Knob Creek	45	1.,2.,3.,4.
7.Glory Hole area	63	1.,2.,3.,4.,5.,6.

significantly less embedded than the Glory Hole area of the South Fork.

Little Salmon River Drainage

Mean embeddedness ranged from a low of 15% in Hard Creek to a high of 42% in Boulder Creek downstream from Pollock Creek (Table 12). The Rapid River drainage ranged from a low of 22% in the West Fork of Rapid River to a high of 32% in Rapid River downstream from Castle Creek. The probability that all sample means are equal is less than or equal to 9 in 100,000 (F=9.446 with 9 and 1082 degrees of freedom).

No location sampled was significantly less embedded than Hard Creek, Upper Boulder Creek, the West Fork of Rapid River or Hazard Creek (Table 13). Only Hard Creek was significantly less embedded than Elk Creek, Lower Boulder Creek and Rapid River upstream from the West Fork of Rapid River. All of these locations were otherwise statistically the same. No difference could be found for Rapid River upstream from Castle Creek and Rapid River downstream from Castle Creek. All locations were significantly less embedded than Boulder Creek downstream from Pollock Creek.

Basalt Drainages

Mean embeddedness ranged from a low of 12% in Anderson Creek to a high of 46% in the East Fork of Brownlee Creek above Brownlee Reservoir (Table 14). The probability that all sample means are equal is less than or equal to 9 in 100,000 (F=12.918 with 20 and 2352 degrees of freedom).

No location sampled was significantly less embedded than Anderson Creek, the Little Weiser River, Mud Creek, the West Fork Weiser River, the East Fork of Lost Creek, Indian Creek above Cuprum, or the East Branch Weiser River (Table 15). All locations sampled were significantly less embedded than Indian Creek above Landore and the East Fork of Brownlee Creek. Statistical comparisons of sample sites within specific drainages were as follows:

Deep Creek There was no statistical difference between the two sample sites in this drainage.

Little Weiser River There was no statistical difference between the Little Weiser River at the Forest boundary and Anderson Creek at the confluence with the mainstem. These two sites had the lowest mean embeddedness values of all other sites sampled in the basalt drainages.

Middle Fork Weiser River There were no statistical differences between the sites in the upper and lower mainstem and Mica Creek.

Upper Weiser River Drainage Five of the six locations sampled in the upper Weiser River drainage were statistically simliar (Mud Creek, West Fork Weiser River, East Branch of Weiser River, Lost Creek at mouth, and East Fork of Lost Creek). The sample location in upper Lost Creek was statistically different than the other sites listed.

Lower Weiser River Area West Pine Creek was the only site sampled in 1984, exhibiting a mean embeddedness that was statisically different than 12 of

Table 12. Mean embeddedness in Little Salmon River tributaries ranged from a low of 15% in Hard Creek to a high of 42% in Boulder Creek downstream from Pollock Creek. The probability that the tabulated means are equal is equal to or less than 9 in 100,000 (F=9.446 with 9 and 1082 degrees of freedom).

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
Upper Boulder Creek	135	20	15 - 24
Boulder Creek downstream from Pollock Creek	119	42	38 - 47
Lower Boulder Creek	113	24	19 - 30
Hard Creek	107	15	10 - 21
Hazard Creek	101	22	17 - 28
Elk Creek	101	24	19 - 28
West Fork of Rapid River	109	22	17 - 26
Rapid River upstream from the West Fork of Rapid River	101	25	20 - 30
Rapid River downstream from Castle Creek	103	32	27 - 38
Rapid River upstream from Castle Creek	103	30	25 - 34

Table 13. Significant differences between mean embeddedness estimates for various locations in the Little Salmon River drainage were identified using a Least Significant Difference test.

LOCATION	MEAN EMBEDDEDNESS	LOCATIONS SIGNIFICANTLY LESS EMBEDDED (P=0.05)
1.Hard Creek	15	
2.Upper Boulder Creek	20	
3.West Fork of Rapid River	22	
4.Hazard Creek	22	
5.Elk Creek	24	1.
6.Lower Boulder Creek	24	1.
7.Rapid River upstream from the West Fork of Rapid River	25	1.
8.Rapid River upstream from Castle Creek	30	1.,2.,3.
9.Rapid River downstream from Castle Creek	32	1.,2.,3.,4.,5.,6.
10.Boulder Creek downstream from Pollock Creek	42	1.,2.,3.,4.,5.,6.,7.,8.,9.

Table 14. Mean embeddedness in streams draining watersheds of primarily basalt origin ranged from a low of 12% in Anderson Creek (tributary to the Little Weiser River) to a high of 46% in the East Fork of Brownlee Creek above Brownlee Reservoir. The probability that the tabulated means are equal is equal to or less than 9 in 100,000 (F=12.918 with 20 and 2352 degrees of freedom).

LOCATION	NUMBER OF SAMPLES	MEAN EMBEDDEDNESS	95% CONFIDENCE INTERVAL ON THE MEAN
Deep Creek downstream from Lake Creek	100	24	19 - 30
Deep Creek downstream from Trail Creek	133	25	21 - 30
Lost Creek at mouth	108	20	15 - 24
West Fork Weiser River	125	15	11 - 19
East Fork of Brownlee Creek	110	46	41 - 51
West Pine Creek	113	32	27 - 37
Crooked River	103	28	23 - 33
Bear Creek at mouth	103	21	15 - 26
Lick Creek	104	23	18 - 27
Mud Creek	158	15	11 - 18
East Branch Weiser River	129	19	14 - 24
Little Weiser River	110	14	9 - 18
Anderson Creek	105	12	8 - 17
East Fork of Lost Creek	112	17	12 - 22
Lost Creek (Upper)	102	30	25 - 36

Table 15. Significant differences between estimates of mean embeddedness for streams draining watersheds of primarily basalt origin were identified using a Least Significant Difference test.

LOCATION	MEAN EMBEDDEDNESS	LOCATIONS SIGNIFICANTLY LESS EMBEDDED (P=0.05)
1. Anderson Creek	12	
2. Little Weiser River	14	
3. Mud Creek	15	
4. West Fork Weiser River	15	
5. East Fork of Lost Creek	17	
6. Indian Creek above Cuprum	18	
7. East Branch Weiser River	19	
8. Lost Creek at mouth	20	1.
9. Bear Creek at mouth	21	1.
10. Lick Creek	23	1.,2.,3.,4.
11. Deep Creek below Lake Creek	24	1.,2.,3.,4.,5.
12. Deep Creek below Trail Creek	25	1.,2.,3.,4.,5.,6.
13. Middle Fork Weiser River (Upper)	25	1.,2.,3.,4.,5.,6.
14. Bear Creek (Upper)	26	1.,2.,3.,4.,5.,6.,7.
15. Mica Creek	28	1.,2.,3.,4.,5.,6.,7.,8.

Table 15. (Continued)

16. Crooked River	28	1.,2.,3.,4.,5.,6.,7.,8.,9.
17. Middle Fork Weiser River (Lower)	30	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.
18. Lost Creek (Upper)	30	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.
19. West Pine Creek	32	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.
20. Indian Creek above Landore	41	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,19.
21. East Fork of Brownlee Creek	46	1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,19.

the 21 sites sampled in basalt drainages.

Wildhorse River The site in Crooked River was statisically different than Bear Creek at the mouth, but not statisically different than either Lick Creek or upper Bear Creek. There was no statisical difference between the two sites in Bear Creek.

Indian Creek Indian Creek at Landore was statistically different than Indian Creek at Cuprum. The site at Landore had the second highest mean embeddedness value of all the basalt watersheds.

Brownlee Creek The East Fork of Brownlee Creek had the highest mean embeddedness value of all sites sampled in the basalt watersheds.

DISCUSSION

Thunder Mountain Mining Area

The Marble Creek drainage generally had a higher level of embeddedness than has been reported for undisturbed areas(Burns, 1984) or than we found in undisturbed locations. Burns noted, while he was in the field, that silt deposits along the banks of Marble Creek and Cottonwood Creek appeared recent, as if from recent storms. He also noted a great deal of channel braiding in Marble Creek. He noted a large amount of beaver activity, completely blocking Marble Creek for at least 200 meters. High levels of embeddedness are consistent with the unstable soils described by Knight, Thompson, Kulesza and Dean (1974).

The very low level of embeddedness found in Monumental Creek upstream from Mule Creek, immediately downstream from Roosevelt Lake, is not suprising. Roosevelt Lake should act as an efficient sediment trap. This extremely good fish habitat condition makes the condition of Monumental Creek downstream from Mule Creek even more disconcerting than would be the case if the Mule Creek effluent resulted in high levels of embeddedness relative to normal undisturbed conditions in Monumental Creek.

Burns(1983) noted that the area immediately upstream of Mule Creek was 15% embedded in 1983. The area he sampled was about 100 meters downstream of the location where mean embeddedness was estimated to be 5% in 1984. Liming(1984) reported this same stream reach to contain 18% fine sediment (95% confidence interval 12%-24%) less than 6.3 mm diameter, based on core samples taken in 1983.

Burns(1983) reported embeddedness of 45% downstream of Mule Creek in 1983 in the same location which we sampled. Our estimate for 1984 is 51%. Liming(1984) showed 45% fine sediment (95% confidence interval 31%-59%) less than 6.3 mm diameter, based on core samples taken in 1983.

A comparison of Monumental Creek immediately upstream and downstream from Mule Creek demonstrates that Mule Creek effluent continued to severly degrade fish habitat in 1984. Levels of embeddedness were about twice those found by Burns(1984) or us in undisturbed areas.

Impacts from Mule Creek effluent were not measurable downstream from the West Fork of Monumental Creek. We speculate that sediment transport energies are increased sufficiently by the West Fork discharge to prevent deposition of excessive amounts of fine sediment downstream.

Stibnite Mining Area

Mean levels of embeddedness are higher than in upstream controls or controls in adjacent drainages in Sugar Creek downstream from the West End Creek mine. Burns(1984) reported 50% embeddedness in this location compared to 48% for our data. This, probably, reflects no real change between years.

Burns(1984) reported embeddedness of 14% in Tamarack Creek, 30% in Sugar Creek upstream from West End Creek and 22% in the East Fork upstream from Vibika Creek, where we found 16%, 26% and 23%, respectively. These conditions also indicate no change between years.

In the East Fork downstream from Sugar Creek Burns(1984) reported 42% mean embeddedness and we found 31%. Burns believes that this reflects a real change and confirms that the location appeared to be cleaner. We did not conduct any statistical comparison because of the slight change in methods between years. These results indicate that this location is returning to near pre-mine conditions. Pre-mine conditions are assumed to be approximated by controls.

Damage to fish habitat from the West End mine has not extended downstream in the East Fork to Vibika Creek and has partially been flushed from the East Fork downstream from Sugar Creek. We speculate that stream energy is sufficient to prevent further buildup of embeddedness in the East Fork provided that the rate of sediment yield from the mine is not increased. To date the opportunity to improve fish habitat in the East Fork by using a sediment budget(Anon., 1981.) has not been realized according to our monitoring.

South Fork Salmon River Drainage

Lick Creek and Blackmare Creek appear to be in the same condition as in 1983. Burns (1984) reported Lick Creek to be 19% embedded compared to our estimate of 19%. He also reported Blackmare Creek to be 21% embeddded compared to our estimate of 20%. The Blackmare Creek results are suprising because of local concern about the effects of a high intensity thunderstorm which turned the South Fork turbid from Blackmare Creek effluent on August 2, 1984, just prior to our sampling.

Results in the mainstem South Fork and Secesh River downstream from Zena Creek show elevated levels of embeddedness relative to the Lower East Fork or Secesh River upstream from Lick Creek. These results are consistent with the works of Lund (1982) and Corley and Newberry (1982) which show higher amounts of fine sediment in the Poverty to Glory section of the South Fork relative to the rest of the drainage. Our findings are also consistent with those of Burns(1984) who reported higher levels of embeddedness in historically developed South Fork subdrainages, including Buckhorn, Camp, Cougar, Cow, Fitsum and Zena Creeks. Megahan, Platts and Kulesza(1980) described the history and changing condition of this area.

Little Salmon River Drainage

Rapid River in the vicinity of Castle Creek is more heavily embedded than many other Little Salmon River locations. This is consistent with mass instability reported by Thompson, Skabelund, Kulesza and Dean(1973). The level of embeddedness is not outside of levels expected in undisturbed watersheds as reported here and by Burns(1984).

Boulder Creek shows high levels of embeddedness immediately downstream from logging and road construction (42%) relative to the upstream control (20%).

Conditions improve downstream. After two tributaries, [illegible]ny and Squirrel Creeks, enter Boulder Creek, embeddedness (24%) is not distinguishable from the upstream control. This is a very similar condition to that described in Monumental Creek downstream from Mule Creek and in Sugar Creek and the East Fork downstream from West End Creek.

Current levels of development appear to have caused no damage to fish habitat in Hard, Hazard and Elk Creeks; however, a great deal of caution should be used because of the relationship described above for Boulder Creek. More data is needed in Little Salmon River tributaries, especially Hard and Hazard Creeks before an empirically based "safe" level of development can be prescribed.

Basalt Drainages

Embeddedness values appear to be more indicative of variations in landtypes within watersheds than of management impacts. Sites with moderate to heavy development histories have relatively low embeddedness values. This observation stands in contrast to the high embeddedness values shown in developed granitic watersheds noted here and by Burns (1984). Some of the data from the basalt watersheds may also reflect management impacts, but until further studies are completed, relationships remain speculative.

The lack of fine sediment in some of the more heavily developed watersheds might be partially explained by the nature of the soil material formed from the dominant bedrock type. In the granitic drainages in the Silver Creek Research Area, samples have shown that the bedload component may range between 47% to 89% of the total sediment load (13 year mean = 65%, personal communication, Walter F. Megahan). In primarily basalt watersheds, Megahan estimates that the bedload component may be no more than 30% of the total load. The particle size distribution of the typical soil formed from basalt materials is relatively high in clays and silts in comparison to a soil derived from granitic parent materials. The finer particles produced in basalt drainages would be more easily transported as suspended sediment, and less likely to become entrained in the streambed.

The lack of fine sediment in heavily developed watersheds may also be partially explained by the fact that the study streams have had a longer period of time within which to adjust to the impacts of development. Major road development has already occurred in most of these areas, and disturbed sites have had a long period of time to stabilize. Stream energies may be more than adequate to handle the existing sediment supply. In fact, stream energies may have been increased as a result of the construction of roads in riparian areas, where stream encroachment may have increased channel gradients.

Preliminary evaluations of the sites sampled in this study area as follows:

Deep Creek The Deep Creek sites were located above and below the influence of historical sedimentation from the Helena mine site (Copper Creek). The two sites were not statistically different, indicating that embeddedness is not now affected by the mine operation.

Mean embeddedness in Deep Creek is statistically different than that measured in the Little Weiser and upper Weiser River areas. Deep Creek is primarily meta-volcanic with strong glacial influence in the headwaters; whereas, the Weiser River areas are dominantly basalt plateau lands. Data from Deep Creek compares well to the Rapid River sites, because of similarities in geology and development history.

Indian Creek The site at Landore appears to have been significantly influenced by a granitic component and a history of mining impacts in the watershed. The site in Indian Creek above Cuprum was located immediately downstream from the mouth of Mann Creek. This tributary delivered a significant amount of sediment to Indian Creek in 1974, as a result of the failure of the settling pond for the Silver King mine. The bedload input from this event appears to have been flushed from the study reach.

East Fork of Brownlee Creek The mean embeddedness value from this site reflects the active geomorphology of the Brownlee area. The East Fork is dominated by fluvial volcanic lands subject to mass movement. Debris torrents are relatively common in this drainage, as evidenced by the poor channel conditions in the study reach. Impacts from road building and grazing may also be reflected in the high embeddedness value in this stream.

Wildhorse River Substrate conditions at the sites sampled in the Wildhorse River system appear good. The difference shown between Bear Creek at the mouth and the site in Crooked River is believed to be related to differences in stream energy.

Weiser River Drainage Substrate conditions in the Little Weiser River appear to be excellent. Sites in the Middle Fork Weiser River are statistically different than those in the Little Weiser. This difference may be attributable to the colluvial/glacial deposits and larger fluvial granitic component in the Middle Fork.

Data for the upper Weiser River area (Mud Creek, West Fork Weiser River, East Branch Weiser River,and Lost Creek) also reflect substrate in good to excellent condition, despite a moderate to heavy development history. Sites in the Middle Fork Weiser River were statistically different than all sites in the upper Weiser River area, with the exception of upper Lost Creek. The low embeddedness values in the upper Weiser area appear to reflect the dominant landtype group - basalt plateau lands and escarpments.

In the Lost Creek drainage, the site at the mouth of Lost Creek is influenced by the sediment trapping effect of Lost Valley Reservoir. The site in upper Lost Creek may reflect contributions from colluvial/glacial materials and the mitigation level on roads in the upper portion of the watershed.

The sample site in West Pine Creek may reflect the location and mitigation levels of roads in this watershed.

More data are needed from basalt watersheds before any relationship between development and embeddedness can be verified. Additional cobble embeddedness measurements are needed in the subject class of streams, especially in the Cuddy Mountain and Sturgill Peak areas. In addition, the study watersheds need to be more thoroughly evaluated in terms of landtype composition and development level in order to properly address the study objective of evaluating man-caused sources of sediment.

General Discussion

Results of this study indicate that a high level of variability in embeddedness may be associated with the geology of a watershed. In some cases, impacts to the stream substrate may be localized in the vicinity of man-caused erosion. Results from the South Fork Salmon River indicate that extensive impacts of a cumulative nature may extend far downstream. Data acquisition needs to be extensive before the extent and degree of impact to fish habitat from man-caused sedimentation can be properly evaluated.

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