

**PROTOCOL
FOR
MONITORING EFFECTIVENESS
OF
CONSTRAINED CHANNELS**
(Dike Removal/Setback, Riprap Removal, Road
Removal/Setback, and Landfill Removal)

MC-5

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ORGANIZATION

This document details the monitoring design, procedures, and quality assurance steps necessary to document and report the effectiveness of stream bank modifications addressing constrained channels:

- **Dike Removal/Setback**
- **Riprap Removal**
- **Road Removal/Setback**
- **Landfill Removal**

This document is in compliance with the Washington Comprehensive Monitoring Strategy (Crawford et al. 2002).

Diking, road construction, fills, and other construction work within the stream's normal flood line can constrain flow within the normal flow channel leading to scouring effects upon stream gravel, loss of hiding cover and food organisms, and unsuitable habitat for rearing juvenile salmon. Unconstrained streams dissipate flood flow energy over a broader valley floor and provide slower velocities for preserving stream channel morphology and rearing habitat for salmon.

The goal of constrained channel projects is to restore the natural flood flow basin width so that gravel, large wood, and normal stream morphology and fish habitat can be restored.

MONITORING GOAL

Determine whether projects that remove or set back dikes, riprap, roads, or landfills are effective at the reach scale in restoring stream morphology and eliminating channel constraints in the treated area.

QUESTIONS TO BE ANSWERED

Has the removal and/or setback reduced channel constraints and increased flood flow capacity for ten years?

Has stream morphology improved over ten years?

NULL HYPOTHESIS

Removal or setback of dikes, riprap, roads, or landfills or reconnected side channels along the stream has had no significant affect upon:

- Improving channel capacity.
- Improving stream morphology and fish habitat as measured by Thalweg residual pool vertical profile area (AREASUM), mean residual depth (RP100), and flood prone width (FPW).

OBJECTIVES

BEFORE PROJECT OBJECTIVES (YEAR 0)

Determine the overall channel capacity and constraints in the impact reaches.

Determine the overall stream morphology using the Thalweg Profile in the impact reaches.

AFTER PROJECT OBJECTIVES (YEARS 1, 3, 5, AND 10)

Determine the overall changes in channel constraints and flow capacity in the impact reaches.

Determine the overall stream morphology using Thalweg Profile in the impact reaches.

RESPONSE INDICATORS

Level 1 --Channel Capacity The channel capacity, as cross-sectional area calculated from mean bankfull width (XBF_W) and depth (XBF_H), measures the overall channel flow capacity. When a channel is constrained the velocity of the water increases to compensate for higher volume. Increased velocity scours stream bottom eliminating pools, large wood, and other structures associated with fish habitat.

Indicator Abbreviation	Description
XBF_H	Mean bankfull depth within the study reach
XBF_W	Mean bankfull width within the study reach

Level 2--Thalweg Profile. The thalweg profile characterizes pool-riffle relationships, sediment deposits, wetted width substrate characteristics, and channel unit-pool forming categories. Stream morphology sampling methods are taken from EMAP (Peck et al. unpubl.), Section 7.4. Protocols summarizing EMAP Table 7-3 and 7-4 are found on page 12. Sampling is based upon establishing 11 regular Transects within each identified stream reach. Pre-project measures of the variation of depth throughout the stream reach (RP100) and the residual pool volume (AREASUM) will be compared to detect post-project changes. Flood prone width (FPW) is measured at the level of flood prone depth. Flood prone depth is defined at two times the bankfull depth. Bankfull depth is defined as the depth from the channel thalweg to the level of the bankfull width. Flood prone width is measured in the field where possible, or can be determined as the channel migration zone by using landmarks and GIS/aerial maps. An average flood prone width is determined for study reach.

Thalweg indicators for constrained channels

Indicator Abbreviation	Description
AREASUM	Mean Thalweg vertical profile area for the study reach
RP100	Mean Thalweg residual depth within the study reach
CHANL	Study reach bankfull channel capacity
FPW	Average flood prone width for the study reach

MONITORING DESIGN

The Board will employ a Before and After Control Impact (BACI) experimental design to test for changes associated with restoring constrained channels (Stewart-Oaten et al. 1986). A BACI design samples the control and impact simultaneously at both locations at designated times before and after the impact has occurred. For this type of restoration, removing a channel constraint would be the impact, that is, the location impacted by the restoration action, and a location upstream of the constrained channel would represent the control.

For constrained channels, the BACI design tests for changes in channel capacity in terms of cross sectional area and stream morphology at the constrained channel location *relative to* the changes in stream morphology and channel capacity observed at a control site upstream. This type of design is required when external factors (e.g., local watershed characteristics) affect the flood flow events at the control sites. The object is to see whether the difference between upstream (control) and downstream (impact) channel capacity in terms of cross sectional area and stream morphology has changed as a result of the channel constraint projects. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplications. It is also not considered cost effective to employ multiple control locations for each passage project as recommended by Underwood. Although the ideal BACI would have multiple years of before data as well as after data, this was not possible with locally sponsored projects where there is a need and desire to complete their project as soon as possible.

The plan is to compare the most recent time period of sampling with Year 0 conditions before the projects. A paired *t*-test will be used to test for differences between control (upstream) and impact (downstream) sites during the most recent impact year and Year 0. In other words, we first compute the difference between the control and impact and use those values in a paired *t*-test. This test assumes that differences between the control and impact sites are only affected by the placing of constrained channels and that external influences affect channel capacity in terms of cross-sectional area and stream morphology in the same way at both the control and impact sites. The paired sample *t*-test does not have the same assumptions for normality and equality of variances of the two-sample *t*-test but only requires that the differences are approximately normally distributed. In fact, the paired-sample test is really equivalent to a one-sample *t*-test for a difference from a specified mean value.

To implement the design, beginning in 2004 we will monitor 10 constrained channels projects funded in Rounds 4-6. The number of projects proposed for funding in each category will be based upon the calculated sample size needed to obtain statistically significant information in the shortest amount of time. Because there are insufficient projects funded in any one year to obtain a proper sample size, multiple years will be used until the critical sample size is reached.

The variance associated with impact and control reaches will not be known until sampling has occurred in Year 0 of both impact and control reaches. After Year 0, a better estimate of the true sample size needed to detect change will be available. Cost estimates and sampling replicates may need to be adjusted at that time.

At the end of the effectiveness monitoring testing, there will be one year of "Before" impact information for all projects for both control and impact reaches, and multiple years of "After" impact information for the same control and impact reaches for each of the projects.

Depending upon circumstances, the results may also be tested for significance, using a linear regression model of the data points for each of the years sampled and for each of the indicators tested.

Testing for significant trends can begin as early as Year 1. Final sampling may be completed in 2014.

DECISION CRITERIA

Effective if a change of 20% or more is not detected for channel capacity between the calculated difference between the paired impact and control reaches by Year 10 at the $\alpha=0.10$ level.

Effective if a change of 20% or more is detected for Thalweg measures of residual pool vertical profile area (AREASUM), mean residual depth (RP100), and flood prone width (FPW) between the calculated difference between the paired impact and control reaches by Year 10 at the $\alpha=0.10$ level.

Table 1. Decision criteria for testing constrained channels

Indicators	Metric	Test Type	Decision Criteria
Mean bank full cross sectional area taken from mean bank full width and depth (CHANL)	Ave. m ²	Linear Regression or Paired <i>t</i> -test	Alpha =0.10 for one-sided test. Effective if it does not detect a 20% or greater change between Year 0 and Year 10.
Mean residual pool vertical profile area (AREASUM)	m ²	Linear Regression or Paired <i>t</i> -test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10.
Mean residual depth (RP100)	cm	Linear Regression or Paired <i>t</i> -test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 10
Flood prone width	Ave. m	Linear Regression or Paired <i>t</i> -test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 10

SAMPLING

SELECTING SAMPLING REACHES

IMPACT REACH

Channel constraint projects are often not very large and may be measured in their entirety, or may require only one stream reach identified, according to the methods on page 9. A detailed written description of the sample reach should be recorded.

CONTROL REACH

An equal number of control reaches upstream of the project site should be selected and designed in the same manner as the impact reaches. If there is only one impact reach, then the control should consist of a distance of equal size immediately upstream of the project site.

BEFORE PROJECT SAMPLING

All channel constraint projects identified for long-term monitoring by the SRFB must have completed pre-project Year 0 monitoring prior to beginning the project.

Year 0 monitoring will consist of:

- Determining the extent and capacity of constrained channel due to the dike, etc., in the impact and control reaches.
- Determining the stream morphology characteristics within the project impact and control reaches using Thalweg Profile.

AFTER PROJECT SAMPLING

Upon completion of the project, Years 1, 3, 5, and 10 monitoring will consist of:

- Determining the extent and capacity of the constrained channel due to removal of the dike, reconnecting the side channel, etc., in the impact and control reaches.
- Measuring instream morphology and structure using the Thalweg Profile within the project impact and control reaches.

METHOD FOR LAYING OUT CONTROL AND IMPACT STREAM REACHES FOR WADEABLE STREAMS

Protocol taken from: *Peck et al. (2003), pp. 63-65, Table 4-4; Mebane et al. (2003)*

EQUIPMENT

Metric tape measure, surveyor stadia rod, handheld GPS device, 3 - 2 ft. pieces of rebar, orange and blue spray paint or plastic rebar caps, engineer flagging tape, waterproof markers

SAMPLING CONCEPT

The concept of EMAP sampling is that randomly selected reaches located on a stream can be used to measure changes in the status and trends of habitat, water quality, and biota over time if taken in a scientifically rigorous manner per specific protocols. We have applied the EMAP field sampling protocols for measuring effectiveness of restoration and acquisition projects. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These "impact" reaches have been matched with "control" reaches of the same length and size on the same stream whenever possible.

Within each sampled project reach a series of Transects A-K are taken across the stream and riparian zone as points of reference for measuring characteristics of the stream and riparian areas. The Transects are then averaged to obtain an average representation of the stream reach.

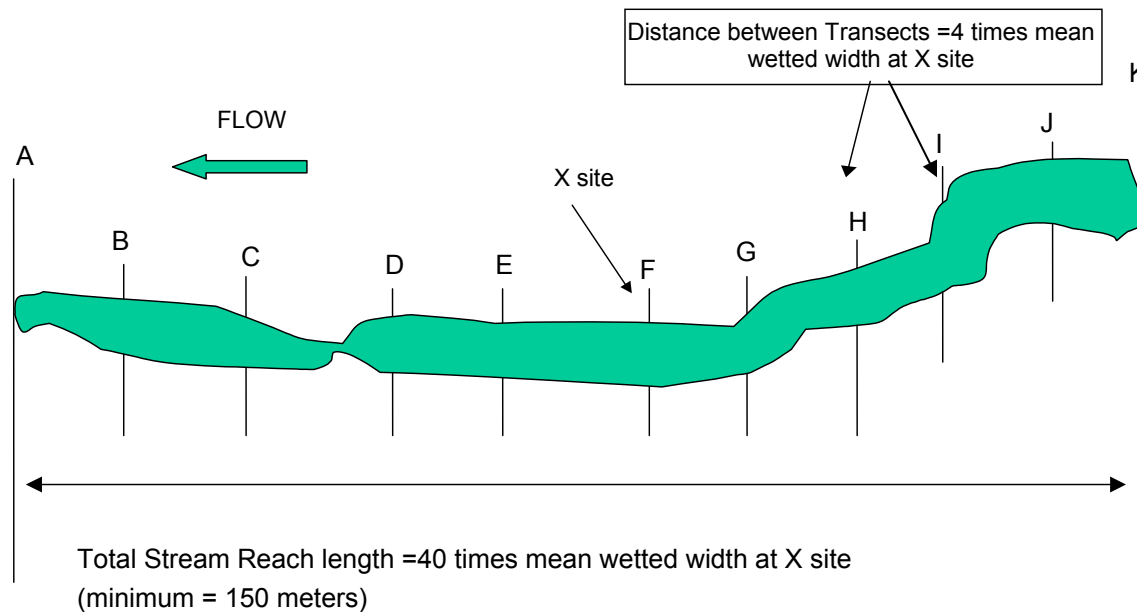


Figure 1. Sampled project reach

LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

Step 1: Using a handheld GPS device, determine the location of the X sites and record latitude and longitude on the stream verification form. The X sites should be considered the center of the Impact and Control study reach. The Impact reach X site must fall within the project affected area. The location of the control X site should be determined based upon the length of the impact reach. Mark the X site on the bank above the high water mark with one of the rebar stakes and a colored plastic cap so that the X site can be found in future years. Use a surveyor's rod or tape measure to determine the wetted width of the channel at five places considered to be of "typical" width within approximately five channel widths upstream and downstream of the X site sample reach location. Multiple that average width by 40 to determine the reach length. For streams less than 4 m in width, the reach should be at minimum 150m, and for streams greater than 12.5 m in width, the maximum reach shall be 500 m. If the impact reach is less than 150 m, measure and include the entire impact area in the sampling reach. Determine the impact reach length based upon the above, and set the control site reach length equal to the impact reach length.

Step 2: Check the condition of the stream upstream and downstream of the X site by having one team member go upstream and one downstream. Each person proceeds until they can see the stream to a distance of 20 times the stream width (equal to one half the sampling reach length) determined in Step 1.

For example if the reach length is determined to be 150 m, each person would proceed 75 m from the X site to lay out the reach boundaries.

NOTE: *For restoration projects less than 40 stream widths, the entire project's length should be sampled and a control reach of similar size should likewise be developed within the treatment stream either upstream or downstream as appropriate.*

Step 3: Determine if the reach needs to be adjusted around the X site due to confluences with lower order streams, lakes, reservoirs, waterfalls, or ponds. Also adjust the boundaries to end and begin with the beginning of a pool or riffle, but not in the center of the pool or riffle. Hankin and Reeves (1988) have shown that the variance of juvenile fish abundance estimates is decreased by using whole pool/riffles in the sample area. To adjust the stream reach, simply add or subtract additional length to Transects A or K, as appropriate (i.e. do not shift the entire reach upstream or downstream to encompass an entire pool). In the case where the treatment site is dry in Year 0, reach lengths should be based upon 20 times the bankfull width.

Step 4: Starting back at the X site, measure a distance of 20 channel widths down one side of the stream using a tape measure. Be careful not to cut corners. Enter the channel to make measurements only when necessary to avoid disturbing the stream channel prior to sampling activities. This endpoint is the downstream end of the reach and is flagged as Transect "A".

Step 5: Using the tape, measure $1/10^{\text{th}}$ (4 channel widths in big streams or 15 m in small streams) of the required stream length upstream from the start point (Transect A). Flag this spot as the next cross section or Transect (Transect B).

Step 6: Proceed upstream with the tape measure and flag the positions of nine additional Transects (labeled "C" through "K" as you move upstream) at intervals equal to $1/10^{\text{th}}$ of the reach length. At the end points and middle of the reach (Transect starting and ending points A and K), install a rebar stake as described in Step 1.

METHOD FOR MEASURING CHANNEL CONSTRAINTS

Protocol taken from: *Peck et al. (2003), Table 7-6; Kauffman et al. (1999)*

PURPOSE

The activities of man often constrain channels by placing roads, dikes, etc. near the streambank. This in turn increases channel velocity during high flow event and causes scouring and loss of fish habitat. The purpose of this protocol is to determine whether the channel constraints have been reduced.

EQUIPMENT

Appropriate waterproof sampling form, waders or hip boots, 50 m measuring tape.

SITE SELECTION

The sample reaches are those laid out according to pages 9-10.

PROCEDURE

Note: *These activities are conducted after completing the Thalweg Profile and represent an evaluation of the entire stream reach.*

Channel Constraint: Determining the degree, extent, and type of channel constraint is based on envisioning the stream at bankfull flow.

Step 1: Classify the stream reach channel pattern as predominantly a single channel, an anastomosing channel, or a braided channel.

- Anastomosing channels have relatively long major and minor channels branching and rejoining in a complex network.
- Braided channels also have multiple branching and rejoining channels, but these sub-channels are generally smaller, shorter and more numerous, often with no obvious dominant channel.

Step 2: After classifying channel pattern, determine whether the channel is constrained within a narrow valley, constrained by local features within a broad valley, unconstrained and free to move about within a broad flood plain, or free to move about, but within a relatively narrow valley floor.

Step 3: Then examine the channel to ascertain the bank and valley features that constrain the stream. Entry choices for the type of constraining features are bedrock, hillslopes, terraces/alluvial fans, and human use (e.g. road, dike, landfill, riprap, etc.).

Step 4: Based on your determinations from Steps 1 through 3, select and record one of the constraint classes shown on the Channel Constraint Form (Figure 2).

Step 5: Estimate the percent of the channel margin in contact with constraining features (for unconstrained channels this is 0%). Record this value on the Channel Constraint Form.

Step 6: Measure the bankfull width at each Transect and each intermediate Transect and record widths on the Bankfull Width Form (Figure 3). Then, visually estimate the average width of the floodplain. As a guideline, flood plain width can be measured as two times the bankfull depth. Bankfull depth is defined as the depth measurement from the channel thalweg to the height of the bankfull width. If an estimation of floodplain width cannot be done visually, utilize GIS and/or aerial photos. Record these values on the Bankfull Width Form (Figure 3).

Step 7: Measure the height of the constraining feature treated by the restoration project and record those values on the Bankfull Width Form (Figure 3).

Step 8: Last, at Transects A, F, and K measure the height of bankfull from the water surface edge to the height at which bankfull flow would occur and record these values on the Bankfull Width Form (Figure 3). These values will be used along with values taken as part of the thalweg profile and physical habitat measurements to calculate bankfull depth and channel capacity (see Summary Statistics below).

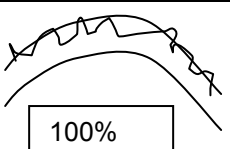
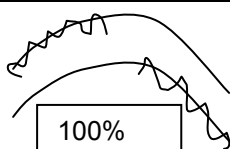
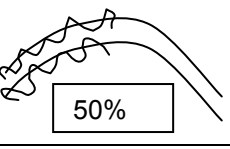
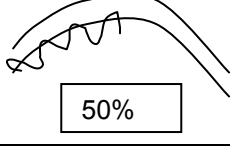
CHANNEL CONSTRAINT FORM		
Site ID:	Date:	
Channel Pattern (Check one)		
<input type="checkbox"/> One channel <input type="checkbox"/> Anastomosing channel – relatively long major and minor channels branching and rejoining <input type="checkbox"/> Braided channel – multiple short channels branching and rejoining – mainly one channel broken up by numerous mid channel bars.		
Channel Constraint (Check one)		
<input type="checkbox"/> Channel very constrained in a V-shape valley (i.e. it is very unlikely to spread out over the valley or erode a new channel during a flood). <input type="checkbox"/> Channel is in broad valley but channel movement by erosion during floods is constrained by incision (flood flows do not commonly spread over valley floor or into multiple channels). <input type="checkbox"/> Channel is in narrow valley and is not very constrained , but limited in movement by relatively narrow valley floor (< 10X bankfull width). <input type="checkbox"/> Channel is unconstrained in broad valley (i.e. during flood it can fill off channel areas and side channels, spread out over flood plain, or easily cut new channels by erosion).		
Constraining Features (Check one)		
<input type="checkbox"/> Bedrock (i.e. channel is a bedrock dominated gorge) <input type="checkbox"/> Hillslope (i.e. channel constrained in a narrow V-shape valley) <input type="checkbox"/> Terrace (i.e. channel is constrained by its own incision into river/stream gravel/soil deposits) <input type="checkbox"/> Human bank alterations (i.e. constrained by rip-rap, landfill, dike, road, etc.) <input type="checkbox"/> No constraining features		
Percent of channel length with margin in contact with constraining feature. _____%	Percent of channel margins Examples	
Bankfull width: _____meters	 100%	 100%
Valley width (Visual estimated average) Note: Be sure to include distances between both sides of valley border for valley width _____m	 50%	 50%
Comments		

Figure 2. Channel Constraint Form

BANKFULL WIDTH FORM						
SITE NAME:			DATE:		VISIT: 1 2	
SITE ID:			TEAM ID:			
Height of constraining feature (m):			Reach Length (m):			
BANKFULL WIDTHS						
Transect	Bankfull Width (m)	Bar Width		Side Channel (X for yes)	Flag	Comments
		Y/N	(m)			
A						
mid A-B						
B						
mid B-C						
C						
mid C-D						
D						
mid D-E						
E						
mid E-F						
F						
mid F-G						
G						
mid G-H						
H						
mid H-I						
I						
mid I-J						
J						
mid J-K						
K						
TOTAL						
MEAN						
BANKFULL HEIGHT (cm)			FLOODPRONE WIDTHS (m)			
1:			1:			
2:			2:			
3:			3:			

Figure 3. Bankfull Width Form

METHOD FOR CHARACTERIZING STREAM MORPHOLOGY, THALWEG PROFILE

Protocol taken from: *Peck et al. (2003), Table 7-3; Kauffman et al. (1999)*

PURPOSE

The Thalweg profile can detect changes in the stream morphology associated with habitat restoration projects designed to improve pool-riffle relationships, provide velocity changes and other structure that is beneficial as hiding and holding habitat for salmonids.

EQUIPMENT

Surveyor's telescoping rod (2-3 m long), 50 m measuring tape, laser range finder, meter stick, surveyor tape, bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms or digital data collection device.

SITE SELECTION

The sample reaches are those laid out according to the methods on pages 9-10.

SAMPLING DURATION

Sampling should occur during the summer low flow period, or when feasible at each project site.

PROCEDURE

The Thalweg Profile is a longitudinal survey of depth, habitat class, presence of soft/small sediment deposits, and off-channel habitat at 100 equally spaced intervals (150 in streams less than 2.5 m wide) along the centerline between the two ends of the sampling reach. "Thalweg" refers to the flow path of the deepest water in a stream channel. Wetted width is measured and substrate size is evaluated at 21 equally spaced cross-sections (at 11 regular Transects A through K plus 10 supplemental cross-sections spaced mid-way between each of these).

Step 1: Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach. For widths < 2.5 m, establish stations every 1 m. For widths between 2.5 and 3.5 m, establish stations every 1.5 m. For widths > 3.5 m, establish stations at increments equal to 0.01 times the sampling reach length.

Step 2: Complete the header information on the Thalweg Profile Form (Figure 4), noting the Transect pair (downstream to upstream). Record the interval distance determined in Step 1 in the "INCREMENT" field on the field data form.

NOTE: *If a side channel is present and contains between 16 and 49% of the total flow, establish secondary cross-section Transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary Transect by checking both "X" and the associated primary Transect letter (e.g., XA, XB, etc.). Collect all channel and riparian cross-section measurements from the side channel.*

Step 3: Begin at the downstream end (station "0") of the first Transect (Transect A).

Step 4: Measure the wetted width if you are at station 0, station 5 (if the stream width defining the reach length is 2.5 m), or station 7 (if the stream width defining the reach length is < 2.5 m). Wetted width

is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.1 m for widths up to about 3 meters, and to the nearest 5% for widths > 3 m. This is 0.2 m for widths of 4 to 6 m, 0.3 m for widths of 7 to 8 m, and 0.5 m for widths of 9 or 10 m, and so on. For dry and intermittent streams, where no water is in the channel, record zero for wetted width.

NOTE: *If a mid-channel bar is present at a station where wetted width is measured, measure the bar width and record it on the field data form.*

Step 5: At station 5 or 7 (see above) classify the substrate particle size at the tip of your depth measuring rod at the left wetted margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted width of the stream. This procedure is identical to the substrate size evaluation procedure described for regular channel cross-sections A through K, except that for these mid-way supplemental cross-sections, substrate size is entered on the Thalweg Profile side of the field form. For dry and intermittent streams, where no water is in the channel, use the bankfull width to collect substrate information.

NOTE: *Collection of substrate data as described in Step 5 above is to be completed in conjunction with the "Method for Measuring Substrate" protocol. Together, these two data collection procedures produce the desired 105 particles used to evaluate substrate composition. Step 5 above should be implemented only if substrate is listed as an evaluation metric for the specified project class where the "Method for Measuring Substrate" protocol is also to be implemented (Channel Connectivity, Constrained Channel).*

Step 6: At each Thalweg Profile station, use a meter ruler or a calibrated pole or rod to locate the deepest point (the "thalweg"), which may not always be located at mid-channel. Measure the thalweg depth to the nearest cm, and record it on the Thalweg Profile form. Read the depth on the side of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

NOTE: *For dry and intermittent streams where no water is in the channel, record zeros for depth.*

NOTE: *At stations where the thalweg is too deep to measure directly, stand in shallower water and extend the surveyor's rod, calibrated rod, or pole at an angle to reach the thalweg. Determine the rod angle by resting the clinometer on the upper surface of the rod and reading the angle on the external scale of the clinometer. Leave the depth reading for the station blank, and record a "U" flag. Record the water level on the rod and the rod angle in the comments section of the field data form. For even deeper depths, it is possible to use the same procedure with a taut string as the measuring device. Tie a weight to one end of a length of string or fishing line and then toss the weight into the deepest channel location. Draw the string up tight and measure the length of the line that is under water. Measure the string angle with the clinometer exactly as done for the surveyor's rod.*

Table 2. Thalweg Channel and Pool Codes

POOL FORMING CODES		CHANNEL UNIT CODES	
N	Not a pool	PP	Pool, Plunge
W	Large Woody Debris	PT	Pool, Trench
R	Rootwad	PL	Pool, Lateral Scour
B	Boulder or Bedrock	PB	Pool, Backwater
F	Unknown, Fluvial	PD	Pool, Impoundment
		GL	Glide
	Combinations eg. WR, BR, WRB	RI	Riffle
		RA	Rapid
		CA	Cascade
		FA	Falls
		DR	Dry Channel

Source: Peck et. al (2003)

Step 7: At the point where the thalweg depth is determined, observe whether unconsolidated, loose (“soft”) deposits of small diameter (<16mm), sediments are present directly beneath your ruler, rod, or pole. Soft/small sediments are defined here as fine gravel, sand, silt, clay or muck readily apparent by “feeling” the bottom with the staff. Record presence or absence in the “SOFT/SMALL SEDIMENT” field on the field data form. Note: A thin coating of fine sediment or silty algae coating the surface of cobbles should not be considered soft/small sediment for this assessment. However, fine sediment coatings should be identified in the comments section of the field form when determining substrate size and type.

Step 8: Determine the channel unit code and pool forming element codes for the station. Record these on the field data form using the standard codes provided in Table 2. For dry and intermittent streams where no water is in the channel, record habitat type as dry channel (DR).

Step 9: If the station cross-section intersects a mid-channel bar, indicate the presence of the bar in the “BAR WIDTH” field on the field data form.

Step 10: Record the presence or absence of a side channel at the station’s cross-section in the “SIDE CHANNEL” field on the field data form.

Step 11: Record the presence or absence of quiescent off-channel aquatic habitats, including sloughs, alcoves and backwater pools in the “BACKWATER” column of the field form.

Step 12: Proceed upstream to the next station and repeat Steps 4 through 11.

Step 13: Repeat Steps 4 through 12 until you reach the next Transect. At this point, complete Channel/Riparian measurements at the new Transect (Section 7.5). Then prepare a new Thalweg Profile and Woody Debris Form and repeat Steps 2 through 12 for each of the reach segments, until you reach the upstream end of the sampling reach (Transect “K”).

THALWEG PROFILE FORM										
SITE NAME:					DATE:		VISIT: 1 2			
SITE ID:					TEAM ID:					
TRANSECT (X) A-B B-C C-D D-E E-F F-G G-H H-I I-J J-K										
THALWEG PROFILE							Increment (m)			
Station	Thalweg Depth cm (XXX)	Wetted Width (XX.X)	Bar Width		Soft/Small sediment (X for yes)	Channel Unit Code	Pool Form Code	Side Channel (X for yes)	Flag	Comments
			Y/N	(XX.X)						
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
TOTAL										
MEAN										
VAR										
SE										
MEAN										
VAR										
SE										

Figure 4. Thalweg Profile Form

METHOD FOR MEASURING SLOPE AND BEARING

Protocol taken from: *Peck et al. (2003), Table 7-6; Kauffman et al. (1999)*

PURPOSE

Using the following methods, the water surface slope and bearing can be determined. These measures can be used to calculate residual pool depth. Residual pool volume is the amount of water that would remain in the pools if there were not flow and the pools were impermeable basins. The intent of measuring this parameter is to show the changes in cross sectional stream complexity typified by pools and riffles.

Slope and bearing are measured using two people by back-sighting downstream between Transects.

EQUIPMENT

Two surveyor's telescoping stadia rods, 50 m measuring tape, laser range finder, Abney hand level or clinometer, bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

PROCEDURE

Step 1: Stand in the center of the channel at the downstream cross-section Transect. Determine if you can see the center of the channel at the next cross-section Transect upstream without sighting across land, (i.e. do not short circuit a meander bend). If not you will have to take supplementary slope and bearing measurements.

Step 2: Have one surveyor position a stadia rod at the water's edge (water surface level) at the downstream Transect (A). Level the stadia rod. The second surveyor shall proceed upstream to the next Transect (B) and similarly position the second stadia rod along the same bank at the waters edge. The second surveyor shall hold and level the Abney hand level (or clinometer) at a known elevation (instrument height) along the upstream stadia rod and shoot back to the downstream stadia rod. Determine the elevation change (cm) by reading the downstream stadia rod and subtracting the instrument height.

Step 3: Walk upstream to the next cross-section Transect and repeat Step 2. Continue this process through Transect K.

Step 4: With the laser range finder, site back downstream on your flagging at the downstream Transect. Read and record the percent slope in the Slope Measurement Form (Figure 6). Record the "PROPORTION" as 100%. In some cases where full line of sight is not available between Transects, it may be necessary to measure elevation changes incrementally as line of sight allows within a given Transect. Incremental elevations should be summed for each Transect and recorded as indicated above.

Step 5: Stand in the middle of the channel at upstream Transect, and site back with your compass to the middle of the channel at the downstream Transect. Record the bearing (degrees) in the Slope Measurement Form. Note that bearing measurements should be taken at each primary Transect (A, B, C, etc) and at the supplemental measurement points.

Residual Pools

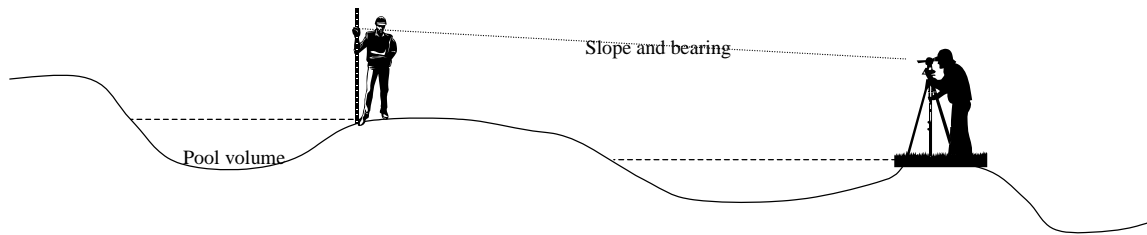


Figure 5. Measurement of Slope and Bearing

SLOPE MEASUREMENT FORM						
Site:		Station:				
Visit #:		Date:				
Transect	Direction	Upstream	Downstream	Distance (m)	Slope (%)	Comments
A-B Main						
A-B 1st Sup						
A-B 2nd Sup						
B-C Main						
B-C 1st Sup						
B-C 2nd Sup						
C-D Main						
C-D 1st Sup						
C-D 2nd Sup						
D-E Main						
D-E 1st Sup						
D-E 2nd Sup						
E-F Main						
E-F 1st Sup						
E-F 2nd Sup						
F-G Main						
F-G 1st Sup						
F-G 2nd Sup						
G-H Main						
G-H 1st Sup						
G-H 2nd Sup						
H-I Main						
H-I 1st Sup						
H-I 2nd Sup						
I-J Main						
I-J 1st Sup						
I-J 2nd Sup						
J-K Main						
J-K 1st Sup						
J-K 2nd Sup						

Figure 6. Slope Measurement Form

SUMMARY STATISTICS

After field data collection, the data are uploaded into an MS Access® database which then computes summary statistics to reflect habitat conditions at the reach scale. These summary statistics were generally developed as part of the EPA EMAP and were selected for this program based on their high signal to noise ratios as compared to other potential summary variables. The following variables are reported for Constrained Channel Projects.

GPS Coordinates

The GPS coordinates taken at Transect A and Transect K in each reach. These response variables are the GPS coordinates in Degrees, Minutes, Seconds, which are entered into the stream verification form onsite.

Sample Date

This is the date that the reach was surveyed, which is entered into the stream verification form onsite.

Reach Length

Reach length is measured onsite as the distance between the start and end of a reach, or calculated as forty times the average wetted width of the stream. The reach length is determined for both the impact and control reaches, as described in the Method For Laying Out Control And Impact Stream Reaches For Wadeable Streams. The Reach Length variable is simply reported as this measurement or calculated distance.

Reach Width

Reach width is calculated as the average wetted width of the reach. A measurement of wetted width is taken at each Transect in meters and entered into the Physical Habitat form. Wetted width and bar width are measured at station 5, between each Transect, in meters during the thalweg profile. Each of the 11 wetted width measurements from the physical habitat form and the 10 measurements of wetted width from the thalweg profile (the width used from the thalweg profile is defined as the wetted width minus the bar width) are summed and divided by the number of measurements to come up with the average wetted width, which is Reach Width, in meters.

Bankfull Width

Bankfull width is measured onsite as the distance between the left bank and right bank of the stream at bankfull height. Bankfull width is measured at each Transect and intermediate Transect in the control reach and impact reach, as described in the Method for Measuring Channel Constraints. The average bankfull width is then calculated for both the control and impact reaches.

Floodprone Width

Flood prone width is measured in the field or using remote sensing via GIS. The width is measured at two times the bankfull height as determined in the field, or if that was not possible, the flood prone width in the valley is measured using landmarks and GIS or aerial photos. Three floodprone widths are taken in the control reach and three in the impact reach. The average floodprone width for each reach is then calculated.

Channel Capacity

Channel capacity is calculated as the channels ability to convey flow at bankfull and is calculated as the combined reach-scale mean bankfull cross-sectional area. Channel capacity is calculated by first determining the average bankfull width and depth; specifically, depth from the edge of the water surface to the mean height at bankfull from the three readings. These averages are then multiplied together to obtain a cross-sectional area of the bankfull channel; this calculation neglects the cross-sectional area of the water in the channel at the time of the survey. Therefore, the reach-scale cross-sectional area of the water in the channel at the time of the survey is calculated. The reach-scale cross-sectional area calculation is based on the depth measurements taken across each transect or the thalweg measurements, as well as the 21 wetted widths taken during the survey. If the depth measurements

taken from across each transect are collected, the average depth values for each transect are calculated (e.g., average water depth from values along transects A and B, B and C, etc.). These average depth values for each transect are then multiplied by the wetted width taken at each of the cross-sections (e.g., wetted width at A and B, B and C, etc.). Based on these mean cross-sectional area values for each transect, the average cross-sectional area for the reach is calculated and added to the cross-sectional area of the bankfull channel. If the depth measurements taken across each transect are not easily obtained (e.g., due to the size and depth of the river), the thalweg measurements can be used instead of the average of all the transect depth measurements. If the thalweg measurements are used, the average between each cross-section is calculated (e.g., A to B, B to C, etc.) and multiplied by the wetted width taken at each of the cross-sections (e.g., wetted width at A and B, B and C, etc.). As previously described, this number is added to the cross-sectional area of the bankfull channel to determine the channel capacity in square meters. Channel capacity should decrease once the constraining feature is removed, indicating that over bank flows will occur more frequently, that floodplain reconnection should be improved, and that floodplain habitat should be better developed.

Mean Residual Pool Vertical Profile Area

The mean residual pool vertical profile area is the calculation of an accumulation of areas over the course of the reach. The input data includes the thalweg depths of the channel, taken at 10 stations dived equally between Transects, the slope of the reach, and the increment which is the distance between stations. At each station we calculate a residual pool profile area, and we accumulate those areas to determine Mean Residual Pool Vertical Profile Area in meters squared per reach. The calculations used to determine Mean Residual Pool Vertical Profile Area are derived from the EPA EMAP program and additional information may be obtained from Phil Kauffman of the EPA.

Mean Residual Pool Area

Mean Residual Pool Area is also referred to as the mean residual depth, and is derived directly from the Mean Residual Pool Vertical Profile Area calculation performed above. It is simply the Mean Residual Pool Vertical Profile Area divided by the total length in meters of the reach, and then multiplied by 100 to get a residual depth in centimeters. The calculations used to determine Mean Residual Pool Area are derived from the EPA EMAP program and additional information may be obtained from Phil Kauffman of the EPA.

Height of Constraining Structure at Bankfull

The height of the constraining structure – generally a levee – is measured at three different points along the reach. The height is measured as the vertical distance from the water surface to the top of the levee or constraining feature. The average of the three measurements is recorded.

Channel Constraint Removed

While onsite, it is determined whether or not the constraining feature has been removed. This is reported as a “Yes” or “No.”

TESTING FOR SIGNIFICANCE

We can create a table, resembling the following, from the data collected for each of the indicators for vertical profile area, mean residual depth, flood prone width, and channel constraints.

Among all of the measures taken in a Thalweg Profile, two measures demonstrate the greatest precision and signal to noise ratio (see Table 3). These are the mean residual Thalweg depth and the residual pool vertical profile area. We wish to test whether the mean residual pool vertical profile area (the cross-sectional area of water that would be contained in pools if no water were flowing) has increased significantly post impact.

The data will be tested using a paired t -test. The paired t -test is a very powerful test for detecting change because it eliminates the variability associated with individual sites by comparing each stream to itself, that is, at upstream and downstream locations within the same stream. The impact reach and control reach for each stream are affected by the same local environmental factors and local characteristics in the size and depth of pools and riffles in contrast with other stream systems with their own unique environmental conditions. In other words, the two observations of the pair are related to each other.

Because the paired t -test is such a powerful test for detecting differences, very small differences may be statistically significant but not biologically meaningful. For this reason, biological significance will be defined as a 20% increase in mean residual depth and residual pool profile area at the impact sites. The statistical test will be one-sided for an Alpha=0.10. We use a one-sided test because a significant decrease in pool area or depth after the impact would not be considered significant, that is, the project would not be considered effective. Therefore, we are not interested in testing for that outcome. The test will be conducted in Years 1, 3, 5, and 10. If the results are significant in any of those years, the channel constraint projects will be considered effective.

Our conclusions are, therefore, based upon the differences of the paired scores for the two (four after completing two replicates) sampled instream structure projects. Though somewhat confusing, it may be helpful to think of the statistic as the "difference of the differences". A one-tailed paired-sample t -test would test the hypothesis:

H_0 : The mean difference is less than or equal to zero.

H_A : The mean difference is greater than zero.

The test statistic is calculated as:

$$t_{n-1} = \frac{\bar{d} - 0}{S_{\bar{d}}}$$

where

\bar{d} = mean of the differences for Year 0 and a subsequent year

S_d = variance of the differences

$S_{\bar{d}} = \frac{S_d}{\sqrt{n}}$ = variance mean

n = number of sites (or site pairs).

Table 3. Composite Thalweg variables exhibiting the best all around precision and signal to noise ratios.

RMSE = σ_{rep} is the root mean square error. The lower the value, the more precise the measurement. **CV** σ_{rep} / \bar{y} (%) is the coefficient of variation. The lower the number, the more precise the measurement. **S/N** = $\sigma_{st(yr)}^2 / \sigma_{rep}^2$ is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in single or multiple sites. Data taken from Kauffmann et al. (1999). *This table is provided for information purposes only.*

Variable	Description	RMSE = σ_{rep}	CV = σ_{rep} / \bar{y} (%)	S/N = $\sigma_{st(yr)}^2 / \sigma_{rep}^2$
AREASUM	Residual Pool vertical Profile Area (m ² /reach)	7.6	25	17
RP100	Mean residual depth for 100 data points m ² /100 m =cm	2.2	19	9

DATA MANAGEMENT PROCEDURES

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the SRFB at the end of the project. Summarized data from the project will be entered into the PRISM database after each sampling season. The PRISM database contains data fields for the following parameters associated with these objectives.

Table 4. PRISM data requirements for instream artificial structure habitat projects

Indicator	Metric	Pre impact Year 0	Post impact Year 1	Post impact Year 3	Post impact Year 5	Post impact Year 10
Dike removed/set back by project	miles	√				
Channel capacity	% change	√	√	√	√	√
Level 1 effective	Yes/No		√	√	√	√
Thalweg Profile impact	Mean residual pool vertical area	√	√	√	√	√
	Mean stream residual depth					
	Flood prone width					
Thalweg Profile control	Mean residual pool vertical area	√	√	√	√	√
	Mean stream residual depth					
	Flood prone width					
Level 2 effective	Yes/No		√	√	√	√

REPORTS

PROGRESS REPORT

A progress report will be presented to the SRFB in writing after the sampling season for Years 1, 3, and 5.

FINAL REPORT

A final report will be presented to the SRFB in writing after the sampling season for Year 10. It shall include:

- Estimates of precision and variance.
- Confidence limits for data.
- Summarized data required for PRISM database by project.
- Determination whether the project met decision criteria for effectiveness.
- Analysis of completeness of data, sources of bias.

Results will be reported to the SRFB during a regular meeting after 1, 3, 5, and 10 years post project. Results will be entered in the PRISM database and will be reported and available over the Interagency Committee for Outdoor Recreation website and the Natural Resources Data Portal.

ESTIMATED COST

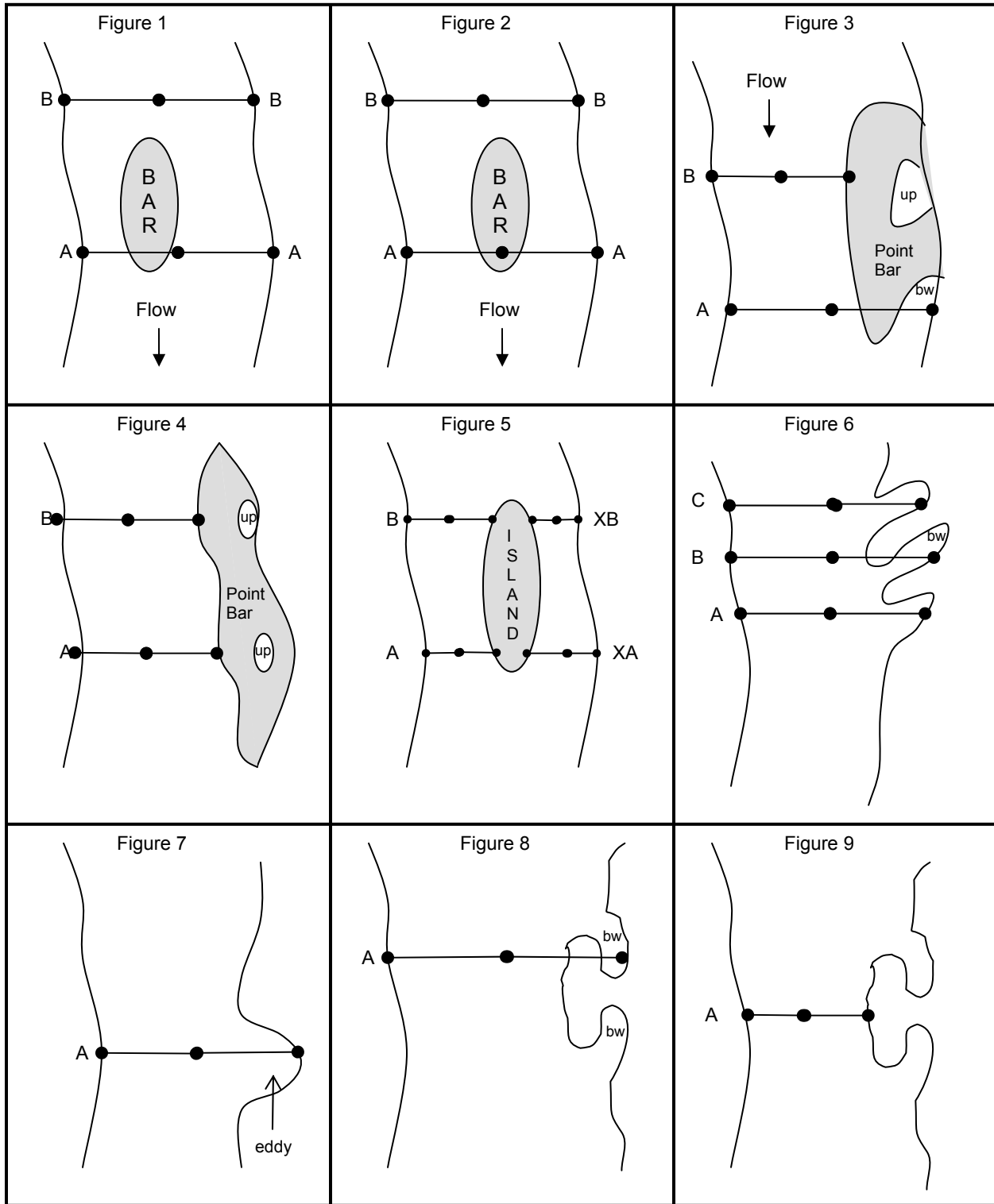
It is estimated that approximately 20 hours per project would be required to conduct all field activities under the protocol. This results in a relative 2004 cost of \$2,300-\$3,600 per project.

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APPENDIX A
Stream Measurement and Densimeter Reading Locations

TRANSECT MEASUREMENTS AND DENSIOMETER READING LOCATIONS



up – unconnected puddle; bw - backwater

- In all figures, flow is from the top of the figure to the bottom of the figure.
- In all figures, each line across the channel represents a Transect and the dots represent the locations of densiometer measurements.
- Measurement locations within the reach are determined based on the conditions present at the time of the survey.
- Substrate measurements (not illustrated in the figures) are made at five equal distance locations across each Transect and each secondary/mid-Transect (e.g., between Transect A and B).
- Right bank is on the right side of the stream when facing downstream; left bank is on the left side of the stream when facing downstream.
- Regardless if a bar is present, densiometer readings occur at the right bank, in the center of the channel, and at the left bank (Figures 1 and 2).
- Wetted width is measured across bars from the right edge of water to the left edge of water (Figures 1 and 2). The bar width is also measured and is independent of the wetted width measurement.
- If a point bar is present (e.g., gray areas in Figures 3 and 4), the edge of water is where the point bar and water meet (i.e., the bank). In Figures 3 and 4, the left bank measurements occur where the point bar and water meet (i.e., the left edge of the water). However, in the case of Transect A, in Figure 3, backwater is present and, therefore, the left edge of water (i.e., the left bank) would be on the left bank of the backwater. Unconnected puddles are never included in any measurements.
- Bars are mid-channel features below the bankfull flow mark that are dry during baseflow conditions. Islands are mid-channel features that are dry even when the stream is experiencing a bankfull flow. Both bars and islands cause the stream to split into side channels. When a mid-channel bar is encountered along the thalweg profile, it is noted on the field form and the active channel is considered to include the bar. Therefore, the wetted width is measured as the distance between the wetted left and right banks. It is measured across and over mid-channel bars and boulders. If mid-channel bars are present, record the bar width in the space provided in the form.
- If a mid-channel feature is as high as the surrounding flood plain, it is considered an island (Figure 5). Treat side channels resulting from islands different from mid-channel bars. Manage the ensuing side channel based on visual estimates of the percent of total flow within the side channel as follows:

Flow less than 15%	Indicate the presence of a side channel on the thalweg field data form.
Flow 16 to 49%	Indicate the presence of a side channel on the thalweg field data form. Establish a secondary Transect across the side channel (Figure 5) designated as "X" plus the primary Transect letter; (e.g., XA), by creating a new record in the physical habitat form and selecting "X" and the appropriate Transect letter (e.g., A through K) in the new record on the field data form. Complete the physical habitat and riparian cross-section measurements for the side channel on this form. No thalweg measurements are made in the side channel. When doing width measurements within a side channel separated by an island, include only the width measurements of the main channel in main channel form, and then measure the side channel width separately, recording these width measurements in the physical habitat side channel form. Refer to Peck et al. (2003) for detailed instructions on side channel measurements.
- When multiple backwaters and eddies are encountered (Figure 6), measurements are made across the entire channel, over depositional areas (e.g., Figure 6, Transect B) to the edge of water.
- When eddies are encountered (Figure 7), measurements are still made from the right bank to the left bank.
- In instances where a depositional area has become a peninsula and the Transect falls in a location where backwater is present (Figure 8), measure from the right bank across the depositional area to the left bank (e.g., Figure 8, Transect A). When the Transect falls in a location where backwater is not present (e.g., Figure 9, Transect A), only measure to where the water meets the edge of the depositional area/peninsula.