Assessment of Stream Health in a Mine-Impacted Stream; Bear Creek, London District, Daniel Boone National Forest, 2019

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Table of Contents

List of Figures

List of Tables

Introduction

The proclamation boundary of the Daniel Boone National Forest (DBNF) in eastern Kentucky encompasses 8,498 km^2 of which 2,865 km^2 are federally owned, including many lands that were historically mined for coal prior to federal ownership. Coal mines, both active and abandoned, can cause acid mine drainage, which impacts water quality and degrades aquatic habitat in near-by waterways. A better understanding of stream health in watersheds with a history of mining is needed to assist resource managers in prioritizing remediation projects and other land management activities.

Bear Creek (3.6 km long) is located on the DBNF London Ranger District within Pulaski County in southeastern Kentucky and, like other watersheds on the district, has a history of mining activity. Coal mining within the Bear Creek watershed, which encompasses approximately 500 acres of underground mines under Forest Service and private surface property, started in 1950 and ceased in the mid-1960s (EEC n.d.). Mining remnants are still evident today along the course of Bear Creek and include mine adits or portals, ventilation openings, coal refuse piles, a coal tipple, and a wooden workshop (EEC n.d.). Water is flowing from several mine portals and openings, and vegetation in these areas is often sparse (Figure 1).

The DBNF partnered with the Forest Service Southern Research Station Center for Aquatic Technology Transfer (CATT) in 2019 to assess stream health in Bear Creek and one of its tributaries. The CATT deployed a team of 4 technicians from May 14-18th, 2019 to complete sampling using the Daniel Boone National Forest stream monitoring program sampling protocols (Krause et al. 2018).

Methods

Site Selections and Layout

Most of the 3.6 km of Bear Creek flows through National Forest System land, but a 0.8 km reach of the headwaters are on private land (Figure 1). Bear Creek at the downstream-most sample site (7) is 4th order and flows directly into the Rockcastle River (8th order), and most of the tributaries to Bear Creek are 1st - 2nd order. Bear Creek is in the Upper Cumberland River Basin (051301) and Bear Creek – Rockcastle River sub-watershed (051301020505) and the Bear Creek sample sites have small catchment areas (0.34 – 4.97 km^2).

We completed fish, macroinvertebrate, and stream habitat inventories at 6 sites on Bear Creek and 2 sites on an unnamed tributary to Bear Creek (Figure 1, Tables 1 and 2). The sample site locations were chosen by DBNF personnel: sites 1-3 and 5-7 were in Bear Creek; sites 4US (upstream) and 4DS (downstream) were on a tributary that joined Bear Creek in the vicinity of historic mining activity. Sample site 1 was upstream, sites 2 and 3 were within, and sites 5, 6, and 7 were downstream of the historic mining area. The tributary sample sites, 4US and 4DS which are located upstream (4US) and downstream (4DS) of a 1.5 m high cascade, were upstream of the historic mining area (Figure 1).

At each sample site, we measured the wetted width of 1-2 fast water (riffle or run) habitat units and calculated the average wetted width. If the average wetted width was ≤3.0 m or ≥7.5 m, the sample length was 120 m or 300 m, respectively (Appendix A). In all other cases, sample length was 40-times the average wetted width.

Fish Sampling

A four-person team using a DC backpack electrofisher sampled for fish at the 8 sample sites in May 2019. The team attempted to apply standard effort of approximately 1 sec/m^2 of wetted stream habitat, and recorded the following data: species, individual counts for adult, age-0, and voucher specimens, electrofishing length (m), time (sec), and voltage, and GPS coordinates of the downstream and upstream sample extent (see Appendix A for detailed field methods).

We did not calculate a fish IBI score using the Kentucky index of biotic integrity due to lack of fish diversity and abundance in headwater systems resulting from their inherent small stream size and higher occurrence of natural barriers (Jacob Culp and Robert Johnson, KY Division of Water, personal communication, 12/03/19).

Macroinvertebrate Sampling and MBI Scoring

A four-person team collected macroinvertebrates using riffle sample and multi-habitat sample methods developed by the Kentucky Division of Water (KDOW 2011) for standardized collection of aquatic macroinvertebrates (see Appendix A and Appendix B for detailed sampling methods). The macroinvertebrate samples were given to the DBNF (Mac Cherry, Forest Hydrologist) for identification by a contracted entomologist and for calculation of the Kentucky macroinvertebrate bioassessment index (MBI) scores.

The MBI scores the sample sites and rates their biotic integrity as either Very-Poor (0-23), Poor (24-47), Fair (48-71), Good (72-82), or Excellent (≥83) (Pond et al. 2003). When an MBI score fell close (± 2 points) to the classification threshold, we conservatively rated the site using both categories (e.g. Fair/Good).

Stream Habitat

A two-person team sampled stream habitat using habitat sampling methods established for Forest-wide stream monitoring on the DBNF (see Appendix A and Appendix C for detailed methods). During data analysis the following attributes were averaged for each sample site: maximum depth, average depth, pool residual depth, wetted width, bankfull channel width, percent fines, gradient, and water temperature.

Because of the small catchment area of the Bear Creek sites (0.34 – 4.97 km^2) we did not attempt to make data comparisons to non-mine impacted sites previously sampled by the CATT for the DBNF monitoring program which have a much larger catchment size requirement of >13 km^2.

Pebble Counts

A four-person team completed pebble counts on riffle stream-bed substrates and on depositional bar features using sampling methods established for Forest-wide stream monitoring on the DBNF (see Appendix A and Appendix D for detailed methods). If no riffle habitat was present within the sample length at a site, then pebble counts were performed in the nearest riffle habitat available up and/or downstream. Pebble count data were used to calculate Riffle Stability Index (RSI), relative bed stability, and median particle sizes for the stream bed (Kappesser 2002). The RSI, which compares the largest mobile particles in the channel with the cumulative particle size distribution, can be used to evaluate channel condition (i.e. the level of excess sediment loading in riffles) and indicate upstream watershed condition (Kappesser 2002). Kappasser (2002) developed a RSI condition rating (developed using Rosgen B and Fb channels in Virginia) where RSI values <70 are indicative of watersheds in good condition and riffles are bedrock or scoured, RSI 70-85 indicates watersheds in fair condition and riffles are somewhat loaded with sediment, and RSI >85 indicates watersheds in poor condition and riffles are loading increasingly with excess sediment.

Water Chemistry

Water chemistry measurements were collected at each sample site with a Hanna HI9829 multi-parameter meter. The meter's probe was placed in shaded stream locations with moderate flow to collect the following: water temperature (C), pH, conductivity (mS/cm), turbidity (FNU), dissolved oxygen (mg/L), and total dissolved solids (mg/L).

Results

Fish Sampling

We did not collect, nor observe, any fish at the Bear Creek sample sites or the upstream site (4US) on the unnamed tributary. The downstream site (4DS) on the unnamed tributary had one species (Creek Chub) present in low quantities (26 individuals) (Table 3). Crayfish were absent at sites 2, 3, and 5, which were closest to the mine locations (Figure 1, Table 1).

Macroinvertebrate Sampling and MBI

We collected a complete macroinvertebrate sample (riffle and multi-habitat) at all sample sites. The MBI rated Bear Creek sites as Very-Poor to Poor and the unnamed tributary as Fair/Good (Figure 2, Table 4).

Stream Habitat

Sample sites were generally low gradient (1-2%) with bankfull channel widths ranging from 2.3-6.6 m (Table 5). Habitat was predominantly fast water types (riffles, runs), with pools occupying more than 30% of the surface area at only the two upstream-most Bear Creek sites (1 and 2) (Figure 3, Table 6). Average depths increased the further downstream the site in Bear Creek (12 cm increasing to 37 cm in pools and 7 cm increasing to 21 cm in riffles) (Figure 3, Table 5). The unnamed tributary had average depths of 11-18 cm in pools and 7-8 cm in riffles (Figure 3, Table 5).

Average percent fines (i.e. surface area of the stream bed consisting on sand, silt, or clay) decreased the further downstream the site in Bear Creek, until an increase at site 7 (Figure 3, Table 5). The opposite trend occurred in the unnamed tributary (Figure 3, Table 5). Sites 1 – 3 had high percent fines (≥35%) in both pools and riffles, while other sites had high percentages in pools or riffles only (Table 5). In pools, fine substrates (sand, silt, or clay) were more common than coarse substrates, while the opposite occurred in riffles (Figures 4 and 5, Table 7).

Nearly all large wood was in the smaller diameter size classes (LW1, LW3) (Table 8). Large diameter pieces (LW2, LW4) were encountered at only 1 site, and in low quantities (Table 8). Rootwads provided added habitat complexity at half of the sites (Table 8). The total amount of large wood (all size classes) per kilometer was lowest at sites 1 and 3 (<100/km) (Figure 6, Table 8).

Potential barriers to fish passage were present in Bear Creek and the unnamed tributary (Appendix E). Between Bear Creek site 1 and 2 are two waterfalls, each with 1.5 m freefall heights (located at N37.00467 W84.38848). The unnamed tributary has a 1.5 m high cascade formed by several large boulders located between sites 4DS and 4US approximately 200 m upstream from the confluence with Bear Creek.

Pebble Counts

The RSI values ranged from 54.6 to 80.5 among the 8 sites (Table 9). The RSI rated sites 1 and 4DS as Fair and the rest as Good (Table 9). The D50 for particle size ranged from 4 – 98 mm for all sites, which falls within the small gravel (3-16 mm), large gravel (17-64 mm), and cobble (65-256 mm) substrate size classes (Table 9).

Water Chemistry

Water temperature during our May sampling was 10.9 – 13.4 C depending on the site (Figure 7, Table 10). The upstream-most site (1) on Bear Creek had a pH of 6.0 and pH declined to 3.1-3.8 at all sites downstream; the unnamed tributary sites had a pH of 5.1 and 5.9 (Figure 7, Table 10). Conductivity was much lower (20-30 mS/cm) at the upstream-most site on Bear Creek (1) and the unnamed tributary sites in comparison to all other Bear Creek sites downstream (111-512 mS/cm) (Figure 7, Table 10). Likewise, the same pattern occurred for total dissolved solids (TDS) which were much lower (10-16 mg/L) at the upstream-most site on Bear Creek (1) and the unnamed tributary sites in comparison to all other Bear Creek sites downstream (56-257 mS/cm) (Figure 7, Table 10). There was no discernable pattern for turbidity which ranged from 0 – 22.7 FNU (Table 10). Dissolved oxygen (DO) was relatively consistent among all sites; ranging from 8.1 – 9.3 mg/L (Table 10).

Discussion

The MBI rating for all of the Bear Creek sites ranged from Very-Poor to Poor; the MBI for the unnamed tributary was Fair/Good. The MBI is formulated based on reference conditions and because all regions of Kentucky have been disturbed by humans, reference sites fall under the classification of least disturbed rather than undisturbed. Several streams on the DBNF served as reference sites during development of the Kentucky MBI because they drain heavily forested, relatively undisturbed areas (Pond et al. 2003). In general, low MBI ratings suggests that past or present day disturbances are responsible for low biological integrity. In Bear Creek the most likely perpetrators include poor water quality and degraded stream habitat, as indicated by low habitat diversity, high percent fines, low pH, high conductivity, and high total dissolved solids. Water quality was worst in areas immediately adjacent to and downstream from the abandoned mine site.

The limited distribution and low abundance of fish (the only site with fish was the tributary downstream of the cascade barrier and upstream of the historic mine activity) further implicate ongoing disturbance from the abandoned mine. Historic mining activity extends from just upstream of site 2 to just upstream of site 3. The stream bed at site 3 was stained orange/red by chemical precipitate from acid mine drainage and effluent inflow from a coal mine pond full of abandoned rail ties and carts (Appendix E). These Bear Creek sites (2, 3, and 5) closest to mine activity had no crayfish, lowest pH, highest conductivity, and highest total dissolved solids. In comparison, the unnamed tributary had fish, crayfish, and much better water quality. Site 1 upstream of the mine activity also had crayfish and better water quality, but no fish due to its isolation by waterfalls and severely degraded downstream habitat and water quality.

The legacy of past land use and its effect on water quality, habitat, and biota in the Bear Creek watershed reflects the challenges facing many National Forests. Information in this report documenting the extent and severity of mining-related declines in water quality and biota in Bear Creek can be used to inform opportunities for remediation and restoration of water quality and stream habitat.

Data Availability

Bear Creek data collected in May 2019 reside in a MS Access database, which is managed by the CATT, and a copy has been provided to Mac Cherry, DBNF Forest Hydrologist. We will work with the DBNF to develop custom queries and reports for the MS Access database, as needed.

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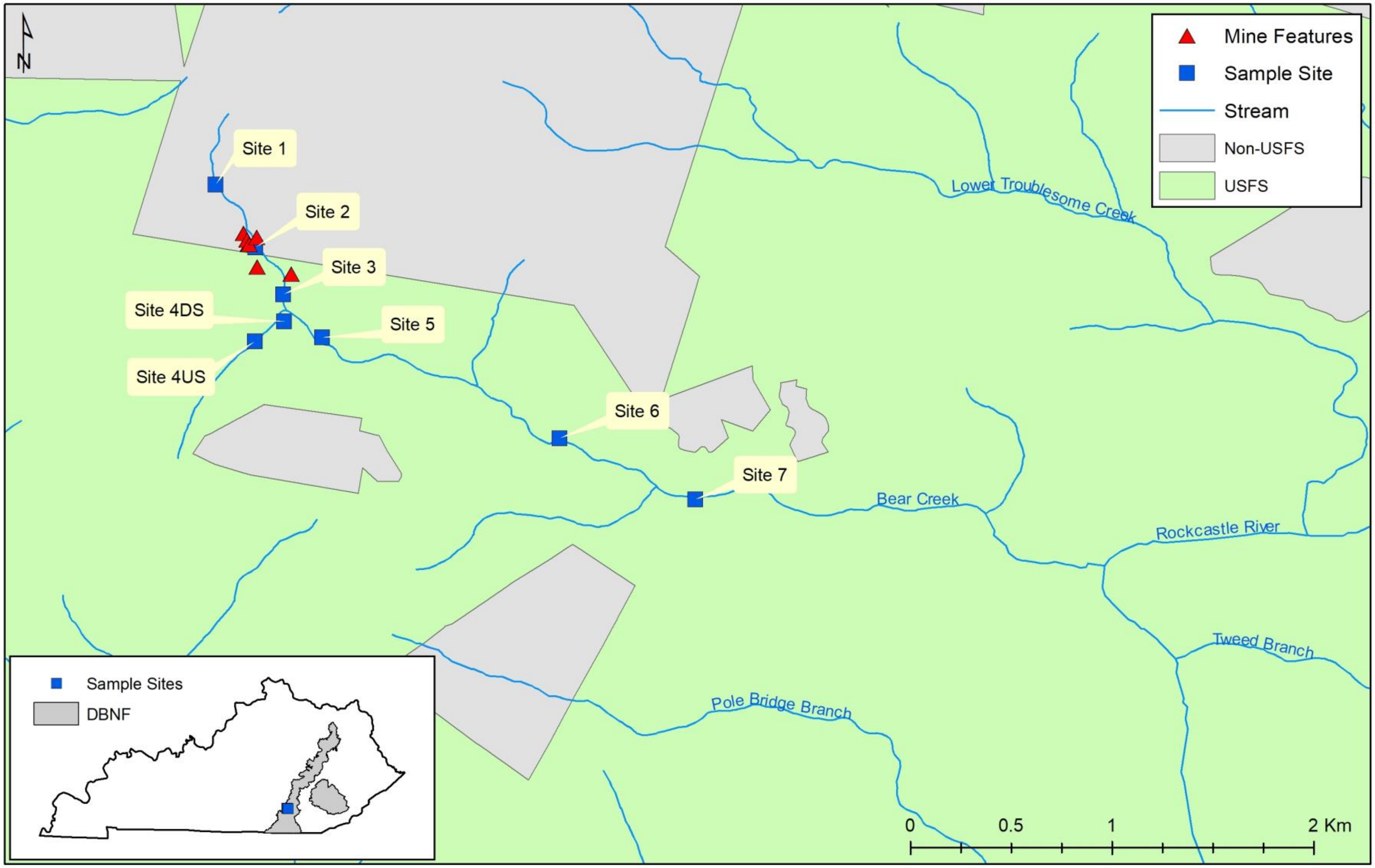


Figure 1. 2019 Bear Creek sample sites (blue) and mine feature locations (red); London Ranger District, Daniel Boone National Forest, Kentucky.

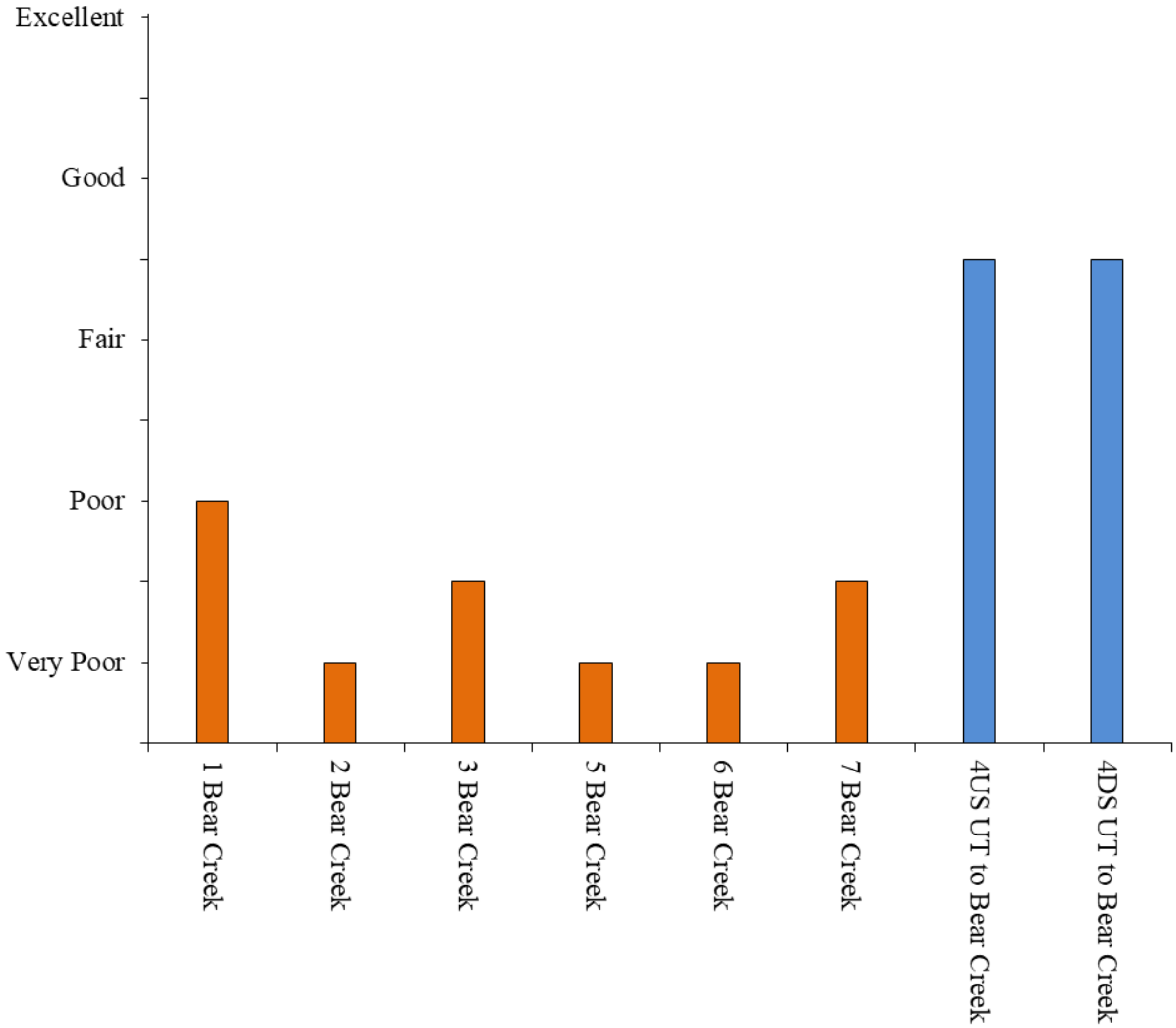


Figure 2. Kentucky macroinvertebrate bioassessment index (MBI) rating results at Bear Creek sample sites (red bars) and an unnamed tributary to Bear Creek (blue bars), May 2019.

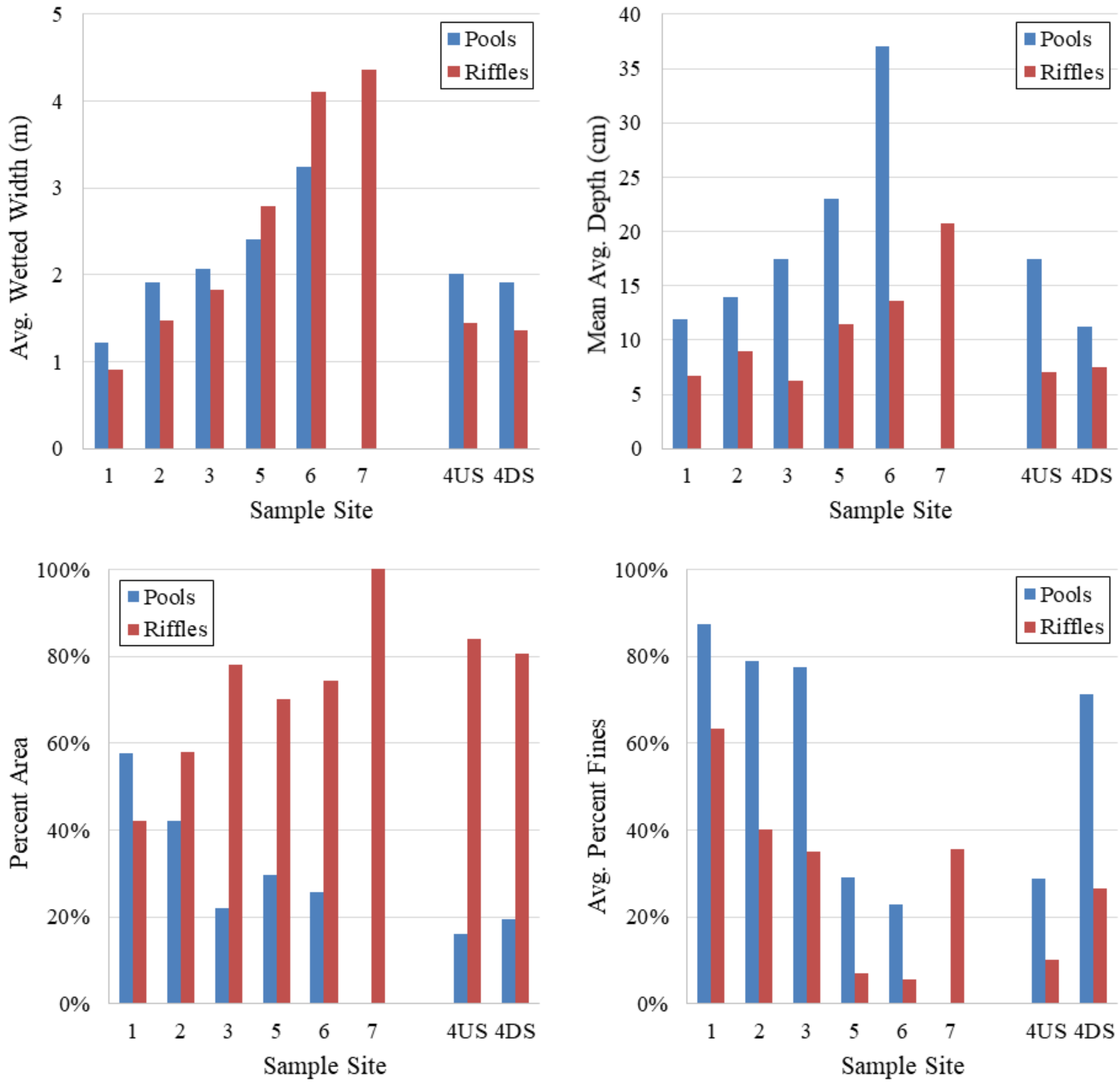


Figure 3. Summary of BVET stream habitat attributes: average wetted width, mean average depth, percent habitat area, and average percent fines (i.e. surface area of the stream bed consisting of sand, silt, or clay) in pools and riffles at Bear Creek sample sites.

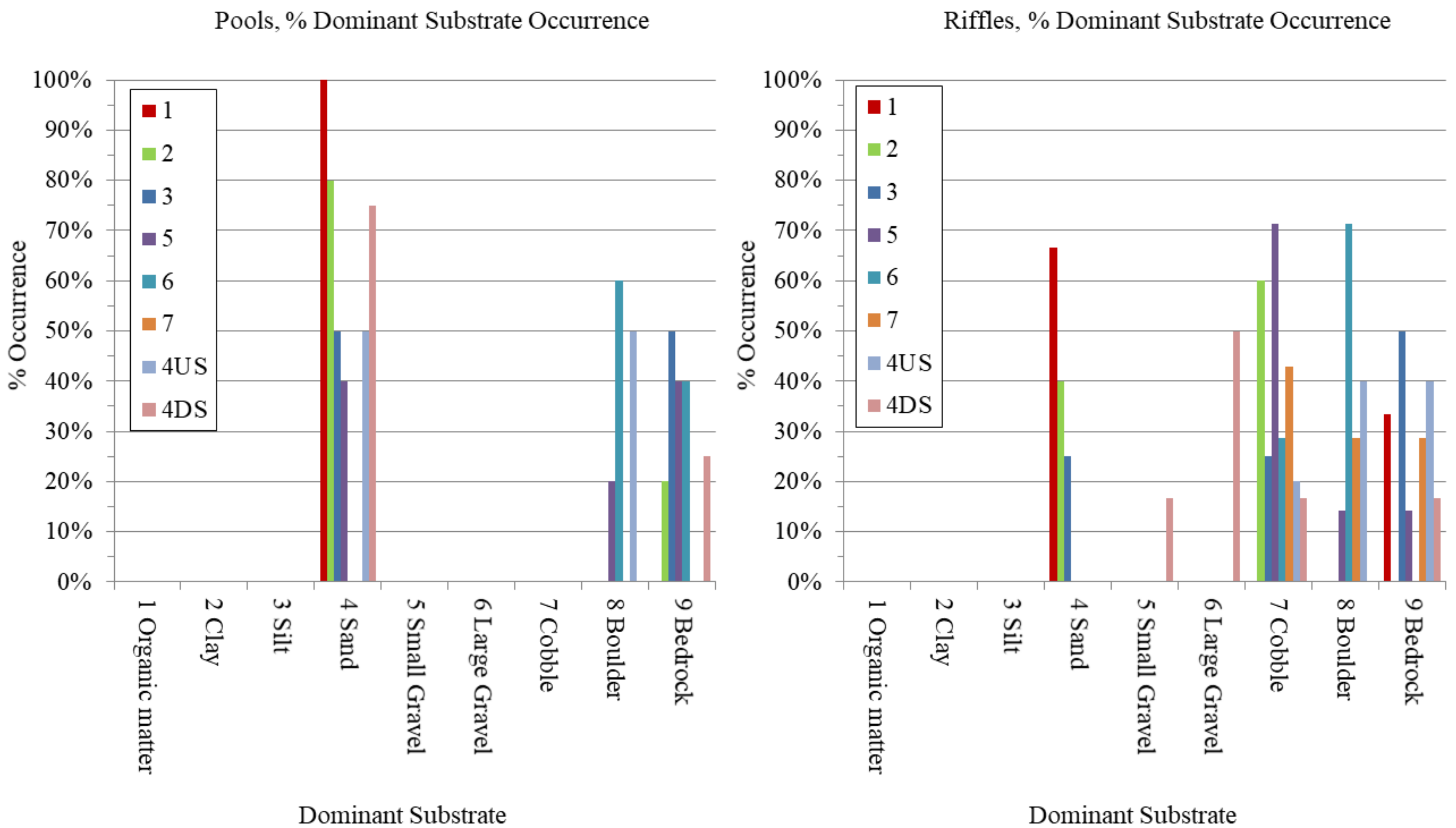
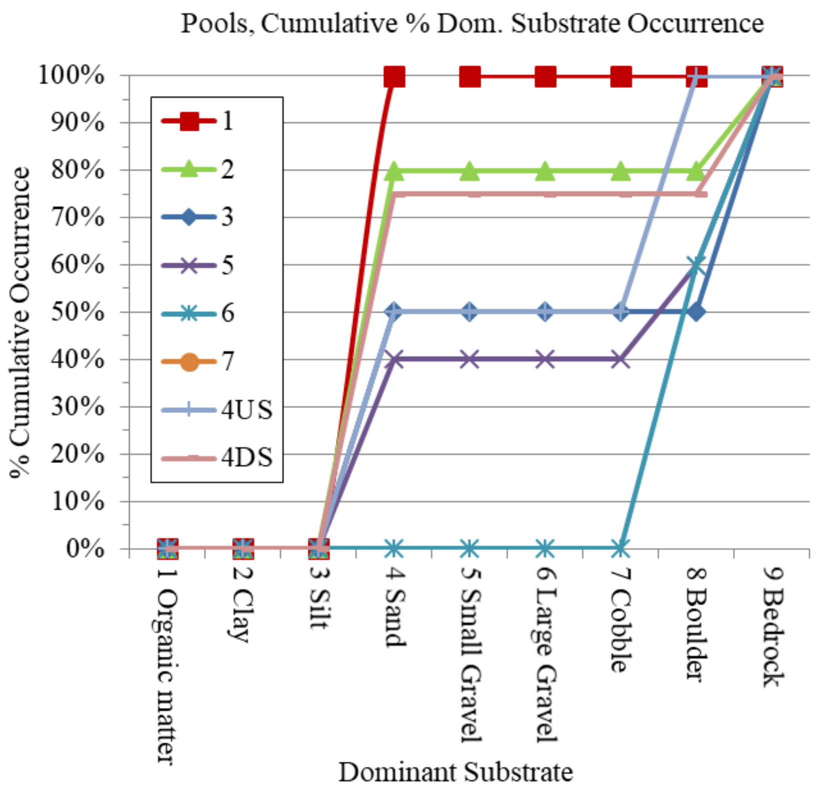


Figure 4. Percent occurrence of dominant substrate size categories in pools and riffles at Bear Creek sample sites (site 7 had no slow water units).



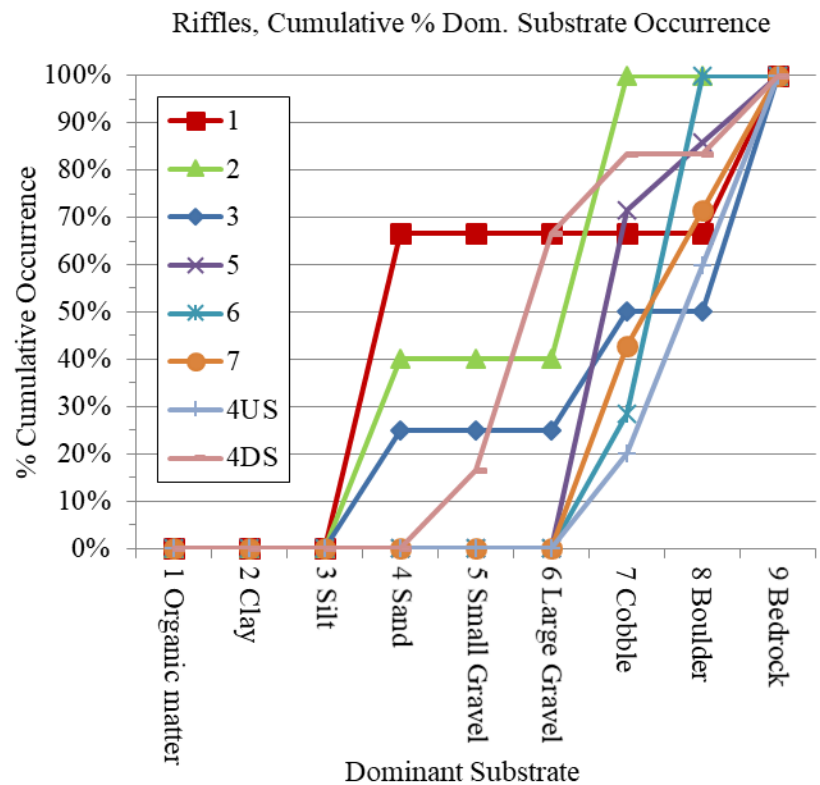


Figure 5. Cumulative percent occurrence of dominant substrate size categories in pools (left graph) and riffles (right graph) at Bear Creek sample sites (site 7 had no slow water units).

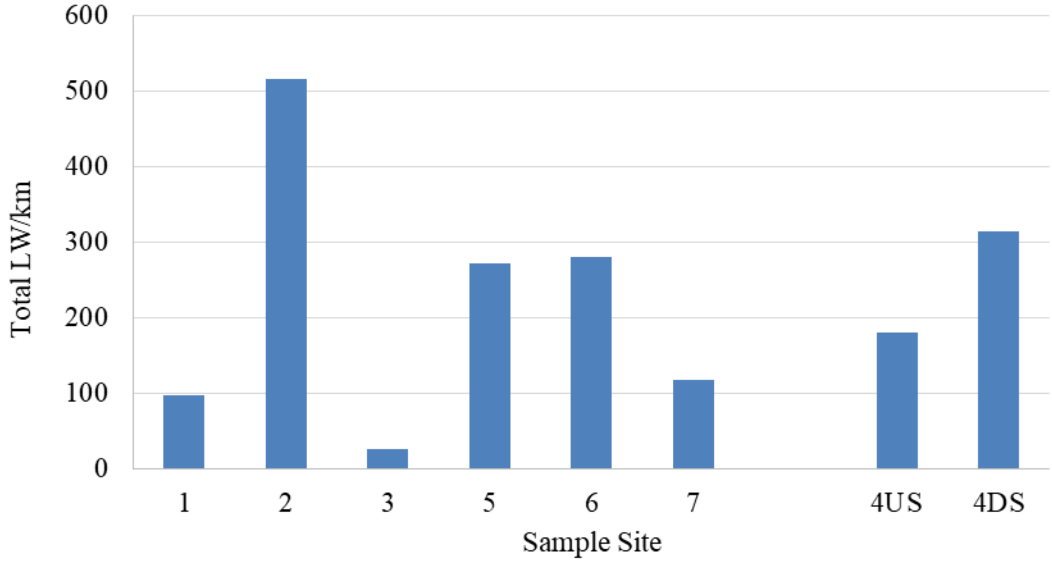


Figure 6. Total large wood per kilometer (size classes 1, 2, 3, and 4; see Appendix B for size classes) at Bear Creek sample sites.

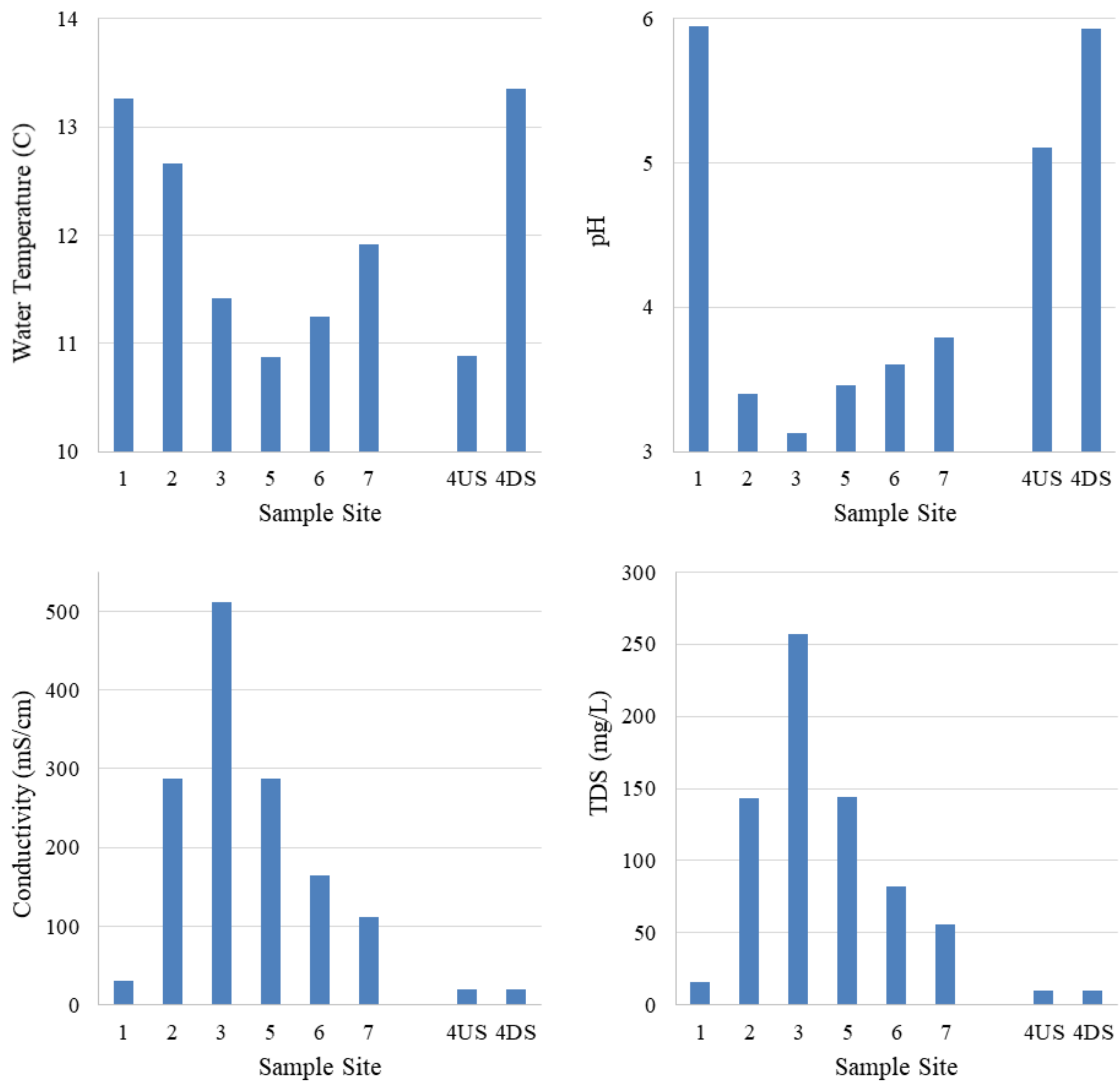


Figure 7. Water chemistry (temperature, pH, conductivity, and total dissolved solids) at Bear Creek sample sites.

Table 1. Data collected at Bear Creek sample sites, May 2019. The MBI criteria considers these samples sites headwater streams due to catchment areas being <12.9 km^2 (<5 mi^2) which should be sampled in February-May (Pond et al. 2003).

Site #	Stream Name	Quad	Catchment Area (km^2)	Avg. width (m)	BVET habitat (m)	Efish (m)	Efish (sec)	Crayfish Observed	Comments
1	Bear Creek	Dykes	0.49	1.4	123	120	141	Yes	2 waterfalls having 1.5 m freefalls are located
2	Bear Creek	Dykes	0.98	1.6	120	120	255	No	between site 1 and 2
3	Bear Creek	Dykes	1.42	1.9	120	120	238	No	
5	Bear Creek	Hail	2.20	2.2	129	120	303	No	
6	Bear Creek	Sawyer	3.60	3.9	161	155	673	Yes	
7	Bear Creek	Sawyer	4.97	4.1	178	164	739	Yes	
4US	Unnamed Tributary	Hail	0.34	1.3	122	120	236	Yes	a 1.5 m high cascade barrier formed by large
4DS	to Bear Creek	Hail	0.34	1.7	127	120	240	Yes	boulders is located between site 4US and 4DS

Table 2. GPS coordinates recorded at the downstream start location of stream habitat and fish inventories at Bear Creek sample sites.

Site #	Stream Name	Coordinates (UTM NAD83)
1	Bear Creek	16 S 732243 4098722
2	Bear Creek	16 S 732409 4098418
3	Bear Creek	16 S 732526 4098187
5	Bear Creek	16 S 732686 4097981
6	Bear Creek	16 S 733642 4097507
7	Bear Creek	16 S 734190 4097220
4US	UT to Bear Creek	16 S 732419 4097952
4DS	UT to Bear Creek	16 S 732533 4098056

Table 3. Total count (adult & age-0) of fish captured at Bear Creek sample sites.

Scientific Name	Common Name	1 Bear Creek	2 Bear Creek	3 Bear Creek	5 Bear Creek	6 Bear Creek	7 Bear Creek	4US UT to Bear Cr.	4DS UT to Bear Cr.
Cyprinidae									
Semotilus atromaculatus	Creek Chub	0	0	0	0	0	0	0	**26**

Table 4. Kentucky macroinvertebrate bioassessment index (MBI) results at Bear Creek sample sites.

	1 Bear Creek	2 Bear Creek	3 Bear Creek	5 Bear Creek	6 Bear Creek	7 Bear Creek	4US UT to Bear Cr.	4DS UT to Bear Cr.
TNI	39	10	12	3	6	12	102	118
$TR_{(gen)}$	20	6	5	3	5	5	24	28
$EPT_{(gen)}$	6	1	0	0	1	1	12	15
%EPT	21	0	0	0	0	0	73	75
%Ephem	8	0	7	0	0	0	47	27
HBIm	4	8	0	8	8	7	3	3
%Cling	46	0	17	0	17	25	68	74
%Chir+Olig	33	0	0	0	50	17	10	3
MBI score	40.9	20.3	24.0	19.1	15.6	23.4	72.8	72.8
Rating	Poor	Very Poor	Very Poor/ Poor	Very Poor	Very Poor	Very Poor/ Poor	Fair/Good	Fair/Good

TNI = total number individuals; $TR_{(gen)}$ = genus taxa richness; $EPT_{(gen)}$ = genus ephemeroptera, plecoptera, trichoptera richness; %EPT = modified percent EPT abundance; %Ephem = percent ephemeroptera; HBIm = modified Hilsenhoff biotic index %Clingers = percent primary clingers; %Chir+Olig = percent chironomidae+oligochaeta;

MBI headwater ratings: Very-Poor 0-23; Poor 24-47; Fair 48-71; Good 72-82; Excellent ≥83

When an MBI score fell close (± 2 points) to the classification threshold, DBNF rated the site using both categories (i.e. Fair/Good)

Table 5. Summary of BVET stream habitat attributes collected at Bear Creek sample sites.

		Mean Avg. Depth (cm)		Mean Max. Depth (cm)		Mean Pool Residual	Avg. Wetted Width (m)		Avg. Bankfull Channel	Avg. % Fines		Avg. Gradient	Avg. Water Temp.	Rosgen
Site #	Stream Name	Pools	Riffles	Pools	Riffles	Depth (cm)*	Pools	Riffles	Width (m)	Pools	Riffles	(%)	(C)	
1	Bear Creek	12	7	21	13	NA	1.2	0.9	2.3	88	63	1	NA	C
2	Bear Creek	14	9	32	29	NA	1.9	1.5	3.3	79	40	4	NA	G
3	Bear Creek	18	6	33	18	NA	2.1	1.8	4.3	78	35	2	NA	G/F
5	Bear Creek	23	11	40	22	14	2.4	2.8	4.8	29	7	2	10	C
6	Bear Creek	37	14	60	30	15	3.2	4.1	6.2	23	6	2	12	B
7	Bear Creek	--	21	--	39	--	--	4.4	6.6	--	36	1	12	C
4US	UT to Bear Creek	18	7	24	17	12	2.0	1.5	3.4	29	10	3	NA	B
4DS	UT to Bear Creek	11	8	24	18	6	1.9	1.4	4.2	71	27	2	NA	F

*Residual pool depth = (average pool depth) – (riffle crest depth)
-- No slow-water habitat (pools or glides) present

Table 6. Stream habitat unit counts and area in pools (includes glides) and riffles (includes runs) observed during BVET habitat inventories at Bear Creek sample sites.

		Habitat Unit Count							Habitat	Habitat Unit Area				
		Slow Water			Fast Water			*Total*	inventory	Pool Area	Riffle Area	*Total*	% Pool	% Riffle
Site #	Stream Name	Pool	Glide	*Total*	Riffle	Run	*Total*	*Units*	length (m)	(m^2)	(m^2)	*Area (m^2)*	Area	Area
1	Bear Creek	7	1	*8*	3	0	*3*	*11*	123	78	57	*135*	58%	42%
2	Bear Creek	2	3	*5*	4	1	*5*	*10*	120	85	117	*203*	42%	58%
3	Bear Creek	0	2	*2*	4	0	*4*	*6*	120	51	180	*231*	22%	78%
5	Bear Creek	5	0	*5*	6	1	*7*	*12*	129	102	241	*344*	30%	70%
6	Bear Creek	4	1	*5*	5	2	*7*	*12*	161	162	466	*628*	26%	74%
7	Bear Creek	0	0	*0*	3	4	*7*	*7*	178	0	748	*748*	0%	100%
4US	UT to Bear Creek	4	0	*4*	5	0	*5*	*9*	122	30	158	*188*	16%	84%
4DS	UT to Bear Creek	3	1	*4*	6	0	*6*	*10*	127	34	140	*174*	19%	81%

Table 7. Dominant and subdominant substrate types observed in pools (P; includes glides) and riffles (R; includes runs and cascades) during BVET habitat inventories at Bear Creek sample sites (see Appendix B for substrate size class descriptions). The first number in each pair is for dominant substrate, the second for subdominant substrate. For example, in pools at site 1 Bear Creek, sand was dominant in 8 pools and subdominant in 0 pools.

	1 Bear Creek		2 Bear Creek		3 Bear Creek		5 Bear Creek		6 Bear Creek		7 Bear Creek		4US UT to Bear Cr.		4DS UT to Bear Cr.	
Substrate Size Class	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R
Organic matter	**0,4**	**0,2**	**0,3**	**0,2**	0,0	0,0	0,0	0,0	0,0	0,0	--	0,0	0,0	0,0	**0,2**	0,0
Clay	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	--	0,0	0,0	0,0	0,0	0,0
Silt	0,0	0,0	**0,1**	**0,3**	0,0	**0,2**	0,0	0,0	0,0	0,0	--	0,0	0,0	0,0	0,0	0,0
Sand	**8,0**	**2,0**	**4,0**	**2,0**	**1,1**	**1,1**	**2,3**	0,0	**0,2**	0,0	--	0,0	**2,1**	**0,1**	**3,1**	**0,1**
Small gravel	0,0	**0,1**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	--	**0,1**	**0,1**	**0,1**	0,0	**1,3**
Large gravel	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,2**	0,0	**0,3**	--	**0,2**	**0,1**	**0,1**	0,0	**3,0**
Cobble	0,0	0,0	**0,1**	**3,0**	0,0	**1,1**	**0,2**	**5,2**	**0,1**	**2,4**	--	**3,3**	**0,1**	**1,2**	**0,1**	**1,2**
Boulder	0,0	0,0	0,0	0,0	0,0	0,0	**1,0**	**1,3**	**3,1**	**5,0**	--	**2,1**	**2,0**	**2,0**	0,0	0,0
Bedrock	**0,4**	**1,0**	**1,0**	0,0	**1,0**	**2,0**	**2,0**	**1,0**	**2,1**	0,0	--	**2,0**	0,0	**2,0**	**1,0**	**1,0**

-- No slow-water habitat (pools or glides) present

Table 8. Large wood per kilometer observed during BVET habitat inventories at Bear Creek sample sites (see Appendix B for large wood size classes).

Site #	Stream Name	Large Wood per Km						Large Wood Count in Sample Reach						Inventory
		LW1/ km	LW2/ km	LW3/ km	LW4/ km	RW/ km	Total LW/km	LW1 n	LW2 n	LW3 n	LW4 n	RW n	Total LW n	Distance (km)
1	Bear Creek	41	0	49	0	8	98	5	0	6	0	1	12	0.12
2	Bear Creek	200	0	292	0	25	517	24	0	35	0	3	62	0.12
3	Bear Creek	0	0	25	0	0	25	0	0	3	0	0	3	0.12
5	Bear Creek	202	0	70	0	0	271	26	0	9	0	0	35	0.13
6	Bear Creek	99	25	149	0	6	280	16	4	24	0	1	45	0.16
7	Bear Creek	118	0	0	0	0	118	21	0	0	0	0	21	0.18
4US	UT to Bear Creek	123	0	57	0	0	180	15	0	7	0	0	22	0.12
4DS	UT to Bear Creek	220	0	87	0	8	315	28	0	11	0	1	40	0.13

Table 9. Riffle stability index results (Kappesser 2002), based on pebble count data collected at Bear Creek sample sites.

Site #	Stream Name	Riffle Stability Index	RSI Condition Score	Bar Sample Geometric Mean	Median Particle Size			
					D25	D50	D75	D84
1	Bear Creek	73.8	Fair	72.2	*	**	1,024	1,024
2	Bear Creek	66.9	Good	71.6	*	4	200	1,024
3	Bear Creek	54.6	Good	95.4	*	54	1,024	1,024
5	Bear Creek	68.3	Good	118.4	*	46	150	220
6	Bear Creek	65.7	Good	116.1	2	58	170	280
7	Bear Creek	56.3	Good	138.7	12	98	210	280
4US	UT to Bear Creek	60.5	Good	64.1	*	14	160	390
4DS	UT to Bear Creek	80.5	Fair	54.6	*	**	32	76

Riffle stability index (RSI) score; <70 = good condition, 70-85 = fair condition, >85 = poor condition
*Could not be calculated because the 0-2 mm substrate size-class comprised >25% of the sample
**Could not be calculated because the 0-2 mm substrate size-class comprised >50% of the sample

Table 10. Water chemistry measurements at Bear Creek sample sites.

Site #	Stream Name	Date	Water Temp. (C)	pH	Conductivity (mS/cm)	Turbidity (FNU)	DO (mg/L)	TDS (mg/L)
1	Bear Creek	5/18/19 9:07 AM	13.3	6.0	30	2.5	8.1	16
2	Bear Creek	5/18/19 8:29 AM	12.7	3.4	288	0.0	8.7	143
3	Bear Creek	5/16/19 9:49 AM	11.4	3.1	512	0.0	9.2	257
5	Bear Creek	5/16/19 8:45 AM	10.9	3.5	287	0.1	9.2	144
6	Bear Creek	5/16/19 11:00 AM	11.3	3.6	164	1.5	9.3	82
7	Bear Creek	5/16/19 12:15 PM	11.9	3.8	111	0.8	9.1	56
4US	UT to Bear Creek	5/16/19 9:26 AM	10.9	5.1	20	22.7	8.3	10
4DS	UT to Bear Creek	5/18/19 10:04 AM	13.4	5.9	20	1.9	8.4	10

Appendix A: Field Methods for Stream Inventory

Sampling Strategy

Day 1 – Macroinvertebrate collection & BVET Inventory

- All team to first site to learn site documentation, site layout, and macroinvertebrate and habitat sampling methods
- While 2 team members conduct the BVET inventory and site layout, 2 or more other team members can collect macroinvertebrates
- Split into several teams (depending on team size) to visit and document other sites, layout sites, and sample macroinvertebrates and habitat

Day 2 – Efish & Pebble Counts

- Perform efish, pebble, and bar-count sampling at sites visited on day 1
- If the team is large enough, the team can split so that two teams are continuing with site documentation, site layout, macroinvertebrate, and habitat sampling methods

Day 3

- Continue with approach from day 2, allowing at least 1 day between macroinvertebrate and fish sampling
- If the fish sampling team catches up with the layout team, then take a day to split into several layout teams as during day 1
- When layout team finishes all sites they can rejoin fish sampling team

This approach should maximize team efficiency and prevent biases associated with sampling fish and macroinvertebrates within the same site in the same day.

Site Documentation

Objective - Record location and description of site for reporting purposes

Methods

- Directions to site
    - Record roads taken to parking area
    - Record trails walked to site
    - Document route to site on quadrangle map

- GPS
    - Record GPS coordinates at start and end of inventory

- Photos
    - Take digital photo from downstream end looking up, upstream end looking down
    - Photograph any pertinent features within the site that may influence habitat and fauna, example, road or trail crossings, erosion, etc.

- Written description
    - Record comments on land use in the site area, for example private land with mowed lawns, all forested, pasture lands, etc.
    - Record comments on other features that may be influencing stream conditions

Site Layout

Objective - Use consistent method to lay out site for fish and macroinvertebrate sampling

Methods

- Locate 1 – 2 riffles or runs and determine the average wetted width by making several measurements and computing the average. Measure width perpendicular to thalweg.

    - If the average wetted width is less than or equal to 3.0 m, then the site length will be 120 m
    - If the average wetted width is greater than or equal to 7.5 m, then the site length will be 300 m
    - If the average wetted width is between 3.0 and 7.5 m, then site length is 40-times the average wetted width, example: average wetted width = 5 m; site length = 5 x 40 = 200m

- Hang a double orange flag at the downstream end of the site. Attach topofil from a hipchain and walk to the midpoint of the site, hang a single orange flag, then continue to the end of the site and hang another single orange flag (hanging the flags to layout the site can be done while performing the BVET inventory)

- Record the average wetted width and site length on the datasheet

- Sites will not be moved to avoid road or trail crossings – moving sites violates the assumptions of the stratified random sample design and invalidates statistical analysis. Document these features fully with photos and written descriptions

- Always begin sites at the downstream end of a defined habitat unit, end points should be at the exact distance as described above

- In large streams make sure the site includes all of a fast water habitat unit and all of a slow water habitat unit

Habitat Inventory (BVET)

Objective – Characterize stream habitat attribute within the sample site.

Methods

- Collect attribute as described in Section 2 of Roghair and Nuckols (2005) (Appendix B)

- Increase frequency of paired (sub-) samples to include at least 3 fast and 3 slow water units within each site
    - Where less than 3 fast or slow occur, sub-sample all units

- Start and end data collection at habitat unit breaks
    - This may extend habitat data collection slightly beyond end of sample site (however, still hang site-end flag at calculated distance, not at the upper end of habitat unit)

Macroinvertebrates Inventory

Objective - Collect assemblage sample

Methods

- Using D-frame nets and a seine collect macroinvertebrates using the riffle sample and multi-habitat sample methods described by KDOW (2011)

- Where possible, keep macroinvertebrate samples within designated sites. If this is not possible be sure to indicate on datasheet.

Kentucky Division of Water (KDOW). 2011. Methods for sampling benthic macroinvertebrate communities in wadeable waters. Kentucky Department for Environmental Protection. Division of Water, Frankfort, KY.

Electrofishing Inventory

Objective - Determine relative abundance and determine catch-per-unit-effort (CPUE). Note: we are not attempting to estimate population size or density for individual species, only assessing the fish assemblage

Methods (based on sampling strategies discussed and approved by R8 and SRS personnel in 3/2005)

- Electrofishing starts in same location as habitat inventory

- Electrofishing ends at location designated in site layout process
    - Habitat inventory may extend beyond end of designated site
    - DO NOT extend electrofishing sample beyond end of designated site

- Single-pass DC backpack electrofishing

- One shocker, 3 netters (a net on the probe can be the 3rd net)

- No blocknets

- Electrofishing effort will be equal to 1.0 seconds for each 1.0 m^2 of wetted area
    - note: this will standardize our effort and remove the potentially confounding effect of changes in wetted width relative to the bankfull channel width in wet or dry years
    - derived Warren et al. data on electrofishing effort in MS streams

- Fish will be counted and released at the site, except for a voucher specimen for each species; endangered species lists will be reviewed before sampling

- Record age-0 fish and all fish older than age-0 separately for each species

- Keep all relic mussel shells encountered

- Record number of crayfish captured (don’t actively net crayfish, but bucket any that end up in the net). If also vouchering fish then keep a couple crayfish specimens (ideally Form I & II males)

Pebble Count Inventory

Objective - Determine the riffle stability index (RSI), bar sample geometric mean, and median particle sizes.

Methods

- Pebble count data is collected using methods modified from those in Kappesser (2002) to characterize the substrate composition of sample sites
- Pebble counts are performed in riffles designated for electrofishing by walking transects perpendicular to the flow within the bankfull channel (Harrelson et al. 1994)
- Walk the transect beginning at the edge of the bankfull channel on one side of the stream and walk heel-to-toe across the stream channel to the opposite bank
- At each step pick up the pebble at the tip of your toe and measure its intermediate axis with a ruler to the nearest millimeter
- For very large particles, the same particle is counted as many times it is encountered
- These procedures are repeated until at least 200 measurements are recorded; Transects are not terminated until the opposite bank is reached even if this results in more than 200 measurements
- Transects are distributed throughout the riffle; If detritus, LW, or other organic materials are encountered the rock substrate found directly below them is sampled
- For the bar sample, measure 30 freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above; Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles
- The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars; The entire bar should be visually inspected to identify the dominant large size of particle present; If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle; For each particle, measure the intermediate axis to the nearest millimeter

Bunte, K. and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadeable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Harrelson, Cheryl C., Rawlins, C. L., and Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Kappesser, G. B. 2002. A riffle stability index to evaluate sediment loading to streams. Journal of the American Water Resources Association. 38:1069-1081.

Appendix B: Field Methods for Macroinvertebrate Sampling

Macroinvertebrate Equipment List

- ☐ Mesh wash bucket
- ☐ Rinse bucket
- ☐ Squirt bottle
- ☐ Seine
- ☐ D-Frame nets
- ☐ PVC ¼ sq meter quadrates
- ☐ Tweezers
- ☐ Collection jars
- ☐ Sample labels
- ☐ Pencils
- ☐ Markers
- ☐ Ethyl alcohol

Macroinvertebrate Sampling Methods

1. **Riffle Sample**
    - Take four 0.25 m^2 samples from midriffle or the thalweg (path of deepest thread of water).
    - For each of the 4 samples, place a seine (600 µm mesh, one meter wide) in moderate to fast current in areas with gravel to cobble substrate. Place some rocks on the bottom edge of the seine to hold it on the channel bottom.
    - Dislodge benthos by vigorously disturbing 0.25 m^2 (20 x 20 in.) in front of the net (use 0.25 m^2 PCV quadrate to sample correct area). Large rocks should be hand washed into the net.
    - After each of the 4 samples is collected wash the contents of the net into a mesh wash bucket to prevent loss of inverts when collecting the next sample. All four samples are composited in the bucket.
    - Find a suitable location on the side of the stream, spread the seine out on the ground, and wash the contents of the bucket onto the seine. With tweezers methodically sort through the sample picking out the invertebrates and placing them in a sample jar containing ethyl alcohol.
    - The picking process can easily take an hour to complete; be patient and thorough. When complete be sure there is a sample label inside the jar as well as one on the outside.
    - *This sample must be kept separate from all other subhabitat collections.*

2. **Multi-Habitat Sample**

    A. **Sweep Sample** - Involves sampling a variety of non-riffle habitats with the aid of an 800 x 900 µm mesh D-frame dipnet. Each habitat is sampled in at least three (3) replicates, where possible.

    1) *Undercut banks/root mats* - sampled by placing a large rootwad into the D-frame dipnet and shaken vigorously. The contents are removed from the dipnet and placed into a mesh wash bucket. Note: if undercut banks are present in both run and pool areas, each is sampled separately with three replicates.

2) *Marginal emergent vegetation* (exclusive of *Justicia americana* beds) – sampled by thrusting (i.e., “jabbing”) the dipnet into the vegetation for ca. 1 m, and then sweeping through the area to collect dislodged organisms. Material is then rinsed in the wash bucket and any sticks, leaves and vegetation are thoroughly washed and inspected before discarding.

3) *Bedrock or slab-rock habitats* - sampled by placing the edge of the dipnet flush on the substrate, disturbing approximately 0.1 m^2 of area to dislodge attached organisms. Material is emptied into a wash bucket.

4) *Justicia americana (water willow) beds* - sampled by working the net through a 1 m section in a jabbing motion. The material is then emptied into a wash-bucket and any *J. americana* stems are thoroughly washed, inspected and discarded.

5) *Leaf Packs* - preferably “conditioned” (i.e., not new-fall material) where possible; samples are taken from a variety of locations (i.e., riffles, runs and pools) and placed into the wash-bucket. The material is thoroughly rinsed to dislodge organisms and then inspected and discarded.

B. Silt, sand, and fine gravel

1) *Netting* - a D-frame dipnet is used to collect sand and silt depositional areas by placing the net on the substrate and vigorously stirring the sediments in front of the net. An area of 0.1 m^2 is sampled for each replicate making sure, where possible, that replicates are taken from different depositional areas.

C. Aufwuchs sample - small invertebrates associated with this habitat are obtained by washing a small amount of rocks, sticks, leaves, filamentous algae and moss into a medium-sized bucket half filled with water. The material is then elutriated and sieved with the nitex sampler.

D. Rock Picking - invertebrates are picked from 15 rocks (large cobble-small boulder size; 5 each from riffle, run and pool). Selected rocks are washed in a bucket half filled with water, then carefully inspected to remove invertebrates with fine-tipped forceps.

E. *Wood Sample* - pieces of submerged wood, ranging from roughly 3 to 6 meters (10 to 20 linear feet) and ranging from 5–15 cm (2–6 inches) in diameter, are individually rinsed into the wash-bucket. Pieces of wood are inspected for burrowers and crevice dwellers. Large diameter, well-aged logs should be inspected and handpicked with fine-tipped forceps.

Macroinvertebrate Sampling Summary

	Sample	Sampling Device	Habitat	Replicates (composited)
1	Riffle*	Kick Seine/Mesh bucket/PVC Sq.	Riffle	4 - 0.25 m^2
2	Sweep - Undercut banks	Dipnet/Mesh Bucket	Undercut Banks/Roots	3
3	Sweep - Emergent vegetation	Dipnet/Mesh Bucket	Emergent Vegetation	3
4	Sweep - Bedrock	Dipnet/Mesh Bucket	Bedrock/Slabrock	3
5	Sweep - Justicia beds	Dipnet/Mesh Bucket	Justicia beds	3
6	Sweep - Leaf packs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
7	Silt,Sand, Fine Gravel	Dipnet/Mesh Bucket	Margins	3
8	Aufwuchs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
9	Rock Picking	Forceps	Riffle-Run-Pool	15 rocks (5-5-5)
10	Wood	Mesh Bucket	Riffle-Run-Pool	3-6 linear m

*Sample contents kept separate from other habitat samples.

Appendix C: Field Methods for Habitat Inventory

Guide to Stream Habitat Characterization using the BVET Methodology in the Daniel Boone National Forest, KY

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Table of Contents

Introduction

The Basinwide Visual Estimation Technique (BVET) is a versatile tool used to assess streamwide habitat conditions in wadeable size streams and rivers. A team of two individuals performs the inventory using two-stage visual estimation techniques described in Hankin and Reeves (1988) and Dolloff et al. (1993). In its most basic form the BVET combines visual estimates with actual measurements to provide a calibrated estimate of stream area with confidence intervals, however the team may inventory any number of other habitat attributes as they walk the length of the stream. Experienced teams can inventory an average of 2-3 km per day, but this will vary depending on stream size and the number of stream attributes inventoried.

Before a team begins a BVET inventory they must receive adequate training, both in the classroom and in the field. Estimating and measuring a large number of habitat attributes can confuse and overwhelm an inexperienced team. Individuals must have an understanding of the basic concepts behind the BVET and be familiar with habitat attributes before they can effectively and efficiently perform an inventory.

In summer 2004, resource managers on the Daniel Boone National Forest (DBNF) requested that the USFS Center for Aquatic Technology Transfer (CATT) implement modified BVET inventories to inventory stream sites previously inventoried in the 1990's. The 1990's inventories followed methods detailed in the 'Daniel Boone National Forest Stream Inventory Work Plan and Sampling Techniques Manual', which were similar in nature to the BVET habitat inventory. After discussion with resource managers from the DBNF, we scaled down the original protocol, eliminating several attributes and modifying others to maximize inventory efficiency during our limited time on the Forest. In summer 2005 the DBNF opted to use identical BVET methods as National Forests in Virginia and North Carolina, which are only slightly different from methods used in Kentucky in 2004.

This document was developed to serve as a guide for classroom and field instructions specific to the ONF BVET habitat inventory and to provide a post-training reference for field teams. It includes an overview of the BVET inventory, defines habitat attributes, instructs how and when to measure attributes, and provides reference sheets for use in the field. Each trainee should receive a copy of this manual and is encouraged to take notes in the spaces provided.

We used an abbreviated version of the BVET to sample habitat within sample sites only. Paired samples were collected more frequently then described here because sample sites were short. Stream attributes were collected as described in Section 2.

References cited in this manual:

Armantrout, N. B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

Bunte, K., and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. General Technical Report SE-83. Asheville, North Carolina: U.S. Department of Agriculture, Southeastern Forest Experimental Station.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Outline of BVET Habitat Inventory

1. Enter 'Header' information on the data sheet: --- 'Header' information includes date, stream, start location, team, etc. and is **vitally** important to record for future reference.

2. Enter downstream of the starting point, then move upstream and begin the inventory. Tie off the hipchain, proceed upstream to the starting point, reset the hipchain to zero, and proceed upstream estimating parameters and recording data in every habitat unit.

3. At the paired sample units perform visual estimates, then perform measurements. Pair a minimum of 3 fast and 3 slow water units; pair more if possible.

4. Progress upstream estimating attributes for every unit until the next paired sample unit is reached, then repeat step 4.

The team should also take care to record roads, trails, tributaries, dams, waterfalls, road crossing types, riparian features (wildlife openings, trails, campsites, roads, timber harvest, etc.), and other pertinent stream features as they progress upstream. Be sure to record hipchain distances when noting such features. Some features may also require a picture number to be associated with them.

The following sections describe the BVET habitat inventory in detail:

Section 1: Getting Started – equipment, header info, random numbers, starting the inventory
Section 2: Habitat Attributes – definitions, how to estimate or measure, when to record
Section 3: Wrapping Up – what to do when the inventory is completed
Section 4: Summary
Section 5: GPS Instructions
Appendix: field guide, random number tables, equipment checklist

Section 1: Getting Started

Equipment List

□ Hipchain	□ Camera
□ Extra string for hipchain	□ Backpack
□ Wading rod	□ Pencils
□ 50 m tape measure	□ Flagging
□ Clinometer	□ Markers
□ Datalogger	□ Waterproof backup datasheets
□ Thermometer	□ Clipboard
□ GPS unit	□ BVET field guide on waterproof paper
□ Topographic map w/NHD_ID	□ Felt bottom wading boots or waders
□ Cell Phone	□ Water
□ First Aid Kit	□ Water Filter
□ Rain Gear (optional)	□ Toilet Paper

The BVET team consists of two individuals, the 'observer' and the 'recorder'. The observer wears the hipchain and carries the wading rod. The recorder wears the data logger and carries other equipment in the backpack. The duties of each individual are listed below.

Duties

Observer	Recorder
Designate habitat units	Locate changes in NHD_ID
Measure distance	Record data
Estimate width	Determine paired sample location
Estimate depths	Classify and count Large Wood (LW)
Classify substrates	Photo-documentation
Locate features	Document features
Estimate percent fines	GPS-documentation

Both team members are needed to measure actual widths, channel widths, riparian areas, gradient, and water temperature at designated units. Although the team has assigned duties, they should not hesitate to consult with each other if they have questions or feel that a mistake may have been made. Working as a team will provide the best possible results.

Header Information

Header information is **vitally important** for future reference. Take the time to record all categories completely and accurately.

Stream Name	Full name of stream
District	National Forest District name
Quad	USGS 1:24,000 quadrangle name
Date	Record date(s) of inventory
Recorder	Full name of recorder
Observer	Full name of observer
GPS	Record at start and end locations, always use NAD83 CONUS, UTM
Location	**Detailed** written description of start point, include landmarks, road #, etc.
Comments	Record signs of activity in area, water conditions, other pertinent information

Starting the Inventory

After the team has organized their gear, determined their measurement interval, selected a random number, and recorded all the header information they are ready to begin the habitat inventory.

The observer should enter the stream slightly downstream of the starting point, tie off the hipchain, progress upstream to the starting point, reset the hipchain to zero and begin walking upstream through the first habitat unit. As the observer moves upstream they use the wading rod to measure depth at several locations in the habitat unit and make observations of unit type, width, substrates, and percent fines. When they reach the upstream end of the habitat unit they stop, turn to face the unit and report the unit type, maximum and average depth, riffle crest depth (where appropriate), dominant and subdominant substrate classes, percent fines, estimated width, and hipchain distance to the recorder.

As the observer moves upstream through the unit, the recorder follows behind, recording the amount of LW in the habitat unit. The recorder also assigns a number to the habitat unit. The recorder tells the observer if a unit is designated for measurements (i.e. if it is a ‘paired sample’ unit) only after they have recorded visual estimates.

The team continues upstream making estimates in every habitat unit and making estimates and measurements in every paired sample unit until the inventory endpoint is reached.

Definitions of habitat attributes, how to measure and when to record them, and what to do when the inventory is complete are covered in the following sections.

Section 2: Stream Attributes

Unit Type (see abbreviations)

Unit Type	***Abbreviation***	**Definition**
Riffle	R	**Fast water, turbulent, gradient <12%**; shallow reaches characterized by water flowing over or around rough bed materials that break the surface during low flows; also **include rapids** (turbulent with intermittent whitewater, breaking waves, and exposed boulders), **chutes** (rapidly flowing water within narrow, steep slots of bedrock), and **sheets** (shallow water flowing over bedrock) if gradient <12%
Cascade	C	**Fast water, turbulent, gradient ≥12%**; highly turbulent series of short falls and small scour basins, with very rapid water movement; also **include sheets** (shallow water flowing over bedrock) and **chutes** (rapidly flowing water within narrow, steep slots of bedrock) if gradient ≥12%
Run	RN	**Fast water, non-turbulent, gradient <12%**; deeper than riffles with little or no surface agitation or flow obstructions and a flat bottom profile
Pool	P	Slow water, surface turbulence may or may not be present, gradient <1%; generally deeper and wider than habitat immediately upstream and downstream, concave bottom profile; includes dammed pools, scour pools, and plunge pools
Glide	G	**Slow water, no surface turbulence, gradient <1%**; shallow with little to no flow and flat bottom profile
Underground	UNGR	Stream channel is dry or not containing enough water to form distinguishable habitat units

*modified from Armantrout (1998)

How to estimate:
Habitat units are separated by 'breaks'. Breaks can be obvious physical barriers, such as a debris dam separating two pools or a small waterfall separating a pool and riffle, or may be less obvious transitional areas. Questions often arise as to whether a break is substantial enough to split two habitat units and where the exact location of the break occurs. When in doubt, the observer should consult with the recorder and the team should 'think like a fish'. To determine if a break should be made, consider whether a fish would have to make an effort to move across the break and into the next habitat unit. If not, then it is probably a single habitat unit.

The channel may have both pool and riffle type habitat in the same cross-sectional area. Determine the predominate habitat type and record it as the unit type. For example if an area contains both pool and riffle, but the majority of the flow is into and out of the pool habitat, then call the unit a pool.

Questions also often arise as to the minimum size of individual habitat units. Generally, if a habitat unit is not at least as long as the wetted channel is wide, then do not count it as a separate habitat unit. This rule may need to be adjusted for streams wider than 5 m. Use best professional judgment in such cases.

See the section 2.1 for a list of features that should also be recorded while performing the inventory.

When to record: every habitat unit

Unit Number (#)

Definition:
Count of habitat units of similar types, used to determine location of paired sample units

How to estimate:
When counting habitat units, group pools and glides (slow water) together, and group riffles, runs, and cascades (fast water) together. For example, consider the following sequence of habitat units:

Pool – Riffle – Pool – Pool – Riffle - Cascade – Riffle - Glide – Riffle – Pool – Run – Pool – Riffle

Habitat units in this sequence would be counted in the following manner (similar types are shaded same color):

Unit Type	Unit Number
P	1
R	1
P	2
P	3
R	2
C	3
R	4
G	4
R	5
P	5
RN	6
P	6
R	7

In the above example, the team has counted six slow water (pool/glide) units and seven fast water (riffle/run/cascade) units.

When to record: every habitat unit; not recorded for features

Distance (m)

Definition:
Number of meters (rounded to the whole meter) from the start of the inventory to the upstream end of the habitat unit or distance from the start of the inventory to upstream end of a feature, used as spatial reference for data analysis and to locate features in the future.

How to estimate:
The observer walks upstream in the middle of the stream channel with a hipchain measuring device. When they reach the upstream break between habitat units or the upstream end of a feature they stop and report the distance to the recorder.

Care should be taken to keep the hipchain string in the middle of the stream, especially around bends and meanders. If the hipchain should break, retreat to the location where the break occurred, tie off the hipchain, and continue. If the hipchain is reset for any reason be sure to note it in the comments.

When to record: every habitat unit and feature

Estimated Width (m)

Definition:
Average wetted width of the habitat unit as estimated visually (typically to half-meter accuracy), used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to estimate:
The observer notes the general shape and width of the unit while walking to the upstream end. When they reach the upstream end of the unit the observer stops, turns to face the unit, and estimates the average wetted width. Measure the wetted width of the stream before starting each day to calibrate yourself.

When to record: every habitat unit

Maximum and Average Depth (cm)

Definitions:
Maximum Depth – vertical distance from substrate to water surface at deepest point in habitat unit
Average Depth – average vertical distance from substrate to water surface in habitat unit

How to estimate:
The observer uses a wading rod marked in 5 cm increments to measure water depth as they walk upstream through the habitat unit. Water depth in deepest spot is recorded as the maximum depth. Average depth is the average of several depth measurements taken throughout the habitat unit.

When to record: every habitat unit

Riffle Crest Depth (cm)

Definition:
Vertical distance from the substrate to the water surface at the deepest point in the riffle crest. The riffle crest is the shallowest continuous line (usually not straight) across the channel where the water surface becomes continuously riffled in the transition area between a riffle (or a run or cascade) and a pool (or glide) (Armantrout 1998); think of it as the last place water would flow out of the pool if the riffle ran dry.

How to estimate:
When the observer reaches the upstream end of a riffle (or a run or cascade) leading into a pool (or glide), they use the wading rod to measure the deepest point in the riffle crest. Record the depth in the RCD column for the riffle habitat row.

When to record: at the upstream end of any riffle, run, or cascade leading into a pool or glide

Dominant and Subdominant Substrate (1-9)

Definitions:
Dominant Substrate – size class of stream bed material that covers the greatest amount of surface area within the wetted channel of the habitat unit.

Subdominant Substrate – size class of stream bed material that covers the 2nd greatest amount of surface area within the wetted channel of the habitat unit.

How to estimate:
The following size classes are used to categorize substrates*. The substrate 'Number' is entered into the dominant and subdominant substrate columns on the datasheet.

Type	*Number*	*Size (mm)*	Description
Organic Matter	1		dead leaves, detritus, etc. – **not live plants**
Clay	2		sticky, holds form when rolled into a ball
Silt	3		slippery, does not hold form when rolled into a ball
Sand	4	silt – 2	grainy, does not hold form when rolled into ball
Small Gravel	5	3-16	sand to thumbnail
Large Gravel	6	17-64	thumbnail to fist
Cobble	7	65-256	fist to head
Boulder	8	>256	larger than head
Bedrock	9		solid rock, parent material, may extend into bank

* these size classes are based on the modified Wentworth scale

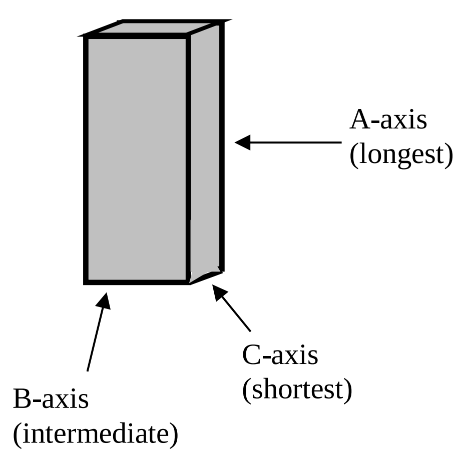
As the observer walks through the unit they scan the substrate. When they reach the upstream end of the unit they stop, turn to face the unit, and determine the dominant and subdominant substrate classes.

Estimate substrate size along the intermediate axis (b-axis). The b-axis is not the longest or shortest axis, but the intermediate length axis (see below). It is the axis that determines what size sieve the particle could pass through. Remember that your eyes are naturally drawn to larger size substrates. Be careful not to bias your estimate by focusing on the large size substrate.

Some units will contain a mixture of particle sizes. Consult with the recorder and use your best professional judgment to choose the dominant and subdominant sizes.

In units where the substrate is covered in moss, algae, or macrophytes classify the underlying substrate and make note of the plant growth in the comments. Only call organic substrate where there is dead and down leaves or other detritus covering the bottom of the unit.

When to record: every habitat unit



Rosgen Channel Type (A-G)

Definitions:
Stream channel classification system described in Rosgen (1996) based on entrenchment, width/depth ratio, sinuosity, and percent slope

How to Measure:
Before the team begins the inventory they should make the measurements described below to determine the channel type. Channel types are based on the following channel characteristics:

	A	B	C	D	E	F	G
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Sinuosity	1 – 1.2	> 1.2	>1.2	n/a	> 1.5	> 1.2	> 1.2
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Although we record channel type for every unit, it was designed to describe a reach of stream. Our main objective here is to locate changes between channel types, which could either be abrupt (such as change from a B to a G near a road crossing) or less obvious transitional areas (such as a natural transition from a B to an A channel as you move upstream). If you think channel type may have changed take the time to make the calculations listed below to determine the channel type for the reach you are entering.

Full channel type descriptions and how to measure each of the channel characteristics in the table above can be found in Rosgen (1998). Never perform measurements in a pool, always attempt to find a run or deep riffle with well-defined bankfull indicators to perform measurements. A summary of each is listed below:

Entrenchment (page 31 & 32 in Rosgen field guide):

- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width the maximum bankfull depth
- stretch a tape across the channel at 2x the maximum bankfull depth (this is the flood prone area)
- divide the flood prone area width by the bankfull width to determine entrenchment ratio

Width to Depth Ratio (page 32 in Rosgen field guide):

- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width and the maximum bankfull depth
- divide bankfull width by depth to determine width to depth ratio

Sinuosity (need aerial photo to determine)

Slope (page 37 in Rosgen field guide):

- Measure riffle to riffle gradient using clinometer

When to measure: every paired fastwater habitat unit*

* record for every fastwater paired unit, but remember this is describing a reach characteristic – see above

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Percent Fines (%)

Definition:
Percent of the total surface area of the stream bed in the wetted area of the habitat unit that consists of sand, silt, or clay substrate particles (i.e. particles < 2 mm diameter).

How to estimate:
As the observer walks through the habitat unit they note the amount of sand, silt, and clay in the habitat unit. When they reach the upstream end of the unit, they stop, turn to face the unit and estimate the amount of the total surface area within the wetted channel that consists of sand, silt, or clay.

Where to estimate: every habitat unit

Large Wood (1-4 and rootwad)

Definition:
Count of dead and down wood within the bankfull channel of a habitat unit

How to estimate:
The recorder classifies and counts LW as they walk through the habitat unit. LW counts are grouped by the size classes listed below:

Category	Length (m)	Diameter (cm)	Description
1	1-5	10-55	short, skinny
2	1-5	>55	short, fat
3	>5	10-55	long, skinny
4	>5	>55	long, fat
RW	rootwad	rootwad	roots on dead and down tree

Only count wood that is:
- 1 m in length and > 10.0 cm in diameter
- Within the bankfull channel
- Fallen, not standing dead

Additionally:
- Count rootwads separately from attached pieces of LW
- Estimate the diameter of LW at the widest end of the piece
- A piece that is forked, but is still joined counts as only one piece of LW
- Only count each piece one time, do not count a piece that is in two habitat units twice
- Enter the total count for each size category into the appropriate column on the datasheet

Where to estimate: every habitat unit

Actual Width (m)

Definition:
Average wetted width of the habitat unit as measured with 50 m tape, used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to measure:
Use a meter tape to measure the wetted width of the stream in at least three locations. Average the measurements to obtain the average wetted width.

Where to measure: paired sample habitat units

Bankfull Channel Width (m)

Definition:
Actual width of channel at bankfull elevation as measured with meter tape. Depending on channel type, bankfull may or may not be represented by the top of the banks. Use bankfull indicators to locate the top of the bankfull channel (Rosgen 1996).

How to measure:
Determine the location of bankfull water depth on both banks of the habitat unit and measure across the channel perpendicular to flow from bankfull to bankfull.

Where to measure: paired sample riffles, runs, or cascades

Riparian Width (m)

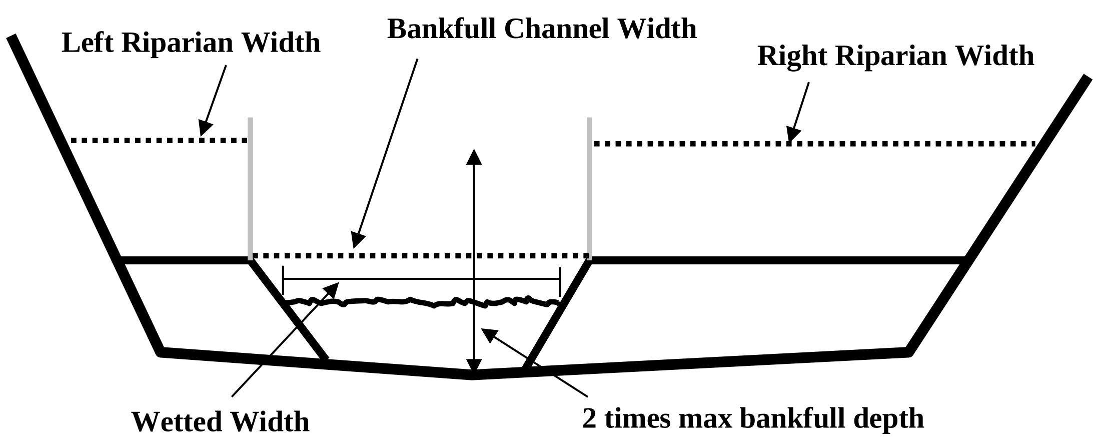
Definition:
Width of the riparian area at an elevation of two times the maximum bankfull depth, measured for both left and right banks (left and right as oriented facing upstream). Maximum bankfull depth is the greatest vertical distance from the substrate to the top of the bankfull channel across a bankfull transect.

How to measure:

- Stretch a measuring tape across the top of the bankfull channel – this is your bankfull transect
- Use a wading rod to find the maximum bankfull depth
- Place the clinometer against the wading rod at two-times the maximum bankfull depth
- Using the clinometer to maintain a slope of zero degrees, site perpendicular to the channel to the intersection with the nearest landform. It may be necessary to site to an intermediate point, move the wading and clinometer, and site again if the tape measure is too short or the view is obstructed
- Measure the distance from the edge of the bankfull channel to the landform – do this separately for the left and right (as facing upstream) riparian areas

Note: if riparian width is more than 50 m, record 51 as the riparian width and note in 'Comments' that riparian width was longer than meter tape

Where to measure: paired sample riffles, runs, or cascades



Gradient (%)

Definition:
Change in vertical elevation per unit of horizontal distance of the water surface (Armantrout 1998)

How to measure:
Gradient is measured in riffles with a clinometer using the following steps:

- Observer stands at upstream end of riffle, recorder stands at downstream end of riffle
- Recorder sites upstream to the height of their eye on the observer using clinometer
- Record the **percent** slope, **not the degrees** (tip the clinometer all the way back to determine which side of the scale is percent)

The recorder should determine the height of their eye on the observer at the beginning of the inventory. Be certain that the observer and recorder are standing with their feet in the same position (preferably with feet at top of water surface) within the stream channel. If the observer is standing on top of a boulder and the recorder is standing in a depression, the measured gradient will be incorrect.

Where to measure: paired sample riffles, runs, or cascades

Water Temperature (C)

Definition:
Temperature of the water in degrees Celsius.

How to measure:
Place the thermometer in moving water in an area not exposed to direct sunlight. Leave the thermometer sit for at least three minutes, then record the water temperature in degrees Celsius.

Where to measure: paired sample riffles, runs, or cascades

Photo (ID#)

Definition:
Photograph of habitat unit or crossing feature.

How to measure:
Take photo facing upstream with observer holding wading rod in picture. Be sure to get entire width (and length if possible) of habitat unit or crossing feature in the photo.

Where to measure: paired sample riffles, runs, or cascades and any crossing features encountered

Features

Definition: Points on a stream that could potentially serve as landmarks, may be natural or manmade.

How to measure: Record the distance to the upstream end of all features and take a photograph of all crossing features.

Where to record: wherever found

Channel Feature	Abbreviation	What to Record
Waterfall[1]	FALL	Distance, estimated height
Tributary	TRIB	Distance, average wetted width, into main channel on left or right (as facing upstream)
Side channel[2]	SCH	Distance, average wetted width, whether it is flowing into or out of main channel on left or right (as facing upstream)
Braid[3]	BRD	Distance at start and distance at end; continue with normal inventory up channel with greatest discharge
Seep (Spring)	SEEP	Distance, left or right bank (as facing upstream), size, coloration
Landslide	SLID	Distance, left or right bank (as facing upstream), estimated size
Other	OTR	Distance, description of feature, *example:* found water intake pipe going to house here; old burned out shack on side of stream; Big Gap campground on left; alligator slide here, etc.

[1] must be vertical with water falling through air to be a waterfall and not a cascade, do not record unless >1m high
[2] two channels, continue with normal inventory up channel with most volume
[3] three or more channels intertwined, continue with normal inventory up channel with most volume

Crossing Feature	Abbreviation	What to Record*
Bridge	BRG	Distance, width, height, road or trail name and type (gravel, paved, dirt, horse, ATV, etc.), photo
Ford	FORD	Distance, road or trail name and type (gravel, paved, dirt, etc.), photo
Dam	DAM	Distance, type, condition, estimated height, dam use, name of road or trail, if applicable; include beaver dams, photo
Culvert	V	Distance, road or trail name, type, # of outlets, diameter/width, height, material, perch (distance from top of water to bottom lip of culvert, natural substrate (present or absent through length), photo

* photograph all crossing features with person and wading rod for scale, record 'Y' in 'Photo' column

We cannot stress enough the importance of fully and accurately describing features. This means getting out a quadrangle map and finding road, trail, and tributary names and recording them in 'Comments' and taking the time to describe the location of features in relation to landmarks found on quadrangle maps.

Take photos of all crossing features!

Section 3: Wrapping Up

End the inventory where:

- Forest Service property ends
- Stream is dry for more than 500 m
- Stream channel is < 1.0 m wide for more than 500 m

Record the following in the Comments:

- Time and date
- Reason for ending the inventory
- Detailed written description of location using landmarks for reference
- **Be sure the header information is completed – GPS, etc**

When you return to home base:

- Immediately download the data and check file to be sure all data downloaded
- Check header information to be sure it is complete
- Save to the computer and create a backup copy
- Document any photographs
- If using paper, make a photocopy of the data and store in secure location

Section 4: Summary

Before starting:
- fill in header information

Record for every habitat unit:
- Unit Type
- Unit Number
- Distance
- Estimated Width
- Maximum Depth
- Average Depth
- Dominant Substrate
- Subdominant Substrate
- Percent Fines
- Large Wood

Record for every riffle, run, or cascade leading into a pool or glide:
- Riffle Crest Depth

Record for every paired sample pool:
- Measured Width

Record for every paired sample riffle:
- Measured Width
- Bankfull Channel Width
- Riparian Width (left and right)
- Gradient
- Rosgen Channel Type
- Water temperature
- Photograph

Record features and full feature descriptions wherever they are encountered.

Photograph all crossings!

Section 5: GPS Instructions

Garmin BVET Waypoint Labels:

Garmin BVET Waypoint Label Examples:

S123	**Start** location of BVET survey
E123	**End** location of BVET survey

123 = Site identification number

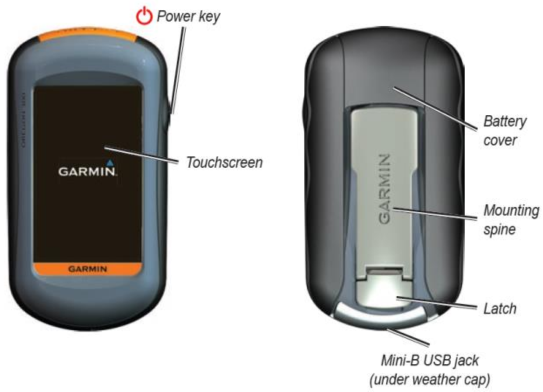
How to Find a Waypoint on GPS:

- Turn Power On.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the **Waypoints** icon with the red golf flag.
- At the bottom of the next screen touch the **ABC** pyramid button.
- Start typing in the name of the desired waypoint. Once the waypoint name is identified by the GPS it will list the waypoints associated with that waypoint name.
    - Note: Touch the left and right arrows at the bottom of the screen to move from letters to numbers to symbols. Touch the down arrow on the letters to get lowercase and up arrow to get back to uppercase.
- Touch the waypoint name you were looking for when the list pops up.
- To navigate to this location touch the big green **Go** button.

Changing Waypoints:

- To switch waypoints close the map screen by touching the **X** close button in the lower left corner of the screen.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the Stop Navigation button and repeat the top process to get to a new waypoint.

Garmin GPS Oregon 400T Cheatsheet



Turn On

- Press Power key, wait for GPS to boot

Turn Off

- Press and hold Power key

Backlight Strength

- Press and quickly release Power key, adjust with touchscreen options

Create New Waypoint

1. To create a waypoint of your current position touch "*Mark Waypoint*"
2. Touch "*Save and Edit*", touch "*Change Name*", type desired label, touch "*Green Check Icon*" to save

Calibrate compass

1. <u>Whenever batteries are removed</u> you must calibrate the compass so the map orients correctly
2. Touch "*Setup*", touch "*Heading*", touch "*Press to Begin Compass Calibration*"
3. Touch "*Start*", hold GPS level and rotate it twice on your palm

Data Fields

1. To change the data fields on the map page touch "*Map*"
2. Touch a data field at the top of the map, then select your desired data field

Calibrating the Touchscreen

1. If the touchscreen buttons are not responding properly, recalibrate the touchscreen
2. While the GPS is turned off, press and hold the power key for ~30 seconds
3. Follow instructions on the screen until calibration is complete

Appendix: Field Guide, Equipment Checklist, Rosgen Worksheet

Record for every habitat unit:

- **Unit Type** – pool, riffle, run, cascade, glide, feature (see below)
- **Unit Number** – group pools & glides; group riffles, runs, cascades
- **Distance (m)** – at upstream end of unit
- **Estimated Width (m)** – visual estimate of average wetted width
- **Maximum Depth (cm)** – deepest spot in unit
- **Average Depth (cm)** – average depth of unit
- **Dominant Substrate (1-9)** – covers greatest amount of surface area in unit
- **Subdominant Substrate (1-9) –** covers 2nd most surface area in unit
- **Percent Fines (%)** – percent of bottom consisting of sand, silt, or clay
- **Large Wood (1-4, RW)** – count of dead and down wood in the bankfull channel

Record for every riffle, run, or cascade leading into a pool or glide:

- **Riffle Crest Depth (cm)** – deepest spot in hydraulic control between riffle type habitat and pool type habitat

Record for paired sample pools:

- **Measured Width (m)** – measurement of average wetted width

Record for paired sample riffles:

- **Measured Width (m)** – measurement of average wetted width
- **Channel Width (m)** – measurement of bankfull channel width
- **Riparian Width (m)** – L&R, measurement of floodplain
- **Gradient (%)** – clinometer measurement of riffle slope
- **Water Temperature (C)** – temperature of water in Celsius
- **Rosgen –** channel type classification
- **Photo (y or n)** – picture of habitat unit or crossing feature

Unit Types

- **Riffle (R)** – fast water, turbulent, gradient <12%; includes rapids, chutes, and sheets if gradient <12%
- **Cascade (C)** – fast water, turbulent, gradient ≥12%, includes sheets and chutes if gradient ≥12%
- **Run (RN)** – fast water, little to no turbulence, gradient <12%, flat bottom profile, deeper than riffles
- **Pool (P)** – slow water, may or may not be turbulent, gradient <1%, includes dammed, scour, and plunge pools
- **Glide (G)** – slow water, no surface turbulence, gradient <1%, shallow with little flow and flat bottom profile
- **Underground (UNGR)** – distance at upstream end, why dry

Features

- **Waterfall (FALL)** – distance, height
- **Tributary (TRIB)** – distance, width, in on L or R
- **Side Channel (SCH)** – distance, width, in or out on L or R
- **Braid (BRD)** – distance at downstream and upstream ends
- **Seep or Spring (SEEP)** – distance, on left or right, amount of flow
- **Landslide (SLID)** – distance, L or R, est. size and cause
- **Other (OTR)** – record distance, describe feature in comments
- **Crossing Features** – photograph and record the following:
- **Bridge (BRG)** – distance, height, width, road or trail name & type
- **Dam (DAM)** – distance, type, est. height, road or trail name &type
- **Ford (FORD)** – distance, road or trail name & type
- **Culvert (V)** – distance, type (pipe, box, open box, arch, open arch), size, material, natural substrate, perch, road or trail name

Substrates

- **Organic Matter** – dead leaves detritus, etc., not living plants
- **Clay** – sticky, holds form when balled
- **Silt** – slick, does not hold form when balled
- **Sand** – >silt-2mm, gritty, doesn't hold form
- **Small Gravel** – 3-16mm, sand to thumbnail
- **Large Gravel** – 17-64mm, thumbnail to fist
- **Cobble** – 65-256mm, fist to head
- **Boulder** – >256, > head
- **Bedrock** – solid parent material

Large Wood

- **#1** <5m long, 10-55cm diameter
- **#2** <5m long, >55cm diameter
- **#3** >5m long, 10-55cm diameter
- **#4** >5m long, >55cm diameter
- **RW** – rootwad, count separately from attached LW, record in comments, do not record wood <10cm diameter, <1m length

Rosgen Channel Types

Rosgen Channel Types	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Measuring Riparian Width (paired fast water units only)

- Place clinometer against the wading rod at two times max bankfull depth
- Use the clinometer as a level – keep the slope at 0.0 – and site to the nearest landform perpendicular to the channel
- Measure the distance from the edge of the bankfull channel to the intersection with the landform
- Do this for both the left and right banks
- If riparian width in more than 50 m, record 51 as the riparian width and in 'Comments' note that riparian was > 50 m wide

End inventory

- End the inventory when the calculated sample distance has been inventoried.

Equipment Checklist

- ☐ hipchain
- ☐ extra string for hipchain
- ☐ wading rod
- ☐ 50 m tape measure
- ☐ clinometer
- ☐ thermometer
- ☐ datalogger
- ☐ GPS unit
- ☐ camera
- ☐ backpack
- ☐ pencils
- ☐ flagging
- ☐ markers
- ☐ waterproof backup datasheets
- ☐ clipboard
- ☐ BVET field guide on waterproof paper
- ☐ topographic maps
- ☐ water
- ☐ water filter
- ☐ lunch
- ☐ first aid kit
- ☐ radio/cell phone
- ☐ toilet paper
- ☐ felt bottom wading boots
- ☐ raingear

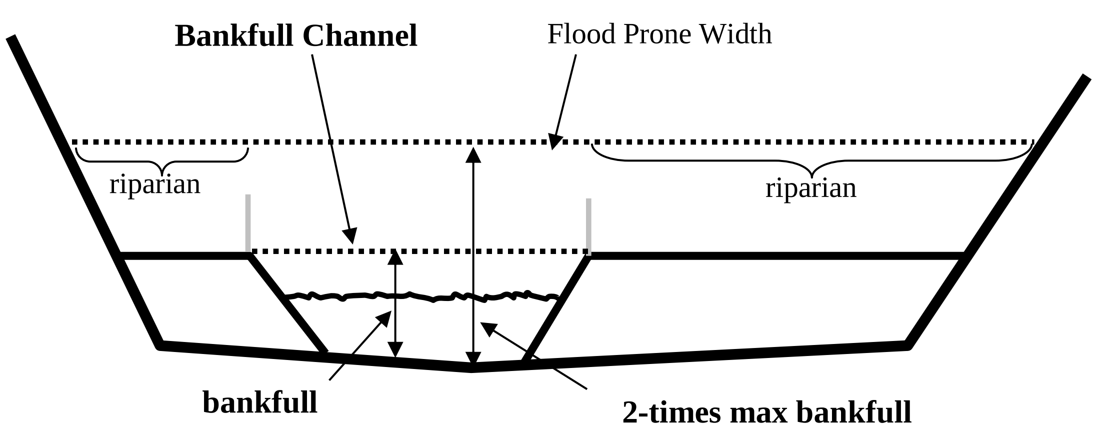
Rosgen Measurements

All measurements should be made across a transect in an area of uniform flow, specifically riffle or run sections with few irregularities in cross-sectional shape. **Avoid** areas influenced by culverts, bridges, tributaries, side-channels, etc.

- What is the **entrenchment ratio**?
    - Entrenchment ratio = flood prone width / bankfull width
    - Floodprone width = width at two-times maximum bankfull depth

- What is the **width/depth ratio**?
    - Width/depth ratio = bankfull width / average bankfull depth
    - Be sure to use same units of measure (centimeters) for width and depth
    - Measure *bankfull* depth (**not** *water* depth) at several locations across transect to obtain average bankfull depth

- What is the **gradient**?
    - Measure riffle to riffle slope (%) with clinometer



Rosgen Worksheet

A. Bankfull Channel Width (m) _____

B. Maximum Bankfull Depth (cm) _____ *2 = _____

C. Average Bankfull Depth (cm) _____

D. Right Riparian Width (m) _____

E. Left Riparian Width (m) _____

F. Gradient (%) _____

Entrenchment Ratio = (A+D+E)/A

(_____ + _____ + _____) / _____ = _____

Width Depth Ratio = (100*A)/C

(100* _____) / _____ = _____

	A	B	C	D	E	F	G
Entrench. ratio	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Gradient (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

*these are the dominant ranges, values may be slightly outside these ranges

Appendix D: Field Methods for Riffle Stability Index

Riffle Stability Index Field Methods

The Riffle Stability Index procedure is best applied to stream channels with gradients from 1.5 to 5 percent. The channel is best described as a Rosgen B-2, B-3, B-4or F-2, F-3, F-4 type. Three riffles are measured within each uniform Rosgen reach. Each riffle selected for measurement should be representative or typical within the reach. An ideal riffle is located in a straight section of reach, has uniform depth in the cross-section, and is at a point of thalweg crossover. Flow is evenly distributed across the channel and is not concentrated toward either bank. For each riffle, field data are gathered to determine the distribution of particle sizes present. An estimate of the common large size of particle capable of movement at bankfull flow is obtained by sampling a nearby bar deposit.

1. Pebble Count - Particle Size Distribution on the Riffle

A particle size distribution is obtained on the riffle by a bed material sampling procedure called a "Wolman Pebble Count". A sample size of at least 200 is necessary for RSI. The sample points are identified by establishing a sampling grid over the riffle, with transects across the channel from bankfull to bankfull over the entire length of riffle. Samples are taken every foot along the transect. Thus, bankfull width in feet will equal the number of samples per transect. Dividing 200 by the number of samples per transect and rounding up will determine the number of transects needed. Spacing between transects is determined by dividing the length of riffle by the number of transects needed. For each sample, the intermediate axis of the particle is measured using a metric caliper, and is tallied by size class. For very large particles, count the same particle as many times as you encounter it. The cumulative percent finer is then calculated for each size class, and plotted on the graph.

2. Bar (Cobble) Count - Dominant Large Particles on a Bar

Measure 30 of the freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above. Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles. The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars. The entire bar should be visually inspected to identify the dominant large size of particle present. If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle. When this is done, a sample size of at least 20 is needed. For each of the particles, the intermediate axis is measured and recorded to the nearest millimeter. Calculate the arithmetic mean of the sample, and compare this with the plotted cumulative particle size distribution for the riffle. On the X axis, find the mean bar sample grain size. Go up to the cumulative particle size distribution, and read from the Y axis the percentile this represents. This percentile is the Riffle Stability Index.

Appendix E: Photos

Photo of one of two waterfalls located between Bear Creek sites 1 and 2; each with 1.5 m freefall heights (located at N37.00467 W84.38848). No photo was taken of the other waterfall or the potential barrier to fish passage on the unnamed tributary; a 1.5 m high cascade formed by several large boulders located between sites 4DS and 4US approximately 200 m upstream from the confluence with Bear Creek.

Bear Creek (site 3) where effluent from a coal mine pond flows in on the right. This location had the most noticeable orange/red staining from chemical precipitate resulting from acid mine drainage.


Outflow from coal mine pond


Outflow from coal mine pond flowing into Bear Creek


Coal mine pond containing rail ties and carts


Stream flowing in/out of cave with mine and equipment inside

Site 1. Upstream-most Bear Creek sample site; upstream of mine activity.

Site 2. Sample site located within historic mining area.

Site 3. Located within historic mining area; distinctive orange/red color present from chemical precipitate resulting from acid mine drainage.

Site 5. Downstream of historic mine activity.

Site 6. Downstream of historic mine activity.

Site 7. Downstream-most Bear Creek sample site; downstream of historic mine activity.

Site 4US. Upstream sample site on the unnamed tributary to Bear Creek; upstream of cascade that is a potential fish passage barrier.

Site 4DS. Downstream sample site on the unnamed tributary to Bear Creek; downstream of cascade that is a potential fish passage barrier.