

PROTOCOL FOR MONITORING EFFECTIVENESS OF FLOODPLAIN ENHANCEMENT PROJECTS

(Dike Removal/Setback, Riprap Removal, Road Removal/Setback, and Landfill Removal, Off-Channel Habitat Creation, Side Channel Creation)

MC-5/6

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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 designed to enhance floodplain connection:

- Dike Removal/Setback
- Riprap Removal
- Road Removal/Setback
- Landfill Removal
- Active creation of side channels and off-channel habitat
- Reconnection of off-channel habitat or side channels

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. Constrained channels are disconnected from the floodplain and are limited in the level of natural processes that can occur in terms of overbank flow, off-channel habitat creation, and LWD recruitment. 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. This rearing habitat is critical for juvenile salmon growth and survival, and is missing from many reaches of major river systems throughout Washington.

Side channel creation and reconnection of side channels can be used in conjunction with floodplain reconnection projects to provide off-channel habitat in the short-term while allowing natural processes to create and maintain floodplain habitat in the long-term. The current shortage of off-channel habitat in many of the major river systems indicates an immediate need for this type of habitat as well as the need to sustain off-channel habitat and floodplain function over the long-term.

The goal of floodplain enhancement projects is to restore the natural flood flow basin width through natural process and active channel creation as needed 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, or build or reconnect off-channel and side channel habitat are effective at the reach scale in restoring stream morphology and eliminating channel constraints in the treated area, as well as providing additional habitat for fish.

QUESTIONS TO BE ANSWERED

- How many acres of new off-channel or floodplain habitat have been created?
- What flood stage is necessary for the newly accessible habitat to be available?
- What is the frequency and duration of inundation for the new habitat?
- Has the removal and/or setback reduced channel constraints and increased flood flow capacity for ten years?
- Has the channel become more frequently connected with the floodplain?
- Has additional off-channel habitat been created within 10 years?
- Has the floodprone width increased?
- What is the level of fish use?
- What species and life stage use the newly available habitat?

NULL HYPOTHESIS

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

- Providing slow water habitat for juvenile rearing.
- 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).
- Increasing the presence and connection of off-channel and side channel habitat as measured through hydraulic modeling and visual observation and repeated topographic and field surveys.
- Increasing juvenile fish abundance in the impacted area (on a case-by-base basis if the site with newly created habitat allows for fish abundance measurements).

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.

Determine pre-project topography of floodplain and channel bed.

Determine pre-project fish density/use of channel, if project/site conditions allow.

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

- Determine the overall changes in channel capacity and constraints in the impact reaches.
- Determine the overall stream morphology using Thalweg Profile in the impact reaches.
- Determine changes in topography of floodplain and channel bed.
- Map any newly created off-channel habitat.
- Develop predictive model for inundation of off-channel habitat.
- Determine fish density in newly created off-channel habitat, if project/site conditions allow.

RESPONSE INDICATORS

Level 1 –Mean Channel Capacity. Channel capacity measures the overall channel flow capacity as a mean bankfull cross-sectional area. 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. Mean Channel Capacity (AvgChCap) is a cross-sectional area calculated by adding the capacity above the water surface to bankfull to the capacity of water in the stream at the time of the survey utilizing bankfull width (XbfWidth), bankfull height (XbfHeight), wetted width (Reach Width), and water depth (Depth) or thalweg measurements. Descriptions for bankfull width, bankfull height, and reach width measurements are provided below in the Method for Measuring Channel Constraints Section and/or in the Summary Statistics section. This metric can also be calculated using the bankfull elevation and channel topography as part of the topographic survey. As the connection with the floodplain increases, the Mean Channel Capacity should decrease, as bankfull flows become more frequent. Failure to reduce the Mean Channel Capacity would indicate that the project is not effectively functioning at increasing floodplain connection.

Indicator Abbreviation	Description
AvgChCap	Cross-sectional area at bankfull flows
XbfWidth	Mean bankfull width within the study reach
XbfHeight	Mean bankfull height within the study reach
Reach Width	Wetted widths
Depth	Mean depth of water in the reach at the time of the survey

Level 2--Thalweg Profile, Floodplain Topography, Channel Bed Topography. 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 23-28. 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 longitudinal-section area (AREASUM) will be compared to detect post-project changes. An average flood-prone width (FPW) is determined for study reach. Descriptions for AREASUM, RP100, FPW, and bankfull depth measurements are provided below in the Method for Measuring Channel Constraints Section and/or in the Summary Statistics section.

Floodplain topography will be assessed using topographic survey in the field, maps, aerial photos, or LIDAR, as available. Changes in mapped topography will be identified. Channel topography will be assessed using bathymetric surveys on larger rivers and RTK GPS for wadeable streams. These methods will be employed before and after project implementation and changes in topography will be measured to assess the amount of off-channel habitat and floodplain habitat created by the project.

Duration and frequency of inundation will be evaluated once the new habitat is completed to assess the capacity for the new habitat to be used based on mean daily flows across the period of record. This indicator should increase with improved connection to off-channel habitat.

Thalweg indicators for constrained channels

Indicator Abbreviation	Description
AREASUM	Mean residual pool vertical profile area for the study reach (m ²) [longitudinal-section of reach]
RP100	Mean residual pool depth within the study reach (cm)
AvgChanCAP	Mean bankfull channel capacity (m ²)
FPW	Average flood-prone width for the study reach
Area of New Habitat Created	Mapped area of new habitat
Volume of New Habitat Created	Volume in m ³ of new habitat at three representative flows
Frequency of Inundation	How many times does inundation occur during the year using mean daily flows for the period of record
Duration of Inundation	Over a period of how many days does inundation occur during the year using mean daily flows for the period of record

Level 3—Fish Use and Density

Fish presence and density will be assessed at the project both before and after project implementation. If the project cannot be surveyed during high flows due to safety concerns, a surrogate off-channel habitat in the area will be used to assess the potential for the newly created habitat to support fish.

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 restoration location *relative to* the changes in stream morphology and channel capacity observed at a control site upstream, or in an untreated side channel. 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 control and impact channel capacity in terms of cross sectional area and stream morphology has changed as a result of the restoration projects. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplication. 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 a desire to complete projects 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 and impact 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 floodplain reconnection project 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.

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.

DECISION CRITERIA

Effective if a change of 20 percent 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 percent 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. Also effective if the area of new off-channel habitat increases over baseline by Year 10.

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 (AvgChanCAP)	Avg. m ²	Linear Regression or Paired <i>t</i> -test	Alpha = 0.10 for one-sided test. Detect a 20% decrease between Year 0 and Year 10.
Mean residual pool vertical profile area (AREASUM)	Avg. 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 (FPW)	Avg. m	Linear Regression or Paired <i>t</i> -test	Alpha = 0.10 for one-sided test. Detect a minimum 20% increase between Base Year 0 and Year 10
Area of new off-channel habitat	m ²	none	Alpha = 0.10 for one-sided test. Detect a minimum 20% increase between Base Year 0 and Year 10
Change in juvenile fish density	Fish/ m ²	Linear Regression or Paired <i>t</i> -test	Alpha = 0.10 for one-sided test. Detect a minimum 20% increase between Base Year 0 and Year 10

SAMPLING

SELECTING SAMPLING REACHES

IMPACT REACH

Floodplain enhancement projects are may be measured in their entirety, or may require only one stream reach identified according to the methods on pages 11-13. 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 floodplain enhancement 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.
- Determining the abundance of juvenile salmon during summer low flow or winter high flows based on expected use by fish, if possible.
- Determining the baseline floodplain and channel topography using remote sensing and field techniques.
- Determining needs for hydraulic modeling to assess the level of floodplain connection from the project plans.

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 floodplain enhancement 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.
- Determining abundance of juvenile salmon in the impact and control reaches during summer low flow or winter high flows based on project objectives, if possible.
- Determining the baseline floodplain and channel topography using remote sensing and field techniques.
- Calculating the level of floodplain connection (duration and frequency) using hydraulic modeling and mean daily flows for the period of record.
- Calculating the area and volume of new habitat created using RTK GPS and/or aerial imagery in repeated surveys through time.

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 (see Figure 1). The Transects are then averaged to obtain an average representation of the stream reach.

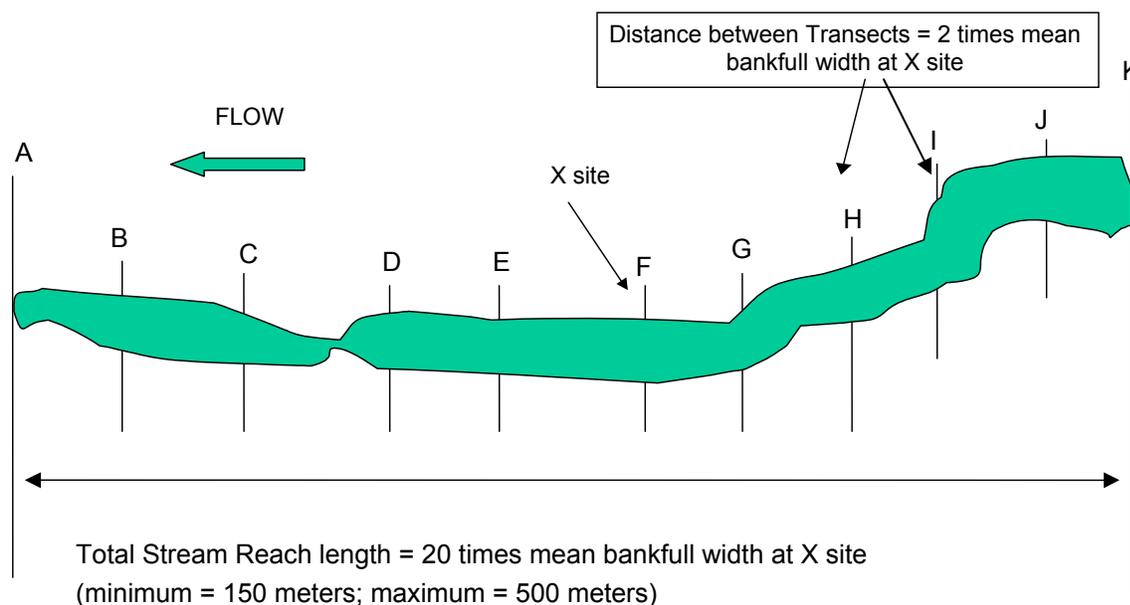


Figure 1. Sampled project reach

LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

Step 1: Using a handheld GPS device, determine the location of the X site and record latitude and longitude on the stream verification form. The X site should be considered the center of the impact or 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. It will be located in the center of the control reach, which will measure the same as the length of the impact reach whenever possible. 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 bankfull width of the channel at five places considered to be of "typical" width within approximately five channel widths distance upstream and downstream of the X site location. Average those five bankfull widths, then multiply that average bankfull width by 20 to determine the reach length. For streams less than 7.5 m in average bankfull width, the reach length should be at minimum 150 m, and for streams greater than 25 m in width, the maximum reach length 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 10 times the bankfull width (equal to one half the sampling reach length) determined in Step 1.

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

NOTE: *For restoration projects less than 20 times bankfull width, 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 measures of the variance of juvenile fish populations 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 still be based upon 20 times the bankfull width.

Step 4: Starting back at the X site, measure a distance of 10 average bankfull 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 $1/10^{\text{th}}$ (2 average bankfull widths in big streams or 15 m in small streams) of the reach length upstream from the start point (Transect A). Flag this spot as the next cross section or Transect (Transect B).

For example, if the reach length is determined to be 200 meters, a Transect will be located every 20 meters, which is equivalent to $1/10^{\text{th}}$ the total reach length.

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

reach end points (Transects A and K) and the middle of the reach (X site or Transect F),, 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 events 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 11-13.

PROCEDURE

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

For the purpose of this method, 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: Record your determinations from Steps 1 through on the Channel Constraint Form – Part 1 (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 – Part 1 (Figure 2 – refer to examples on form).

Step 6: Measure the height of the constraining feature treated by the restoration project from the water surface at Transects A, F, and K, as shown in Figure 4. The height is measured as the vertical distance from the water surface to the top of the constraining feature. Record those values on the Channel Constraint Form – Part 2 (Figure 3).

Step 7: Measure bankfull height at Transects A, F, and K as shown in Figure 4. Bankfull height is the height from the water surface to bankfull level. In unconstrained channels, bankfull level is the point where over bank flow begins during a flood event. Refer to an example schematic cross-section of a stream in Figure 5. Bankfull is identified by interpreting the evidence of bankfull flow atop the banks of the stream. The most consistent indicators of bankfull flow are areas of deposition, as the top of these deposits (i.e., gravel bars) define the active floodplain (USFS 2006). In entrenched channels with disconnected or undeveloped floodplains, ordinary high water (OHW) level is used instead of bankfull (USFS 2008). Look for other indicators, which include:

- a change in vegetation (i.e., from none to some, or from herbaceous to woody);
- a change in bank topography (a change in slope of the bank above the water's edge); a
- line defining the lower limit of lichen colonization;
- a stain line visible on bare substrate;
- a defined scour line (exposed roots, etc.); and
- a line of organic debris on the ground (but not debris hanging in vegetation) (USFS 2006).

Record bankfull height values measured at Transects A, F, and K on the Channel Constraint Form – Part 2 (Figure 3). Bankfull height values will be used along with values taken as part of the thalweg profile and physical habitat measurements to calculate channel capacity (see Summary Statistics section below).

Step 8: Measure bankfull depth at Transects A, F, and K as shown in Figure 4. Bankfull depth is measured from the channel thalweg to the point where over-bank flow begins during a flood event (bankfull), or at the OHW level in a constrained channel. See the description of bankfull and OHW indicators in Step 7 above. Note that bankfull depth is basically bankfull height plus thalweg depth. See an example schematic cross-section of a stream in Figure 5. Record these values on the Channel Constraint Form – Part 2 (Figure 3).

Step 9: At Transects A, F, and K, measure the flood-prone width (FPW). As a guideline, FPW can be measured at the level of flood-prone depth, which is approximately two times the bankfull depth as shown in Figure 6. If a measurement of FPW cannot be performed in the field, collect location points at flood-prone depth, and utilize GIS and/or aerial photos. Record these values on the Channel Constraint Form – Part 2 (Figure 3).

Step 10: Measure the bankfull width at each Transect and each intermediate Transect and record widths on the Channel Constraint Form – Part 2 (Figure 3). Bankfull width is the distance between the left bank and right bank at the point where over-bank flow begins during a flood event (bankfull), or at the OHW level in a constrained channel. See the description of bankfull and OHW indicators in Step 7 above.

Step 11: Use a GPS in the field to collect coordinates of the perimeter of the newly created habitat. Acquire aerial photos of the site to show the current topography and habitat of the impact reach, and overlay the polygon depicting the area of newly created habitat. Calculate the acres of habitat created (m^2). Research river data to document or model floodplain inundation using GIS and recent topography data, recent LiDAR data, or recent aerial photos showing project implementation. Document the flood stage, the volume of water in the floodplain, and the frequency that the newly created habitat will likely be flooded each year based on the elevation and average high water levels. Determine if monitoring for fish use is possible in the newly created habitat, and if so, during what time of year – low summer flow or high winter flows. Topographic surveys may be needed at some sites to collect these data.

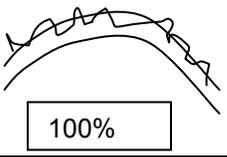
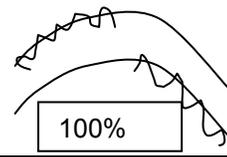
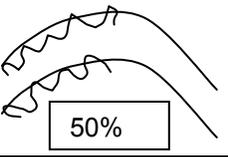
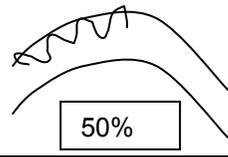
CHANNEL CONSTRAINT FORM			
SITE NAME:	DATE: VISIT:		
SITE ID:	TEAM ID:		
Reach Length (m):			
Channel Pattern (Check one)			
<input type="checkbox"/> One channel <input type="checkbox"/> Anastomosing channel – relatively long major and minor channels branching and rejoining <input type="checkbox"/> Braided 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		
 100%	 100%	 50%	 50%
Valley width (m) Note: Average the distance from edge to edge, and if not possible, note that it is at least a certain distance. Use topo map to estimate when cannot be measured in the field. _____m			
Comments			

Figure 2. Channel Constraint Form (Part 1)

CHANNEL CONSTRAINT FORM					
SITE NAME:			DATE:		VISIT:
SITE ID:			TEAM ID:		
			Reach Length (m):		
BANKFULL WIDTHS					
Transect	Bankfull Width (m)	Transect	Bankfull Width (m)	Transect	Bankfull Width (m)
A		D'		H	
A'		E		H'	
B		E'		I	
B'		F		I'	
C		F'		J	
C'		G		J'	
D		G'		K	
Height of Constraining Feature (cm)		Bankfull Height (cm)	Bankfull Depths (cm)	Flood-prone Widths (m)	
A		A	A	A	
F		F	F	F	
K		K	K	K	

Figure 3. Channel Constraint Form (Part 2)

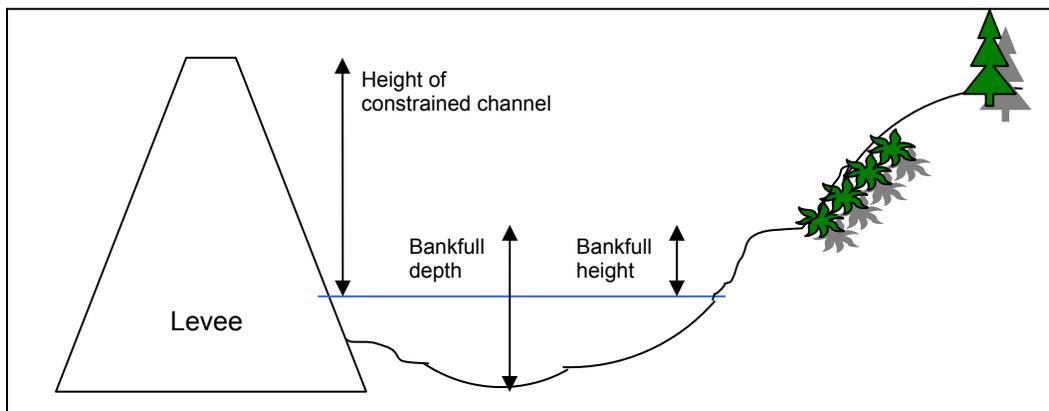
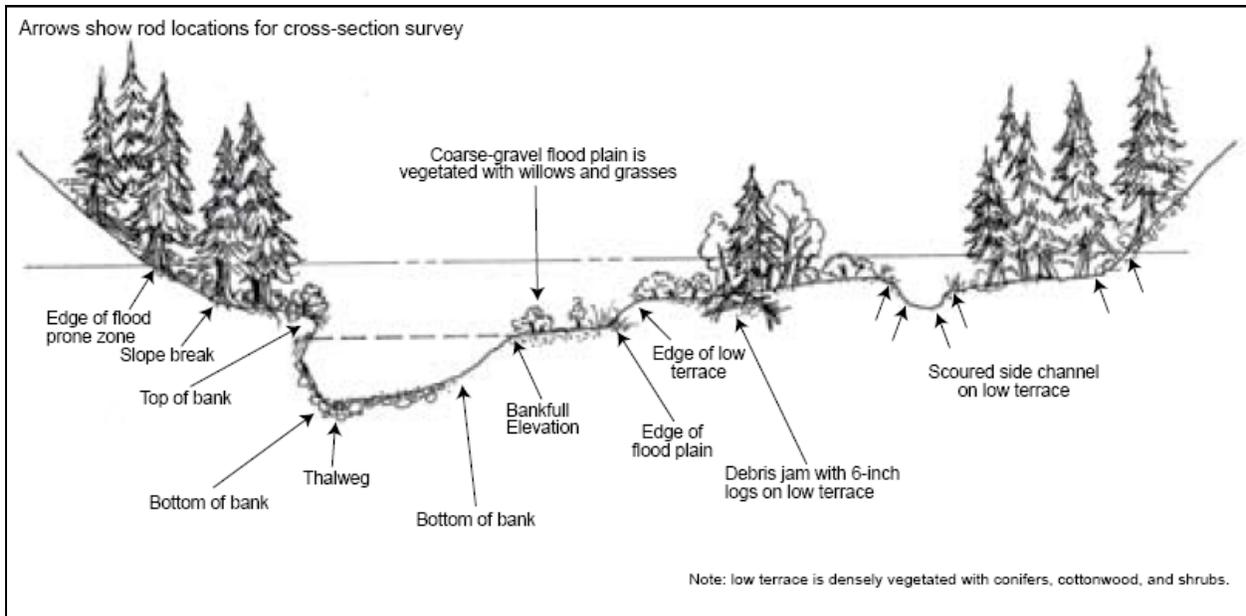
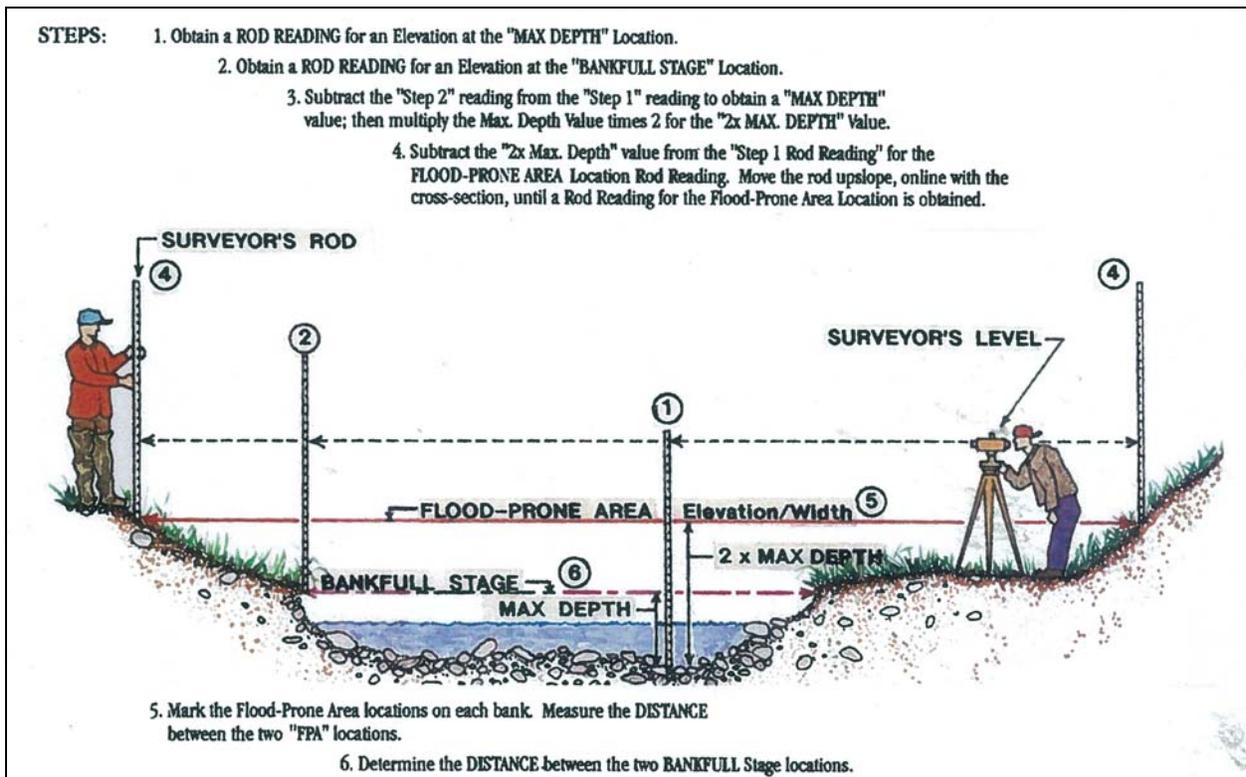


Figure 4. Example Channel Survey Measurements



Source: USFS 2008

Figure 5. Schematic channel cross section



Source: Rosgen and Silvey 1998, Field Guide for Stream Classification

Figure 6. Flood-Prone Width Field Method

METHOD FOR CHARACTERIZING RIPARIAN VEGETATION STRUCTURE

Protocol taken from: *Peck et al. (2003), Table 7-10; Kauffman et al. (1999)*

PURPOSE

This protocol is designed to determine the changes in riparian vegetation due to a restoration project where riparian vegetation has been planted.

EQUIPMENT

Convex spherical densiometer, field waterproof forms, hip boots or waders

SITE SELECTION

The sample reaches are those laid out according to the methods on pages 11-13.

SAMPLING DURATION

Sampling should occur during June-August when vegetation is at its maximum growth, or when feasible at each project site.

PROCEDURES FOR MEASURING RIPARIAN VEGETATION AND STRUCTURE

Following are taken from Table 7-10 of EMAP protocols:

Step 1: Standing in mid-channel at a Transect (A-K), estimate a 5m distance upstream and downstream (10m length total).

Step 2: Facing the left bank (left as you face downstream), estimate a distance of 10m back into the riparian vegetation or until an enclosure is encountered. On steeply sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.

Step 3: Within this 10 m X 10 m area, conceptually divide the riparian vegetation into three layers: a canopy layer (>5 m [16ft] high), an understory (0.5 to 5 m [20 inches to 16ft.] high), and a ground cover layer (<0.5 m high).

Step 4: Within this 10 m X 10 m area, determine the dominant vegetation type for the canopy layer as Deciduous, Coniferous, Broadleaf Evergreen, Mixed, or None. Consider the layer mixed if more than 10% of the aerial coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the "Visual Riparian Estimates" section of the Channel/Riparian Cross Section Form (Figure 7).

Step 5: Determine separately the aerial cover class of large trees (>0.3 m [1ft] diameter breast height [DBH]) and small trees (<0.3m DBH) within the canopy layer. Estimate aerial cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form ("0"= absent: zero cover, "1"= sparse: <10%, "2"= moderate: 10-40%, "3"=heavy: 40-75%, or "4"= very heavy: >75%).

Step 6: Look at the understory layer. Determine the dominant vegetation type for the understory layer as described in Step 4.

Step 7: Determine the aerial cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described in Step 5 for large trees.

Step 8: Look at the ground cover layer. Determine the aerial cover class for woody shrubs and seedlings, non-woody vegetation as described in Step 5 for large canopy trees, and the amount of bare ground present. Note that Reed's canary grass often meets the height requirements for the understory layer, but should always be counted as ground cover.

Step 9: Repeat steps 1 through 8 for the right bank.

Step 10: Repeat steps 1 through 9 for all Transects, using a separate field data form for each Transect. Once vegetation has been accounted for in a layer, it should not be included in subsequent layers as they are evaluated.

Riparian Vegetation Cover	Left Bank					Right bank					Flag
	Canopy (> 5m high)										
Vegetation type	D	C	E	M	N	D	C	E	M	N	
Big trees (trunk > 0.3m DBH) XCL	0	1	2	3	4	0	1	2	3	4	
Small trees (trunk < 0.3m DBH) XCS	0	1	2	3	4	0	1	2	3	4	
	Understory (0.5 to 5m high)										
Vegetation type	D	C	E	M	N	D	C	E	M	N	
Woody shrubs and saplings XMW	0	1	2	3	4	0	1	2	3	4	
Non-woody herbs grasses and forbs XMH	0	1	2	3	4	0	1	2	3	4	
	Ground Cover (0.5m high)										
Woody shrubs & saplings XGW	0	1	2	3	4	0	1	2	3	4	
Non-woody herbs grasses and forbs XGH	0	1	2	3	4	0	1	2	3	4	
Barren dirt or duff XGB	0	1	2	3	4	0	1	2	3	4	

Figure 7. Form for recording visual riparian estimates

Note: Use one form for each Transect (A – K)

The following table taken from Kauffman et al. (1999) details the parameter codes and precision metrics of EMAP procedures conducted in Oregon (Table 2). Parameters in bold type are the most precise. This table is provided for information purposes only.

Table 2. Parameter codes and precision metrics of EMAP procedures conducted in Oregon.

Code	Variable name and description	RMSE = σ_{rep}	CV = $\sigma_{rep} /$ "(%)"	S/N = $\sigma_{st(yr)}^2 /$ σ_{rep}^2
XCL	Large diameter tree canopy cover (proportion of riparian)	0.057	38	4.6
XCS	Small diameter tree canopy cover (proportion of riparian)	0.12	55	1.4
XC	Tree canopy cover (proportion of riparian)	0.12	33	2.4
XPCAN	Tree canopy presence (proportion of riparian)	0.08	8.7	10
XMW	Mid-layer woody vegetation cover (proportion of riparian)	0.12	41	0.9
XMH	Mid-layer herbaceous vegetation cover (proportion of riparian)	0.13	100	0.9
XM	Mid-layer vegetation cover (proportion of riparian)	0.19	44	0.6
XPMID	Mid-layer vegetation presence (proportion of riparian)	0.03	3.5	2.1
XGW	Ground layer woody vegetation cover (proportion of riparian)	0.17	77	0.1
XGH	Ground layer herbaceous vegetation cover (proportion of riparian)	0.16	40	1.1
XGB	Ground layer barren or duff cover (proportion of riparian)	0.07	47	2.0
XG	Ground layer vegetation cover (proportion of riparian)	0.22	36	0
PCAN_C	Conifer riparian canopy (proportion of riparian)	0.11	58	8.5
PCAN_D	Broadleaf deciduous riparian canopy (proportion of riparian)	0.13	31	7.4
PCAN_M	Mixed conifer-broadleaf canopy (proportion of riparian)	0.16	65	2.9
PMID_C	Conifer riparian mid-layer (proportion of riparian)	0.02	55	37
PMID_D	Broadleaf deciduous riparian mid-layer (proportion of riparian)	0.33	58	0.7
PMID_M	Mixed conifer-broadleaf canopy (proportion of riparian)	0.32	87	0.6

PROCEDURES FOR MEASURING CANOPY COVER

Canopy cover is determined for the stream reach in the treatment and control areas at each of the 11 cross-section Transects. A convex spherical densiometer (Model B) is used. Six measurements are obtained at each cross section Transect at mid-channel.

Step 1: At each cross-section Transect, stand in the stream at mid-channel and face upstream.

Step 2: Hold the densiometer 0.3 m (1 ft.) above the stream. Hold the densiometer level using the bubble level. Move the densiometer in front of you so that your face is just below the apex of the taped "V".

Step 3: Count the number of grid intersection points within the “V” that are covered by either a tree, a leaf, a high branch, or other shade providing feature (Reed’s canary grass, bridge or other fixed structure, stream bank, etc.). Record the value (0-17) in the CENUP field of the canopy cover measurement section of the form.

Step 4: Face toward the left bank (left as you face downstream). Repeat steps 2 and 3, recording the value in CENL field of the data form.

Step 5: Repeat steps 2 and 3 facing downstream, and again while facing the right bank (right as you look downstream). Record the values in the CENDWN and CENR fields of the field data form.

Step 6: Repeat steps 2 and 3 again, this time facing the bank while standing first at the left bank, then the right bank, while holding the densiometer approximately 0.3 m (1 ft.) above the water surface and at the wetted edge. Record the value in the LFT and RGT fields of the data form.

Step 7: Repeat steps 1-6 for each cross-section Transect (A-K). Record data for each Transect on a separate data form.

Step 8: If for some reason a measure cannot be taken, indicate in the “Flag” column. This situation would occur if there is no access to one side of the channel, or if the channel is too wide or deep to cross, so middle measurements cannot be taken. If measurements cannot be taken they will not be estimated.

Location	1-17	Flag
CENUP		
CENL		
CENDWN		
CENR		
LFT		
RGT		

Figure 8. Form for tallying canopy density

Each of the measures taken at the center of the stream are summed for all 11 Transects and converted to a percentage based upon a maximum score of 17 per Transect. The results are then averaged to produce a mean % canopy density at mid-stream (XCDENMID).

Each of the measures taken at the banks of the stream are summed for all 11 Transects and converted to a percentage based upon a maximum score of 17 per Transect. The results are then averaged to produce a mean % canopy density at the stream bank (XCDENBK).

Each of the measures are totaled and averaged to produce the following table of riparian vegetative cover.

Table 3. The shaded composite variables are considered the most important in terms of their precision and are the ones that will be used to determine effectiveness of riparian plantings. **RMSE** = σ_{rep} is the root mean square error. The lower the value, the more precise the measurement. **CV** $\sigma_{rep} / \%$ 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 a single or multiple sites. This table is provided to demonstrate the best indicators for testing significance.

Variable	Description	RMSE = σ_{rep}	CV = $\sigma_{rep} / \%$	S/N = $\sigma_{st(yr)}^2 / \sigma_{rep}^2$
XCDENBK	Mean % canopy density at bank (Densiometer reading)	3.9	4.4	17
XC DENMID	Mean % canopy density mid-stream (densiometer reading)	5.8	8.1	15
XCM	Mean riparian canopy + mean mid-layer cover	0.22	33	1.4
XPCM	Riparian canopy and mid-layer presence (proportion of reach)	0.08	9.8	7.9
XPCMG	3-layer riparian vegetation presence (proportion of reach)	0.08	9.8	8.0

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 11-13.

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 and bankfull width are 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 bankfull width used to determine the length of the sampling reach. For bankfull widths < 7.5 m, establish stations every 1 m. For bankfull widths of 7.5 m or greater, establish stations at increments equal to 0.01 times the sampling reach length.

For example, if the reach length is determined to be 300 meters, a measurement station will be located every 3 meters, which is equivalent to 0.01 times the total reach length.

Step 2: Complete the header information on the Thalweg Profile Form (Figure 9), 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 7.5 m or greater), or station 7 (if the stream width defining the reach length is < 7.5 m). Wetted width is measured across and over mid-channel bars and boulders. Record the wetted 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: Measure bankfull width if you are at station 0, station 5 (if the stream width defining the reach length is 7.5 m or greater), or station 7 (if the stream width defining the reach length is < 7.5 m). Bankfull width is measured perpendicular to the stream channel and is measured to the nearest 0.1 meter. When local bankfull indicators are not present use the bankfull height to approximate bankfull. Bankfull height can be determined by measuring the vertical distance from the water's surface to the dominant bankfull elevation throughout the reach. When side channels are present, record the bankfull width of each channel individually. Record bankfull widths in the Bankfull Width Form (Figure 10).

Step 6: 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% (right wetted margin) 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 determine locations at which 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 7: Identify bankfull using the following indicators:

1. Examine streambanks for an active floodplain. This is a relatively flat, depositional area that is commonly vegetated and above the current water level unless there is a large amount of spring runoff or there has been a substantial rain event (i.e. stream running at bankfull stage).
2. Examine depositional features such as point bars. The highest elevation of a point bar usually indicates the lowest possible elevation for bankfull stage. However, depositional features can form both above and below the bankfull elevation when unusual flows occur during years preceding the survey. Large floods can form bars that extend above bankfull whereas several years of low flows can result in bars forming below bankfull elevation.
3. A break in slope of the banks and/or change in the particle size distribution from coarser bed load particles to finer particles deposited during bank overflow conditions.
4. Define an elevation where mature key riparian woody vegetation exists. The lowest elevation of birch, alder, and dogwood can be useful, whereas willows are often found below the bankfull elevation.
5. Examine the ceiling of undercut banks. This elevation is normally below the bankfull elevation.

6. Stream channels actively attempt to reform bankfull features such as floodplains after shifts or down cutting in the channel. Be careful not to confuse old floodplains and terraces with the present indicators.

Note that all six indicators may *not* be present. After you identify bankfull, measure the vertical distance from the water's surface to the dominant bankfull elevation measured throughout the reach. This vertical distance can be used when bankfull indicators are not present at a particular point along the streambank. Bankfull height is needed for streambank measurements, bankfull widths, pebble counts, large wood, and cross-sections.

Step 8: 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 zero 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 laser range finder on the upper surface of the rod and reading the angle on the external scale of the laser range finder. 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 laser range finder exactly as done for the surveyor's rod.*

Table 4. 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 9: At the point where the thalweg depth is determined, observe whether unconsolidated, loose ("soft") deposits of small diameter (<16 mm), 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 the 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 10: 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 11: 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 12: 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 13: 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 14: Proceed upstream to the next station and repeat Steps 4 through 13.

Step 15: Repeat Steps 4 through 14 until you reach the next Transect. At this point, complete Channel/Riparian measurements at the new Transect. Then prepare a new Thalweg Profile 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										

Figure 9. Thalweg Profile Form

Bankfull Width Form			
Site ID _____ Station _____ Date _____ Year _____			
Surveyors _____			
Transect	Station	Bankfull Width (m)	Comments
A	0		
A¹	5		
B	0		
B¹	5		
C	0		
C¹	5		
D	0		
D¹	5		
E	0		
E¹	5		
F	0		
F¹	5		
G	0		
G¹	5		
H	0		
H¹	5		
I	0		
I¹	5		
J	0		
J¹	5		
K	0		

Figure 10. Bankfull Width Form

METHOD FOR MEASURING POOL ATTRIBUTES

Modified Protocol taken from: *Heitke et al. (2010) pp. 44-46*

PURPOSE

Determining the changes in the percentage of fines and embeddedness within the impact and control areas pre- and post-project in order to determine any significant changes.

EQUIPMENT

Meter stick, surveyor's rod, metric tape

SITE SELECTION

The sample reaches should be laid out according to page 11-13.

SAMPLE DURATION

Counts should be taken during summer low flow period when turbidity and visibility is normally at its best. This may not be true for glacial streams.

PROCEDURE

Step 1: Fill out header information on Pool Attribute Form (Figure 11). Then, while working from downstream to upstream, locate each pool. For each pool encountered, complete steps 2-4 as described below.

Pools are defined as the following:

- Pools are depressions in the streambed that are concave in profile, laterally and longitudinally.
- Pools are bound by a 'head' crest (upstream break in streambed slope) and a 'tail' crest (downstream break in streambed slope).
- Only consider main channel pools where the thalweg runs through the pool, and not backwater pools.
- Pools span at least 50% of the wetted channel width at any location within the pool. So a pool that spans 50% of the wetted channel width at one point, but spans <50% elsewhere is a qualifying pool.
- Side channels - when islands are present only consider pools in the main channel; don't measure pools in side channels.

Step 2: For each pool encountered, measure pool-tail crest depth to the nearest centimeter (cm) and record. Pool-tail depth is measured at the maximum depth along the pool tail crest, which is normally, but not always, the thalweg. To find this point, imagine that the water in the stream is 'turned off'. You want to measure the depth of the last spot that would have flowing water before the stream stopped flowing.

Step 3: Measure maximum depth of each pool encountered and record. Maximum depth is the deepest point in the pool. Locate it by probing the pool with a meter stick or surveyors rod. If unsafe to measure maximum pool depth, estimate the maximum depth.

Step 4: Measure pool width at the widest point of each pool encountered and record.

METHOD FOR CHARACTERIZING FLOODPLAIN TOPOGRAPHY AND CHANNEL TOPOGRAPHY

Protocol taken from: *Harrelson et al. (1994)*

PURPOSE

Using aerial photography, LIDAR, digital elevation models, or field surveying methods, map the existing topography for the project site to determine floodplain and channel topography changes as a result of the constraint removal.

EQUIPMENT

Appropriate waterproof sampling form, waders or hip boots, 50 m measuring tape, surveyor's level, leveling rod, field book, small survey stakes, and steel rebar

SITE SELECTION

The sample reaches are those laid out according to pages 11-13.

PROCEDURE

A basic field survey establishes the horizontal and vertical location of a series of points in relation to a starting point called a benchmark. The U.S. Geological Survey typically uses brass monuments set in rock, a concrete pylon, or a pipe driven deeply into the ground. Use an established benchmark if it is within the survey area. Usually, though, a new benchmark will need to be established. Locate the benchmark outside the channel and floodplain, if possible, yet near enough to be clearly visible.

Conduct the longitudinal profile survey when you conduct the benchmark and monumented cross-section surveys. The cross-section is the basis for delineating channel form. The longitudinal profile survey is important for measuring the slope of the water surface, channel bed, floodplain, and terraces.

Vertical distances can be measured with a basic surveyor's level, a self-leveling level, or a laser level. These include real-time kinematic (RTK) position or total station radial survey equipment. These procedures apply to a self-leveling level. For other types of equipment, refer to the proper manual or instruction sheet, as specific procedures for using these types of equipment are not available here. This protocol describes the basic method to conduct a survey, regardless of the equipment used.

Cross Section Survey

Step 1: Find or establish permanent markers for endpoints using rebar on either side of the cross sectional transect, starting with Transect A or K.

Step 2: Establish the benchmark elevation and survey controls.

Step 3: Triangulate between a benchmark, the nearest endpoint, and another permanent feature.

Step 4: Stretch the measuring tape tight and level above the water from the triangulated endpoint to the opposite endpoint of the transect.

Step 5: Measure elevations with the surveyor's level, starting with the benchmark to establish the height of the instrument. Start the channel cross-section from the left endpoint. Along the tape, shoot an elevation at each change in important feature, or at intervals that delineate important features. Set the rod on slope breaks (such as the edge of the low terrace), on indicators of active floodplain boundaries or

bankfull discharge, and on other features of interest. **Always measure the edge of the water.** Once in the channel, shoot elevations at regular intervals (either channel width divided by 20, or 1 to 2 foot intervals) with additional shots to capture features such as breaks in slope. Avoid the tops of isolated boulders and logs (or shoot at close intervals to accurately record large ones.) Continue across the channel to the right endpoint stake. If necessary, go beyond the stake to measure terrace features on the far bank. Record distance and depth measurements in the field notebook. Distances are usually measured to tenths of feet for cross-section and profile surveys. Elevations are always recorded for hundredths of feet when leveling benchmarks, turning points, height of instrument, or slope.

Step 6: Close the survey loop by taking a reading back to the initial benchmark. If movement across the stream is difficult or if vegetation obstructs a clear shot, move the instrument the distance of a channel's width along the bank on the same side of the stream and close the survey loop back to the benchmark. Calculate closure in the field before leaving the site and repeat measurements if necessary.

Step 7: Plot the data in the field notebook and evaluate for any errors.

Step 8: Measure channel slope. The rod person moves upstream from the cross-section to incorporate one complete pool-riffle or step-pool sequence, if present. Start at a distinct feature (top of riffle, pool, etc) and measure the distance from the cross-section to each point with a flag to the nearest tenth of a foot. Shoot elevations at water surface and bankfull.

Step 9: Repeat the procedure downstream, ending on the same channel feature as at the starting point.

Longitudinal Profile Measurement

Step 1: Define the extent of the survey to measure both banks, the active floodplain, and one or more stream terraces.

Step 2: Flag the channel and related features. Place flags where a sighting with the level is possible.

Step 3: Set up the level so the benchmark and most of the site is visible. Having to move the level often adds time and complexity to the survey.

Step 4: Measure distances to each intermediate transect with a tape down the stream centerline.

Step 5: Place stakes or flags at each intermediate transect. The station/intermediate transect is the right angle project from the baseline or channel center to the baseline along the bank. The longitudinal profile aims to delineate indicators and features accurately. The stakes/flags places are used primarily to guide estimation of distances. They do not necessarily fix the locations where measurements are made.

Step 6: Measure elevations of important features. Measure distances using the stakes/flags as references. Place the rod and shoot individual elevations of the channel bottom at the center of the stream, bankfull indicators, floodplains, and terraces where they are most apparent and record distance and elevation in the field book. Move the instrument as needed. Mark the water level at the transect if the survey will be continued the next day.

Step 7: Plot the data in the field logbook and fit the present water surface and bankfull (or floodplain) elevations. Connect the points identifying the channel bottom with straight lines. The lines of slope for the entire reach should closely parallel each other.

METHOD FOR MEASURING SLOPE AND BEARING**

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

****Note:** *Depending on the ability to accurately measure water surface slope with the channel topography survey, this method may not be necessary.*

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 water's 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 (Figure 12). Determine the elevation change (cm) by reading the downstream stadia rod and subtracting the instrument height. Record numbers on Slope Measurement Form (Figure 13).

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 13). 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 (Figure 13). Note that bearing measurements should be taken at each primary Transect (A, B, C, etc) and at the supplemental measurement points.

Residual Pools

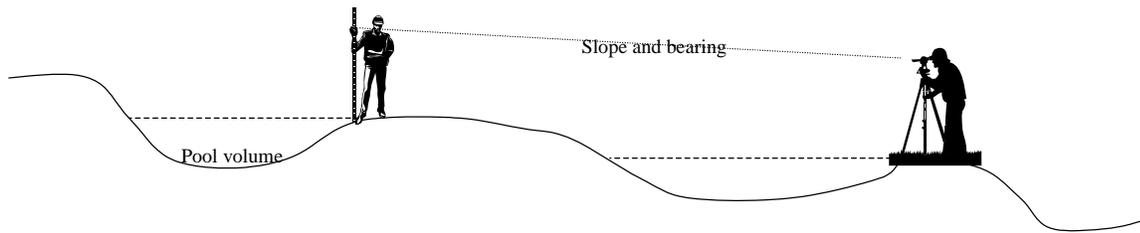


Figure 12. Measurement of Slope and Bearing

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 13. Slope Measurement Form

SUMMARY STATISTICS

After field data collection, the data are uploaded into an MS Access® database which is used to calculate 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.

Sample Date

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

Project Site Verification Measurements

GPS Coordinates

The GPS coordinates are collected at Transect A, F and K in each reach in Latitude/Longitude in Degrees, Minutes, Seconds, which are entered into the stream verification form onsite. GPS coordinates of the newly created habitat are collected either as points, lines, or polygons. The points or shape files are placed on an aerial photo for documentation of created habitat, and the area in acres is calculated.

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.

In- Channel Data Collection

Bankfull Height (XbfHeight)

Bankfull height is measured at Transects A, F, and K. Bankfull height is measured onsite as the height from the water surface at the edge to the height at which over bank flow would occur during a flood event. Bankfull is identified by interpreting the evidence of bankfull flow atop the banks of the stream. The most consistent indicators of bankfull flow are the areas of deposition; the top of these deposits (i.e., gravel bars) define the active floodplain. In entrenched channels with disconnected or undeveloped floodplains, look for other indicators which include: a change in vegetation (i.e., from none to some, or from herbaceous to woody); a change in bank topography (a change in slope of the bank above the water's edge); a line defining the lower limit of lichen colonization; a stain line visible on bare substrate; a defined scour line (exposed roots, etc.); a line of organic debris on the ground (but not debris hanging in vegetation). (USFS 2006). Bankfull height is used in the channel capacity calculation.

Bankfull Width (XbfWidth)

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. Bankfull width and is used in the channel capacity calculation.

Flood-prone Width (FPW)

Flood prone width is measured in the field at Transects A, F, and K in both the control reach and impact reach. The average flood-prone width for each reach is then calculated. As a guideline, FPW can be measured at the level of flood-prone depth, which is approximately two times the bankfull depth as shown in Figure 6. If a measurement of FPW cannot be performed in the field, collect location points at flood-prone depth, and utilize GIS and/or aerial photos.

Channel Capacity (AvgChCap)

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 height; 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 from the water surface up. As this calculation neglects the cross-sectional area of the water in the channel at the time of the survey, 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 maximum thalweg depth at the transect multiplied by the wetted width for each transect, as well as the 21 wetted widths taken during the survey. The maximum thalweg 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.

To summarize, the Average Channel Capacity (AvgChCap) calculation includes

- bankfull height - "XbfHeight"
- bankfull width - "XbfWidth"
- average cross-sectional area - "AvgXSecArea" - intermediate calculation using the maximum thalweg depth at the transect multiplied by the wetted width measures at stations 5 or 7 to the transect (calculating the average area below water surface)
- bank full channel capacity - "BnkFullChCap" - intermediate calculation using the average of the 3 measured bankfull heights multiplied by the average of the bankfull widths (calculating the average area above the water surface to bankfull)
- AvgChancap - the sum of "BnkFullChCap" and "AvgXSecArea" to get the average cross-sectional area from streambed to bankfull

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.

Maximum Pool Depth Average

The Maximum Pool Depth Average is an average of the maximum pool depths (measured in cm) obtained through the Method for Measuring Pool Attributes and recorded on the Pool Attributes Form. Using the maximum pool depths for all pools within the reach, calculate the average by summing the maximum pool depths and dividing by the number of pools within the reach. This will be calculated for the impact and control reaches.

Pool Tail Crest Depth Average

The Pool Tail Crest Depth Average is an average of the pool tail crest depths (measured in cm) obtained through the Method for Measuring Pool Attributes and recorded on the Pool Attributes Form. Using the pool tail crest depths for all pools within the reach, calculate the average by summing the pool tail crest depths and dividing by the number of pools within the reach. This will be calculated for the impact and control reaches.

Changes in Fish Density

The difference in the fish densities detected in the project reach before and after project implementation as compared to a control reach.

Channel Constraint and Connectivity Data Collection**Height of Constraining Feature**

The height of the constraining feature – generally a levee – is measured at Transects A, F, and K. The height is measured as the vertical distance from the water surface to the top of the constraining feature. The average of the three measurements is calculated.

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.”

Sinuosity Changes

Determine changes in the river pattern using GIS and thalweg data.

Pool/riffle ratio

Determine changes in fish habitat by assessing the pool to riffle ratio in each reach.

Bankfull Width to Depth Ratio

Assess changes in fish habitat by assessing the bankfull width to bankfull depth ratio.

Area of New Habitat Created

A measure of the new habitat created by the project either through natural processes or through new off-channel habitat creation.

Volume of New Habitat Created

A measure of the new habitat created by the project either through natural processes or through new off-channel habitat creation.

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 5). 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 5. 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 6. PRISM data requirements for floodplain enhancement 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		√	√	√	√
Level 3 Effective	Increase in Fish Density		√	√	√	√

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

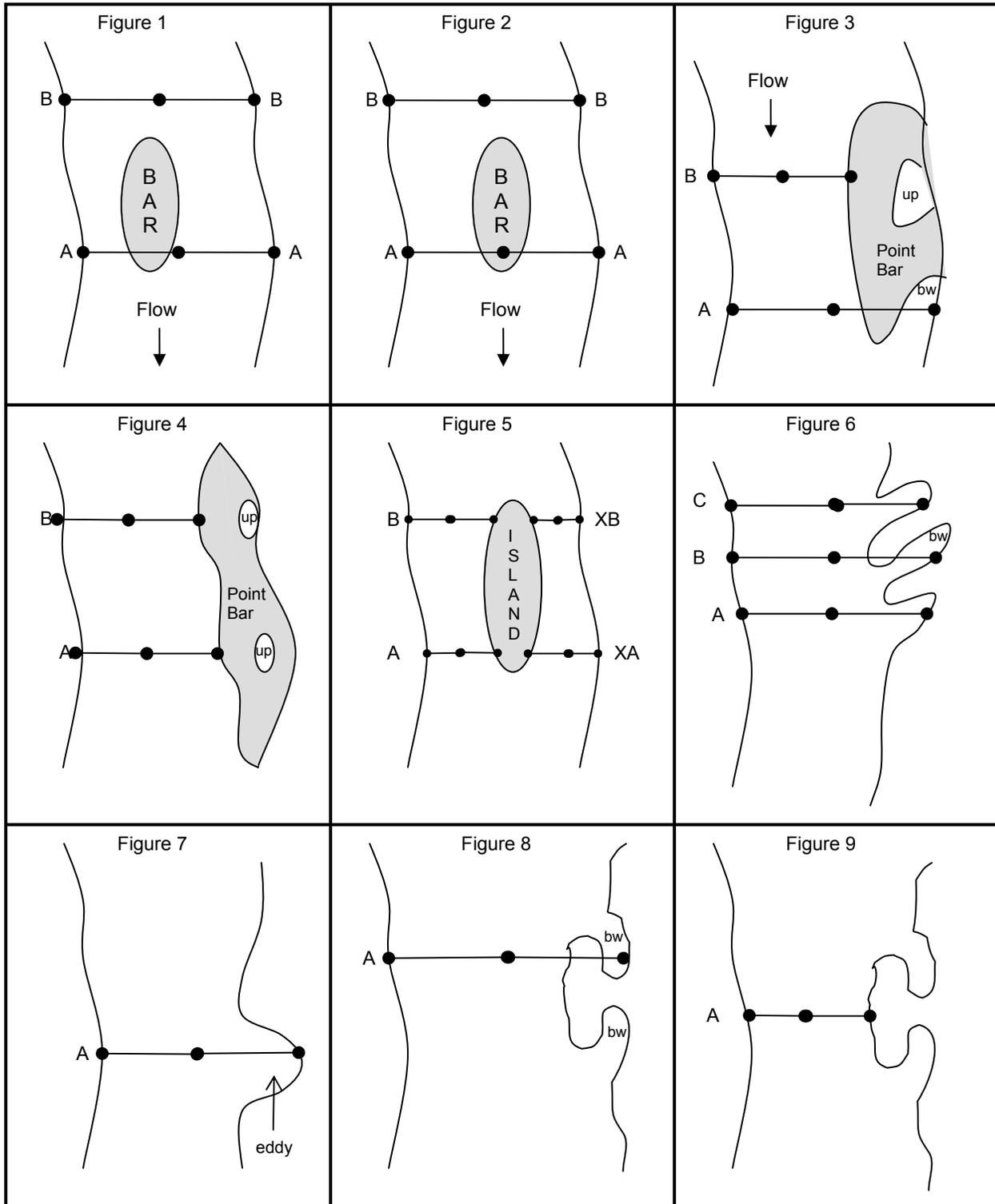
A gross estimate of a stream topographic survey could cost around \$12K-\$15K for a survey using three field technicians.

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APPENDIX A
Stream Measurement and Densimeter Reading Locations

TRANSECT MEASUREMENTS AND DENSIOMETER READING LOCATIONS



Notes:

- 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.