Scientific Protocol for Salmonid Habitat Surveys Within the Columbia Habitat Monitoring Program

2016 Version

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SAFETY REMINDER FOR ALL CHaMP SUMMER FIELD STAFF:

"No job is so important and no service so urgent that we cannot take time to perform our work safely."

---*Elliot Mainzer*, Administrator and Chief Executive Officer Bonneville Power Administration

BPA Driving Safety Reminder

Drive alert and remember these quick four tips of **GOAL** (Get Out And Look):

- Before entering your vehicle, look for obstacles in your path and plan how you will avoid them.
- If traveling with another employee, ask that person to be your spotter.
- Choose parking locations that will limit the risk of backing accidents.
- When possible, back into a parking spot so you can leave pulling out.

"Walking around your vehicle prior to backing is a best practice we can all use 24/7 at work, home and play. Your commitment to GOAL improves everyone's safety…." says Brad Bea, BPA's chief safety officer.

Report any accidents to your respective CHaMP crew leader or supervisor.

THINK SAFETY ALL THE TIME

SECTION 1: INTRODUCTION

1.1 Policy Background

The 2008 Biological Opinion (BiOp) on the Federal Columbia River Power System (FCRPS) identified offsite mitigation actions, largely in the form of habitat restoration and changes in land management, as a means to offset mortality imposed by the FCRPS on anadromous salmonids. In 2010 the Bonneville Power Administration (BPA) began development of the Columbia Habitat Monitoring Program (CHaMP) to meet FCRPS Action Agency (2010) programmatic prescriptions for habitat monitoring, and also to help meet adaptive management requirements and other prescriptions of the 2008 BiOp.

CHaMP (BPA Project 2011-006) is a fish-centric habitat status and trends monitoring program designed for implementation across the Columbia River Basin's salmon and steelhead populations. The CHaMP protocol measures the quantity and quality of, and changes in, stream habitat for salmonid fishes of interest under the BiOp. CHaMP is the result of collaboration among BPA, the National Oceanic and Atmospheric Administration (NOAA) and other regional fish management agencies to implement a tributary habitat condition assessment program. CHaMP was also designed to help measure habitat responses to land management and stream restoration actions by evaluating the effectiveness of restoration, rehabilitation, and conservation actions across the basin. In 2010, BPA specifically tasked the Integrated Status and Effectiveness Monitoring Program (ISEMP), one of its projects (Project No. 2003-017-00) with assessing and developing standardized monitoring protocols for fish and fish habitat in the Columbia River Basin, and recommending a habitat protocol for BPA-funded Columbia River Basin monitoring programs to adopt. Based on ISEMP's initial recommendations (Bouwes et al. 2010), BPA and several collaborating agencies, with technical and coordination assistance from ISEMP, began to build CHaMP through the development of a set of coordinated proposals.

To determine and define various elements of the CHaMP protocol, Bouwes et al. (2010, 2011) assessed the applicability of commonly used attributes in stream habitat monitoring protocols, reviewed fish habitat requirements in the context of stream habitat attributes and geomorphic processes, and assessed whether existing habitat protocols provided information that relates the quality of stream habitat to fish production. This culminated in a draft habitat monitoring protocol for projects that support the FCRPS and salmonid recovery planning.

The methods and approaches were field tested and revised by ISEMP during the summer and fall of 2010. At the same time, ISEMP data collected in the Wenatchee and Entiat subbasins since 2003 were analyzed. Finally, a rule set (see below) was used to evaluate all possible metrics and indicators envisioned during the protocol development process or that were documented in other protocols. Results from both field testing and data analyses were used to define and refine the list of metrics and indicators included in the CHaMP protocol in 2011 (Bouwes et al. 2011). The 2011 pilot year represented year one of protocol implementation under the CHaMP sampling design.

1.2 The Basis for CHaMP

Anadromous salmonids spawn and rear in most of the accessible streams of the Pacific Northwest, and it is reasonable to assume that the quality and quantity of habitat in these environments determines multiple population processes of these fishes. Tributary habitat monitoring programs are expected to describe the physical and biological characteristics of stream habitat across the range of these target species and both the development and success of management plans will in part be based on this information. This is predicated on the management community understanding how habitat characteristics change under different management scenarios, and how this change ameliorates vital parameters at different salmonid life stages. However, considerable uncertainties still exist as to how management strategies improve salmonid habitat to lead to recovery of listed species. While empirical models (e.g., regressions) may improve our understanding and help identify patterns, their ability to predict future outcomes under different management scenarios is limited. A mechanistic and process-based understanding has greater potential to extrapolate observed patterns across time and space. Therefore, monitoring programs must collect information that is rich enough to allow further discovery and testing of presently unknown and potentially important complex interactions from the watershed, population, and within watershed extents to salmonid population dynamics. At many of the locations where the CHaMP protocol is implemented fish surveys are also conducted, allowing for these fish-habitat relationships to be tested and developed.

CHaMP was designed to measure stream characteristics that impact fish performance. Ecologists often evaluate an organism’s response to its environment by measuring surrogates to fitness, such as growth, survival, and reproductive output. When combined with measures of organism abundance, these surrogates can be used to estimate population production, an informative population-level performance metric (Almodovar et al. 2006). The process of identifying indicators of habitat characteristics that affect salmonid performance begins by linking environmental factors to measurements of salmonid growth, survival, and production. Characteristics influencing salmonid performance monitored by CHaMP can be summarized as stream temperature, production, and morphology. Water quality can also influence fish performance, but the ability to monitor this is an extensive effort and CHaMP will defer to water quality monitoring programs to collect this information. Stream temperature, production, and morphology are influenced by the landscape, land use and stream restoration. Here we provide a very brief summary of how habitat responds to the landscape, and how habitat influences salmonid vital parameters. A more complete discussion was provided in the 2011 version of the CHaMP protocol document (Bouwes et al. 2011). More in depth discussions can be found in Spence et al. (1996).

1.2.1 Temperature

Temperature influences nearly every physiological process of an organism. For salmonids, this can be summarized as effects on consumption, respiration, processing of energy and waste, activity, and growth/development rates. These effects of temperature on juvenile and adult fish physiology are well documented in bioenergetics models (Hanson et al. 1997). Temperature, in turn, is influenced by hydrology, channel morphology, and riparian vegetation and is thus influenced by multiple processes that are influenced by land use, so temperature can be an excellent indicator of impairment. Variables affecting temperature include canopy cover, riparian vegetation, topography, stream width, bed material, channel morphology, and local climate, and can be measured during CHaMP assessments or via remote sensing data. Temperature can be measured with temperature loggers at fine temporal resolution and also at a finer spatial resolution with thermal infrared aerial photography (Torgersen et al. 2001). In CHaMP, water temperature is measured via loggers at all sites and the information will be modeled to extrapolate between sites.

1.2.2 Production

Measuring production across trophic levels in stream food webs is an enormous effort and impractical for rapid assessment programs so CHaMP evaluates proxies to this important driver of fish production. Production of food for fish is potentially determined by within-stream primary production, such as algal production, and terrestrial inputs such as riparian invertebrates. Factors driving primary production are nutrients, sunlight, substrate, flow regime, and food web dynamics. CHaMP does not measure primary production but rather some of these influences: we measure alkalinity and conductivity which can be indicative of parent bedrock material that is responsible for nutrient inputs, and we measure canopy cover, riparian vegetation types, and solar input to describe sunlight and terrestrial inputs. While we measure discharge at the site, continuous flows are measured by nearby stream gauges or estimated by models. A direct measure of the food source of salmonids may prove to be the most effective means to estimate food production. The main food source for salmonids is aquatic and terrestrial macroinvertebrates (Filbert and Hawkins 1995) with the majority of their food items consisting of invertebrates drifting in the water column (Cada et al. 1987; Romaniszyn et al. 2007). Thus, the collection of invertebrate drift is perhaps the most direct measurement of food availability (Filbert and Hawkins 1995) and is the approach used in CHaMP.

1.2.3 Channel Morphology

Channel morphology affects how and where salmonids forage and occupy refugia from water velocity, temperature, predators, and competitors. The distribution of channel attributes such as large wood, substrate, and fish cover also affects how fish make a living. For example, an effective foraging strategy is to maximize encounter rates with drifting invertebrates (high velocity) while minimizing energy expenditures through swimming (low velocity). Thus, salmonids will often hold in low velocity positions that offer searching access to high velocity zones such as the head of a pool, or behind boulders, cobble, and logs. These structures, along with overhanging banks and vegetation, may also provide refugia from avian, mammalian, and fish predators. In addition, juvenile salmonids may bury into gravels to avoid predators, extreme temperatures, and flows. These gravels are also important for spawners to deposit their eggs into. Fine sediments may fill interstitial spaces between gravels and suffocate eggs or prevent juveniles from concealing. Fine sediments may also reduce suitable substrate for invertebrates, and periphyton. CHaMP measures channel units and gradient as a course scale distribution of water velocities and depth. Stream topography is also collected and can be used to create hydraulic models to obtain fine scale resolution of velocities. For each channel unit, substrate type, large wood, fish cover (e.g., vegetation, undercut banks) are recorded. In fast water units, CHaMP measures the size of streambed particles to evaluate fish velocity refugia (e.g., cobble and boulders). In addition, the amount of fine sediment in pool-tails where salmonids generally build redds is also observed.

The factors described above cannot be viewed in isolation but represent the decisions salmonids must make within a day, season, or year to balance the trade-offs of where to feed, hide, rest, and spawn. Greater habitat complexity has a higher likelihood of containing the conditions needed and reducing the distance fish must travel to balance risks to predators, velocities, temperatures, and foraging. The relative distribution of depths, velocities, large wood, substrate, temperature, undercut banks, overhanging vegetation, and backwaters can be used to describe habitat complexity (Harvey 1998, Harvey et al. 1999). Knowledge of geomorphic channel type, channel unit type, and the distribution of channel units can approximate this information about how habitat complexity affects the survival of salmonid species (Bisson et al. 1988; Bisson et al. 2006).

1.2.4 Channel Dynamics

Channel dynamics are influenced by the rate of delivery of water and sediment, sediment size, gradient, geology type, tributary inputs and structures (e.g., large wood, beaver dams, and boulders). Therefore, geomorphic characteristics are created by the interaction of water and sediments within a valley type. How sediments and water are transported to the stream is another means by which land use can impact streams. Many variables can be measured to provide information on the various processes described above; however, rapid assessment approaches need to capture gross indicators of change due to land use activities. The major factors that these processes affect can be directly measured (e.g., temperature and discharge), but an indication as to why these factors are in their observed state will be more informative as to how land use is impacting streams and if restoration opportunities exist. Variables affecting geomorphic and hydrologic processes include sediment size and quantity, structure (e.g., large wood), gradient, discharge, channel topography, local climate and riparian vegetation.

A review of juvenile, spawner, and egg life stages of salmonids is used here to provide insight into factors that might be measured to describe habitat quality. Although habitat quality is important, habitat quantity can limit the production of populations as carrying capacity can be achieved very quickly when low amounts of adequate habitat is available or when populations are very high (density dependence). Habitat quantity is often defined with areal dimensions but territories, foraging opportunities, predator avoidance and thermal and velocity preferences can occur in three dimensions and thus volumes may be a more relevant description. Both habitat quality and quantity can be influenced by land management and stream restoration. Linking the information collected from CHaMP with a mechanistic and process-based understanding will aid in achieving these goals.

1.3 The CHaMP Protocol

CHaMP relies on a single protocol that emphasizes a systematic, programmatic approach to data collection and management – from equipment preparation through data QC/QA procedures – that is implemented across multiple jurisdictions. The CHaMP protocol is designed to maintain the rapid nature of existing stream habitat protocols and to collect data that fits within a geomorphological hierarchy, spanning spatial scales ranging from within-unit topographical features to channel units to geomorphic reaches to watershed and subbasin scales. The protocol is structured around describing salmonid habitat, not only in how it directly relates to the specific life history requirements of the salmonid species, but also in how land management and stream restoration might influence habitat. Thus, habitat is the nexus by which tributary actions defined under the 2008 BiOp result in changes in ESA listed salmon and steelhead population growth. The CHaMP protocol can be divided into two components: the survey design which describes how sites are distributed in space and when they are visited, and the response design or the methods used to collect data at a site.

1.3.1 Survey Design

The CHaMP survey design is constructed to detect status and trends of select habitat indicators at three spatial scales: 1) across all watersheds, 2) across salmon and steelhead populations, and 3) within each watershed (e.g., by valley type or geomorphic reach type).

Status is described relatively over these extents as a frequency distribution of the metric scores inferred from the spatial/temporal design with indicators derived from these distributions (e.g., mean, median, achievement of a particular criterion, spatial pattern, and differences among component watersheds). The absolute status is the extrapolation of this distribution to the spatial extent. The ability to estimate the status of a particular stream habitat indicator improves with an increase in the number of unique sites. At its simplest, trend is expressed as some underlying, consistent (e.g., linear) change over the duration of the study. The ability to detect a trend in a particular stream habitat indicator improves with site revisits through time. As more data are collected over time, it might be possible to describe patterns of change (e.g., wet vs dry years) in addition to an underlying linear change across these extents (e.g., improvements due to stream restoration).

CHaMP uses a survey design based on panels to achieve a reasonable balance in site allocation to meet status and trend objectives. Sites are selected based on a spatially balanced design (EPA's generalized random tessellation stratified, GRTS, Stevens and Olsen 2003, 2004) that distributes sampling effort across a stream network such that unbiased, representative samples can be collected at discrete monitoring locations. Within each watershed, half of the year's sites are allocated to an annual panel and half are allocated to unique sites. Over a three year period, CHaMP will generate a new "unique site" panel each year, but then repeat these three panels for future three year cycles. As a result, the annual set of trend sites becomes a set of sites to which a linear model can be fit in as little as three years, but also allows a sample size of 25 for a status estimate each year and about 50 for an aggregate three year status estimate. To capture both status and trend, monitoring must occur for three cycles of a three-year sampling panel, or at least 9 years. Sampling is conducted in wadeable, perennial streams below natural impassible barriers within Technical Recovery Team (TRT) population boundaries. Measurements collected at individual sites are used to derive the generation of site-level metrics from which watershed-scale indicators are constructed. The inference design describes the process used to estimate indicators for the watershed based on metrics collected at the sample sites. This may occur for a single time period resulting in a status estimate for the indicator or it may involve making estimates across multiple time periods when trends are of interest. CHaMP will characterize stream responses to watershed restoration and/or management actions in at least one population within each steelhead and spring Chinook Major Population Group (MPG) that has, or will have, "fish-in" and "fish-out" monitoring.

1.3.2 The Response Design

The CHaMP response design draws together methods from many existing protocols as well as recently developed approaches to collecting and analyzing temperature and channel morphology. The CHaMP response design falls into two major groups: collection of topographic data (X, Y, Z points) and collection of non-topographic habitat attributes (e.g., LWD, sediment, fish cover, etc.). CHaMP takes advantage of recent methods and technological tools such as GPS, total stations with flexible mapping software, LiDAR, photogrammetry, and sonar, which are easier to use and allow more accurate surveys of topography than previously available. Two field personnel will collect the topographic survey data, and a third person will collect the auxiliary habitat data.

Sampling occurs at sites that are approximately 20 times the bankfull width in length within a discrete geomorphic channel type (Montgomery and Buffington 1997, Beechie et al. 2006). A total station is used to delineate and record the perimeters of channel units to create a planform view of the site that depicts the arrangement of channel units. Channel units are classified based on a slightly simplified Hawkins et al. (1993) system. Using a hierarchical classification scheme allows summarization of channel units at different levels of resolution depending on the question asked, and allows comparison to other habitat classification schemes that may be used by other protocols (e.g., pools and non-pools). This information can be used to estimate areas and volumes of channel unit types.

The total station topographic survey is also used to generate a high resolution Digital Elevation Model (DEM) of the site. A total station survey requires two people. One person operates the survey instrument while the other person places a stadia rod and prism along topographic features. Approximately 500-1000 points are typically collected with the total station in a day of surveying. These points capture the major grade breaks in the streambed and bank topography. Gradient lines are used to capture distinct features such as top-of-bank, edge-of-water, and bankfull indicators. The spatial information collected during the total station survey is referenced to a known point (collected from GPS) established by the surveyors and compass-derived orientation.

As the site topography is being surveyed, the third crew member collects stream habitat attribute information (e.g., substrate composition, etc.) for each channel unit, and makes estimates of large wood, substrate type, undercut banks and other fish cover. This auxiliary habitat data provides distributional information and allows identification of interactions between channel morphology and structural attributes. For example, Chinook prefer to spawn in riffles located near large wood cover rather than in riffles with similar substrate characteristics but without cover. Crews measure 210 streambed particles in fast water units and fines in pool-tails. The sum of the channel unit level information can be summarized by unit type (e.g., pools) or by site, as is commonly done in other habitat monitoring protocols.

Habitat attribute information collected at the site level includes: macroinvertebrate drift, alkalinity, conductivity, temperature and stream discharge. Drift nets are placed above the site and collect drifting benthic and terrestrial invertebrates over the course of the survey. Discharge is estimated at a suitable cross-section using the EMAP protocol (Peck et al. 2001). Temperature probes for air and water are deployed to take hourly temperature for 1 or 3 years, depending on the watershed-specific temporal design that is used. Finally a site map is drawn for each site to document qualitative information such as human influences and disturbances, as well as benchmark locations, channel unit locations, and other distinguishing characteristics. Certain site level attribute information is collected at transects throughout the site. Information collected along transects includes an estimate of the amount of solar radiation entering the stream and the characteristics of a 10 m x 10 m plot of riparian vegetation, which is noted on both banks at these transects.

With the CHaMP response design, a spatially explicit representation of the site (3D map of the site with location of attributes such as wood and cover) is captured and stored digitally. Retrospective analyses at spatial scales finer than the reach, such as hydraulic jumps or channel units, are possible in the event that we discover more powerful fish-habitat relationships.

1.4 Metrics and Indicators

Metrics and indicators are the units of information most useful and relevant to making inferences and decisions about the management of salmon habitat. Metrics are discrete summarizations of reality resulting from the reduction or processing of measurements taken at a site within a particular temporal period, and differ from each other by the spatial and temporal scales, and by the level of scientific sampling design, used in their creation. Indicators result from the reduction of metrics across sites and temporal periods. In both cases, metrics and indicators are the common language among data collectors, scientists, and natural resource decision makers, even those involved in different monitoring programs. A measurement and related methodology was included in the CHaMP protocol if it were used to calculate a metric that met each of the following three rules:

1) *Information Content*: Habitat metrics and indicators must provide information directly related to salmonid productivity, including survival and growth, as documented by peer reviewed literature, modeling, or existing data analysis.

2) *Data Form*: Habitat metrics and indicators must provide statistical information with robust data quality. The data generated for a prospective metric must be repeatable, detect heterogeneity, and have adequate properties for modeling/statistics (e.g., variance distributions must meet statistical assumptions for modeling or testing).

3) *Feasibility*: Habitat metrics and indicators need to be generated by field tools or software that are readily implementable as of the time field testing in fall 2010 (i.e., does not rely on future technological advances). Feasibility is also bounded by the need to fit all survey work within a three-person-day field survey at 80-90 percent of all sites likely to be encountered.

1.5 Data Management and QC/QA

Topographic survey data and auxiliary data will be captured using separate data logger applications. Auxiliary data (wood loading, substrate composition, etc.) will be captured by a single crew member using a handheld data logger. As the crew member completes sampling they will enter data into forms under the Site, Channel Unit, and Transect tabs. For categorical data, the appropriate value will be selected from a pull down list. For numeric data, values will be entered using an on-screen numeric pad. Numeric values that fall outside an expect range will produce a warning to the crew member that asks the crew member to review the value and to either accept the value as a correct value or enter a new value. This warning system will limit the potential for entering erroneous data; however, it does not prohibit crew entering of extreme values. Additional warnings will be triggered if required values are not entered for a given data form. A detailed user guide will be provided for the auxiliary data entry application.

Data quality assurance review will be conducted on a daily basis by crew members and on a weekly basis by the crew supervisor. The QA review will test for completeness, outliers in numeric data, and outliers in basic summary metrics. At the end of each day, the crew member will be prompted to verify the number of channel units, total wood pieces, and number of drift samples. Additionally, the crew will be prompted to review any values recorded as a missing value. Next the crew will view and verify any numeric outliers. Finally, a short series of graphs will be presented to allow the crew to verify graphical data against their mental image of the site. At the end of each week, the crew supervisor will perform a similar audit of the data.

It is the responsibility of CHaMP crews to process their own topographic survey data. Data quality assurance for the topographic survey data takes place at four checkpoints within the flow of data from origination on the total station to data storage and web availability (Figure 1). These checkpoints will reduce the likelihood of data errors compounding throughout data processing. The four checkpoints are:

1. Data origination (total station)
2. End of day data review (total station/data logger)
3. End of week data processing and review (laptop)
4. Centralized database checks (CHaMP data system)

The crew lead is responsible for creation and submission of the original point file, a lines file (breaklines), a clean TIN, and a quality assurance report (table in geodatabase). These should be produced within one week of initial data collection. Having field crews create, review, and edit TINs is part of the quality assurance process and helps ensure that data have been collected properly since, in our experience, conducting a topographic survey results in a vivid memory of the site's morphology. Thus, the field crew is in the best position for making the appropriate edits to the TINs to reflect the site (e.g., connecting of gradient breaklines, removal of false "dams", etc.). We believe that giving field crews this responsibility creates a sense of ownership of the data, a visual goal, and a feedback loop that will improve future surveys.

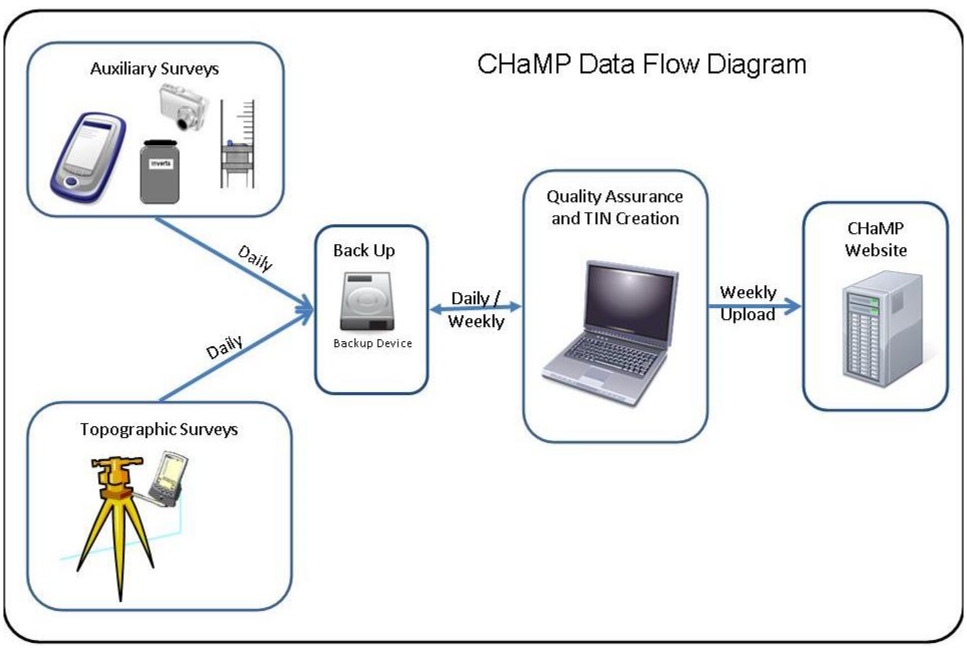

Figure 1. The flow of data within CHaMP.

1.5.1 The Importance of Data Integrity

The products of the CHaMP surveys (e.g., DEMs) will allow for the calculation of more channel geomorphology metrics than will be used by CHaMP as indicators (e.g., bankfull width, cross-section width, wetted width, width-to-depth ratio, floodplain width, etc.). These additional metrics will allow CHaMP channel geomorphology data to be used by other monitoring programs. The development of high resolution DEMs will provide richer and more accurate and precise information for several applications, including hydraulic modeling, fish habitat models, and sediment budgeting, than cross-sectional approaches (Wheaton 2008, Wheaton et al. 2010). In addition, the creation of DEMs does not require reoccupation of monumented cross-sections (Brasington et al. 2000), and is more flexible in the ability to extract information that is comparable to other protocols (e.g., a cross-section at a desired resolution can be extracted from a DEM) with greater repeatability (Wheaton 2008).

In addition, the biological and physical reach information collected by CHaMP will be used in models that estimate fish responses to the environment with a mechanistic basis. The synthesis of this information will provide metrics of fish performance that are meaningful and intuitive. Therefore, strict adherence to the CHaMP protocol, techniques, and error management (QC/QA) is essential to ensure that data are collected and processed correctly, that values fall within acceptable ranges and tolerance limits, and that file formats are ‘clean’ and ready for use in additional CHaMP data analysis steps and/or modeling processes such as using DEMs for hydraulic and fish habitat models, and for sediment budgeting.

SECTION 2: SAMPLING DESIGN AND SITE SELECTION

The CHaMP monitoring design is comprised of four component designs as advocated by NCEAS (2010):

1) The spatial design, which describes how sites will be selected for monitoring from the spatial domain;
2) The temporal design, which describes sampling frequency and revisit schedule for monitoring sites;
3) The response design, which describes what and how measurements are taken and how site-level metrics are calculated, and
4) The inference design, which describes how indicators are estimated from site-level metrics across a population and time period.

This section provides details on the spatial and temporal design.

CHaMP monitoring watersheds were selected to represent at least one population within each steelhead and spring Chinook MPG which have, or will have, “fish-in” and “fish-out” monitoring as identified in RPA 50.6 (AA/NOAA/NPCC RM&E Workgroup 2010). Selection of monitoring sites within watersheds follows the GRTS design that aims to achieve spatial balance between a simple random sample and a systematic sample (Stevens and Olsen 2003, 2004). The GRTS algorithm results in samples that are distributed across a target population that is defined based on monitoring objectives. The CHaMP target population will be drawn from the National Hydrography Dataset Plus (1:100k scale) using the following criteria:

- Wadeable streams
- Perennial streams
- Below natural impassable barriers to salmonid migration
- Within TRT population boundaries
- Within the union of TRT population boundaries where multiple populations exist
- Accessible within institutional crew safety constraints.

The CHaMP statistician will work with project collaborators to finalize sample allocation during the spring of the initial sampling year.

2.1 Site Allocation

2.1.1 Spatial Design

CHaMP monitoring watersheds will be allocated funding to sample 25 sites in each year, with some exceptions for watersheds with overlapping TRT populations. Sampling effort will be balanced across valley type (source, transport and response valley segments) and landownership since some indicators and site accessibility are dependent upon these factors. Crossing two landownership levels by three valley types creates six unique subsets of the target population, called multi-density categories. All potential sites within a CHaMP watershed will be allocated to a multi-density category within the target frame. Based on the distribution of sites across the categories, samples may be allocated to ensure even distribution of the sample effort across categories and to ensure statistical power for indicator estimation. Under the default scenario each multi-density category will receive 4 samples.

2.1.2 Temporal Design

The temporal design for CHaMP monitoring watersheds will follow one of two possible panel designs, where a panel is defined as a set of sites that have the same revisit schedule. For watersheds where trend estimation is of primary concern, a single annual panel design will be used. Under this design all 25 sites will be revisited on an annual basis. A split panel design (Figure 2) will be used for watersheds where there is a need to balance status and trend estimation. Under the split panel design 13 sites will be revisited on an annual basis and 12 sites will be allocated to each of three rotating panels that will be visited once every three years.

The motivation of these two temporal designs stems from a need to balance the power to 1) estimate status of the population at a point in time and 2) estimate trends in the population across time. While status is best estimated by sampling as many sites as possible across the broadest geographical distribution, trends are best estimated by repeated sampling of the same set of sites over time. Establishing two or more panels provides the possibility to balance priority of status estimation versus trend estimation.

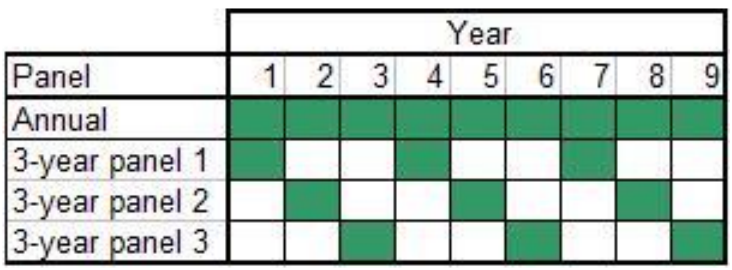

Figure 2. The split panel design to be used by CHaMP in watersheds where status and trend evaluations need to be balanced.

2.2 Site Evaluation

The goal of site evaluation is to relate on-the-ground reality to the sample frame and to assess conditions that may limit a field crew's access to sites. When attributing the sample frame (during the two previous steps) sites in the sample frame are assigned to a multi-density category based on one or more attributes derived from GIS. However, the GIS layers may not accurately represent on-the-ground reality and therefore during site evaluation a local biologist evaluates sites to verify that they lie within the range of the target population and that they were correctly assigned to a multi-density category. If a site was incorrectly assigned, the site is rejected from sampling and the error is noted. The site evaluation process does not aim to "correct" site attributes determined from the GIS layer; rather it provides information about error in the sample frame and supports statistical procedures to account for underlying error in the sample frame. Evaluations of sites relative to the sample frame are unlikely to change and therefore only need to be performed once.

The second objective of site evaluation is to assess conditions that may limit the ability of field crews' to access the site. The two primary concerns are crew safety and landowner permission. Each institution may have its own policies regarding field crew safety and sites should be evaluated against the institutional constraints of the field crew who will be conducting field sampling. Collaborating agencies must document any institutional safety constraints and get approval for these constraints from the CHaMP coordinator to ensure the adequacy of the final sample design.

Private landownership may also limit access to individual sites. Prior to sampling sites that require access through private lands, access permission must be obtained directly from the landowner. Private landowner permission must be clearly documented. Access conditions may vary from year-to-year and sites that are scheduled for revisiting may need to be re-evaluated prior to each visit.

Site evaluation will be completed following “A Field Manual of Scientific Protocols for Site Evaluation within the Columbia Habitat Monitoring Program” published by ISEMP in 2011.

SECTION 3: SURVEY WORKFLOW

This section describes an idealized workflow for a three member survey crew. The specific workflow of an organization or crew may further depend upon the number of crew members and availability of data loggers and other sampling equipment. Auxiliary workflow refers to data collected (i.e. channel unit attributes) that are independent from the topographic survey (total station and prism rod). Topographic survey workflow will vary depending on the complexity and size of stream as well as surveyor/rodman experience.

1) Locate and establish the bottom of site.
2) For new sites, two people identify bankfull elevations, measure bankfull widths, and determine the width category. At revisits, crew members identify bankfull elevations. Width category will be predetermined at revisits.
3) Two members (auxiliary and rodman) lay out the site transects and identify/flag channel units. Meanwhile, the total station operator (gunner) establishes and surveys new benchmarks at new sites and locates and re-occupies benchmarks at revisits. When the rodman completes laying out the site, he/she returns to assist gunner with benchmarks and begins the topographic survey.
4) Auxiliary Workflow:
    a. After laying out the site and while at the top of site, establish drift nets and collect water chemistry and top of site marker information.
    b. Work downstream collecting transect information (photos, solar input, and riparian).
    c. Proceed upstream collecting all channel unit level information including: ocular substrate, fish cover, wood, pool tail fines, and undercut banks. At the top of site, check drift nets.
    d. Work downstream collecting pebble count measurements and measure discharge.
    e. While at the bottom of site, collect benchmark, monument, and bottom of site information.
    f. Draw site map, establish/collect information on water temperature loggers, and collect control point information.
    g. When complete, collect drift nets and assist topographic survey crew with brush control or an additional rod.
5) Topographic Workflow:
    a. After surveying benchmarks, traverse to stream and survey points along the bottom of site cross-section (transect 1).
    b. Rodman works up one side of the stream collecting a combination of edge of water, top of bank, and toe of bank points until there is no longer a line of site between the total station and prism.
    c. Rodman works back downstream collecting thalweg, topographic, and channel unit points within the stream channel. For larger streams, only sample half of the channel.
    d. Rodman works up opposite side of the stream (see b.)
    e. Fill in additional in-channel points (islands, bars) and capture topographic points in the floodplain.
    f. Rodman reviews survey on total station. Gunner checks backsight and traverses to new station location.
    g. Repeat steps a-f until entire site is effectively surveyed. Finish by surveying points along the top of site cross-section (transect 21) and checking backsight.

SECTION 4: SITE LAYOUT

References: Harrelson et al. (1994).

Equipment: Flagging, rebar, monument caps, hammer, identification tags, measuring tape, GPS, compass, and map.

4.1 Locating New Sites

Objective: Determine the location for establishing the bottom and top of the site.

Step 1. Navigate to the X-site location using provided coordinates.

i. The X-site location is the mid-point of a kilometer-long sampling area.

ii. The X-site must be within the stream channel. If your coordinates do not fall within the stream, navigate to the closest adjacent point along the stream channel and consider this your X-site location.

Step 2. Establish the bottom of site location.

i. The bottom of site location represents the downstream-most extent of the site survey, which is ideally the X-site.

ii. The bottom of site may be shifted up or downstream from the X-site as long as the entire site falls within the one kilometer sampling area.

   a. A site should not contain inflowing tributaries. Shift your site to avoid tributaries contributing > 16% of the total stream flow when possible.

   b. If your site is very long (width category ≥ 22 m), shift the bottom of site downstream of the X-site. This will ensure the site does not extend past the 1 km sampling area.

   c. Place the bottom of the site at a channel unit break when possible. Never establish the bottom of site in the middle of a pool.

   d. Shift the bottom of site to be contained within one channel class if the site falls within a distinct boundary between 2 channel classes (e.g., mouth of bedrock canyon opening to broad alluvial valley). Do not shift the site to avoid man-made obstacles such as bridges, culverts, rip-rap, or channelization.

iii. Record the bottom of site GPS coordinates at the center of the wetted channel.

Step 3. Identify bankfull elevation.

The bankfull elevation is the location along the stream banks where the stream flow fills the channel to the top of the banks and the water begins to overflow onto the floodplain (Leopold et al. 1964).

Identify the bankfull elevation using the indicators defined by Harrelson et al. (1994) in Table 1.

Several indicators should be examined to properly determine bankfull elevation.

i. Indicators should be more distinguishable at non-constrained channel types where the tops of point bars, changes in substrate, and permanent vegetation may be the most reliable indicators.

ii. In constrained channels, especially those dominated by boulders and bedrock substrate, indicators may be more difficult to identify. Under these circumstances the crew may have to depend on stain lines, or move further up or downstream of a site to find reliable indicators.

Table 1. Types of indicators used to determine the bankfull elevation at a site.

Indicator	**Description**
Change in Slope	The change from a vertical bank to a horizontal surface is the best identifier of bankfull, especially in low-gradient meandering streams. Many banks have multiple breaks, so examine banks at several sections of the site for comparison. Slope breaks also mark the extent of stream terraces which are old floodplains above the active bankfull elevation. Terraces will generally have soil structure and perennial vegetation. Avoid confusing the elevation of the lower terrace with that of bankfull; they may be close in elevation.
Top of Point Bars	Point bars consist of bed material deposited on the inside of meander bends. The top elevation of point bars usually indicates the lowest possible bankfull stage. Multiple point bar elevations may be left from flows both above and below the bankfull elevation.
Change in Vegetation	Look for the lower limit of perennial vegetation on the bank or a sharp break in the density or type of vegetation. Often willow and alders form root lines near the bankfull elevation. The lower limit of mosses or lichens on rocks or banks, or a break from mosses to other plants may also help identify the bankfull elevation.
Change in Bank Materials	Look for changes in bank particle size, usually from coarse particles to a finer particle matrix (which is often associated with a change in slope).
Undercuts Banks	Look for bank sections where the perennial vegetation forms a dense root mat. Feel up beneath this root mat and estimate the upper extent of the undercut. This is usually slightly below bankfull stage. Undercut banks are best used as indicators in steep channels lacking floodplains.
Stain Lines	Look for water lines on rocks that indicate where rocks are frequently inundated. Stain lines are often left by lower, more frequent flows, so stain lines should only be used to assist in identifying bankfull along with another indicator or when no other indicators exist at a site.

4.2 Site Layout for New Sites

Objective: Determine width category, place transects, establish site markers, benchmarks, and benchmark monuments.

Step 1. Determine the site width category and site length.

i. Measure and record the bankfull width perpendicular to the bankfull channel at the bottom of site.

ii. Measure and record 4 additional bankfull width measurements at distances upstream (as measured in a straight line from the center of the wetted channel), equal to the first bankfull width measurement.

iii. Average the 5 bankfull width measurements and consult Table 2 to determine the site width category and site length.

iv. *Note*: If one of the five measurements falls where there is an island (≥ bankfull elevation), exclude the portion of the island ≥ bankfull from your width measurement.

Table 2. Width category and site lengths according to the average bankfull width determined during site layout.

Average Bankfull Width (m)	Width Category (m)	Site Length (m)
≤ 6	6	120
> 6 and ≤ 8	8	160
> 8 and ≤ 10	10	200
> 10 and ≤ 12	12	240
> 12 and ≤ 14	14	280
> 14 and ≤ 16	16	320
> 16 and ≤ 18	18	360
> 18 and ≤ 20	20	400
> 20 and ≤ 22	22	440
> 22 and ≤ 24	24	480
> 24 and ≤ 26	26	520
> 26 and ≤ 28	28	560
> 28	30	600

Step 2. Lay out the site.

Each new site will consist of 21 transects spaced at intervals equal to the site width category (Table 2).

i. Locate the center of the main wetted channel at the bottom of the site and establish transect 1, placing transect flags perpendicular to the wetted channel.

ii. Stretch a tape from the center of the main wetted channel at transect 1 a distance equal to the site width category and establish transect 2. All tape measurements are straight line distances (i.e., do not measure along the thalweg or bend the tape around meander bends).

iii. Continue this process of establishing transects upstream until 21 transects have been established. Transect 21 will always be the top of site for newly established sites.

iv. In braided sections, follow the center of the main channel (e.g., the channel containing the greatest amount of the total flow).

Step 3. Establish a minimum of 3 benchmarks.

Properly established benchmarks are integral to re-occupying a survey coordinate system at subsequent visits. Establish benchmarks that can be surveyed repeatedly over many years. New site surveys establish benchmark locations and the coordinate system that will be used for future surveys. Therefore, it is imperative that benchmarks be established with the following criteria: stability, geometry, and inter-visibility.

Stability refers to placing the benchmarks in locations that will be unaltered by natural processes or humans. Geometry refers to placing benchmarks in a large equilateral triangle as far apart as possible. Inter-visibility refers to the ability to see each benchmark location from the other 2 benchmark locations.

i. Characteristics of optimal benchmark locations include (Figure 3):

   a. Locations outside of the active stream channel.

   b. The ability to acquire a reasonable GPS signal (accuracy must be less than 15m).

   c. Locations distributed as far apart as possible while still visible to one another. Attempt to distribute benchmarks as far along the entire length of a site as possible.

   d. Arrangement in an equilateral triangle. Ideally the stream will be contained within the equilateral triangle but this may not always be possible. If a stream has open space on one side, utilize it to the fullest extent. An equilateral triangle that extends the entire site length on one side of the stream is more ideal that a triangle that only spans ¼ the length of a site on both sides of the stream.

   e. Locations that can be re-occupied by a tripod. For example, do not place benchmarks too close to trees, fence posts, or other structures that would preclude proper set up of a total station.

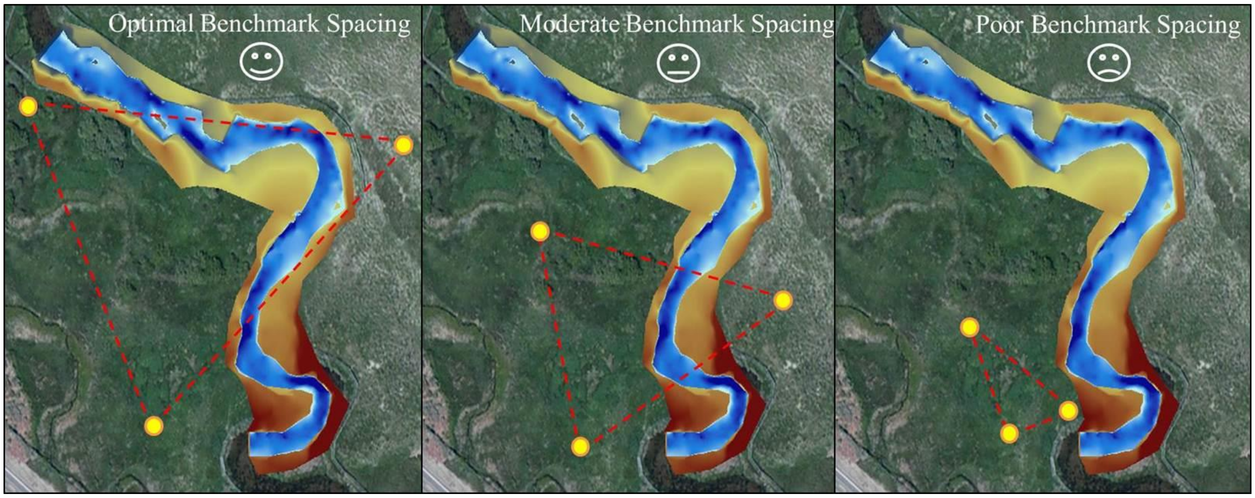

Figure 3. Examples of optimally, moderately, and poorly spaced benchmarks. Optimally placed benchmarks are as far apart as possible while still maintaining an equilateral triangle, are inter-visible, and extend the length of the site. Poorly placed benchmarks are close in proximity, in a non-equilateral triangle, and not inter-visible.

ii. To establish benchmarks, drive a 5/8" piece of rebar (> 16" long) into the ground using a rock or a hammer, leaving approximately 3" of rebar above ground. Place a survey cap on rebar and establish a ring of rocks surrounding the benchmark to make it visible for future surveys.

   a. At some sites such as wilderness sites or sites located on private land, alternative, less conspicuous benchmarks may be required. Alternative benchmark techniques include:

      i. Rock etching: etch an 'x' into bedrock or a large boulder. Establish the 'x' in a discrete location.

   b. When using alternative benchmark techniques, include a detailed description (e.g., X is on the south side of the boulder, 6 cm from the ground; benchmark is located at the northeast corner of the concrete pad). All benchmarks need to be visible, stable, and easily located with detailed instructions.

Step 4. Record benchmark data.

i. Record benchmark number and type (e.g., capped rebar, chiseled boulder, or other). If 'Other' is selected as the benchmark type, be sure to include a detailed description of the benchmark in order to relocate the exact position for future surveys.

   a. Label all new benchmarks with a three digit number corresponding to the year they are established. For new benchmarks established in 2016, benchmark numbers will begin with "6" followed by two digits denoting the benchmark number (i.e., bm601, bm602, bm603, etc.).

ii. Record GPS coordinates, elevation, and accuracy for all three benchmarks. The GPS unit must be placed directly on top of the benchmark when capturing coordinates.

iii. Record the bank location (left or right) for each benchmark. Left and right banks are determined by looking in the downstream direction.

iv. Record the monument number (Step 5) that will be used to relocate the benchmark. Record notes that may be useful when relocating the benchmark.

Step 5. Establish benchmark monument(s).

Monuments are used to relocate benchmarks. Optimal monuments are located at easily identifiable, permanent features in the landscape. These features include large trees, large boulders, and artificial structures (e.g., fence posts, buildings, etc.). Because benchmarks will be spread out, it may be necessary to establish multiple monuments. Typically, a monument should not be greater than 50 m from the benchmark it is associated with. Monuments are numbered sequentially, independent upon year established (e.g., 1, 2, 3, etc.).

For each monument established:

i. Securely nail or attach a tag to the monument. Record the site number and monument number on the tag.

ii. Record the monument number.

iii. Take and record a bearing and distance from the monument to the benchmark(s).

iv. Record GPS coordinates and accuracy.

   a. Coordinates should be in UTM coordinate system and include UTM zone, easting, northing and accuracy.

v. Describe the location of the monument(s).

   a. Record bank location (left or right) and the distance from the monument to the nearest stream bank.

   b. Include a general description of the site monument location and any other information that would be useful for relocating the monument. If the monument is a tree, record the common name of the tree species and diameter at breast height (DBH).

vi. Take a photo of the monument. Include enough of the surrounding environment in the photo to locate the monument at a later date.

Step 6. Establish bottom and top of site markers.

Site markers are used to relocate the top and bottom of the site.

i. Place one site marker in line with the bottom transect and one in line with the top transect in a place that will not be eroded or disturbed through time. Site markers can be rebar with attached tag (preferred) or a tag nailed or tied to a tree. Make sure that markers are visible and can be relocated at a later date. Rebar site markers at the bottom and top of site can also be surveyed in and used as additional benchmarks or control points.

ii. Record GPS coordinates and accuracy for bottom and top site markers as well as which bank the marker is located (right or left).

iii. Record the marker type (rebar or tree) and distance upstream or downstream from the bottom or top transect. Record a distance of 0 m upstream or downstream for markers that line up directly with transects. Also record the distance inland from the nearest bank to the marker.

iv. Take a photo of each site marker. Good site marker photos should include flagging on the site marker and have a wide enough field of view to relocate the markers and bottom or top transects on subsequent visits.

v. Record any notes that may be useful when relocating the bottom and top site markers (e.g., "Bottom of site marker is located on a large cottonwood tree, 5 m upstream from the bottom of the site and 7 m from the bank on river right.").

4.3 Site Layout for Revisits

Objective: Re-establish site using previously established site markers, width category, benchmarks, and monuments.

In order to relocate previously sampled sites, crews will be provided with the following information and resources:

1) Driving and hiking directions
2) Site maps, scouting notes and maps (if available)
3) Site photographs
4) UTM coordinates for monuments, benchmarks, site markers and temperature loggers

Step 1. Determine bottom of site location.

i. Re-establish the exact bottom of site (transect 1) location from the previous survey.

ii. To lay out the site the same as in previous years, it is imperative that the bottom of site lines up with that of the previous survey. Use existing site information (site marker, site map, UTM coordinates, and photos) to determine the location.

Step 2. Lay out the site.

i. Each revisit survey will be contained within the previously established bottom (transect 1) and top (transect 21) of site boundaries (Figure 4A). The location of transects 2 through 20 will vary somewhat between surveys due to changes in channel morphology and measurements.

ii. Locate the center of the wetted channel at the bottom of site and place the flag on the stream bank in line with the transect running perpendicular to the channel.

iii. Following the center of the wetted channel, stretch the tape from transect 1 upstream a distance equal to the previously established site width category. Establish transect 2.

iv. Continue this process of establishing transects upstream until you reach the top of site.

   a. It is imperative that the exact top of site from the previous survey is located correctly. Use existing site information (site marker, site map, UTM coordinates, and photos) to determine the location. Place transect flags at the top of site perpendicular to the channel.

v. If the measured site layout results in a site length that would be longer than previous visits (i.e., < 21 transects fit between the original bottom and top of site locations), establish the second to last transect flag that fits before the original top of site and establish transect 21 at the original top of site (Figure 4B). Measure the distance between the last transect and the top of site (transect 21). Record the new site length.

a. Record "Not measured" for all transect measurements (photos, solar input, and riparian structure) that cannot be measured due to < 21 transects at revisit sites.

vi. If the measured site layout results in a shorter site length than previous visits (> 21 transects fit between the original bottom and top of site), establish transect 20 where it is measured and establish transect 21 at the original top of site (Figure 4C). Measure the distance from transect 20 to the original top of site (transect 21) and record the new site length.

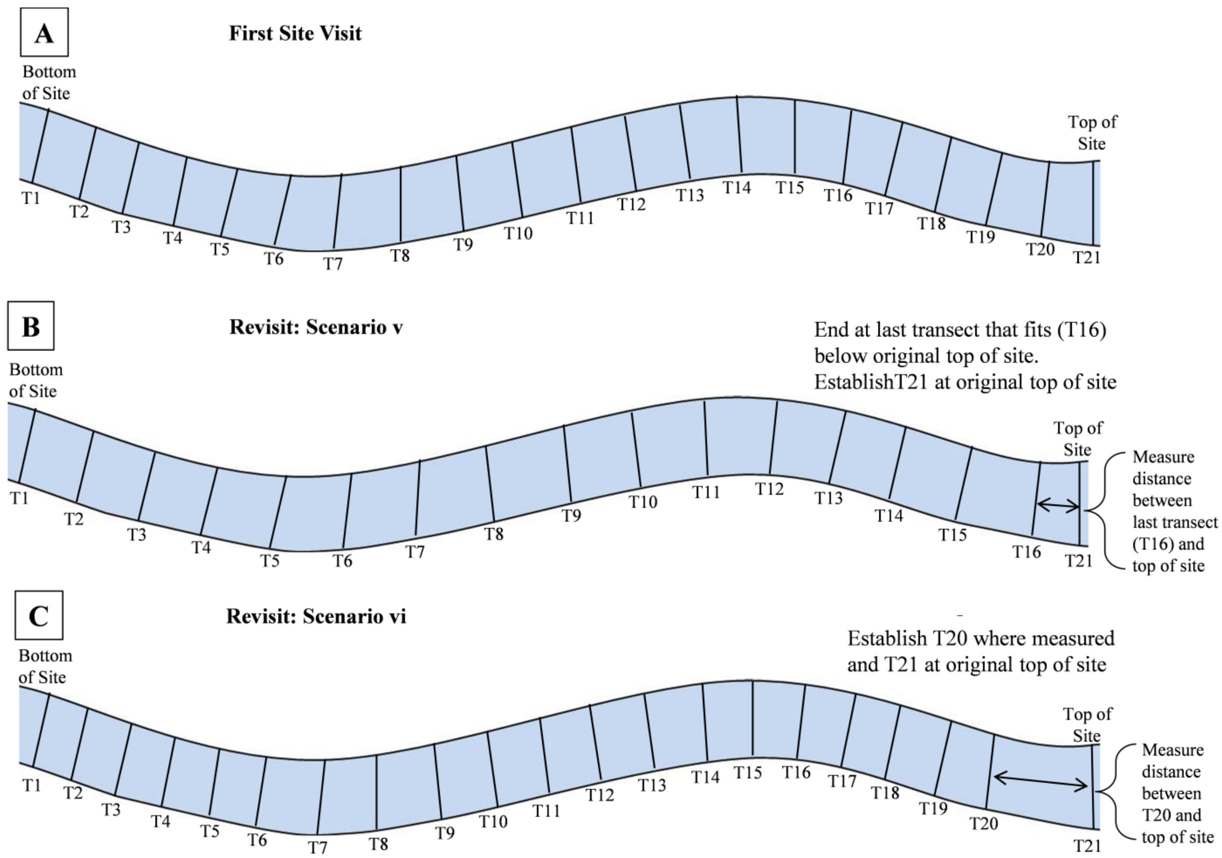

Figure 4. How to adjust transect spacing when a revisit site layout is either too long (B) or short (C) and does not match the initial site visit length (A). Once the initial bottom and top of site have been established, these locations will be used for the bottom and top of site (transect 1 and 21) on all subsequent visits.

Step 3. Document changes.

i. While laying out revisit sites, transect locations may not match previous surveys due to changes in channel characteristics between surveys. Document any significant changes observed between consecutive sampling events (i.e., the main channel being in a different location).

Step 4. Locate previously established benchmarks, monuments, and site markers.

i. Locate benchmarks and record data.

   a. Locate all previously established benchmarks and verify information pertaining to benchmark number, benchmark type, bank location (left or right), the closest monument number, distance and bearing, as well as the distance from the bottom of site (transect 1) to the benchmark.

   b. Determine the quality and condition of each benchmark (e.g., whether it will be an active or retired benchmark during the revisit survey). Benchmarks that have been physically disturbed will be "retired". A retired benchmark is one which the spatial location has been compromised. Remove the benchmark and establish a new benchmark.

   c. Note that before retiring a benchmark, survey the benchmark to validate that the horizontal error exceeds 0.05 m or vertical error exceeds 0.03 m. If benchmarks have poor spatial configuration but their spatial location has not been compromised, leave the benchmarks and establish additional benchmarks.

   d. Record GPS coordinates and accuracy for newly established benchmarks but do not record new GPS coordinates for previously established benchmarks.

ii. Locate previously established monuments and record data.

   a. Locate all previously established monuments and verify information pertaining to monument type, bank location, distance to bank, and where applicable, tree species and DBH.

   b. If monument is missing, establish a new monument and record all information associated with monument.

   c. Take a new photo of each monument. Include enough of the surrounding environment in the photo to locate the monument on subsequent visits.

iii. Locate previously established site markers and record data.

   a. Locate top and bottom of site markers and verify information pertaining to the marker type and bank location.

   b. If site marker is missing, establish a new marker and record all information associated with the new marker.

   c. Take a new photo of each site marker. Include flagging on the actual site marker and have a wide enough field of view to locate the marker on subsequent visits.

SECTION 5: CHANNEL TOPOGRAPHIC SURVEY

Equipment: Total station (with tribrach and data logger), tripods, prism rod with topographic foot, backsight setup, tape measure, notebook, pencils, radios (2), flagging, umbrella or total station cover.

Objective: Conduct a topographic survey of the stream channel and surrounding floodplain.

The topographic survey consists of using a surveying instrument to collect a series of points and lines that capture topographic features within the stream channel and surrounding floodplain. Each point is attributed with a location (X, Y, and Z coordinates) and a description code. Points with the same description codes can also be connected to make lines. These points and lines are used to construct a Digital Elevation Model (DEM) that represents a continuous topographic surface of the channel topography.

During the topographic survey it is the responsibility of the person operating the prism rod to efficiently survey points and lines that accurately represent the channel's topography. The person operating the survey instrument captures these point locations during the survey. Table 3 provides descriptions of common terms used for topographic survey methods.

Refer to Appendix I for an overview of control network strategy. Total Station operating procedures are found in the Total Station Procedures Manual for the Columbia Habitat Monitoring Program.

5.1 Establishing a New Site Survey

Reference: Section 2.1: Total Station Procedures Manual.

Step 1. Choose a benchmark or control point for the first station setup.

i. Optimal locations for the first setup include:

   a. A vantage point that offers maximum line of sight to the channel for conducting the topographic survey, thereby minimizing the number of additional setups required for completing a survey.

   b. Line of sight to all three benchmark locations.

   c. Over a benchmark if both 'a' and 'b' are met.

ii. Control points refer to temporary or permanently monumented locations that are occupied by and/or used to orient the survey instrument during a survey.

   a. Control points can be monumented by placing nail and whiskers in the ground, by etching a small "X" on a stable rock, or by establishing a piece of capped rebar. If the control point is one that is likely to persist until the next visit to the site (i.e., outside the active channel), consider using capped rebar. Control points are uniquely identified using the code "cp" and numbered sequentially in the order they are utilized during the survey (cp501, cp502, cp503 etc.). Benchmarks used as permanent control points are given the corresponding benchmark code (e.g., bm501, bm502, or bm503).

iii. After establishing an optimal location for the first station setup point, turn on, level, and measure the height of the instrument above the first occupied control point or benchmark.

Step 2. Start a survey and establish the first station setup location on the instrument.

i. Open the survey template file on the total station. The template has preloaded codes that may be used during the survey (Table 3). Name the survey file using the following convention: SiteID-Date-Organization (e.g., CBW05583-007395-20160710-ODFW). Use hyphens in place of underscores, spaces, or decimals when naming file.

ii. Navigate to the station setup menu of the survey instrument and initiate the setup routine. Choose to set up on a known point, and enter the appropriate code for the first setup point.

a. The first occupied point will always be labeled “cp501” unless it is established over a benchmark (whereas it would be labeled bm501, bm503, or bm503).

b. The first occupied point of a new survey will always have the following coordinates: 3000 northing, 2000 easting, and 1000 elevation. These coordinates establish the first point in the assumed coordinate system (Table 3).

Step 3. Establish a backsight and orient the survey instrument.

i. The orientation of the survey instrument is established by shooting to a backsight. The first backsight used during the initial setup of the instrument can be established over any of the permanently monumented benchmarks or control points. Establish a backsight over the benchmark/control point that is farthest from the occupied point.

ii. Set up and level a tripod with tribrach and prism or survey rod with bipod and prism over the benchmark or control point used for backsighting.

iii. Make sure that the total station is pointed at the backsight.

iv. Check backsight and record error in the field notebook. Make sure the error is not greater than 0.030 m for horizontal error and 0.015 m for vertical error. Repeat procedures if backsight error is unacceptable. See Section 5.4, Step 2 for backsight error troubleshooting steps.

Step 4. Survey in the benchmarks and any visible control points.

i. Survey in each benchmark and control point.

ii. Extra care should be taken to level the tripod or bipod and prism when shooting benchmark points as these points will be used to re-establish the location and orient the survey instrument during future surveys of the site.

iii. Begin survey following the methodology outlined in Section 5.5: Point Collection Methods.

Table 3. Descriptions of commonly used terms used for topographic survey methods.

Term	Description
Assumed Coordinate System	Fictional coordinate system of a survey established by attributing the first occupied point of a new site survey with the following coordinates: 3000 northing, 2000 easting, 1000 elevation. All new site surveys will be attributed an assumed coordinate system during the initial survey.
Backsight	Survey routine used to establish a basis for horizontal, vertical, and angular measurements within the surveying instrument. Backsight checks are used to assure the continued accuracy of a survey.
Benchmark	A permanent control point (typically capped rebar) used to establish new site surveys, and establish revisit site surveys. There are a minimum of 3 benchmarks established at each site.
Control File	File containing benchmarks and control points from previous surveys that are used to re-occupy the established coordinate system.
Control Point	Any permanent or temporary location used to set up or orient the surveying instrument. Includes any station setup, benchmark, and backsight locations.
Established Coordinate System	Spatially accurate coordinate system (Universal Transverse Mercator) established after the first survey of a site. All revisit site surveys must re-occupy the exact same established coordinate system as the first survey.
Foresight	A foresight is a control point that will be used for a future station setup location.
New Site Survey	The topographic survey of a new site where an established coordinate system has not been previously established. New benchmarks and control points must be established. The survey is conducted in an assumed coordinate system.
Re-occupy	To orient the surveying instrument into an established coordinate system for revisit site surveys using previously existing benchmarks and control points.
Resection	Survey routine used to re-occupy an established coordinate system by surveying at least 2 known benchmarks or control points from a centralized, previously unsurveyed point.
Revisit Site Survey	The topographic survey of a previously surveyed site where benchmarks and control points have been established. A Revisit Survey is conducted in a previously established coordinate system.
Stake Point	Survey routine used to check the accuracy of benchmark and control point locations when re-occupying an established coordinate system. Also used to re-locate the position of benchmarks and control points.
Traverse	Survey routine used to move the surveying instrument from one control point to the next. Done by 1) surveying a new control point (foresight) where instrument will be moved, 2) moving instrument to new location, and 3) backsighting to previous station setup location.

5.2 Revisit Site Surveys

Reference: Section 2.2: Total Station Procedures Manual.

When revisiting a site it is imperative to be in the same coordinate system as the previous site survey(s). This is accomplished by re-occupying the previously established coordinate system using the permanently monumented benchmarks. In order to correctly re-occupy an established coordinate system during a site revisit, at least two known points must be inter-visible from each other or from a common point. The preferred revisit survey scenario involves setting up the survey instrument over a benchmark, backsighting to another benchmark, and conducting an accuracy check to the third benchmark. Make a concerted effort to clear vegetation or obstructions to make all benchmarks inter-visible from each other. Unforeseen factors may make it difficult or even impossible to locate benchmarks or see them from other benchmark locations. Therefore, you need to perform the appropriate station setup routine depending on the scenario encountered in the field. Utilize Figure 5 to determine the correct station setup routine option for re-occupying an established coordinate system during a revisit site survey. Refer to Appendix K for a benchmark evaluation dichotomous key.

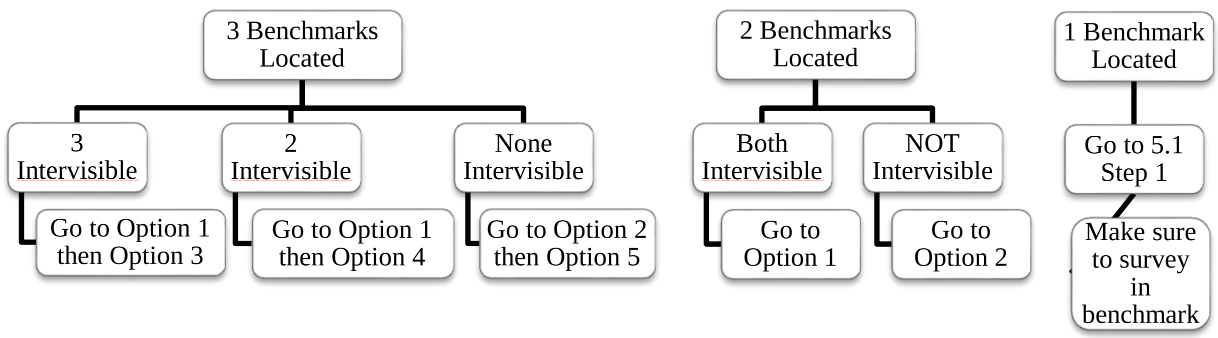

Figure 5. Revisit site scenarios used to determine the correct station setup routine after relocating benchmarks. Note that if no benchmarks are relocated, establish new benchmarks and proceed to Section 5.1, Step 2.

5.2.1 Site Revisit Survey Options

Option 1: At least two benchmarks are inter-visible.

Reference: Section 2.2: Total Station Procedures Manual

Step 1. Start a revisit survey by establishing the first station setup.

i. Set up surveying instrument over a benchmark that is visible from at least one other benchmark.

ii. Open the survey template file on the total station. The template has preloaded codes that may be used during the survey (Table 4). Name the survey file using the following convention: SiteID-Date-Organization (e.g., CBW05583-007395-20160710-ODFW). Use hyphens in place of underscores, spaces, or decimals when naming files.

iii. Import the site control file which contains previously established benchmarks and control points. The site control file will have the naming format **SiteID-Control-2016.**

iv. Navigate to the station setup menu of the surveying instrument and initiate the setup routine. Choose to set up on a known point and select the appropriate point from the list (i.e., bm1). Note that during each site revisit a new numbering sequence is used for new benchmarks and control points to differentiate when they were established (i.e., bm601 for 2016).

Step 2. Establish a backsight over a known point to orient the survey instrument.

i. The orientation of the survey instrument is established by backsighting to a second benchmark. Set up and level a tripod with tribrach and prism or survey rod with bipod and prism over the benchmark used for backsighting. Select the appropriate backsight point from the menu (i.e., bm2).

ii. Make sure that the total station is pointed at the backsight.

iii. Check backsight and record error in the field notebook. Make sure the error is not greater than 0.050 m for horizontal error and 0.030 m for vertical error. Repeat procedure if backsight error is unacceptable. If survey crew is unable to establish revisit survey within error thresholds, see Section 5.4, Step 3 regarding revisit backsight checks.

iv. If necessary, establish additional benchmarks as described in Section 4.2, Step 3.

v. If backsight errors are acceptable and three benchmarks are inter-visible, go to Option 3. If only 2 are inter-visible go to Option 4.

Option 2: At least two benchmarks exist but are NOT inter-visible.

Reference: Section 2.4: Total Station Procedures Manual.

Step 1. Start a revisit survey by establishing the first station setup using the resection procedure.

i. Locate a point that is visible from at least two other benchmarks and set up the surveying instrument.

ii. Open the survey template file on total station. The template has preloaded codes that may be used during the survey (Table 4). Name the survey file using the following convention: SiteID-Date-Organization (e.g., CBW05583-007395-20160710-ODFW). Use hyphens in place of underscores, spaces, or decimals when naming files.

iii. Import the site control file which contains previously established benchmarks. The site control file will have the naming format **SiteID-Control-2016.**

Step 2. Perform a resection following procedures outlined in Section 2.4 of the Total Station Procedures Manual.

i. Make sure the error is not greater than 0.050 m for horizontal error and 0.030 m for vertical error. Start surveying. If three benchmarks exist but only two were used to resection, proceed to Option 4. If benchmarks cannot be resectioned within the error tolerance thresholds, begin surveying using procedures outlined in Section 5.1, Step 2. When establishing this new survey, make sure to pull in existing benchmarks from the previous survey. Keep the names consistent, retire the existing benchmarks and establish new ones.

ii. Be sure to survey all existing benchmarks and make sure that at least three benchmarks are inter-visible as described in Section 4.2, Step 3.

iii. If all three benchmarks were used during the resection, start surveying. If only two benchmarks were used during the resection, go to Option 5.

Option 3: Use Stake Point routine to survey third benchmark.

Reference: Section 2.3: Total Station Procedures Manual.

i. Complete Option 1.

ii. From the first station setup location over the benchmark, use the Stake Points routine to "stake out" the third benchmark and evaluate the error results.

iii. If the third benchmark is not within the error tolerance but the other benchmarks are, retire third benchmark and establish a new one.

iv. Start surveying!

Option 4: Use Stake Point routine to survey third benchmark during the topographic survey.

Reference: Section 2.3: Total Station Procedures Manual.

i. Complete Option 1.

ii. As the topographic survey is conducted you must find an opportunity to use the Stake Points function to survey the third benchmark.

iii. If the third benchmark is not within the error tolerance but the other benchmarks are, retire third benchmark and establish a new one.

iv. Start surveying!

Option 5: Use Stake Point routine to survey third benchmark.

Reference: Section 2.3: Total Station Procedures Manual.

i. Complete Option 2.

ii. Immediately use the Stake Points procedures to survey the third benchmark or as the topographic survey is conducted you must find an opportunity to use the Stake Points function to survey the third benchmark.

iii. Start surveying!

5.3 Traversing

Reference: Section 2.5: Total Station Procedures Manual

Objective: To move the surveying instrument from one station setup location to the next, a traverse is required to propagate the coordinate system. This next station setup location is called a foresight and is typically a control point.

Step 1. Traverse to the next station setup location and move instrument.

i. Check the backsight one last time and record error in the field notebook. Repeat procedures until the backsight error is within the acceptable limits. If error exceeds threshold, follow instructions outlined in Section 5.4.

ii. Assemble the second tripod or bipod over the control point that will be the foresight (i.e., cp502). Record the prism height above the point (rod height).

iii. From the current station setup location (cp501), survey in the new control point using the 'Traverse' routine.

iv. Moving forward: If you are using two tripods you will now have one tripod at the instrument and one tripod at the foresight. Remove the instrument from the tribrach, place it in the case, and move to the foresight. At the foresight, remove the prism from the tribrach and install the instrument (cp502). Check level bubbles and measure height of instrument. Install the prism on the tribrach at the previous station setup location (cp501). Check level bubbles and measure height of prism.

Step 2. Occupying the second station setup location (Figure 6).

i. With the instrument set up and leveled on the second station (cp502), the orientation of the survey instrument is established by shooting to the backsight (previous station setup location; cp501).

ii. Make sure that the total station is pointed at your previous station setup location (cp501) and conduct a backsight.

iii. Check backsight and record error in the field notebook. Make sure the error is not greater than 0.030 m for horizontal error and 0.015 m for vertical error. Repeat procedures if backsight error is unacceptable (see Section 5.4 for backsight error troubleshooting steps).

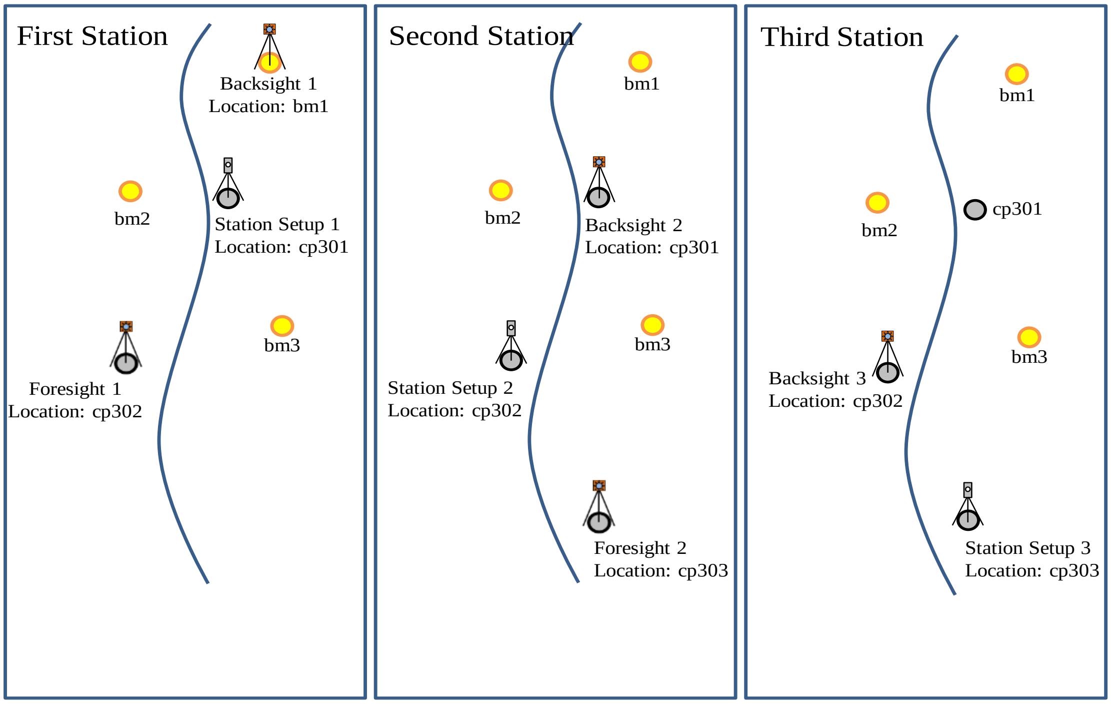

Figure 6. Illustration depicting station setup, backsight and foresight locations for the first station setup, after traversing to the second station setup, and after traversing to the third station setup.

5.4 Backsight Checks

Reference: Section 2.6: Total Station Procedures Manual.

Horizontal, vertical, and angular errors can occur during surveying due to a number of issues. Therefore it is important to periodically perform backsight checks to ensure that the survey is within the allowable error constraints. Performing regular backsight checks also limits the total number of points that need to be resurveyed should a problem arise.

Step 1. Perform a backsight check:

i. For every 50 to 100 points collected. Opportune times to perform a backsight check include when the rod person is taking a break and/or struggling through vegetation to position themselves for their next point.

ii. If the survey instrument or tripod legs have been bumped or knocked out of level. Make sure to check that the instrument is centered over point and re-level station before checking backsight.

iii. If the instrument has been exposed to a noticeable shift in temperature over the course of the survey (e.g., heating up in the sun).

iv. Before and after moving the survey instrument.

v. Before closing the survey.

Step 2. During a backsight check, if horizontal error exceeds 0.030 m or vertical error exceeds 0.015 m for new sites, conduct the following checks.

i. Re-measure the height of rod and the height of instrument and check that they were recorded correctly within survey instrument. Re-check backsight error.

ii. If error remains unacceptable, re-level the survey instrument, conduct the setup or traverse routine again, and re-check the backsight error.

iii. If error persists, double-check that the currently occupied point number and the backsight point number are entered correctly.

iv. If backsight error is unresolved once the above checks have been conducted, move survey instrument back to the previous successfully occupied station setup location. Conduct setup routine and survey in a new control point. Move and set up survey instrument on the newly surveyed control point and check backsight error.

Step 3. When establishing a revisit survey, if horizontal error exceeds 0.050 m or vertical error exceeds 0.030 m upon setup, conduct the following required checks in addition to those steps outlined above in Step 2, i-iii.

i. Check occupied point and backsight point coordinates. Compare the coordinates in the surveying instrument.

ii. If possible, backsight to an alternate known point (benchmark or control point) and check error values.

iii. If error persists once the above have been checked, set up instrument over an alternate known point (benchmark or control points) and check backsight errors using the other benchmark locations.

iv. If unable to reduce error values once all above checks have been conducted, record error values in field notebook and begin survey using procedures outlined in Section 5.1, Step 2. When establishing this new survey, make sure to pull in existing benchmarks from the previous survey. Keep the names consistent, retire the existing benchmarks and establish new ones.

5.5 Point Collection Methods

Objective: Capture X, Y, and Z coordinates as points and lines that collectively represent the topographic surface of the stream channel and floodplain.

Many topographic surveys are time-limited, thus topographic points and lines must be collected efficiently and strategically to maximize the quality and utility of the DEM. The number of survey points collected is dependent on the size and complexity of the site. Complex topography should be represented with a higher density of points (approx. 1,000-1,200 points) compared to more simple planar topography (500-600 points). Larger sites may have more points overall but generally have less topographic complexity and a lower density of points.

Collect survey points at locations that represent changes in slope (inflection points). When capturing streambed topography, avoid capturing elements of bed roughness (e.g., substrate). Instead, focus effort on capturing the bedform of the channel. Extend survey points far enough into the floodplain so that the areal extent of the survey encompasses all large and small side channels in areas where lateral migration may occur.

Survey points and lines are attributed with a description code that is used to further represent features in the stream channel (Figure 7). Use the topographic descriptions in Table 4 to identify and code survey points and lines throughout the site.

Points: Points are used to capture changes in topography that are not captured by lines. Use points to capture non-linear features including general topographic features and channel unit boundaries.

Lines: Lines are connections between two or more survey points and are used to efficiently capture visible contours or breaks in the stream channel topography. Lines are best used where there are identifiable linear features such as the edges of water, and tops and toes of banks.

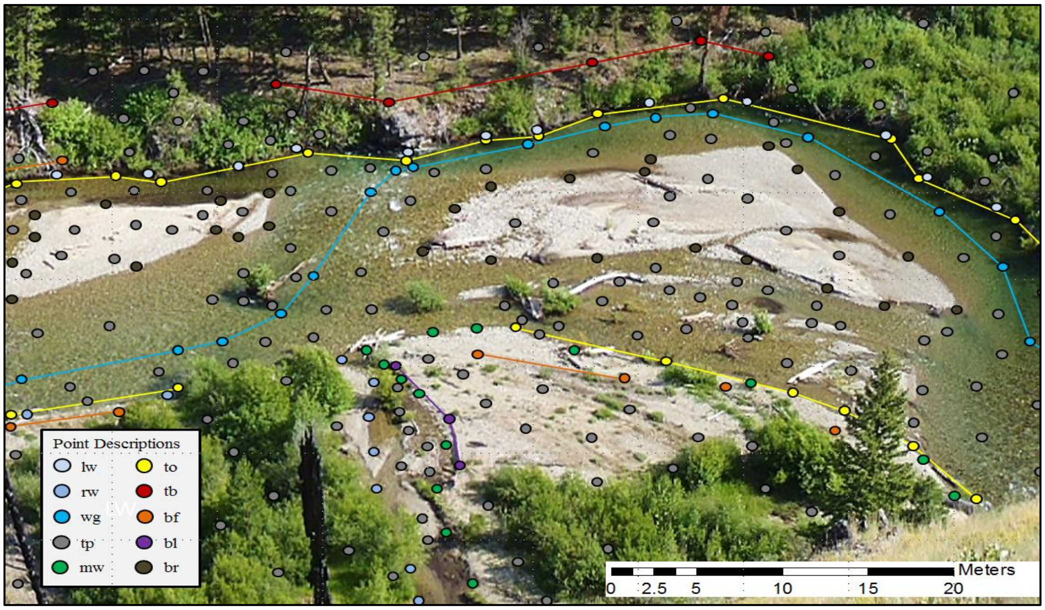

Figure 7. Representation of topographic points and descriptions used to capture the topography of the stream during surveys.

Table 4. List of codes used to identify unique points and lines in the topographic survey. Note that some codes are required for all CHaMP surveys.

Description Code	***Name***	***Feature Type***	***Required***	***Definition***
Water Surface Features				
lw	Left edge of water	Line or Point	Yes, Minimum of 50	Lines or points describing the elevation of the left wetted edge of the channel.
rw	Right edge of water	Line or Point	Yes, Minimum of 50	Lines or points describing the elevation of the right wetted edge of the channel.
mw	Mid-channel island	Line or Points	Yes, If island exists	Lines or points describing the wetted elevation of mid-channel qualifying islands (see Section 6.1).
br	Mid-channel bar	Line or Points	No	Lines or points describing the wetted elevation of mid-channel bars, large boulders, and non-qualifying islands.
ws	Water surface	Points	No	Points describing the water surface elevation above the stream bed at overhanging banks and mid-channel locations.
Channel Features				
bf	Bankfull	Line or Point	Yes, Minimum of 20	Lines or points describing the bankfull elevation.
bl	Breakline	Line	No	Other gradient breaklines as needed.
in	Inflow point	Point	Yes	Point at the upstream (top) end of the site indicating the inflow point of the thalweg.
out	Outflow point	Point	Yes	Point at the downstream (bottom) end of the site indicating the outflow point of the thalweg.
tb	Top of bank	Line	Yes	Lines describing the top of bank elevation.
to	Toe of bank	Line	Yes	Lines describing the toe of bank, or the line separating the active stream bed from the bank. Toe locations can be in and out of the water.
tp	Topography	Point	Yes	Points describing general channel topography.
u#	Channel unit	Point	Yes	Point describing channel unit perimeter within the wetted channel (named *u1*, *u2*, etc.).
wg	Thalweg	Line or Point	Yes, Minimum of 20	Lines or points describing the longitudinal thalweg profile.
Control Network				
cp#	Control point	Point	Yes	Control points used as station or backsight setup locations (*cp501*, *cp502*, etc.).
bm#	Benchmark	Point	Yes, Minimum of 3	Established benchmarks (*bm501*, *bm502*, etc.).
bos/tos	Control point	Point	No	Control points (rebar) used to define the bottom (*bos*) and top (*tos*) of site location markers.

Bottom and Top of Site Cross-Sections

Bottom and top of site cross-sections define the downstream and upstream extent of the topographic survey and provide a clean start and finish for the survey (Figure 8). The bottom of site cross-section is at transect 1 and the top of site cross-section is at transect 21.

i. The bottom of site cross-section at transect 1 must have a point indicating the outflow point at the thalweg coded *out*.

ii. The top of site cross-section at transect 21 must have a point indicating the inflow point at the thalweg coded *in*.

iii. Cross-sections must have a minimum of 9 survey points. Required point descriptions include inflow or outflow points (*in*, *out*) and left and right edge of water points (*lw*, *rw*). If bankfull, top of bank, and toe of bank (bf, tb, to) features exist at these cross-sections, it is important to collect these points with the proper description.

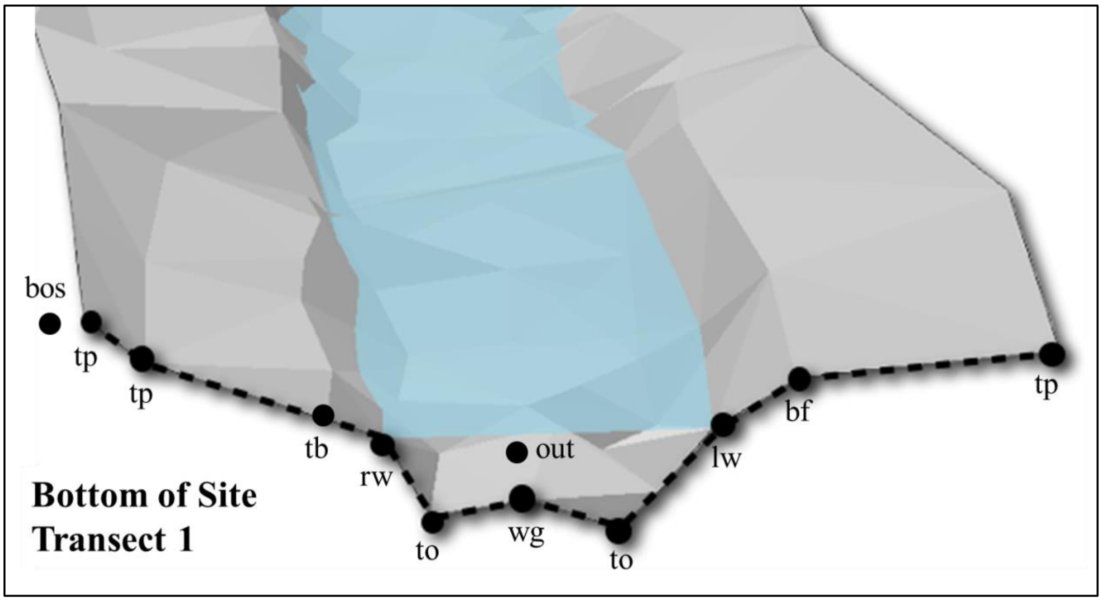

Figure 8. Channel cross-sectional view showing proper delineation of the bottom of site cross-section at transect 1.

Water Surface Features – *lw, rw, ws, mw, br*

Wetted surface feature codes are used to represent the planform and elevation of the water surface.

Left and right wetted edge of the channel – *lw, rw*

i. Left and right wetted edge features represent locations where the water surface elevation comes in contact with the stream bed or bank.

ii. Always survey *lw* and *rw* points on the furthest outside perimeter of the main channel or side channels. Use alternative codes to describe the edge of water for islands (*mw*) and bars (*br*) on the inside perimeter of the main channel and qualifying side channels (Figure 15).

iii. Survey *lw* and *rw* points as either lines or points. Lines make the survey processing easier to interpret and help to create better topographic surfaces.

iv. In streams that are flat and straight, fewer points will be needed to adequately represent the wetted channel edge (approximately 50 points per edge). Add more points to the edge of water for streams that feature a complex planform and water surface elevations. Complex edge of water areas should be collected using lines.

Wetted edge of mid-channel islands – *mw*

i. Mid-wetted (*mw)* island points and lines are used to indicate water surface elevations surrounding qualifying mid-channel islands.

ii. Only survey *mw* points or lines at locations representing the wetted perimeter of qualifying islands (length ≥ average bankfull width and completely surrounded by water; see Section 6.1).

Wetted edge of mid-channel bars – *br*

i. Bar (*br*) points and lines are used to indicate water surface elevations surrounding mid-channel bars, non-qualifying islands, and large boulders.

ii. Survey enough *br* points at the wetted edge of mid-channel bars and non-qualifying islands to provide a general representation of their wetted perimeter.

iii. Place topographic points (*tp)* on mid-channel bars and non-qualifying islands to represent the topography above and below the water surface elevation.

Water surface – *ws*

i. Water surface points (*ws*) are used to represent locations where the water surface elevation is above the stream bed (Figure 9A).

ii. Survey *ws* points at locations where edge of water points (*lw/rw*) are not appropriate such as at overhanging banks. Also survey *ws* points at mid-channel locations where the lateral water surface elevation is not uniform (i.e., pitched riffles; Figure 9B).

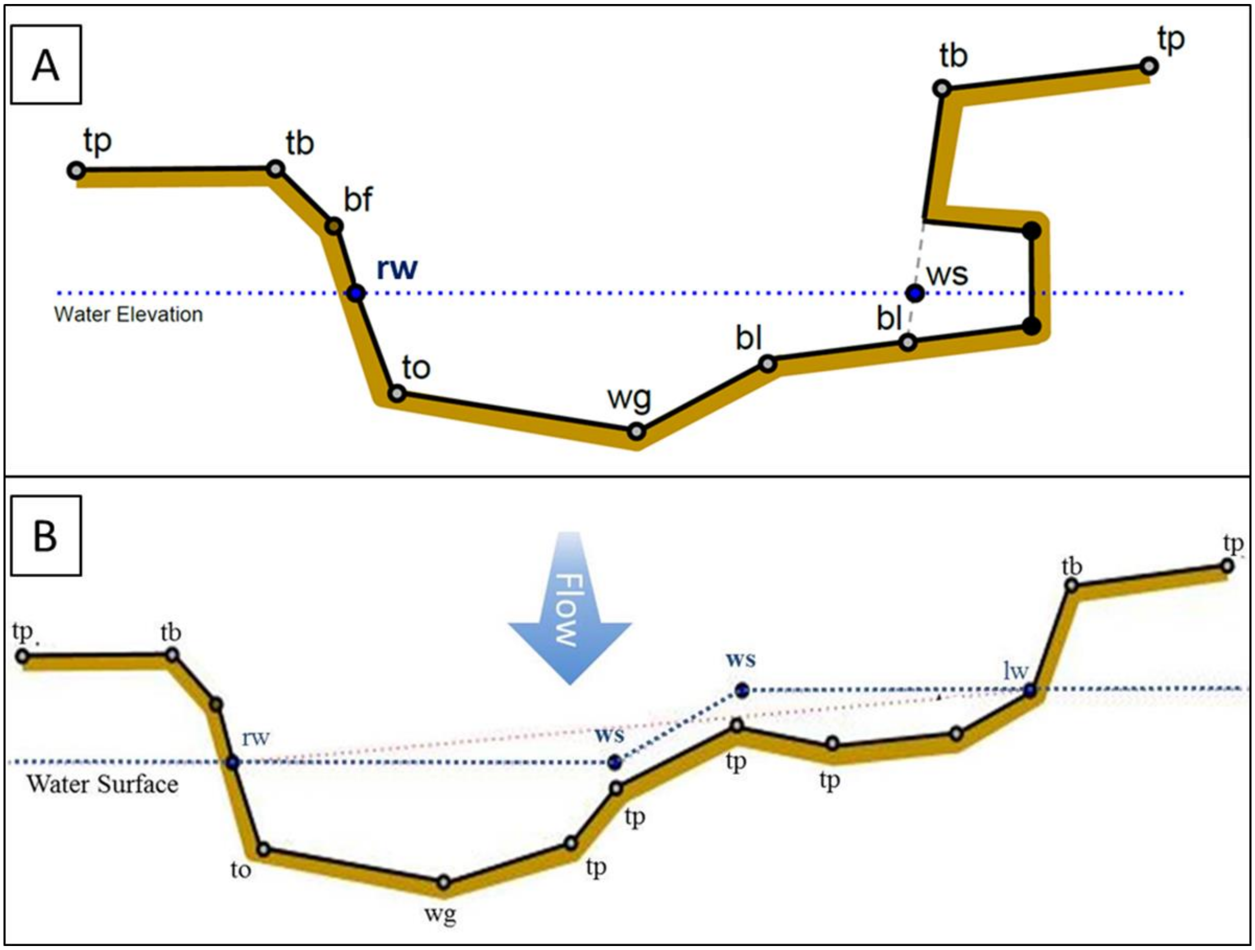

Figure 9. Channel cross-section indicating how water surface points (*ws*) are used to represent A) the water surface elevation at overhanging banks and B) mid-channel water surface gradient changes (i.e., pitched riffles).

<u>Top and Toe of Bank Features – *tb, to*</u>

Top of bank – *tb*

i. Top of bank lines are used to accurately represent convex gradient breaks that occur where steeper stream banks transition to flat floodplain-like features (Figure 10).

ii. In general, top of bank lines will run parallel to the channel but at times may run perpendicular to the channel on more complex banks.

Toe of bank – *to*

i. Toe of bank lines are used to represent the bottom of the stream bank where the stream bed (typically courser substrate) and bank (typically finer substrate) meet. These concave gradient breaks occur where the stream bed transitions into a steeper stream bank.

ii. The toe of bank can be both inside and outside of the water.

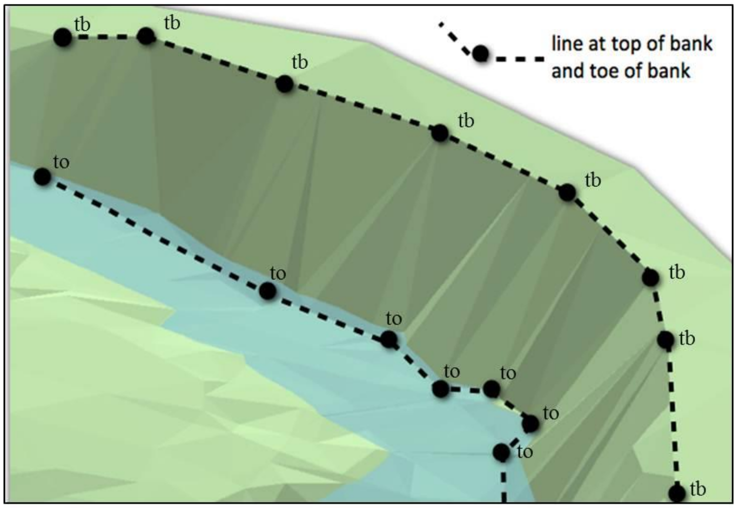

Figure 10. Channel view showing proper use of top of bank (*tb*) and toe of bank (*to*) lines.

Bankfull elevation - *bf*

Survey bank features that are indicative of the bankfull elevation (Table 1). Bankfull features can be surveyed using points or lines (Figure 11).

i. Use lines to survey bankfull features along consistent gradient breaks. These lines should be surveyed where stream banks transition to flat floodplain like bank features that are consistent with the bankfull elevation, and anywhere that the bankfull elevation represents a continuous linear feature in the landscape.

ii. Use points to survey bankfull features where the bankfull elevation is identifiable but does not appear as a continuous linear feature in the landscape.

A minimum of 20 bankfull points are required to be surveyed throughout the length of the site at locations that have good bankfull indicators as described in Table 1.

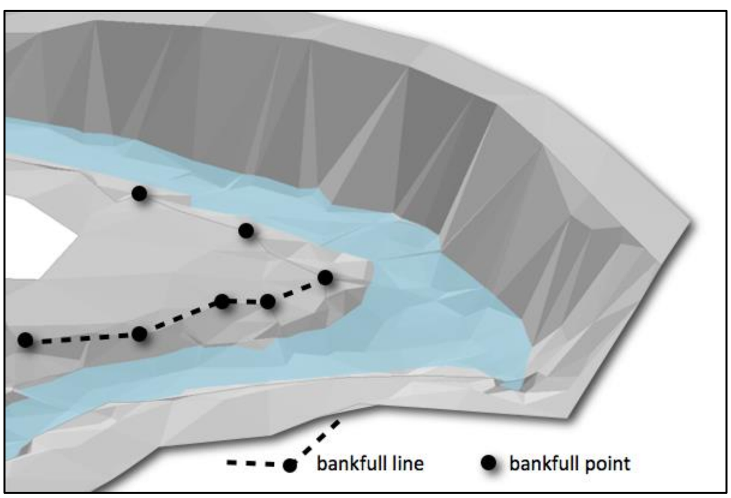

Figure 11. Channel view of lines and points representing the bankfull elevation.

Main Channel Thalweg - *wg*

The thalweg is the deepest point of the wetted channel with the most continuous flow. Survey thalweg (*wg*) points and lines at inflection points that accurately represent the thalweg profile (Figure 12). Take a minimum of 20 points throughout the site.

i. Use lines to survey the thalweg profile on sections of channel when it is identifiable as a line running roughly parallel with the channel. Thalweg lines should extend the distance of the site in very small streams (usually 6 m wide or less) and contain enough points to capture inflection points in the thalweg (Figures 12 and 13).

ii. In steeper streams dominated by rapids and cascades and in some plane-bed streams, the thalweg profile will often be discontinuous. In this situation, survey the thalweg profile using a series of points (Figure 13).

iii. Only label *wg* points and lines in the main channel. Use breaklines (*bl*) and/or topo points (*tp*) to capture the thalweg in all large and small side channels (Section 6.1).

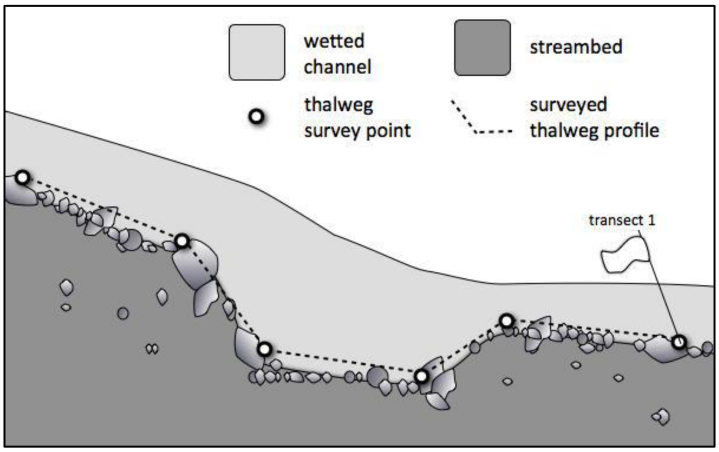

Figure 12. Longitudinal view of the stream channel showing the location of survey points that effectively capture inflection points in the thalweg profile.

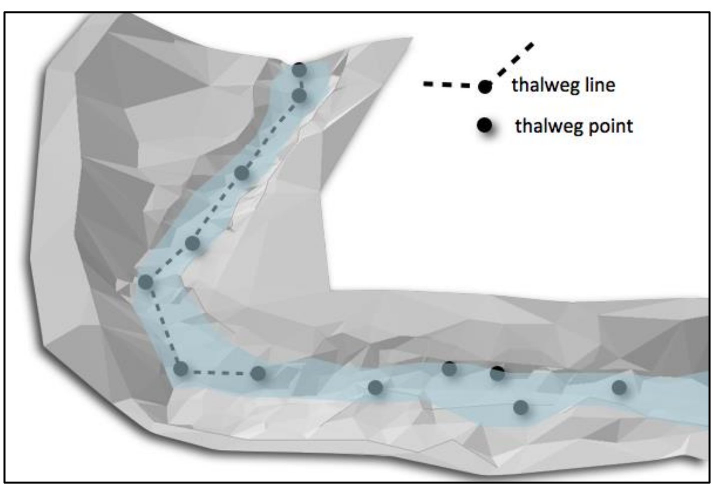

Figure 13. Channel view of lines and points representing the thalweg.

<u>Channel Unit Perimeter – *u#*</u>

i. Channel unit perimeter points are surveyed to provide a representative outline of channel units. Channel units may be adequately represented by at least two points or up to as many as 8 points if they are larger and more complex.

ii. For each channel unit point, use a code that is consistent with the channel unit number being recorded (e.g., u1, u2, etc.).

iii. In general, points describing the perimeter of channel units are surveyed at the edge of water (Figure 14). However, complex units may require additional channel unit vertices located in the wetted channel.

   a. In areas where multiple units converge in the wetted channel it may be necessary to survey additional perimeter points that represent the boundaries of each unit.

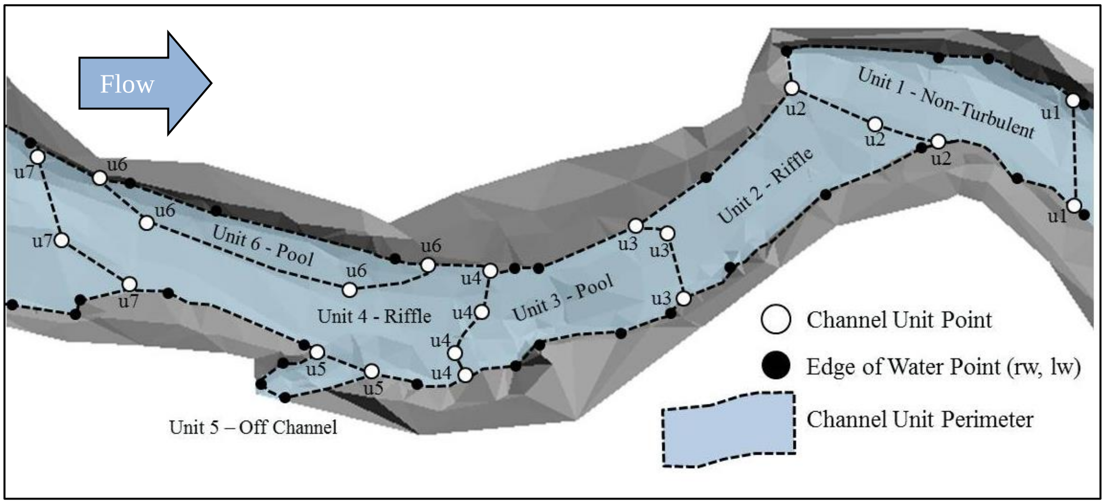

Figure 14. Channel unit perimeter and edge of water points.

<u>Topographic Points – *tp*</u>

i. Survey topographic points to represent topographic features that do not follow a consistent line or fit any other definition listed in Table 4.

ii. Topographic points can be sparse in areas that are topographically uniform, and should be denser in areas that are topographically complex.

iii. Always capture the deepest portion of the stream, tail crest of pools, and maximum depth of pools using topographic points (if not already captured by thalweg (*wg*) points).

<u>Breaklines - *bl*</u>

i. Survey breaklines to represent linear features in the landscape along any consistent gradient breaks that are not represented by other line codes.

ii. Breaklines may run parallel or perpendicular to the channel, and are often used to represent obvious breaks in the channel including tops and bottoms of steep drops (e.g., falls), and artificial structures (e.g., bridge columns).

<u>Side Channels and Islands</u>

i. Side Channels.

a. All large and small side channels will be encompassed in the topographic survey.

b. Survey side channels using the same set of procedures and codes as the main channel when possible. Use breaklines and/or topo points (*tp*) to capture the thalweg of all side channels.

c. Some small side channels are very brushy making surveying difficult. In these instances, at a minimum survey the thalweg as a breakline (*bl*) and edge of water (*lw/rw* and *mw*) lines throughout the side channel along with topo (tp) points on either bank. Survey additional codes (*tb*, *to*) to further define the side channel when possible.

d. Other side channels can have little to no flow. In instances where a small side channel is only partially wet (island forms a peninsula), survey edge of water (*lw/rw*) points/lines along the wetted perimeter (Figure 15D).

ii. Islands.

a. The wetted perimeter of qualifying mid-channel islands should be represented with the *mw* code (Figure 15A and C). Collect bankfull, top of bank, toe of bank, and topographic points where appropriate to adequately represent the topography of the island.

b. Survey the perimeter or all non-qualifying islands, bars, and large boulders with the *br* code (Figure 15B).

c. Survey channel unit perimeters in all side channels (including Small Side Channel Units).

d. Refer to the decision tree in Figure 17 for the use of specific topographic codes when encountering qualifying side channels and islands.

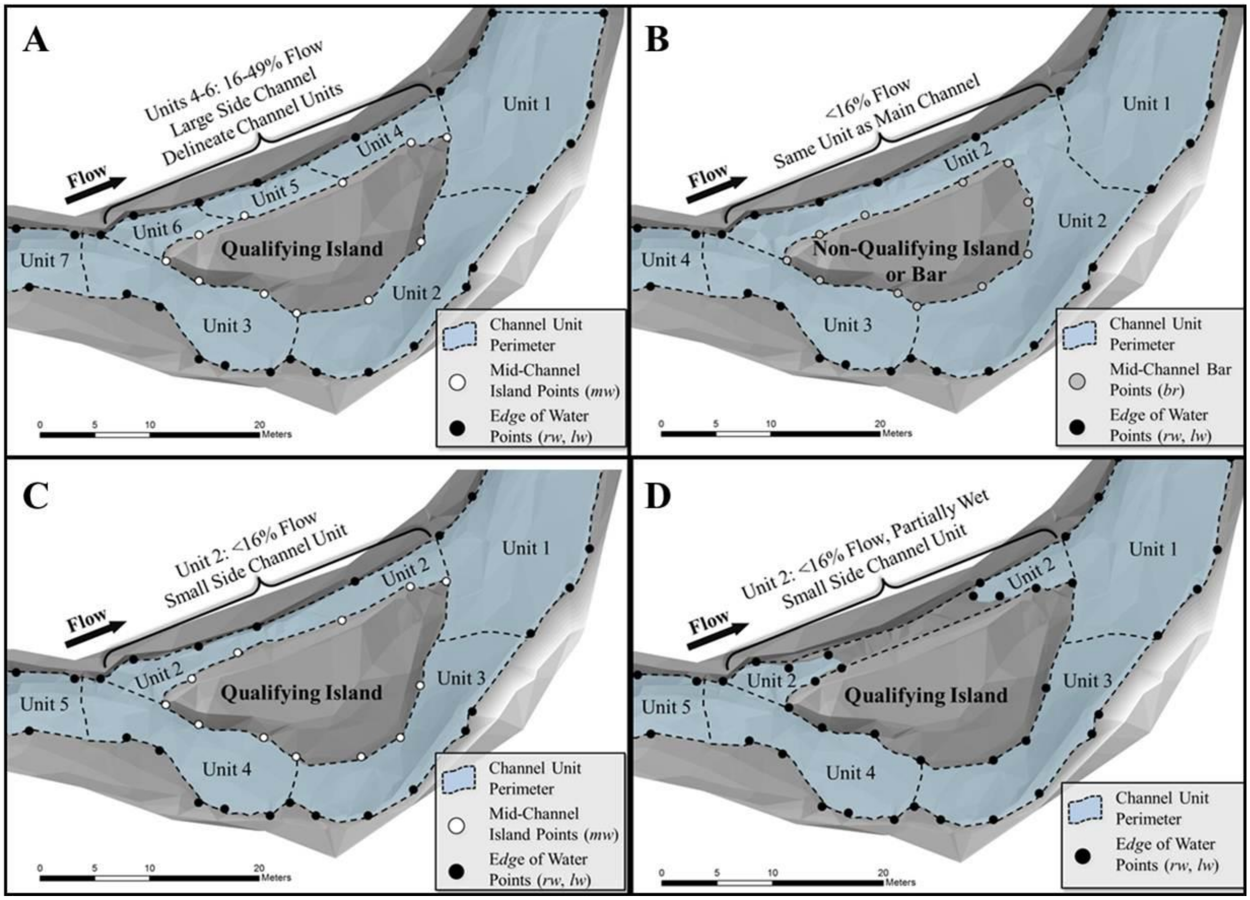

Figure 15. Channel planform view indicating water surface feature codes (*lw/rw*, *mw*, or *br*) used for a A) qualifying island with a large side channel, B) non-qualifying island or bar, C) qualifying island with a continuously wetted small side channel, and D) qualifying island with a partially dry small side channel.

SECTION 6: CHANNEL SEGMENTS AND SIDE CHANNELS

Equipment: N/A

Objective: Identify and label the main channel and different side channel types.

6.1 Channel Segment Numbers and Side Channel Classification

Channel segment numbers are used to differentiate the main channel from side channels. Assign a unique channel segment number to the main channel and all qualifying side channels.

Step 1. Identify the main channel.

i. Main (primary) channel: Contains the greatest amount of stream flow at a site.

Step 2. Identify side channels.

i. Side channel: To be considered a side channel, the channel must be separated from another channel by an island that is ≥ the bankfull elevation for a length ≥ the average bankfull width. At small sites that are 120 m in length, an island must be ≥ 6 m to qualify.

   a. If a channel is separated from another channel by an island that is shorter than the average bankfull width (or < 6 m at small sites), then consider the channel part of the adjacent channel.

   b. If a channel is separated from another channel by a bar (< bankfull elevation) or boulder, then consider the side channel part of the adjacent channel.

Step 3. Identify side channel type.

i. Determine if side channel is qualifying or non-qualifying.

   a. Qualifying side channel: Channel is located within the active bankfull channel and separated from another channel by an island ≥ the average bankfull width.

      i. Qualifying side channels are further divided into large and small side channels (see Step 3, ii.).

      ii. Refer to the decision tree in Figure 17 regarding segment number and channel unit designations for qualifying side channels.

   b. Non-qualifying side channel: Channel is located outside the active bankfull channel or possesses one or more of the following characteristics:

      i. The elevation of the channel's streambed is above bankfull at any point.

      ii. Channel lacks a continuously defined streambed or developed streambanks.

      iii. Channel contains terrestrial vegetation.

ii. Determine whether qualifying side channel is large or small.

Visually estimate stream flow at both the upstream and downstream ends of the side channel as a percentage of the total flow at the site.

   a. Large side channel: Has between 16% and 49% flow at either end.

   b. Small side channel: Has < 16% flow at both ends.

Step 4. Assign segment numbers to channels.

i. The main channel is assigned “Segment 1” throughout the site (Figure 16).

ii. The first large or small side channel encountered when laying out the site (moving upstream) is designated as “Segment 2”. Designate additional qualifying side channels sequentially (2, 3, 4, etc.) until all large and small side channels have been uniquely numbered (Figure 16).

iii. Do not assign segment numbers to non-qualifying side channels.

Note: If a qualifying side channel continues downstream beyond the bottom of site, begin surveying the side channel in line with the bottom of site. Likewise, end surveying a side channel in line with the top of site.

Note: If a large side channel splits and each channel contains > 16% of the total stream flow, assign the original segment number to the largest channel and assign a new segment number to the second channel. If a large side channel splits, and flow in either channel is < 16% of the total flow, assign the original channel segment number to the largest channel, and assign a new segment number to the smaller channel (now considered a small side channel).

Step 5. Record measurements. What to measure in each channel type:

i. <u>Main channel</u>:

   a. Classify channel units, collect all channel unit attributes, and conduct topographic survey.

ii. <u>Large side channels</u>:

   a. Classify channel units, collect all channel unit attributes, and conduct topo survey.

iii. <u>Small side channels</u>:

   a. Classify the entire side channel (both wet and dry portions) as a Small Side Channel unit (Figure 15C) and conduct topographic survey.

   b. Quantify Large Woody Debris (Section 8.4). Do not collect any additional channel unit attributes.

   c. Categorize the side channel as continuously wet, partially wet, or dry.

   d. Estimate the total length of the side channel centerline.

   e. Estimate the average bankfull width of the side channel.

   f. Estimate the percent of the bankfull channel area that is wet at the time of sampling.

iii. <u>Non-qualifying side channels</u>:

   a. Capture the area where the side channel enters/exits the adjacent channel in the topographic survey but <u>do not</u> conduct the topo survey throughout the side channel.

   b. Do not classify channel units, collect any channel unit attributes, or categorize it.

   c. Do not estimate side channel length, width, or percent wetted.

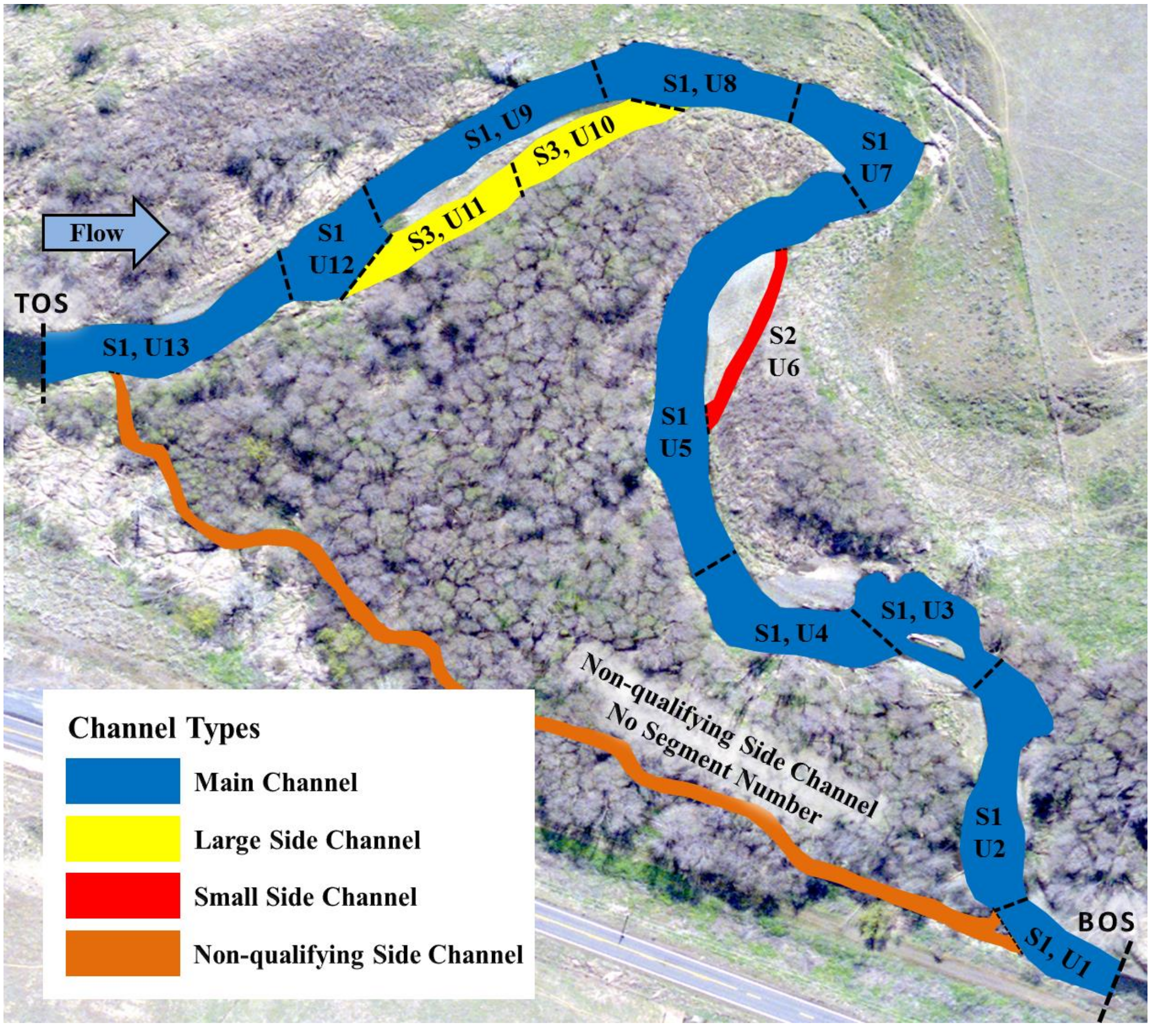

Figure 16. How to number channel segments within a site. The main channel is assigned segment 1 throughout the site. Both large and small side channels are assigned sequential segment numbers working upstream. In the figure, channel segment numbers are preceded with a "S" (S1-S3) and channel unit numbers with a "U" (U1-13).

Qualifying Side Channel Decision Tree

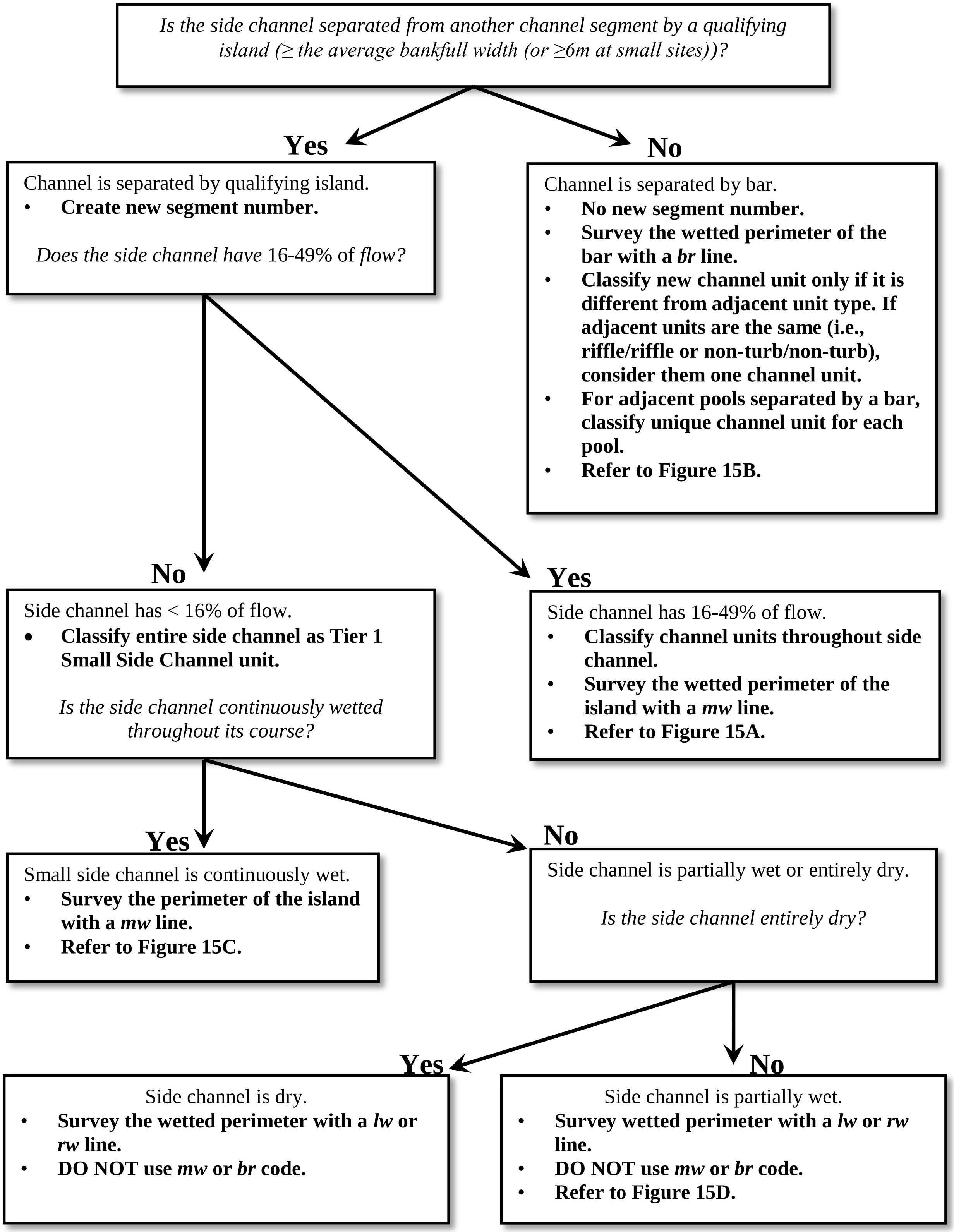

Figure 17. Decision tree outlining segment number and channel unit designations, along with topographic codes for qualifying side channels and islands.

SECTION 7: CHANNEL UNITS

References: Hawkins et al. (1993), Bisson et al (2006).

Equipment: Flagging, sharpie, depth rod, clinometer.

Objective: Delineate channel unit boundaries and classify channel units.

7.1 Channel Unit Classification

The interactions among stream flow, sediment load, and channel resistance contribute to the formation of distinct areas (units) within the stream channel. These channel units, as a result, can be distinguished by their morphology (gradient, depth, shape), hydraulic properties (velocity & turbulence), and bed roughness (substrate size). Many fish habitat attributes are measured at the channel unit level.

Channel units are classified using a two-tiered hierarchical system (Figure 18). At the coarsest level, Tier I units are distinguished by gradient, relative stream velocity/flow, and/or turbulence and include four classes: Fast Water Turbulent, Fast Water Non-Turbulent, Slow Water/Pool, and Small Side Channels. Tier I Fast Water Turbulent and Slow Water/Pool units are further subdivided into Tier II subclasses. Tier II subclasses are differentiated by gradient, hydraulic properties, as well as the primary processes that form them. Below is a general definition of each Tier I class:

Fast Water Turbulent channel units are topographical high points in the bed profile that feature moderate to steep gradients, coarse substrate, and tend to have consistently turbulent flow. The bedform of these units generally lacks longitudinal and/or lateral concavity (Figure 19).

Fast Water Non-Turbulent channel units feature low gradients, dominantly sand to cobble substrate, and smooth laminar flow. Often, fast water non-turbulent units have a gentle slope, similar to pools, but are distinguished from pools by their general lack of lateral and longitudinal concavity. These channel units are generally deeper than riffles.

Slow Water/Pool channel units are topographical low points in the bed profile that feature very low gradients, smooth laminar flow, and possess lateral and longitudinal concavity (Figure 19). Also included in this class is the Tier II subclass of Off Channel units. Off Channel units include backwaters and alcove type units that are connected to the main channel or large side channel but have little (< 1%) to no flow through them. The thalweg never passes through Off Channel units.

Small Side Channel units are small side channels (Section 6.1) that contain < 16% of the total stream flow.

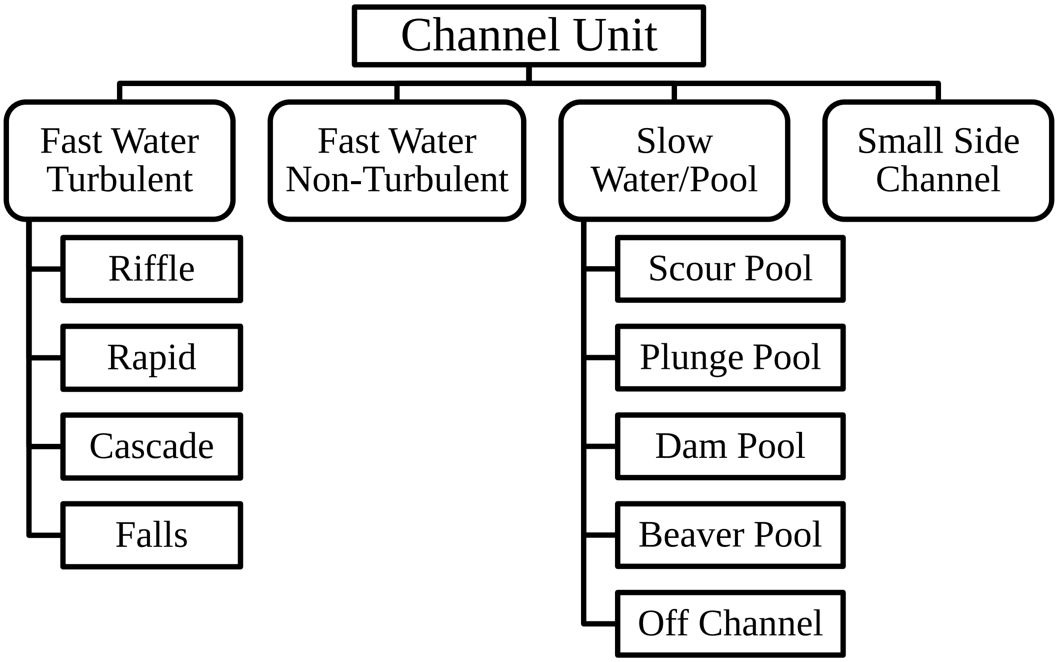

Figure 18. Two-tiered hierarchical classification system used to identify channel units. The classification structure is a modification of the system developed by Hawkins et al. (1993) as reported in Bisson et al. (2006).

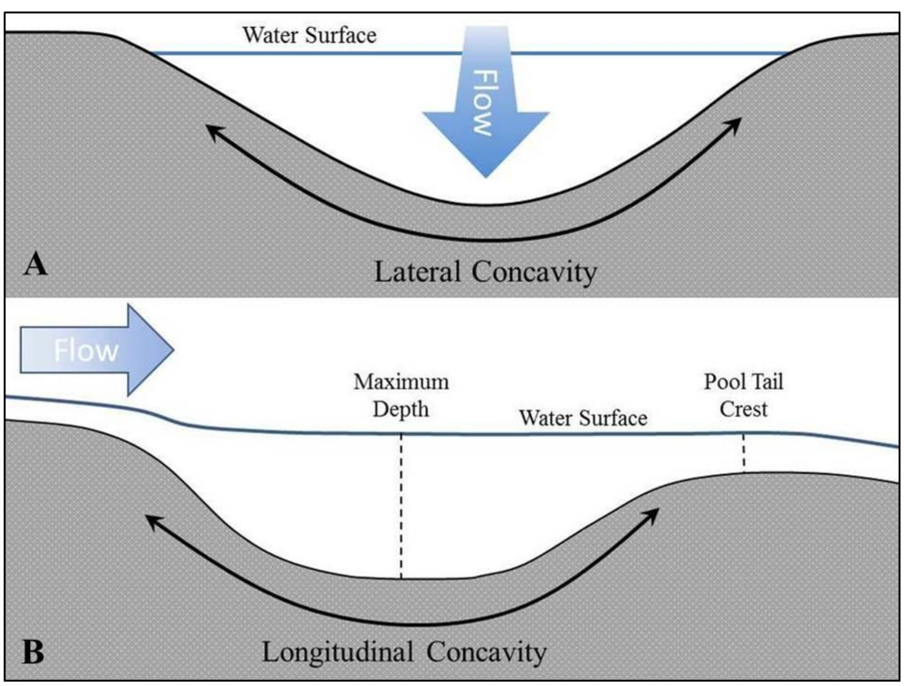

Figure 19. Representation of pool A) cross-sectional (lateral) and B) longitudinal concavity.

Step 1. Identify channel units and their boundaries.
Use the following criteria as a guide when identifying distinct channel units.

i. In general, ***channel units are at least as long as the average wetted channel width.*** At larger sites (width category ≥ 12m), channel units may be shorter than the average wetted channel width. Channel units are relatively homogeneous, localized areas of the stream channel characterized by four elements:
   a. Water surface gradient
   b. Bedform (concavity)
   c. Bed material composition
   d. Flow characteristics (e.g., velocity, turbulence)

   Look for distinct changes in these elements (Table 5) to determine unit boundaries (Figure 14).

ii. Use the descriptions found in Table 5 as well as the dichotomous keys to assist in classifying all Tier I (Figure 20) and Tier II (Figures 21 and 22) channel units. The classification trees are read from top to bottom.

iii. Flag the unit boundaries and assign a unique number to each unit (e.g., *u1*, *u2*, etc.) working upstream. Communicate the number of channel units, segment numbers, and any details about complex unit boundaries to the crew members conducting the topographic survey so unit perimeters can be surveyed correctly.

Table 5. Criteria used to delineate and classify Tier I channel units.

Tier I Classification	Gradient	Bedform Profile	Substrate Composition	Flow Character
Fast Water Turbulent	> 1%	Topographic high points in the bed profile	Generally have coarse substrate (cobbles and boulders)	Fast, turbulent flow
Fast Water Non-Turbulent	< 1%	Uniform depth, low complexity	Generally small cobble, gravels, and fine substrate	Smooth, even flow (laminar), minimal surface turbulence
Slow Water/Pool	0 - 1%	Pools are laterally and longitudinally concave (Figure 19). Off Channel units have little to no flow through them	Variable, generally smaller sorted substrate	Generally laminar flow
Small Side Channel*	NA	NA.	NA.	NA

*Small Side Channels are differentiated from other channel unit types using criteria listed in Section 6.

Tier I Classification Tree

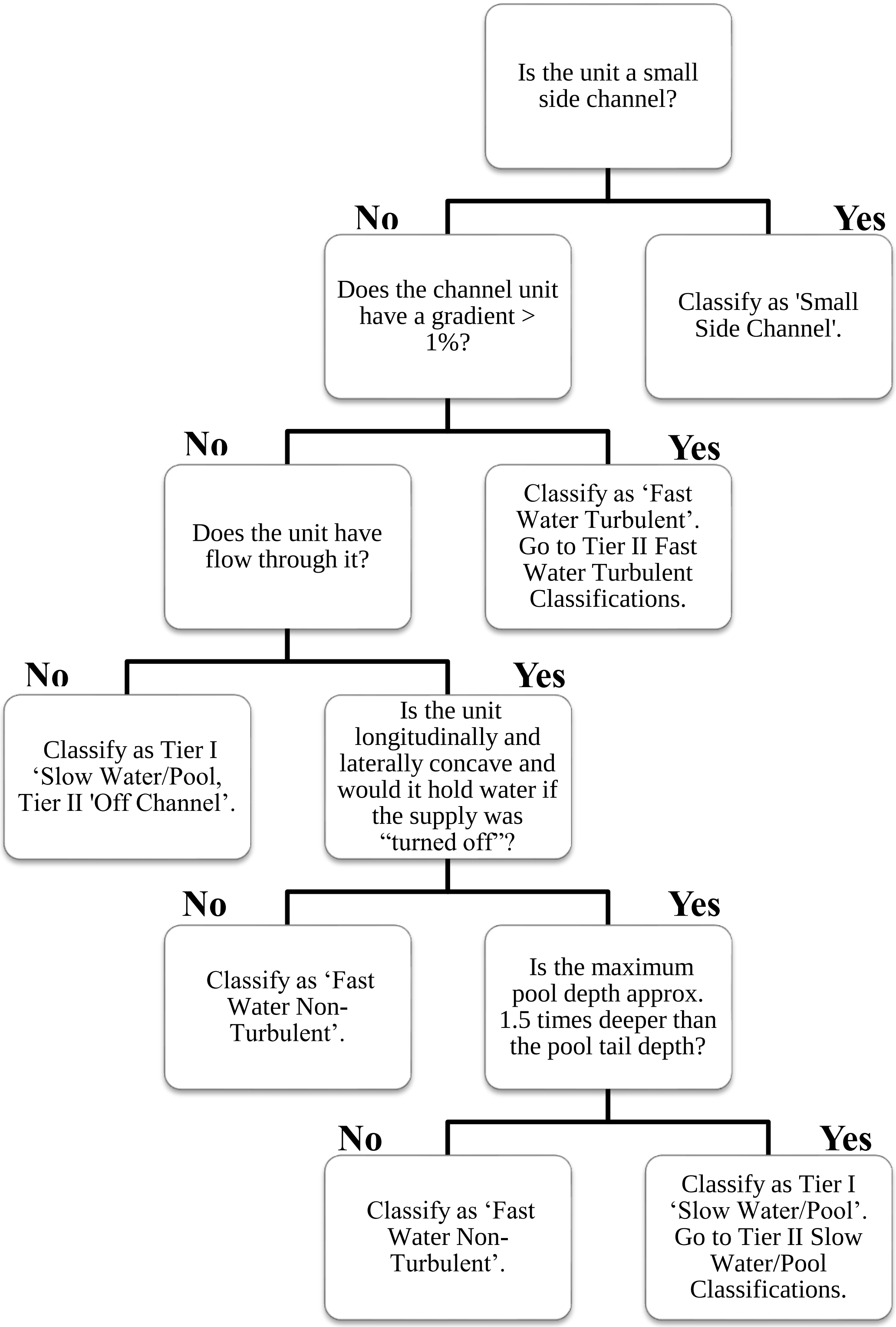

Figure 20. Dichotomous key of criteria used to classify Tier I (Slow Water/Pool, Fast Water, and Small Side Channel) channel units.

Tier II Classification Trees

Fast Water Turbulent

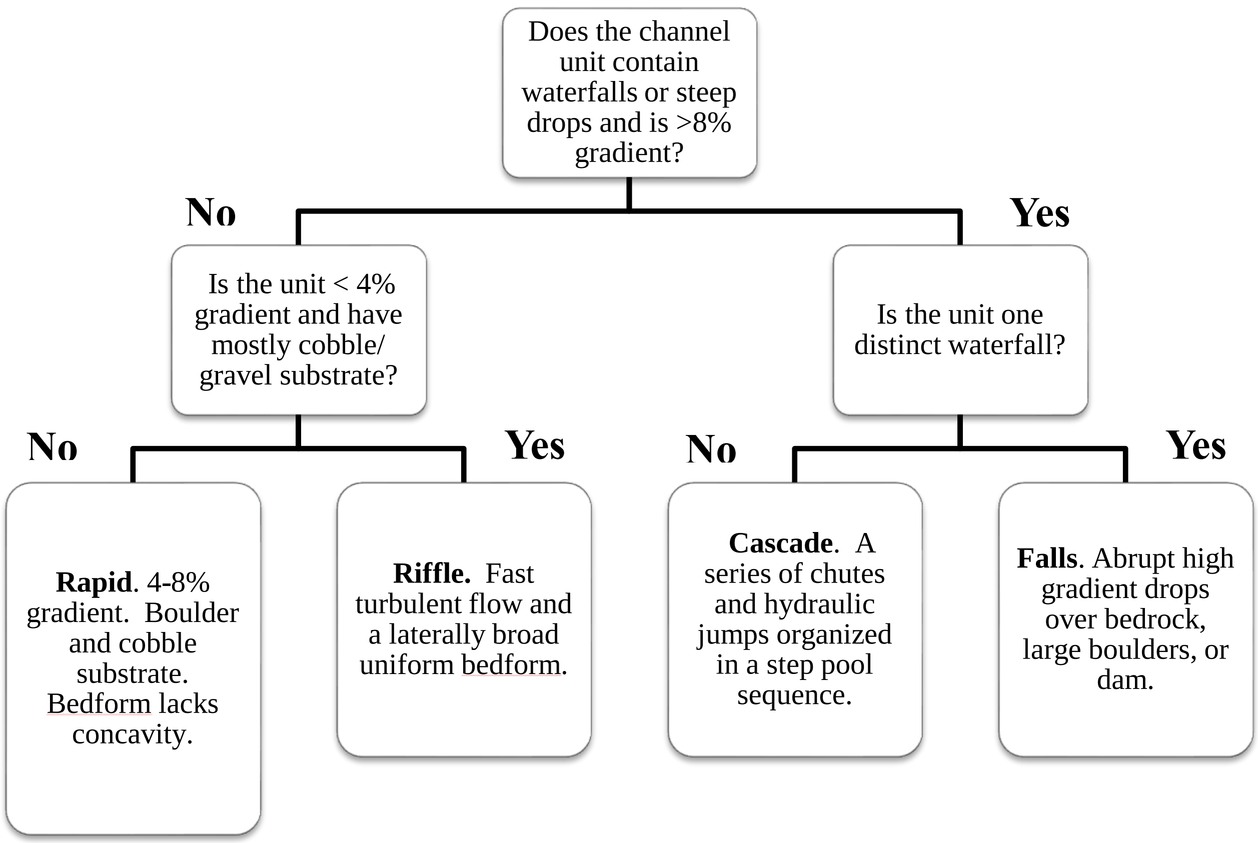

Figure 21. Dichotomous key of criteria used to classify Tier II Fast Water Turbulent channel units.

Tier II Classification Trees continued

Slow Water/Pools

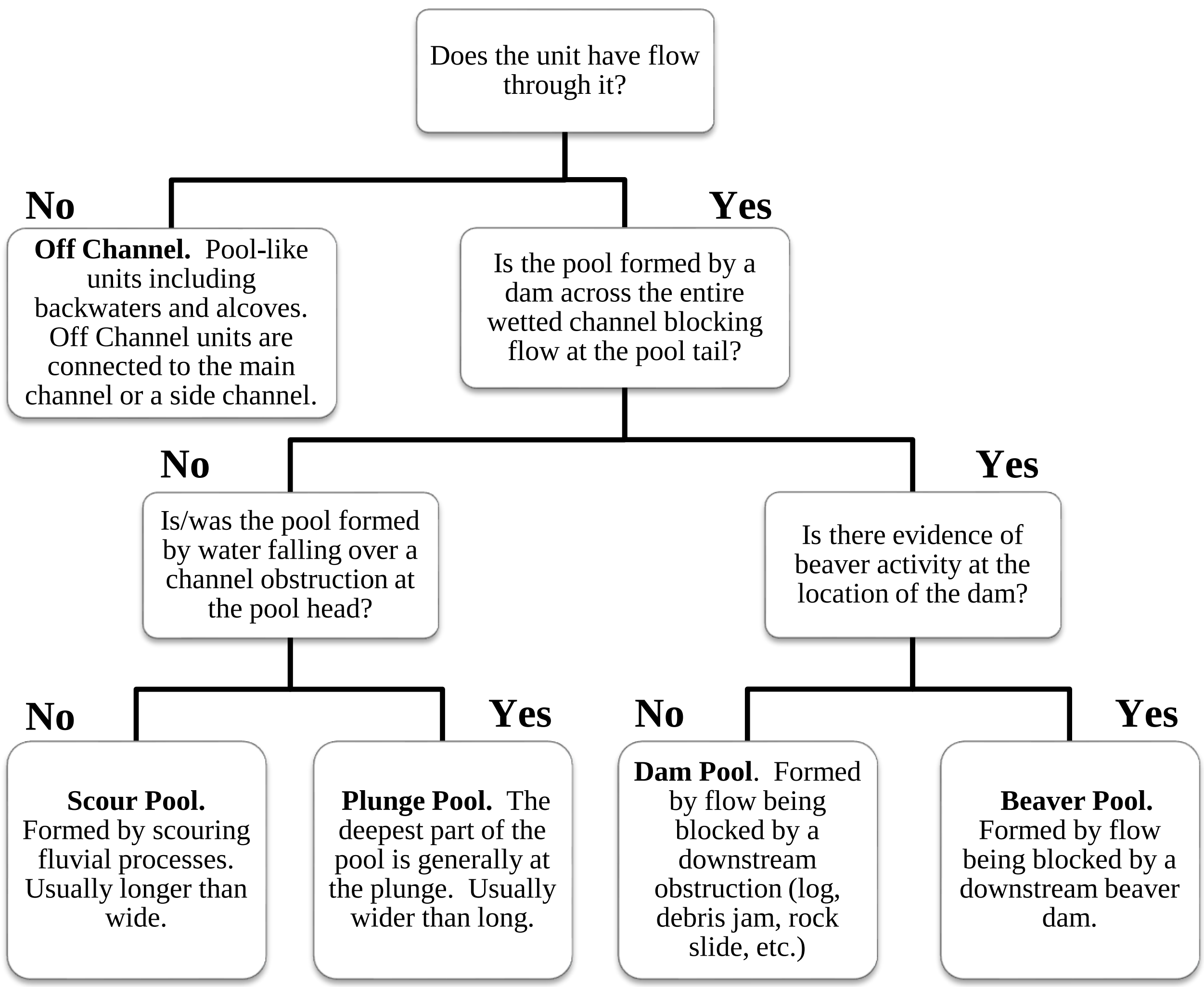

Figure 22. Dichotomous key of criteria used to classify Tier II Slow Water/Pool channel units.

SECTION 8: CHANNEL UNIT LEVEL ATTRIBUTES

8.1 Fish Cover

References: Peck et al. 2001.

Equipment: N/A

Objective: Estimate the type and total area of cover available to fish within each channel unit.

Fish cover is defined as the proportion of the channel unit area that provides refuge to salmonids.

Step 1. Visually estimate the proportion of the wetted surface area within each channel unit that is covered by each of the fish cover elements listed in Table 6.

i. All fish cover elements must be within the wetted channel or ≤ 1 m above the water's surface.

ii. Round measurements to the nearest 5%.

iii. The sum of all fish cover elements should be at least 100%. If fish cover of different categories overlaps, count overlapping areas twice, resulting in a total percentage > 100%.

Table 6. Definitions of fish cover elements evaluated at each channel unit.

Cover Element	Cover Element Definition
Woody debris	Wetted area of the channel unit covered by dead woody debris. There is no size requirement for woody debris to be considered fish cover. Include boards, railroad ties, wood placed for restoration purposes, etc.
Overhanging vegetation and live tree roots	Wetted area of the channel unit covered by live, terrestrial vegetation. Live tree roots suspended over the water and/or submerged. Non-qualifying undercuts are included, qualifying undercuts are not (Section 8.5).
Aquatic vegetation	Wetted area of the channel unit covered by aquatic macrophytes and filamentous algae.
Artificial structures	Wetted area of the channel unit covered by artificial structures including materials discarded in the stream (tires, old cars, concrete, etc.). Rip-rap and logs placed for restoration purposes are not included in this category.
Total NO fish cover	Wetted area of the channel unit that is not covered by the fish cover elements listed above. Consider qualifying undercuts a part of NO fish cover.

8.2 Ocular Substrate Composition

Equipment: N/A

Objective: Visually estimate the substrate composition of each channel unit and record the percentage of each size class.

Step 1. Estimate the percentage of each substrate size class.

i. Visually survey the substrate composition of each channel unit and record the percentage of each substrate class (Table 7) within the wetted surface area.

ii. Round estimates to the nearest 5%.

iii. You may not be able to see the entire wetted surface area of a channel unit due to visual obstructions (aquatic vegetation, wood, or other debris). When this occurs, estimate the area you can see.

iv. The total of all classes should equal 100%.

v. If a thin layer of fine sediment is covering a larger particle, then measure the fine sediment, not the larger particle. Conversely, if individual fine sediment particles are resting on top of a larger rock; measure the rock.

Table 7. Ocular substrate size classes. Estimate b-axis diameter of particles.

Substrate Type	Size class (mm)	Description
Bedrock	N/A	Exposed bedrock surface
Boulders	> 256	Basketball size and greater
Cobbles	64 to 256	Tennis ball to basketball size
Coarse gravel	16 to 64	Marble to tennis ball size
Fine gravel	2 to 16	Small pebble to marble size
Sand	0.06 to 2	Smaller than ladybug size, but visible as particles and gritty between fingers
Fines	< 0.06	Silt and clay that is not gritty between fingers

8.3 Pool Tail Fines

References: Heitke et al. (2008).

Equipment: Fines grid, underwater sighting tube or snorkel and mask.

Objective: Quantify the percentage of surface substrate < 2 mm and between 2-6 mm at the tails of pools and non-turbulent channel units.

Step 1. Identify measurement locations.

i. Collect measurements at the first 10 scour and plunge pools encountered within the main channel and large side channels (16-49% flow) while moving from the bottom of site upstream. Do not sample in dam pools.

ii. If fewer than 10 pools exist at a site, extend sampling into only main channel non-turbulent units (starting from the bottom of site) until ten measurements are collected or there are no more qualifying units. Sample at the bottom end of non-turbulent channel units in a similar fashion to pool tails.

Note: Do not take measurements if the bottom of site intersects a pool and the pool tail is located downstream of the bottom of site boundary.

Step 2. Sample surface fines.

i. Assess surface fines using a 14 x 14 inch grid with 49 evenly distributed intersections. Include the top right corner of the grid for a total of 50 intersections.

ii. Take 3 measurements per pool or non-turbulent unit.

   a. Place the center of the grid at 25, 50, and 75% of the distance across the wetted channel, making sure the grid is parallel to the shape of the pool tail crest (Figure 23).

   b. The bottom edge of the grid should be upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less.

   c. If a portion of the fines grid lands on substrate 512 mm or larger in size (b-axis), record the intersections affected as non-measurable.

   d. Do not overlap fines grid placements/measurements at a pool tail. If all three grids do not fit within the pool tail without overlapping, record the overlapping grid as "not measured". State in notes that "grids overlapped".

iii. Record the number of intersections that are underlain with fine sediment or sand < 2 mm in diameter at the b-axis.

iv. Record the number of intersections that are underlain with sediment 2-6 mm in diameter at the b-axis.

v. Aquatic vegetation, organic debris, roots, or wood may be covering the substrate.

   a. First attempt to identify the particle size under each intersection. If this is not possible, then record these intersections as non-measurable.

b. If the grid is located in an area that has greater than 75% non-measureable intersections, shift the grid to a location where more grid measurements can be made.

vi. If a thin layer of fine sediment is covering a larger particle, then measure the fine sediment, not the larger particle. Conversely, if individual fine sediment particles are resting on top of a larger rock; measure the rock.

vii. Do not count substrate that is suspended in aquatic vegetation or surface algae.

viii. Enter the channel unit number where measurements were collected.

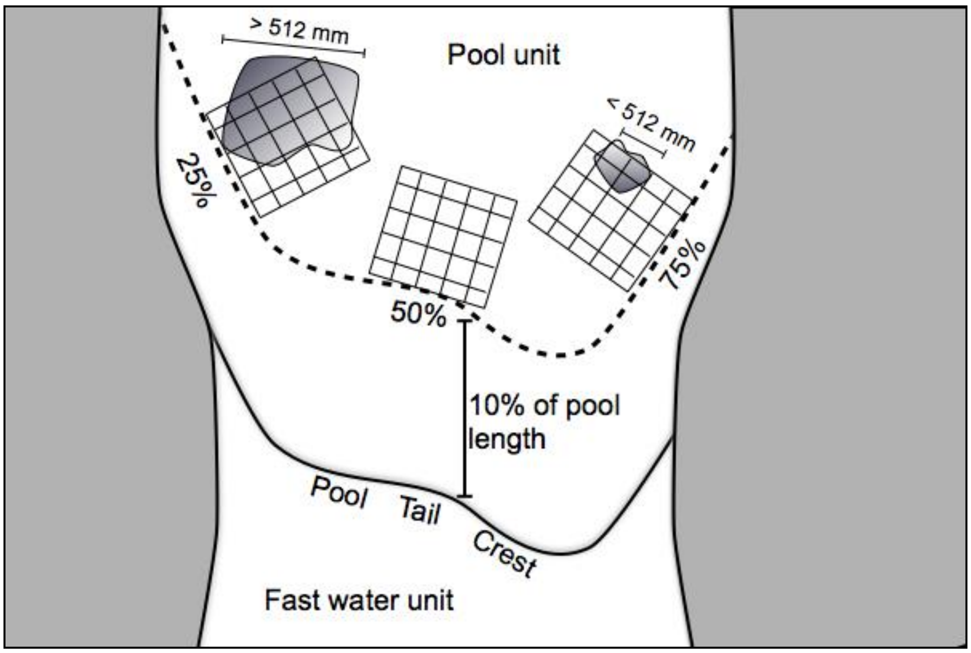

Figure 23. Location and orientation of pool tail fines grids relative to the pool tail crest. In this figure, all intersections of the fines grid at the 50% and 75% placements will be counted and recorded. For the 25% placement, the intersections of the fines grid that land on the boulder (substrate ≥ 512 mm) will be recorded as non-measurable.

8.4 Large Woody Debris (LWD)

Equipment: Depth rod, tape measure, range finder.

Objective: Quantify the number and dimensions of qualifying LWD pieces for each channel unit within the site.

Step 1. Identify qualifying LWD within the bankfull channel and prism.

i. LWD and root wads must be dead with the exception of newly fallen trees that are uprooted from the bank but still have green foliage.

ii. LWD size qualifications:

  a. Must have a b-axis diameter ≥ 10 cm, measured at the midpoint of the piece. For LWD with attached roots, the diameter is measured at the midpoint between where the main stem joins the root mass (e.g., root collar) and the top of the piece (Figure 24).

  b. Must be ≥ 1 m in length. The length of LWD with attached roots is measured from the end of the main root mass to the top of the trunk.

iii. For LWD embedded in the stream bank, the exposed portion must meet the minimum length and diameter requirements to qualify. Quantify the length and diameter of the exposed portion of the piece.

iv. If a LWD piece is broken or cracked, consider it one piece if the two pieces are attached at any point along the break.

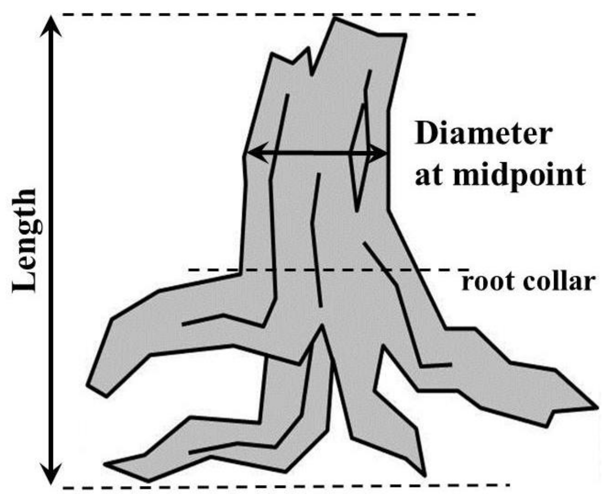

Figure 24. Depiction of diameter and length measurement locations for LWD with attached roots.

Step 2. Classify qualifying LWD as "wet" or "dry".

i. All LWD located within the bankfull channel is classified as either "wet" or "dry" (Figure 25).

a. Classify piece as "wet" if a portion of the main stem or root that touches the water is ≥ 10 cm in diameter (Figure 25).

b. Classify piece as "dry" if a portion of the main stem or root ≥ 10 cm in diameter intersects the bankfull channel but is outside of the wetted channel (i.e. would get wet at bankfull flows).

ii. Classify pieces outside the bankfull channel but within the bankfull prism as "dry" if they meet <u>both</u> of the criteria below. The bankfull prism refers to the area directly above the bankfull channel elevation (Figure 25).

a. Piece is in the bankfull prism and is suspended vertically above the bankfull channel by other pieces of LWD.

b. Piece would fall into the bankfull channel if the supporting LWD was removed (Figure 25).

Note: These pieces frequently occur in large wood aggregates or "jams".

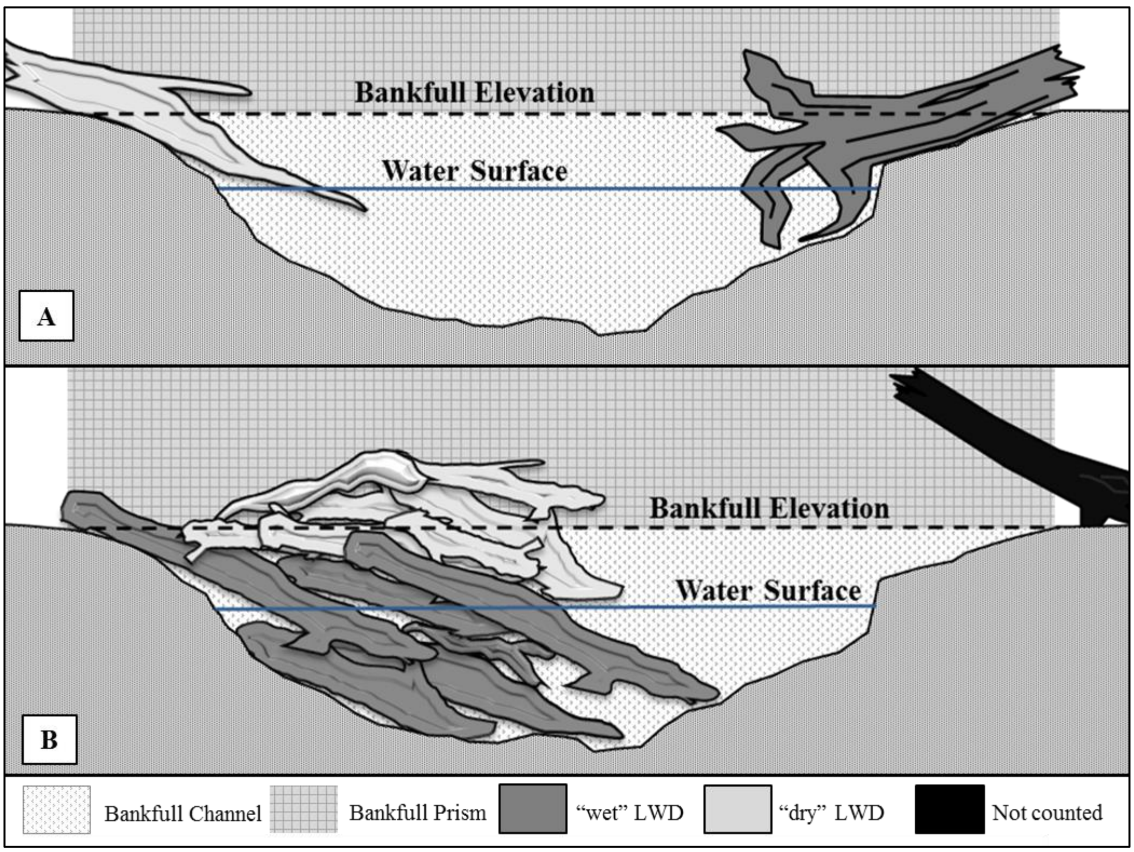

Figure 25. Cross-section view depicting LWD wet/dry scenarios for qualifying pieces. Grey pieces are classified "wet" and light grey pieces "dry". **Panel A)** LWD piece on left is "dry" because the portion of the main stem touching the water is < 10 cm. LWD piece on right is "wet" because a root ≥ 10 cm diameter touches the water. **Panel B)** Note that "dry" pieces above the bankfull elevation but within the bankfull prism are supported by other LWD pieces and are counted (see Step 2).

Step 3. Record the length and diameter of qualifying LWD pieces.

i. Measure and record the length and diameter of the first 10 qualifying LWD pieces encountered at the site.

ii. Estimate and record the length and diameter of the next 9 LWD pieces and measure the 10^{th}. Repeat this process of measuring every 10^{th} piece (#20, #30, #40, etc.) until all qualifying pieces have been quantified.

iii. In addition to measuring pieces described in steps i and ii above, also measure the first 10 LWD pieces that are ≥ 15m long.

iv. Record length to the nearest 0.1 m, and diameter measurements to the nearest 0.01 m.

v. If a piece cannot be measured accurately, estimate the length and diameter and measure a different qualifying piece.

Step 4: Assign qualifying LWD pieces to a channel unit.

i. Assign each piece of LWD to one channel unit. If a piece of LWD is present in two or more channel units, assign it to the unit that contains the highest proportion of the piece's volume.

ii. If a piece of LWD is outside wetted portion of the channel but within the bankfull channel, assign this 'dry' piece to the nearest channel unit.

Note: Tally all qualifying LWD pieces within the entire bankfull channel including those pieces within all large and small side channels.

Step 5: Determine if pieces crossing the bottom / top of site boundaries qualify.

i. A LWD piece that crosses the bottom / top of site boundary qualifies if it meets the size criteria (Step 1), and a ≥ 10 cm portion of the main stem or root intersects the site's bankfull channel. Classify the piece as "wet" or "dry" using the criteria in Step 2.

Note: A piece is "wet" if the portion intersecting the site's bankfull channel is out of the water but a ≥ 10 cm portion of the main stem or root touches the water up / downstream of the site.

8.5 Undercut Banks

Equipment: Depth rod, GPS enabled data logger.

Objective: Quantify undercut banks in the main channel and large side channels.

Step 1. Identify qualifying undercut banks.

i. Undercut banks are continuous cave-like features in the stream bank formed by overhanging bank material and/or tree roots.

ii. Qualifying undercut banks:

   a. Provide fish cover at the time of sampling.

   b. Have a width ≥ 20 cm.

   c. Are ≥ 1 m long, measured along the edge of water.

   d. Include undercuts with ceilings ≤ 1 m above the water surface (Figure 27).

Step 2. Estimate the length of the undercut.

i. Determine the upstream and downstream boundaries of the undercut and measure the length along the edge of water.

ii. Only measure the portion of the undercut that meets the minimum width requirement (Step 3; Figure 26).

iii. When there are two or more qualifying undercuts separated by a distance of less than 0.5 m, consider them one undercut but do not account for the distance between them in the length estimate (Figure 26).

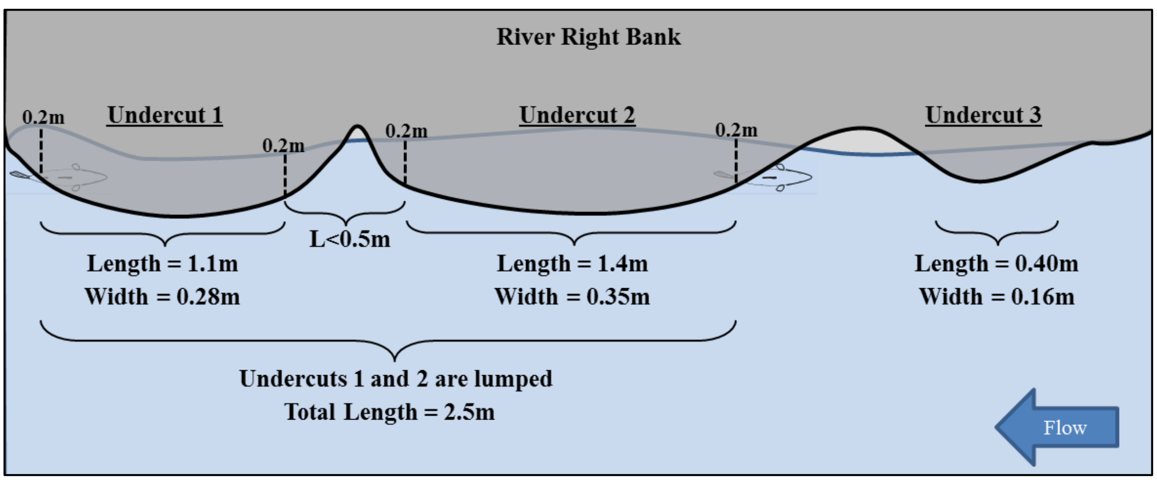

Figure 26. Top down view depicting three undercuts. Undercut 1 and 2 both meet minimum length and width requirements and are considered one undercut because the width separating them is < 0.50 m. Undercut 3 does not meet the minimum length or width requirements and is not recorded.

Step 3. Measure and record the width of qualifying undercuts.

i. Measure the wetted widths of the undercut parallel to the water's surface and perpendicular to the direction of flow.

ii. Undercut width is measured as the wetted horizontal distance from the outermost edge of the overhanging bank to the back "wall" of the undercut at its widest point (Figure 27).

iii. Measure undercut widths at 3 points located at 25, 50 and 75% of the qualifying undercut length. The average width of the three points must be ≥ 20 cm to qualify.

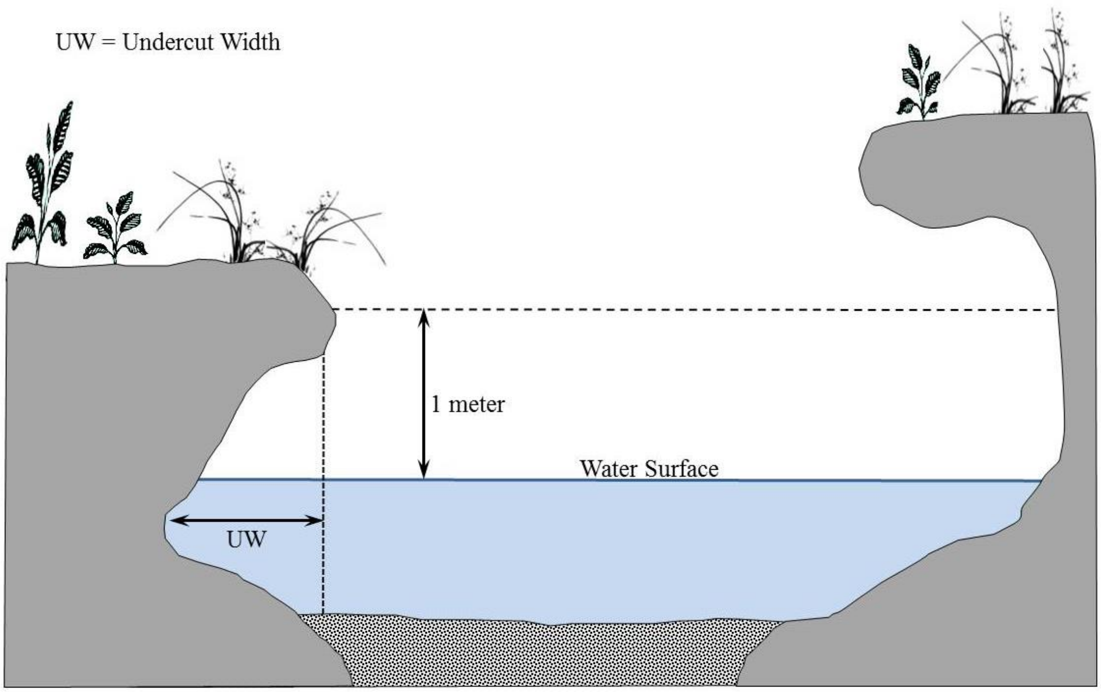

Figure 27. Where to measure the wetted width of an undercut bank (left). The bank on the right has a cave-like feature, but it's ceiling is > 1 m above the water's surface; therefore it does not qualify as an undercut bank.

Step 4. Record GPS coordinates and accuracy at the midpoint of each undercut (Figure 28).

Step 5. Assign qualifying undercuts to their corresponding channel unit and stream bank.

i. Record the channel unit that the undercut falls within (Figure 28).

ii. Assign each undercut to the corresponding stream bank (left/right bank or island).

iii. Some undercuts extend between two channel units:

   a. If a single undercut extends between two channel units, consider it two distinct undercuts separated at the channel unit boundary (Figure 28). Each individual undercut must meet length and width requirements.

   b. If a single undercut extends between two channel units and one of the portions does not meet the minimum length requirement, consider it one undercut and assign the undercut to the channel unit that contains the greater proportion of its length. Similarly, if a single qualifying undercut extends between two channel units but neither portion qualifies based on length, consider it one undercut and assign it to the unit with the greater proportion.

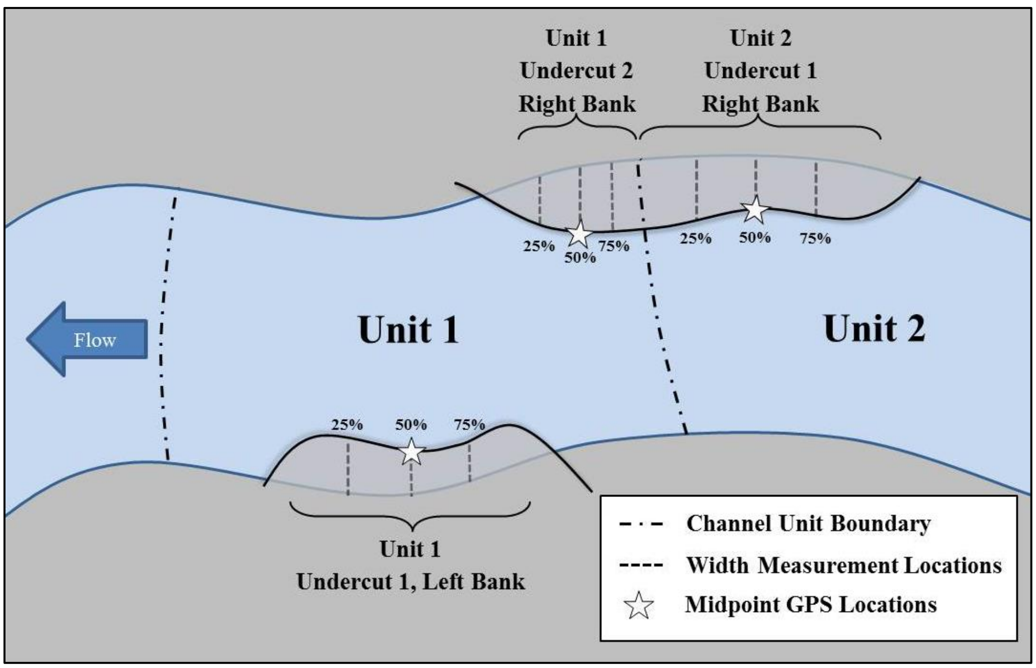

Figure 28. Top down view depicting locational measurements taken at each qualifying undercut.

8.6 Particle Size Distribution and Cobble Embeddedness

Equipment: Gravelometer, depth rod.

Objective: Quantify the size distribution of substrate in fast water habitats and to estimate cobble embeddedness.

8.6.1 Particle Size Distribution

Step 1. Determine where to place cross-sections.

i. Count the number of Tier II riffle channel units that occur within the main channel and large side channels.

   a. If there are ≥10 riffles, place one cross-section in each of the first 10 riffles (working upstream).

   b. If there are less than 10 riffles, evenly distribute additional cross-sections into riffles according to the proportion of stream length that each unit comprises relative to the other riffles. If there is not enough space to conduct all measurements in riffles (see Step 1, ii, c), then evenly distribute remaining cross-sections into non-turbulent units (working upstream). If there is not enough space to conduct all measurements in riffles and non-turbulent units, then distribute remaining cross-sections into rapids.

ii. Cross-section location and spacing.

   a. When there is only one cross-section in a unit, place the cross-section at the midpoint of the unit.

   b. When there are multiple cross-sections in a unit, equally space the cross-sections throughout the unit (Figure 29). Cross-sections should be oriented perpendicular to the bankfull channel.

   c. Cross-sections should not be closer than $1/100^{th}$ of the site length apart. Move additional cross-sections to the next largest unit if too crowded. For example, the minimum spacing between cross-sections at a 120 m long site would be 1.2 m.

   d. Cross-sections should not cross two or more laterally adjacent channel units.

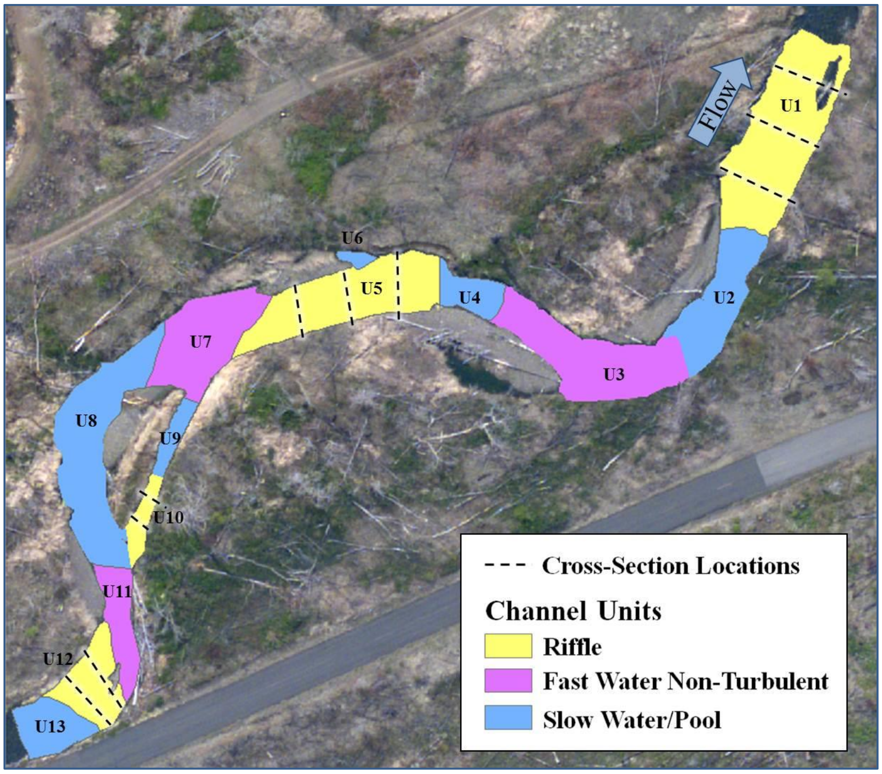

Figure 29. Example of how to distribute pebble count cross-sections at a site.

Step 2. Select 11 sampling points at each cross-section.

i. At each cross-section, visually divide the cross-section into 11 equally spaced sampling points running perpendicular to the stream channel, and spanning the width of the bankfull channel. (Figure 30).

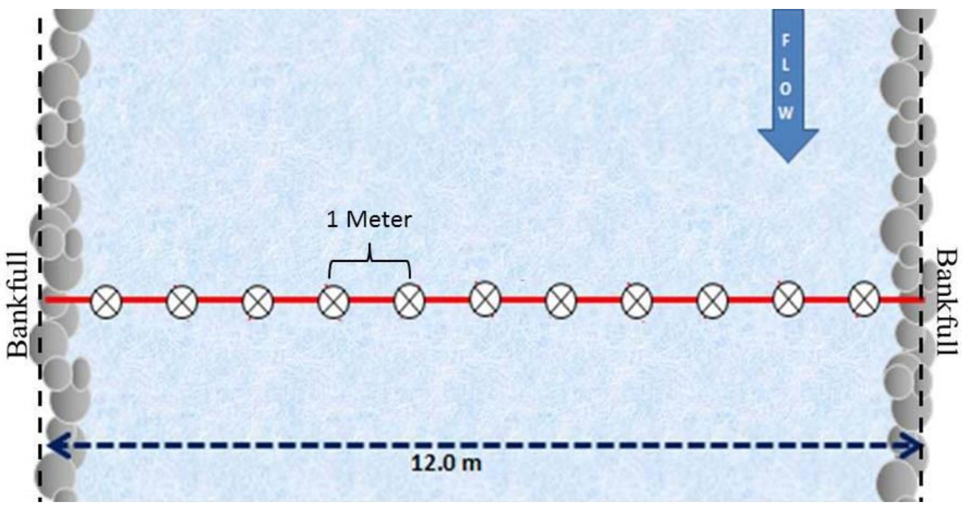

Figure 30. Example of a cross-section layout. In this example, distance between samples is 1 m, because the bankfull width is 12 m. Particle sample location is shown with a circle and crosshairs.

Step 3. Select and measure particles.

i. Select particles at sample points by turning your eye away and extending your finger down and picking up the first particle that you feel at the tip of your boot.

a. Use a gravelometer (Figure 31) to classify the b-axis of each particle. Record the size category (Table 8) for the largest square opening that the particle does not fit through. For example, if the particle fits through the 180 mm square but does not fit through the 128 mm square it is classified as the 128-180 mm size class.

b. Record silt and clay particles that are < 0.06 mm in the 0.0002-0.06 mm size class. Silt and clay particles are smooth when rubbed between the thumb and fingers whereas sand rolls between the fingers (is gritty).

c. Use the thin edge of the gravelometer to determine sand particles between 0.06 and 2 mm. (Note the thin edge of the gravelometer is 2 mm wide).

d. For particles > 128 mm and < 512 mm, measure the b-axis using the notches at the top of the gravelometer.

e. For particles > 512 mm, measure and record the length of the b-axis using the top edge of the gravelometer or a depth rod.

f. Record "bedrock" when encountered at sample points.

g. If your finger touches a thin layer of fine sediment covering a larger particle, then measure the fine sediment, not the larger particle. Conversely, if your finger touches a rock covered by individual fine sediment particles; measure the rock.

h. **Do not measure stream bank particles**.

i. For embedded particles that cannot be removed from the stream bed, use the notched edge of the gravelometer or the depth rod to measure the b-axis, and record the appropriate size class.

Figure 31. Gravelometer used to classify the b-axis of particles.

Table 8. Size categories for sediment in the range of silt/clay to bedrock. Record the size range that the particle falls within (e.g., 45-64).

Description of particle size		Size Range (mm) Lower	Size Range (mm) Upper
Bedrock		**n/a**	n/a
Boulder	mega	**> 4000**	n/a
	very large	**2896**	4000
		2048	2896
	large	**1448**	2048
		1024	1448
	medium	**724**	1024
		512	724
	small	**362**	512
		256	362
Cobble	large	**180**	256
		128	180
	small	**90**	128
		64	90
Gravel	very coarse	**45**	64
		32	45
	coarse	**22.6**	32
		16	22.6
	medium	**11.3**	16
		8	11.3
	fine	**5.7**	8
		4	5.7
	very fine	**2**	4
Sand		**0.06**	2
Silt/Clay		**0.0002**	0.06

8.6.2 Cobble Embeddedness

Cobble embeddedness is a measure of the degree to which a cobble is buried by fine sediment.

Embeddedness is the percentage of a cobble's surface that is surrounded by fine sediment < 2 mm (sand and silt/clay). High cobble embeddedness results in a reduction of interstitial spaces between particles and makes the substrate more difficult to move (think of a fish's tail).

i. Estimate embeddedness for all cobble-sized particles (64 mm – 256 mm) that are selected during particle size distribution sampling. Record estimates to the nearest 5%.

ii. Embeddedness is estimated as the product of two values:

   a. The percentage of the cobble's surface that is buried below the surface of the streambed (Figure 32A), and

   b. The percentage of fine sediment < 2 mm in the depression immediately surrounding the cobble (Figure 32B).

Step 1. Estimate percent buried.

i. Before removing a particle from the streambed for measurement, feel around the edge of the particle to determine at what point the particle is below the stream bed surface and note the boundary between the portion of the particle that was buried and the portion that was not buried (Figure 32A).

ii. Remove the particle and estimate the percent that is buried by comparing the proportion of the particle's surface that was exposed vs. buried (Figure 32A).

Note: If a cobble cannot be removed from the streambed, the particle is at least 50% buried. Measure the b-axis of the particle and confirm that it is a qualifying cobble.

Step 2. Estimate percent fines.

i. Examine the substrate within the depression immediately surrounding the cobble where the buried portion of the cobble was removed, and visually estimate the percent of the substrate that is composed of fine sediment < 2 mm. If the substrate is not clearly visible due to water surface turbulence or turbidity, manually collect a small grab sample of the substrate, hold the sample above the water surface, and visually estimate percent fines for the sample.

Step 3. For each cobble, record the percent buried and percent fines.

i. If a cobble is 0% buried, do not record percent fines.

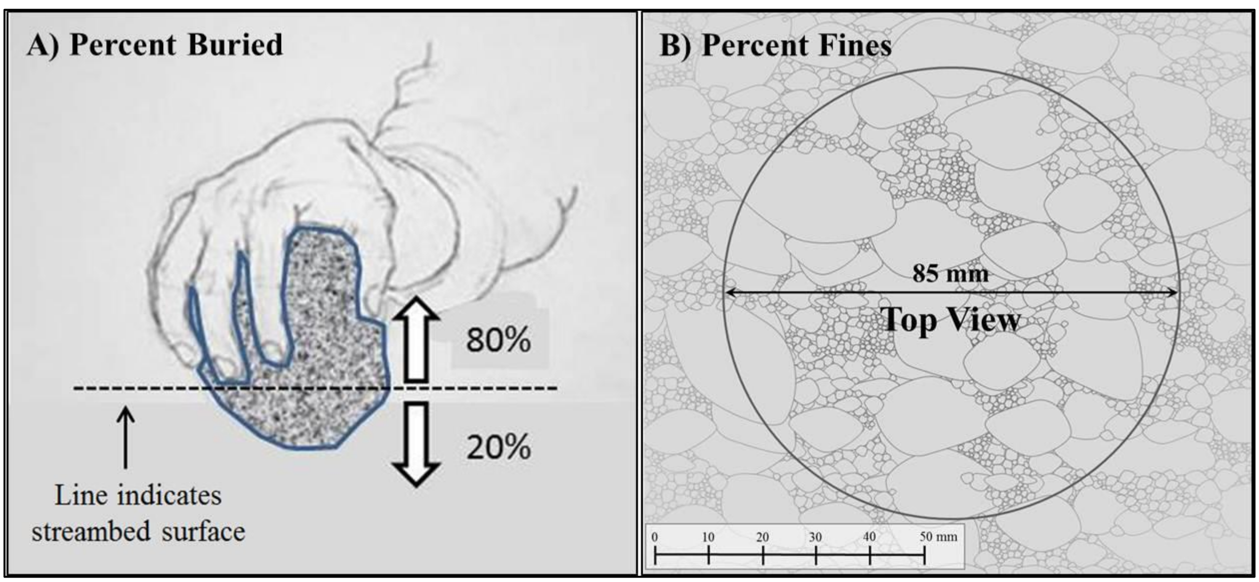

Figure 32. Illustrations depicting the two methods used to estimate embeddedness: percent buried (Panel A) and percent fines (Panel B). Panel A) The cobble is buried 20% beneath the streambed surface. Panel B) The sediment in the depression immediately surrounding and beneath the cobble (indicated by the circle) is composed of approximately 10% of fine sediment < 2 mm.

SECTION 9: SITE LEVEL ATTRIBUTES

9.1 Site Map

References: Modified from Heitke et al. (2011).

Equipment: Paper, pencil, clipboard.

Objective: Draw a site map which contains important features to characterize the site.

The site map will be used in conjunction with site photos, UTM coordinates, and verbal descriptions to assist a crew in relocating a site in the future. Site maps (Figure 33) are important to help characterize a site and relocate benchmarks, control points, monuments, and temperature loggers. It is essential that the artist takes his/her time to accurately draw to scale the unique and significant features of each site. Attempt to reference the location of Tier 1 channel units and side channels. Also indicate the presence of anthropogenic influences such as logging, cattle grazing, dikes, etc. Table 9 identifies features that may be included in each site map along with some commonly used symbols.

Table 9. Site map features and commonly used symbols.

Features (Labels)	**Symbol**	**Features**	**Symbol**
Benchmarks (BM1, etc.)	☒	Road	- - - -
Site Monuments (Mon1-*n*)	☆	Fence	-/-/-/-/-
Bottom and Top Site Markers (BSM,TSM)	▲	Coniferous	
Control Points (CP301, etc.)	✳	Deciduous	
Stream Temp Logger location	Labeled	Herbaceous	
North Arrow	N ⟶	Stump	
Flow Direction	Flow ⟶	Large Wood	
Pools	(P)	Wood Jam	
Bars		Cut Bank	
		Upslope Area	

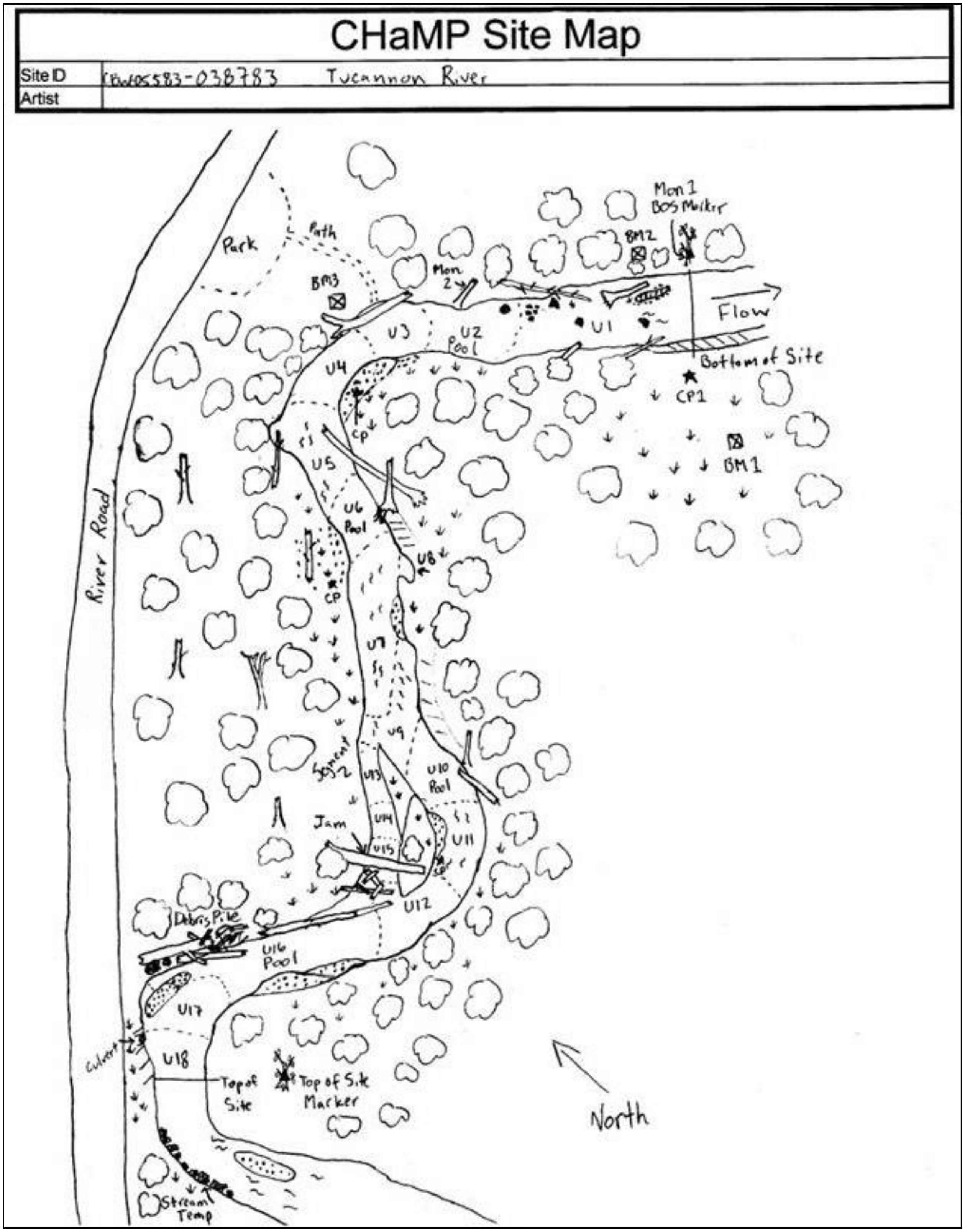

Figure 33. An example of a site map used to help characterize a site's unique and significant features.

9.2 Photos

References: Modified from Heitke et al. (2011).

Equipment: Data Logger/Camera, depth rod, compass.

Objective: Capture site characteristics with photos and replicate photos from previous visits to track changes over time.

Photos are used to help characterize and visually assess site conditions and are essential when relocating sites for future sampling.

Follow these steps when taking photographs:

i. Always take a photo of the Site ID first. Record the stream name, full site name, and date on a blank piece of paper and take a photo of the paper. This should be the first photo in the series of site photos.

ii. Lighting is critical for quality pictures. Always attempt to take photos during optimal light conditions. Avoid photographs where much of the site is shaded and/or only partially illuminated. To ensure quality photos, take photos when the sun is at a low angle in the morning or evening and have the sun at your back.

iii. Do not use the zoom for any image

iv. Capture all images in landscape format.

9.2.1 New Sites

i. Site Overview: Taken from a point that best captures site characteristics. Attempt to gain a good view on top of a hill or other aerial vantage point (Figure 34). Take site overview photos even when the stream is not visible in the photo to capture the surrounding riparian area and floodplain. Never take an overview photo from the stream channel.

   a. Record GPS coordinates of photo location.

   b. Take a compass bearing to indicate the direction the camera was pointed for the photo.

   c. Write a descriptive note describing the photo location.

Figure 34. Example of a good site overview photo. Photo captures the stream as well as the surrounding riparian area and floodplain.

ii. Transect: Photos are taken from the center of the **bankfull** channel at transects 1, 6, 11, 16, and 21.

   a. Position the camera 1.5 m from the ground (use a depth rod as a guide). Ensure that photos are at least 0.5 m above the water surface if water is deeper than 1 m.

   b. At each transect, take a photo from the bankfull center: facing upstream (center up), facing the left bank (center left), facing downstream (center down), and facing the right bank (center right).

iii. Other: Additional required photos include monuments, bottom and top site markers, and stream temperature logger locations. Crews are encouraged to take extra photos that may add context to a site such as large cut banks, side channels, LWD jams, or where channel migration has/may occur.

9.2.2 Revisit Sites

At revisit sites, both repeat photos and new photos will be captured. Old photos will be provided. When repeating old photos, the primary objective is to duplicate them as closely as possible. Examine features in the old photo to pinpoint its location (Figure 35).

i. **Repeat Photos**

   a. Transects: Replicate one photo looking upstream and one photo looking downstream at the following three transect locations; at the bottom of site (T1), at the middle of site (T11), and at the top of site (T21). Do not capture left and right photos at these locations.

   b. Site Overview: Evaluate the Site Overview photo provided and replicate photo using GPS coordinates and compass bearing provided.

ii. **Repeat Photo Instructions**

a. The transect 11 location may not be in the same precise location as past surveys. Use the current transect location as a starting point to relocate the old photo location. The exact location of the bottom and top of site were located during site set up (Section 4.3). Replicate photos at these exact locations.

b. After locating original photo point, use unique objects in the original photo frame to line up photo correctly (Figure 35).

c. Pay particular attention to the corners of the old photo, does your photo have the same features in each corner?

d. Does your photo look like it is too close or too far away? If so move.

e. Is the horizon the same? For example, is the meadow behind the stream towards the top of the old photo, but near the middle of yours? If so make the necessary adjustments.

f. Once you take the new photo, compare it to the old version. If they don't match, shoot it again.

iii. New Photos

a. <u>Transects:</u> New photos are taken from the center of the **bankfull** channel at transects 6 and 16. At each transect, take a photo from the bankfull center: facing upstream (center up), facing the left bank (center left), facing downstream (center down), and facing the right bank (center right).

b. <u>Other:</u> Additional new required photos include monuments, bottom and top site markers, and stream temperature logger locations. Crews are encouraged to take extra photos that may add context to a site such as large cut banks, side channels, LWD jams, or where channel migration has/may occur.

Figure 35. Example of a good repeat photo. Photo captures both sides of the stream as well as the woody debris in the foreground. The trees are also lined up in the exact location as the previous year's photo.

9.3 Solar Input

Equipment: Solmetric SunEye.

Objective: Measure the amount of solar radiation entering the stream channel at evenly spaced transects throughout the site.

The Solmetric SunEye device is used to measure solar radiation at the center of the wetted channel at all odd numbered transects (1, 3, 5, 7,…21). To ensure accuracy in estimation of solar radiation, it is critical to capture good quality images. Adequate atmospheric conditions are necessary to achieve usable images. These conditions include low sun angle (dawn or dusk is ideal) or uniform overcast sky and absence of sun “flares” or “spots”. It is also important to hold the SunEye as level and steady as possible to ensure that images are clear and representative of the vegetation directly overhead. See Appendix F for Solmetric SunEye operating instructions. The SunEye captures images that are called “skylines”. Each skyline image is stored in a work session. Name the session using the Site ID and date (e.g., CBW06683-457806-20140801-ODFW).

Step 1. Determine solar input measurement locations.

i. Collect solar input measurements at the center of the main wetted channel at all odd numbered transects within a site (1-21).

   Note: For revisit sites, if a site has less than 21 transects, record “not measured, feature does not exist” for the missing odd numbered transect locations.

ii. If a mid-channel bar occurs in the center of the wetted channel, the solar reading in this case would fall over a dry surface.

iii. If an island occurs in the center of the wetted channel, conduct the solar reading at the center of the main channel.

Step 2. Collect solar input measurements.

i. Holding the SunEye 30 cm above the wetted or dry surface, orient the instrument so the heading is centered on true South and ensure that the instrument is level. Stand on the North side of the instrument.

ii. Capture the skyline image. Review the image to ensure that it is not blurry and that your head is not blocking the sun path (Figure 36). Retake image as many times as necessary. Delete all bad images.

iii. For each transect, record the skyline number in the Data Logger (“01”, “02”, etc.).

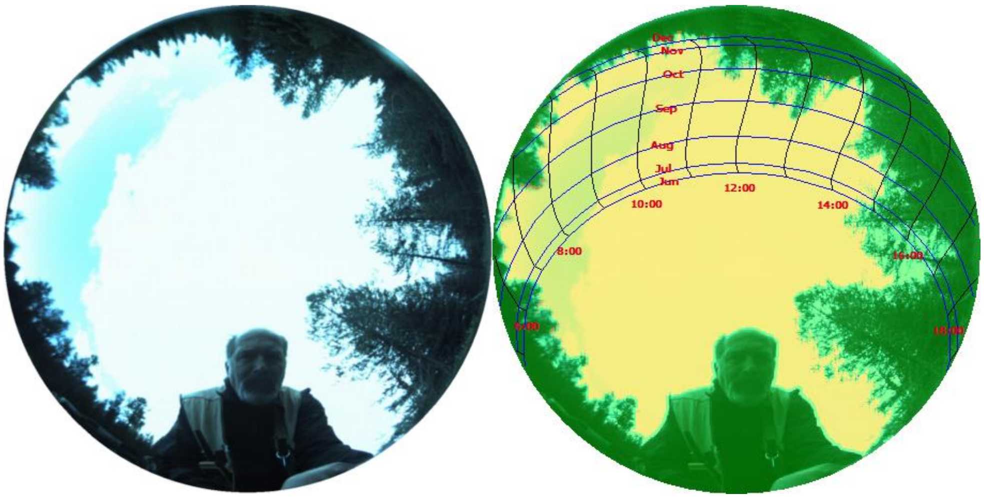

Figure 36. Example of a quality skyline image that clearly captures the surrounding vegetation and an image showing how the skyline image is converted to calculate solar input.

9.4 Riparian Structure

References: Modified from Kaufmann et al. (1999) and Peck et al. (2001).

Equipment: N/A

Objective: Quantify the effective areal cover, size, and type of riparian vegetation at each site.

Step 1. Lay out plots.

i. At transects 1, 6, 11, and 21, visually estimate a 10 m by 10 m square plot on both the right and left banks centered on each transect. Plot boundaries should extend 5 m upstream and downstream from the transect and a distance of 10 m back into the riparian vegetation from the edge of the bankfull channel.

ii. If a large or small side channel is present along a transect, locate plot(s) on the outermost bank. Do not locate plots on islands or bars.

iii. On steeply-sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.

Step 2. Conduct visual estimations of areal cover from the center of each plot at all 5 transects.

Within each 10 m by 10 m plot, visually divide the riparian vegetation into three vertical layers: canopy layer (> 5 m), understory layer (0.5 to 5 m), and a ground cover layer (< 0.5 m). For each vertical layer, estimate areal cover as the amount of shadow that would be cast by that particular layer alone if the sun was directly overhead. Round all estimates to the nearest 5%.

Note: Estimates of areal cover for the canopy and understory layers will only sum to 100% when there is no open sky visible through the foliage.

i. Canopy Layer (> 5 m):

   a. *By vegetation type:* Estimate the percentage areal cover in the canopy layer alone that is contributed by each of the following vegetation types: 1) coniferous, 2) deciduous, 3) broadleaf evergreen (Russian-olive), and 4) dead woody vegetation.

   b. *By size:* Estimate the percentage areal cover in the canopy layer alone that is contributed by each of the following size categories: 1) large trees (> 0.3 m diameter at breast height (DBH)), and 2) small trees (< 0.3 m DBH).

Note: The sum of canopy layer by vegetation type must equal the sum of canopy layer by size.

ii. Understory Layer (0.5 to 5 m):

*By vegetation type: E*stimate the percentage areal cover in the understory layer alone that is contributed by each of the following vegetation types: 1) coniferous trees or shrubs, 2) deciduous trees or shrubs, 3) broadleaf evergreen (e.g., Oregon grape, sagebrush, ceanothus/buckbrush), 4) forbs and grasses, and 5) dead woody vegetation.

iii. Ground Cover Layer (< 0.5 m):

Estimate the percentage of the ground covered by the following categories: 1) trees, woody shrubs and tree seedlings (including basal area of live or dead trees), 2) forbs and grasses (includes moss and lichens), 3) bare dirt, 4) duff or woody debris, and 5) rock. Cover percentages should sum to 100%.

9.5 Water Temperature

Reference: Isaak et al. (2010).

Equipment: Onset TidbiT, PVC housing material/cables, epoxy, rubber gloves, underwater viewer.

Objective: Install year round water temperature sensors at sites using one of two installation methods.

Water temperature sensors will be placed at all annual and rotating panel sites within each CHaMP subbasin. At new sites where sensors have not been established, it is important that watershed leads make a concerted effort to install all sensors before high summer temperatures (approx. July 15). When early flow conditions do not permit installation with the epoxy method, use the wire method initially and have the crew members apply the epoxy method (where applicable) after flows have subsided. Temperature data should be downloaded in the fall and before high spring flows.

9.5.1 Establishing New Sensors

Step 1. Identify sensor placement location.

i. Epoxy Method: Search for a large rock or boulder (charismatic megaboulders are best) that will be immobile during large floods and is easy for others to identify on subsequent site visits. Finding a good rock is the most important step to a successful sensor installation. If a suitable rock is not available, consider placement using the wire method.

   a. Optimal placement locations for rock and boulder secured sensors include:

      i. Rocks, boulders, or structures that will not move or be disturbed at high flows.

      ii. Boulders large enough that they protrude above the low flow water surface and wide enough that they can effectively shield the sensor from moving rocks or debris during high flows.

      iii. Areas downstream of large rocks in pockets of relatively calm water with smaller substrate sizes.

      iv. A relatively flat downstream attachment surface that is deep enough to remain submerged in flowing water for the entire year.

ii. Cable Method: If there is not a suitable rock or boulder within or in close proximity (100 m) to the site, identify a secure location such as the base of a tree or root wad to attach the sensor using a metal cable.

   a. Optimal placement locations for cable secured sensors include:

      i. Areas with sufficient stream flow that will maintain year-round flow, but outside of strong currents. Also consider whether the sensor attached to the wire will move at high flows and place sensor so that it will not get hung up in vegetation or left on the bank.

      ii. Locations away from seeps or steep banks on the side of stream in order to avoid groundwater influences.

iii. Camouflaged or inconspicuous locations at sites with high public use. In these instances, vegetation, grasses, or cobbles may be used to cover wire or hold wire in place.

b. Suitable locations for attaching sensors may be relatively rare within low-gradient, meadow reaches. In these instances, examine potential placement locations no more than 100 m upstream or downstream of the site and away from tributary influences.

Step 2. Install and record sensor location details.

i. After identifying a suitable sensor placement location:

a. Record sensor serial number.

b. Install sensor.

c. Take a GPS reading. Record UTM coordinates, accuracy, and the date and time installed.

d. Record the stream bank that the sensor is nearest to and the distance from that stream bank. If cable is attached to a tree on the bank, record the distance from bank as 0.

e. Record the attachment method as cable or epoxy.

f. Take a photo of the sensor location. Include enough of the surrounding environment in the photo to relocate the sensor.

g. Write a detailed description of the sensor location in the placement location field. Description should include distance from site bottom and any other pertinent information for relocating sensor at subsequent visits. The more detail the better. For example: Sensor attached to grey, rectangular boulder 1 m in diameter near river left (~1.5 m from bank), 5 m upstream from transect 12 OR Sensor is attached to the base of a small willow, ~ 6 m downstream from top of site on river right.

h. Note sensor location on site map.

i. After sensor has been in the water for approximately 1 hour, measure and record the instantaneous water temperature near the sensor using a handheld thermometer. Record the date and time instantaneous temperature is measured. It is preferable to measure the instantaneous water temperature at the top of the hour when the installed sensor will be recording information.

9.5.2 Previously Installed Sensors

Step 1. Locate previously installed sensor.

i. Use existing photographs, GPS coordinates, and site maps to locate the previously installed water temperature sensor.

a. If sensor location is found but sensor is missing, search downstream to see if sensor can be found. Note if sensor cannot be located. Establish a new sensor using the criteria outlined above.

Step 2. Download sensor data and record information

i. Remove the sensor from the housing unit and confirm that the correct sensor serial number was recorded when originally installed. Avoid removing sensor from the water when it will be recording one of its hourly temperature measurements (on the hour).

   a. Download sensor using the sensor shuttle (Appendix G).

   b. Note whether the red light on the sensor is blinking. If there is no blinking light, replace the sensor and notify the watershed lead.

   c. Record in the sensor condition field the current condition of the sensor as being submerged in flowing water, submerged in non-flowing water, dry, or missing.

   d. Record if the sensor has been left in place, removed, or moved to a more suitable location. Move the sensor if it is in non-flowing water or buried in sediment. Replace sensor with a new one if it is missing. Record action in the action field.

   e. Take a new GPS reading. Record UTM coordinates, accuracy, and the date and time sensor was downloaded or checked.

   f. Verify and update sensor location information as needed such as stream bank, distance from bank, attachment method, and location description.

   g. Take a new photo of the sensor.

   h. Measure and record the instantaneous water temperature near the sensor using a handheld thermometer. Record the date and time instantaneous temperature is measured. It is preferable to measurement the instantaneous water temperature at the top of the hour when the installed sensor will be recording information.

   i. Note the sensor location in the site map.

9.6 Discharge

Reference: Peck et al. (2001).

Equipment: Velocity meter, tape measure, pins, depth rod.

Objective: Measure depth and velocity at increments along a cross-section in order to calculate discharge of the site at the time of sampling.

Depth and velocity measurements are made at one carefully chosen channel cross-section. It is important to choose a channel cross-section that is as much like a canal as possible to get the best estimate of the amount of water flowing through the site. A Fast Water Non-Turbulent area with a U-shaped channel cross-section that is free of obstructions provides the best conditions for measuring discharge. You may remove rocks and other obstructions to improve the cross-section before any measurements are made. At smaller streams during low flows, velocity with a flow meter may be impossible to measure.

Step 1. Identify cross-section location.

i. Locate a cross-section in the stream channel that has most of the following qualities:
   a. Segment of stream above and below the selected cross-section is straight.
   b. Depths are mostly greater than 15 cm, and velocities are mostly greater than 0.15 m/s. Do not measure discharge in a pool.
   c. "U" shaped channel with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
   d. Flow is relatively uniform with no eddies, backwaters, or excessive turbulence.
   e. Is located in close proximity to the bottom of site.

ii. If an appropriate cross-section location cannot be identified within a site, extend the search upstream or preferably downstream of the site boundary, avoiding locations that would differ in flow from that of the site such as entry areas of tributaries and side channels within the site extent.

iii. Avoid locating cross-sections where 100% of the flow is not in the channel (side channels are present). If this situation is unavoidable, such as a braided channel, take separate cross-section measurements, one in the main channel and one in the side channel(s).

Step 2. Set up cross-section and identify measurement locations.

i. Stretch and secure a meter tape across the stream perpendicular to the flow with the “zero” end on the left bank.

ii. Divide the total wetted stream width into 15 to 20 equally spaced intervals (Figure 37).
   a. To determine interval width, divide the width by 20 and round up to a convenient number.
   b. Intervals should not be spaced less than 10 cm apart, even if this results in less than 15 intervals.

iii. Take the first depth and velocity measurement at the left edge of water. If depth is 0, record velocity as 0. Conduct the second measurement one interval out from the left bank and continue measurements at each interval. The last depth and velocity measurement will be at the right edge of water.

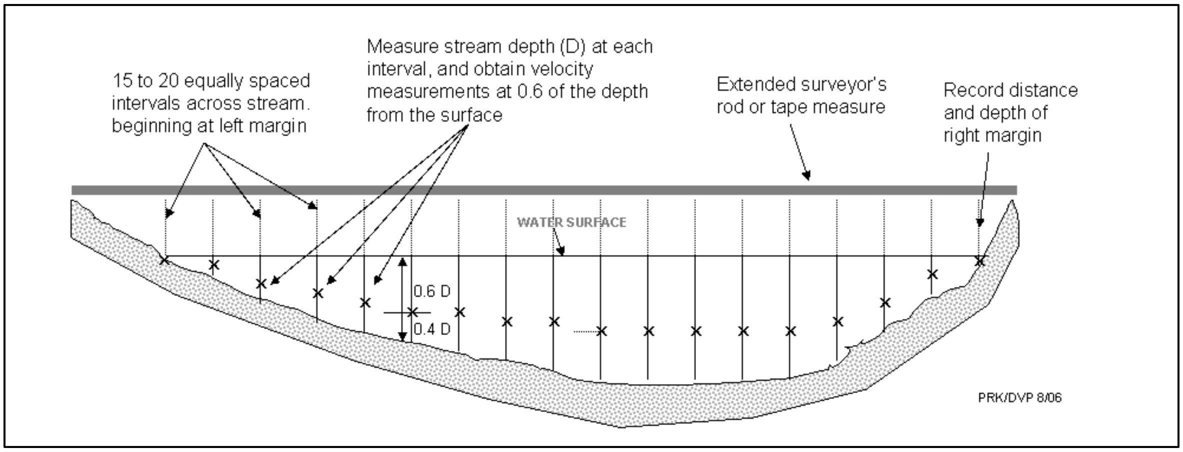

Figure 37. Cross-section of a streambed showing location of discharge measurements.

Step 3. Measure depth and velocity.

i. Stand downstream of the velocity meter when taking measurements.

ii. If the depth is 0 record the velocity as 0. If velocity is negative (-), record the measured velocity.

iii. Place the topset rod in the stream at the interval point and record the water depth. Set the topset rod to the correct height. This will raise or lower the velocity probe to 60% of the water depth at that interval. Position the velocity probe directly perpendicular to the stream channel and hold the topset rod vertically level. Wait for the progress on the velocity meter to go through a full 10 second cycle (i.e., fully through 0% to 100%). Record the velocity. Move to the next interval point and repeat the same procedure until depth and velocity measurements have been recorded for all intervals.

iv. Take the last depth and velocity measure at the right edge of water. Verify that the tape distance of your final measurement recorded in the data logger is equal to the tape distance at the right wetted edge.

9.7 Water Chemistry

Equipment: Conductivity meter, thermometer, alkalinity test kit.

Objective: Measure conductivity, instantaneous water temperature, and alkalinity at the upstream end of each site above the last transect flag. Take each measurement in flowing water near the center of the channel.

Step 1. Measure conductivity.

i. Collect a sample of water from the stream using the 20 ml sample cup provided with the conductivity meter. The sample should be from underneath the surface of the water (hold the cup upside down when dipping it into the stream, then turn it upright to get water sample).

ii. Measure conductivity using the conductivity meter and record in micro-Siemens per centimeter (µs/cm).

iii. Recalibrate the conductivity meter after every sampling hitch according to the instruction manual.

Step 2. Measure instantaneous water temperature.

i. Measure and record the instantaneous water temperature at the time of conductivity sampling using the conductivity meter (if applicable) or a handheld thermometer.

Step 3. Measure alkalinity.

i. Using the alkalinity test kit, measure and record Total Alkalinity to the nearest 4 parts per million (ppm).

ii. Instructions for using the LaMotte Alkalinity Test Kit can be found in Appendix J.

9.8 Macroinvertebrate Sampling

Equipment: Drift nets (500 µm mesh, mouth = 40 cm X 20 cm, 1 m ½" rebar, 2 cm tall vertical spacers, hammer or mallet, mesh sieve ≤ 500 µm, forceps/tweezers, spray bottle, plastic wash tub/bucket, 95% ethanol (EtOH), leak-proof sample jars (screw-top only), pre-printed sample jar labels (laser printed on Rite-in-the-Rain paper only), pencils, packaging tape.

Objective: Collect a quantitative sample that describes the abundance and composition of macroinvertebrates actively drifting in the water column and at the surface of the stream.

Step 1. Determine the drift cross-section location.

i. Drift nets will always be deployed above the site to avoid unintentional introduction of debris or macroinvertebrates into the drift. Do not disturb the stream substrate or riparian vegetation upstream of nets.

ii. The ideal drift cross-section location is near the downstream end of a Fast Water channel unit (e.g., riffle or non-turbulent) with a length approximately equal to the average length of Fast Water channel units within the site.

iii. Ideal drift cross-sections have as many of the following characteristics as possible.

  a. Segment of stream above and below the drift cross-section is straight.

  b. Depths range from 15 – 30 cm; 10 and 40 cm are minimum and maximum depths.

  c. Moderate velocities between 0.3 and 0.6 m/s are ideal for drift sampling. Drift nets become difficult to maintain and often clog at high flows. At low flows they are inefficient at capturing macroinvertebrates.

  d. "U" shaped channel with a uniform streambed free of large boulders, woody debris, brush, and dense aquatic vegetation.

  e. Flow is relatively uniform with no eddies, backwaters, or excessive turbulence.

Note: Drift cross-section locations will be very similar to ideal locations for measuring stream discharge.

Step 2. Determine net deployment locations along drift cross-section.

i. Two drift nets will be deployed adjacent to one another along your drift sample cross-section (Figure 38).

ii. Choose two net deployment locations along your drift cross-section that best meet flow and depth criteria in step 1.

iii. Ideally nets will be separated, not side-by-side.

iv. In small streams it may be necessary to place drift nets side-by-side so that each net can be deployed in areas of the channel that meet depth and flow criteria.

v. In extremely small streams there may only be space for a single net to be set in a location that best meets depth and flow criteria.

vi. In some cases (i.e. small streams), it may be necessary to move rocks and remove aquatic vegetation in order to create ideal conditions for drift sampling.

Step 3. Deploy drift nets.

i. Orient drift nets perpendicular to, and facing the stream flow (Figure 38).

ii. Anchor drift nets in the stream channel between two pieces of rebar driven into the streambed roughly 25 cm apart.

iii. Suspend the bottom of the net mouth 2 cm above the streambed by sliding vertical spacers over each piece of rebar (Figure 39). The spacers are used to ensure that the bottom of the net does not come in contact with the stream bed and deters invertebrates from crawling into the net.

Figure 38. View of active drift nets looking upstream.

iv. The top of the net mouth should always extend above the stream surface.

v. Deploy drift nets at least two hours after sunrise and pull them at least two hours before sunset. Sunrise/sunset times for individual locations are available at: http://aa.usno.navy.mil/data/docs/RS_OneYear.php

vi. When installing the nets, leave the collection cup off so that anything that might be swept into the net during installation passes through. Insert collection cup after installing nets.

vii. Strive for a sampling duration of at least three hours. Do not disturb the nets during the collection period.

a. Monitor the nets while sampling as often as necessary to check for signs of net clogging. Drift nets may become clogged at high velocities and in streams carrying large amounts of suspended material. Clogged nets cause water to back up at the net mouth, potentially jeopardizing the validity of the sample.

b. If debris levels are high or net clogging is apparent, sample for a shorter duration. Drift samples should be employed for a minimum of 1.5 hours.

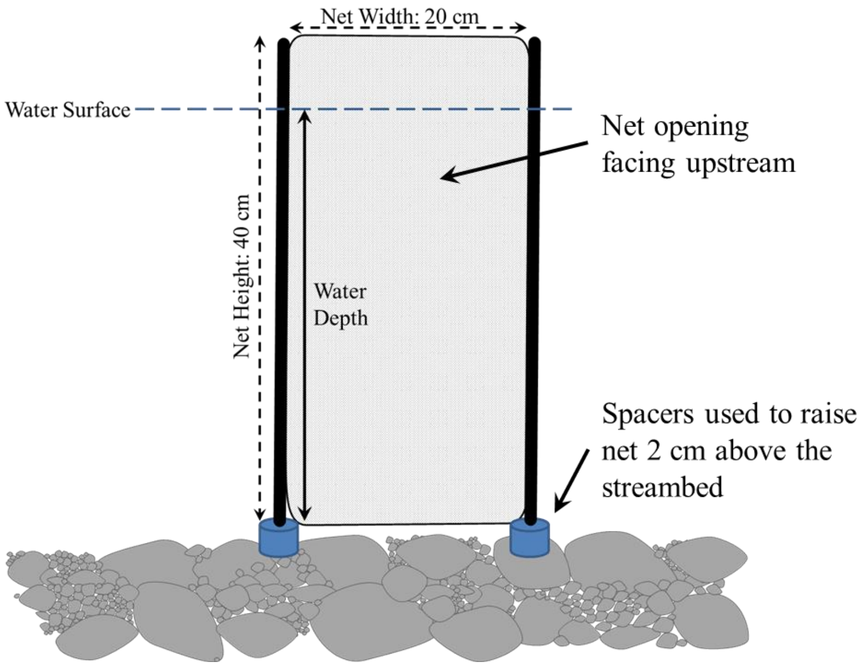

Figure 39. Prevent the bottom of the net from resting on the streambed by using 2 cm vertical spacers. The depth of flow is measured from the water surface to the bottom of the net mouth.

Step 4. Measure and record data.

i. Record the start and end time, depth, and flow velocity at each net.

   a. Record the start time and end time for each net to the nearest minute.

   b. Measure and record the depth of flow entering the net just after setting and just before removing each net. The depth of flow is measured from the water surface to the bottom of the net mouth (Figure 39).

   c. Measure and record the flow velocity entering each net just after setting and just before removing each net. Take the initial velocity measurement immediately after attaching the cup. The flow velocity is measured at the center of the net mouth at a depth equal to 60% of the depth from the water surface to the bottom of the net mouth.

Step 5. Collect drift sample.

i. After completing the sample, lift the net vertically without disturbing the substrate.

ii. Hold the net vertically (cup down!) and rinse material into the bottom of the drift net cup using a spray bottle.

   a. Transfer the material (invertebrates and organic matter) retained in the net into sample jars with a small spoon and rinse any remaining material in the net into the jar with a squirt bottle.

b. Fill the jar(s) with 95% ethanol (EtOH) using at least a 1:1 ratio of EtOH to macroinvertebrates/organic matter. Use additional jars if the volume of invertebrates/debris fills more than ½ of the sample jar.

c. Label the jars inside and out with the project name (CHaMP), complete Site ID, date, crew, and net number using Rite-in-the-Rain labels. Only use pencil to write on labels. Attach labels on the outside of jars using clear packaging tape.

d. If there are multiple jars, label them as 1 of 2, 2 of 2, etc. Repeat this process for samples collected in each individual drift net.

e. <u>Do not combine the contents of separate drift net samples</u>.

f. EtOH works as a disinfectant and is not really a preservative. Therefore, use adequate quantities of EtOH (1:1 ratio) and attempt to keep samples cool (i.e., in coolers or refrigerators) while awaiting shipment. Avoid keeping samples in the sun or in hot vehicles.

Step 6. Ship Samples.

i. Samples are required to be shipped to the Rhithron laboratory weekly or at the end of each hitch. Make sure that samples are soaked in the 1:1 ratio of EtOH for at least 48 hours before shipping. If necessary to meet this requirement, samples collected on the last day of a hitch may be held until the next shipment.

ii. Do not ship samples full of alcohol. Take the following steps before shipping samples:

a. Decant the alcohol until samples are just moist and ship with overnight delivery (be careful about weekend delivery schedules). Rhithron will recharge in fresh EtOH on arrival.

b. Verify that each jar is adequately labeled and that labels are legible.

c. Pre-notify Rhithron for each shipment to ensure that someone is on hand to receive and process the samples.

d. Complete the chain-of-custody document. Include one copy by email to pre-notifying Rhithron, include a copy in the shipment box, and retain a copy for your records.

SECTION 10: DATA MANAGEMENT

The CHaMP data management plan is integral to ensuring successful capture, quality assurance, and archiving of CHaMP field data along with the derivation and reporting of site-level metrics. The data system will be comprised of field data capture tools and a centralized database with an online interface. The online interface will support pre-season site evaluations, tracking project metadata, uploading field data, quality assurance procedures, and reporting derived metrics. Under this plan, data will initially be captured on handheld field computers and then uploaded to the online database when internet connectivity is available. A standard set of field data capture devices will be provided which will include data entry applications for the topographic and auxiliary habitat surveys. This two-part system allows remote capture of data and centralized management of metadata, field measurements, and derived metrics. Collectively, these tools support CHaMP's data documentation, data capture, data quality, information archiving, standard metric calculation, and project reporting needs.

Data management activities will be conducted during pre-season, field-season, and post-season activities (Table 10).

Table 10. Timing of data management activities throughout the year.

Timing	Data Management Activities
Pre-Season (April-June 15th)	Document project, statistical design, and site evaluation metadata.
Field-Season (June 15-Sept 30th)	Daily data capture and quality assurance review of topographic and auxiliary data. Complete weekly quality assurance procedures and generated TIN file for each site. Perform weekly uploads of datasets to CHaMP website.
Post-Season (Oct 1- Oct 30th)	Ensure datasets are complete. Perform quality assurance on completed datasets and derived site-level metrics.

10.1 Pre-season Documentation

Thorough documentation is essential for long-term scientific datasets. Documentation provides the opportunity to use data properly for both planned and unplanned analyses and decision making. Documentation must capture the statistical design for sampling, measurement procedures, data quality, and data reduction steps. Most documentation during the startup year for each watershed will occur in both narrative (e.g., this document) and structured (database) formats. Capturing documentation directly in the CHaMP database will ensure direct linkage with data and will support searching of data.

The project and statistical design information will be entered directly to the CHaMP website using the Project and Study Design utilities by each CHaMP project supervisor. Project information will include agency, staff, roles, BPA project number, watersheds to be monitored, and other pertinent information. Study design information will include the extent of sampling frame, defined stratum, list of GRTS sites within each stratum, sampling allocation across stratum, and temporal sampling frequency. All projects will participate in a three day workshop that will walk participants through the process of defining the study design for their given watershed. Decisions made during the workshop about study design will be recorded through the CHaMP website using the Study Design utility. This information will be stored and tracked directly with raw measurements and derived metrics.

Following the study design workshop, the project supervisor will begin evaluating sites for inclusion in the summer sampling effort. The evaluation process will be completed through the CHaMP website using the GRTS Site Evaluation utility. Each site is evaluated for its conformance to the statistical design, its ability to be safely access by field crew, and to arrange for access permission on private land. Evaluations rely on assessments using Google satellite images, USGS quad maps, landownership maps, other GIS layers, local knowledge, and in limited situations, field reconnaissance. Evaluations will be recorded in the Site Evaluation form. The evaluation process will produce a list of sites to be visited for the given year, along with latitude and longitude coordinates. The list will be saved as a text file and loaded to a hand-held field computer.

10.2 Field Data Capture and Field Quality Assurance

Topographic survey data and auxiliary data will be captured using separate data logger applications. Auxiliary data (wood loading, substrate composition, etc.) will be captured by a single crew member using a handheld field computer. Upon arriving at the site, the crew member will launch the application, then select the site and crew and enter data about current environmental conditions. As the crew member completes sampling they will enter data into forms under the Site, Channel Unit, and Transect tabs. For categorical data, the appropriate value will be selected from a pull down list. For numeric data, values will be entered using an on-screen numeric pad. Numeric values that fall outside an expected range will produce a warning to the crew member. The warning asks the crew member to review the value and to either accept the value as a correct value or enter a new value. This warning system will limit the potential for entering erroneous data; however, it does not prohibit crew entering of extreme values. Additional warnings will be triggered if required values are not entered for a given data form. A detailed user guide will be provided for the auxiliary data entry application.

Data quality assurance review will be conducted on a daily basis by crew members and on a weekly basis by the crew supervisor. The quality assurance review will test for completeness, outliers in numeric data, and outliers in basic summary metrics. At the end of each day, the crew member will be prompted to verify the number of channel units, total wood pieces, and number of drift samples. Additionally, the crew will be prompted to review any values recorded as a missing value. Next the crew will view and verify any numeric outliers. At the end of each week, the crew supervisor will perform a similar audit of the data.

The topography survey will create a raw topographic point file (x, y, z data) from which several geo-rectified products will be developed using Arc GIS 10 software. A triangular irregular network (TIN) and DEM will be created as the base topographic products from the survey.

Data quality assurance for the topographic survey data will take place at four checkpoints within the flow of data from origination on the total station to data storage and web availability. These checkpoints will reduce the likelihood of data errors compounding throughout data processing. The four checkpoints are:

1. Data origination (total station)
2. End of day data review (total station/data logger)
3. End of week data processing and review (laptop)
4. Centralized database checks (CHaMP data system)

The crew lead is responsible for creation and submission of the original point file, a lines file (breaklines), a clean TIN, and a quality assurance report (table in geodatabase). These should be produced within one week of initial data collection.

10.3 Data Back Up and Submittal

At the end of each sampling day field crew should back up data files to an external hard drive. It is critical that a daily back up is made in case the data logger is damaged or lost during field activities. The hard drive must be stored in a safe location and not taken into the field during sampling. The external hard drive should be stored in a waterproof and impact resistant case (e.g., a Pelican case) for crews that are working in remote locations and don't have daily access to a bunk house. On a weekly basis, the crew supervisor must upload all data files for the week to the CHaMP website. This upload process will require an internet connection.

10.4 Metric Generation and End of Season Quality Assurance Review

Site-level metrics will be generated from data submitted to the CHaMP website. These metrics will be presented in graphical and map format for all sites. At the end of each field season, crew supervisors will review raw measurements and derived metrics for data completeness, numeric outliers, and ecologic sense. Crew supervisors will be presented with a series of graphs through the CHaMP website and asked to verify data quality.

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Appendix A: Equipment Check List

Method	**Equipment**	**Check/Status**
All methods	Data Logger or clipboard with complete set of forms	
All methods	GPS	
All methods	Flagging/flags, Sharpies	
All methods	Metal forestry tags	
All methods	Tape measure	
Site Setup	Rebar caps	
Site Setup	Rebar	
Site Setup	Hammer	
Site Setup	Aluminum tag	
Site Setup	Map	
Channel topographic survey	Total station (with tribrach and data logger)	
Channel topographic survey	Tripod	
Channel topographic survey	Prism rod with topographic foot	
Channel topographic survey	Radios (2)	
Channel topographic survey	Umbrella or total station cover	
Channel unit level	Gravelometer	
Channel unit level	Fines grid and viewer	
Channel unit level	Marked shovel	
Channel unit level	Depth rod	
Site level – Map	Rite-in-the-rain paper	
Site level – Photos	Data Logger, camera, compass	
Site level - Solar input	Solar Pathfinder, SunEye	
Water temperature	Onset temperature sensor/Tidbit	
Water temperature	Sensor housing	

Water temperature	Wire brush	
Water temperature	Rubber gloves	
Water temperature	Fox epoxy	
Water temperature	Installation wire	
Water temperature	Handheld thermometer	
Discharge	30 Meter Tape/surveyors rod	
Discharge	Velocity meter probe	
Discharge	Pins	
Discharge	Depth Rod	
Water Chemistry	Conductivity Meter	
Water Chemistry	Alkalinity Meter	
Drift macroinvertebrates	Drift nets - 1000µm mesh, mouth = 40cm X 20cm, mesh sieve less than or equal to 500 µm	
Drift macroinvertebrates	Sample jars, sample jar labels	
Drift macroinvertebrates	Ethanol	
Drift macroinvertebrates	Waterproof labels	
Drift macroinvertebrates	Stopwatch	
Drift macroinvertebrates	Forceps/tweezers	
Drift macroinvertebrates	plastic bucket, plastic wash tub	
Drift macroinvertebrates	spray bottle	
Drift macroinvertebrates	packaging tape	
Drift macroinvertebrates	portable velocity meter	

Appendix B: Fish Habitat Requirements Summary

Table 11. Habitat attributes that directly and indirectly affect the growth of juvenile salmonids in stream environments.

Limiting Factor	Direct Mechanism	Direct Habitat Attributes	Indirect Mechanism	Indirect Habitat Attributes
Food	Energy inputs to salmonids come mainly from **drifting invertebrates.**	**Drift biomass** is the most direct measure of food availability. **Benthic biomass** and drift biomass may be correlated	Factors that affect the amount of food, are: inputs from **terrestrial vegetation**, **riffle substrate** available for invertebrates, and **primary production**	**Canopy cover** (AP, LiDAR, solar pathfinder).**Riffle substrate** (pebble counts in riffles). **Gross Primary Production** and **Stream Respiration** can be estimated with a DO sonde
Temperature	**Temperature** affects all physiological processes including consumption rate and metabolism which in turn affect growth rates	**Site temperature** measured with temperature logger year round.	see factors related to temperature but include **shade, bed material, thermal buffers from riparian veg, climate, hyporheic exchange, tributaries, upstream flows, channel form**	**Channel unit geometry, Canopy cover** (AP, LiDAR, solar pathfinder, ..).**discharge, air temperature, humidity, substrate composition, valley topography** (estimated from external data sources)
Activity	Activity occurs during **foraging**, and **holding position** in moving water, **migration**, predator and competitor **avoidance** (see below)	Foraging: Requires high velocity (encounter rate) and low velocity (holding) zones found in pool heads (**channel units**) and behind structure in fast moving water (**cobble, lwd**).	**Migration** between resting, foraging, predator avoidance, high velocity currents, and thermal refugia depends on the proximately of microhabitats within the home range and obstacles between them.	**Habitat complexity** is difficult to measure but includes **frequency, size, and location of channel units, and structure.** Location of barriers through inventories and GIS

Table 12. Habitat attributes that directly and indirectly affect the mortality of juvenile salmonids in stream environments.

Limiting Factor	Direct Mechanism	Direct Habitat Attributes	Indirect Mechanism	Indirect Habitat Attributes
Starvation	Consumed energy does not meet energy expenses, see above review for **growth**			
Predation	Salmonids must avoid **predators**	**Predator** presence and abundance	**Hiding cover** for salmonids	**Substrate composition, LWD, channel unit geometry, Undercut banks** measured during field surveys
			Habitat suitability for predator species	Presence of predators will be dependent on **climate, channel unit characteristics, water temperature.**
Physical Processes	High **velocity** causes mortality during high flow events.	Temporally continuous **discharge** measurements	Channel complexity as **LWD, substrate composition, channel geometry and planform** offer refuge from flow events	Field surveys of **channel unit characteristics** and **structure (LWD, substrate)**
Water Quality	Extreme levels of **toxins** or low levels of **required components (DO)**	Temporally continuous measure of **temperature,** which is related to levels of **DO**	**Benthic invertebrate** community composition is related to many water quality parameters	Field collections of **benthic macroinvertebrates**

Table 13. Habitat attributes that directly and indirectly affect the survival to spawning for adult salmonids in stream environments.

Limiting Factor	Direct Mechanism	Direct Habitat Attributes	Indirect Mechanism
Migration barriers	**Barriers** include dams, culverts, waterfalls, diversions	**Location of barriers** through stream networks through inventories and GIS layers	
Temperature	**Temperature** has to be suitable, and in places isolated thermal refugia is highly selected for and necessary for survival.	**Temporally continuous temperature** monitoring at sites, **spatially continuous temperature** information estimated using GIS models	see Temperature review in juvenile growth
Predation	Avoid predation from terrestrial and aquatic predators. Cover such as **boulders, large wood, undercut banks, and pools** to help avoid predators.	Spatially explicit **location of cover elements to suitable spawning habitat** collected by field surveys	see Predation review in juvenile survival

Table 14. Habitat attributes that directly and indirectly affect salmonid egg to fry survival in stream environments.

Limiting Factor	Direct Mechanism	Direct Habitat Attributes	Indirect Mechanism	Indirect Habitat Attributes
Scour	High flows scour substrate which contains deposited eggs		Steep, incised channels have more ability to scour redds during high flows	Measurements of **channel geometry, planform, gradient, and availability of suitable spawning channel types** from field surveys
			Suitable substrate that allows burial of eggs to depths where scour is avoided	Field assessments of f**ine sediment (e.g., pool-tail fines sampling)**
Dissolved Oxygen	Sufficient **DO** to allow diffusion of oxygen to eggs	Field measurements of **DO**	DO is highly dependent on water **temperature**	Temporally continuous **temperature** monitoring
			Certain **channel unit types** (pool tails) have increased **hyporheic exchange**, more flow passing over eggs	Quantity and quality of channel unit types measured during field surveys
			Fine sediment affects flow through substrate to eggs	**Substrate composition** assessments (subsurface fines) assessed during field surveys
Temperature	Temperature affects development time of eggs	Temporally continuous **temperature** monitoring, **cumulative temperature (degree day)** dictates emergence timing		

Appendix C: Monitoring Attribute Review

Table 15. Ranges of precision and accuracy measures of various categories of stream habitat attributes.

Attribute	Metric	RMSE	CV	S:N	Correlation (R^2) to "truth"	Source
Bank Attributes	Bank Angle	-	20.6	17.13		USDA Gen Tech Rpt RMRS-GTR-122. 2004
	Undercut Depth	-	0.06	20.6		Unpublished data
Large Woody Debris	LWD Frequency	1.21 – 1.77	16.4 – 64.5	87.1 – 4.4	.96 - .71	Roper et al. 2010
	LWD Frequency	0.9 – 17.9	18.6 – 42	13.87 - .74	NA	Whitacre et al. 2007
Thalweg Profile	Gradient	0.02 - 1.01	5.9 - 29.5	4.9 - 188.2	0.98 - 0.99	Roper et al. 2010
	Sinuosity	0.04 - 0.11	3.1 - 8.8	1.0 - 13.0	0.76 - 0.95	Roper et al. 2010
Pools	% Pools	5.5 - 12.9	21.8 - 80.7	0.4 - 13.5	0.38 - 0.95	Roper et al. 2010
	Pool Frequency	9.2 - 27.0	22.5 - 77.3	0.2 - 5	0.03 - 0.43	Roper et al. 2010
	Residual Pool Depth	2.5 - 18.4	12.7 - 54.9	0.2 - 11.9	0.12 - 0.94	Roper et al. 2010
Stream width	Bankfull width	0.33-2.58	7.3 - 35.9	2.5 - 58.1	0.52-0.73	Roper et al. 2010
	Width-to-depth	2.9-7.9	19.0 - 30.1	1.5 - 2.1	0.00-0.49	Roper et al. 2010
Substrate	%Fines	4.8 - 14	26 - 64	0.3 - 7	0.07 - 0.84	Roper et al. 2010
	Pebble Counts/D_{50}	14 - 24	28 - 66	1.0 - 6.0	0.73-0.92	Roper et al 2010
	Embeddedness	-	-	-	-	Sylte and Fischenich 2002

Specific measures of each attributes performance can be ranked using the proposed ranking scheme of Roper et al. (2010). These ranks are meant as guidelines only and may not be applicable in every situation: RMSE –attribute specific, can't be ranked across attributes, CV – low > 35%, moderate 20-35%, high < 20%, S:N – low < 2.5, moderate 2.5 – 6.5, high > 6.5, Correlation to the truth – low < 50%, moderate 50-75%, High > 75%.

Table 16. Summary of metric review for various attributes collected under fish habitat monitoring protocols.

Category Reviewed	Stream bank attributes
Metric(s) Reviewed	Bank stability, bank angle, undercut banks
Critical function of the attribute	• For Fish Habitat –how accelerated erosion of stream banks affects quality/availability of spawning gravel, cover, shelter from predators, oxygen levels, stream temp. • Stream Character - sediment budget, how accelerated erosion affects the biological and physical functions of streams.
Protocols reviewed	ISEMP, PIBO, EMAP, MIMs, Winward, USDA – ARS Sedimentation laboratory, EPA WARSS (Rosgen BEHI)
Measurement limitations from the literature	• Difficult to quantify bank stability • Problems with detecting heterogeneity for rapid streambank stability assessments.
Do metrics capture the critical function?	• Stability – No. 90% of Bank stability measurements are considered stable banks. This approach is too gross of a metric and does not detect heterogeneity. • Quantity of undercut banks difficult to determine from point estimates.
If current protocol inadequate, what should be adopted (short term & long-term)	• Either more comprehensive bank geometry measurements and/or fluvial geomorphic audit conducted over large reach lengths. Compliment bank data with finer resolution riparian vegetation assessment. • Undercut depth should be measured continuously at the channel unit scale as a measure of fish cover. • Do not estimate bank stability until measurements are more meaningful.
Category Reviewed	Fish Cover
Metric(s) Reviewed	LWD, undercut banks, visual assessments of 10 cover types developed by EMAP (Artificial structures, Boulders, Small woody debris, Bryophytes, Filamentous algae, LWD, Live trees or roots, Macrophytes, Overhanging vegetation, and Undercut banks.
Critical function of the attribute	• Fish Habitat –LWD and other forms of cover provide velocity predator refuge, rearing habitat, and feeding habitat. • Stream Character – LWD creates channel complexity and low velocity areas next to high velocity habitats that increase feeding opportunity while preserving energy.
Protocols reviewed	AREMP, PIBO, EMAP, CDFG, NIFC, ODFW, and Upper Columbia (ISEMP).
Measurement limitations from the literature	• LWD pieces – the studies reviewed showed that LWD measurements were variable in precision and repeatability between protocols, but relatively precise within protocols. • LWD aggregates – Assessment of aggregates not reviewed in the literature. • Little consistency among protocols on definition of LWD aggregates. • Aggregates are measured at the reach scale and are not informative on how they relate to function.
Do metrics capture the critical function?	• LWD pieces – , LWD metric is reported at the site level (LWD pieces/100 meters), and fish do not likely respond to average reach conditions. • LWD aggregates –LWD aggregates are rarely related to channel unit and therefore do not measure how they function for fish (i.e., LWD aggregates in a pool provide important cover and LWD aggregates in riffles provide slow water refugia near fast water feeding areas.
If current protocol inadequate, what should be adopted	LWD – Short term • Relate function to fish by assessing LWD at the channel unit scale. • Adopt a minimum LWD size classification that best allows comparison between

(short term & long-term)	protocols. LWD – Long term • Develop measurements of LWD recruitment potential, LWD transport, and LWD stability to assess the LWD budgets of monitored reaches. This might best be achieved by remote sensing. Fish Cover – Short term • Continue using established EMAP protocol of visually assessing 10 different fish cover elements. Fish Cover – Long term • Develop measurements of fish cover that are quickly assessed, and directly relate to fish. • Collect cover at the channel unit scale to provide information about function for fish.
Category Reviewed	Invertebrate sampling
Metric(s) Reviewed	Food availability (Benthic, Drift), diversity indices, site impairment
Critical function of the attribute	• Some programs collect benthic invertebrates as a measure of site impairment via diversity analysis or presence/absence of indicator species • Invertebrates are the main food resource of juvenile salmonids, however invertebrates are not evaluated as a food resource.
Protocols reviewed	EMAP, PIBO, ISEMP
Measurement limitations from the literature	• Some start-up time is required to move to processing invertebrate drift samples as most companies are currently process benthic samples. • Benthic samples require professional taxonomists to identify invertebrates at fine taxonomic resolution. • Invertebrate drift samples can be highly variable at the site level, but directly related to salmonid growth.
Do metrics capture the critical function?	• Diversity indices of benthic invertebrate samples may describe water quality, but do not adequately describe food availability for salmonids.
If current protocol inadequate, what should be adopted (short term & long-term)	• Invertebrate data often not related to fish, could improve this by starting to collect drift and benthic samples and relate these to fish growth (Figure 40). • If relationships exist across a broad range of stream and watershed types food abundance could be used as a predictor of abundance and ultimately related to stream habitat features that increase food availability.

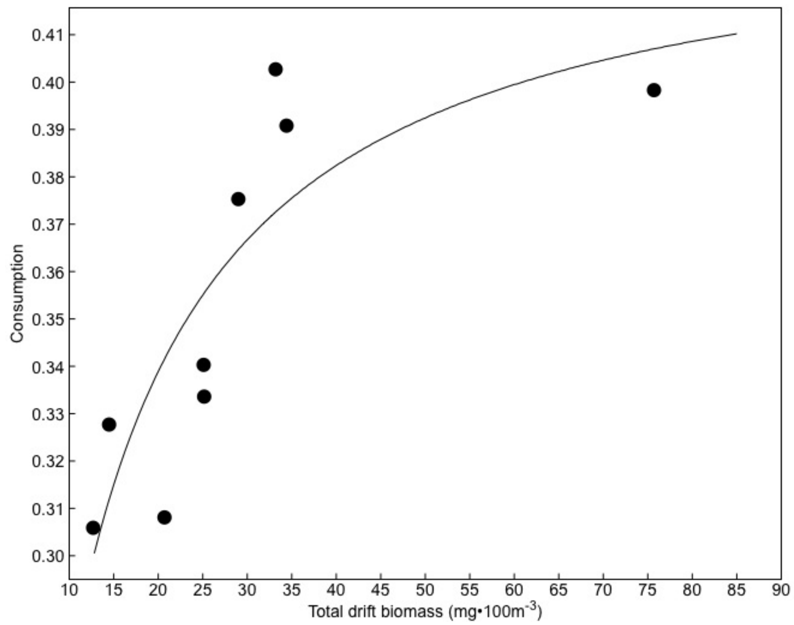


Figure 400. Relationship between fish consumption and total drift biomass in Bridge Creek.

Category Reviewed	Pools
Metric(s) Reviewed	Pool Frequency, Percent Pools, Residual Pool Depth
Critical function of the attribute	• Dimensions - Space to avoid predators, forage effectively, and avoid high velocity. • Velocity - Fish refuge from high velocity, access to high velocity areas for optimal drift foraging. • Spatial Context - Location of pool habitat relative to other channel types (riffles, etc...).
Protocols reviewed	AREMP 2007, Downie 2004, Heitke et al. 2008, Merritt 2009, Moberg 2009, Moore et al. 2006, Overton et al. 1997, Peck et al. 2001, Pleus et al. 1999, USFS 2009
Measurement limitations from the literature	• Depth - Estimates of pool volume highly sensitive to precision of tail crest depth measurement (Keim and Skaugset 2002) • Percent Pools and Pool Frequency are imprecise metrics (Roper et al. 2010). • Velocity - Pool velocities are rarely measured, flow characteristics are visually classified. • Spatial Context - Varying levels of spatial context, from measuring attributes only at the reach scale (Heitke et al. 2008; AREMP 2007) to measuring all attributes relative to individual channel units (Moore 2006)
Do metrics capture the critical function?	Pool Dimensions - • Depth - Majority of protocols collect only residual pool depth (single tail crest and max depth). • Length, Width, Area, Volume - In general only a single wetted or bankfull width is recorded. Spatial Context - • Majority of protocols are not capable of relating cover, LWD, substrate composition, or other physical attributes to a specific pool unit. • Strict definitions of pool habitat (e.g., pools not measured in secondary/tertiary channels, thalweg must pass through pools). Strict definitions may cause channel segments featuring low velocities and high channel depths to be classified as non-pool habitat.

If current protocol inadequate, what should be adopted (short term & long-term)	Short Term: • Measure all physical attributes relative to channel units • Increase the number of depth and width measurements for more accurate area and volume estimates. • Sample pools in all flowing stream channels (i.e., not only from within the primary channel). Long Term: • Surveys of stream channel topography using a total survey station or RTK (Real Time Kinematic) GPS. The resulting DEM can be used to calculate metrics of pool frequency, area, volume, and percent pools.
Category Reviewed	Riparian vegetation
Metric(s) Reviewed	Cover, wetland status, bank stability, change
Critical function of the attribute	• Bank stability • Water table connectivity • Sources of LWD • Regeneration
Protocols reviewed	PIBO, EMAP, Coles-Ritchie et al (2004)
Measurement limitations from the literature	• PIBO , Coles-Ritchie et al (2004) require plant identification (community level to species level) • EMAP estimates only cover and neglects streambank vegetation. • Repeatability is a concern with all of the methods that were reviewed
Do metrics capture the critical function?	• PIBO measures bank stability along the greenline and within a Daubenmire plot at each cross-sectional transect. Done by using established values for defined communities that quantifies the community's bank stabilizing status. Estimates woody regeneration along the greenline by aging established plants. Greenline also provides a wetland indicator status by community to detect groundwater connection. (A move from community level to species level identification of late) • Coles-Ritchie et al. (2004) measures bank stability and water table connectivity using species level data and indicator status used in PIBO. • EMAP provides data on regeneration by binning trees by size classes.
If current protocol inadequate, what should be adopted (short term & long-term)	• The amount of vegetation cover as per EMAP cover classes should be collected at each habitat unit to determine average cover at a site. • To estimate potential productivity and solar input a solar pathfinder should be used as per Platts et al. (1987); modified to the habitat unit method outlined in Appendix D.
Category Reviewed	Stream Width
Metric(s) Reviewed	Bankfull width, cross-section width, floodplain width, wetted width, width-to-depth ratio
Critical function of the attribute	• Stream size/potential discharge, incision/channel shape (i.e., is it downcut, large width to depth ratio) • Critical measure for site calculating averages for other metrics • Bankfull width is an important hydrologic concept that can be very important for characterizing various hydrologic measures of stream discharge and sediment transport
Protocols reviewed	AREMP, CDFG, EMAP, NPS, ODFW, PIBO, UC
Measurement limitations from the literature	• All measures of stream/floodplain width are intuitively appealing concepts but has been notoriously difficult to consistently identify in the field; numerous subtle signs have to be identified in the field and these signs are not always present (e.g., signs of recent high flows) • The concept of bankfull width is also stream dependent and may not be applicable in all situations • Many protocols stop cross-sections at "bankfull width"; this prevents information being collected in floodplain areas and may make it difficult to

	detect channel changes • Wetted width is obviously highly flow dependent and cannot be used to compare streams when sampling over extended periods, unless stream is at baseflow • Width-to-depth ratios are calculated because it is assumed that wide shallow streams are the result of human disturbance; however, because this metric relies on a ratio it is susceptible to larger errors and has been shown to have poor internal consistency, limited ability to detect environmental heterogeneity, and poor correlation with the truth (Roper et al. 2010)
Do metrics capture the critical function?	• Stream width (however it is measured) is an important metric for putting other stream habitat metrics in context; despite the problems associated with measuring width consistently, increased training and better protocols have improved consistency in measuring these attributes.
If current protocol inadequate, what should be adopted (short term & long-term)	• If using to detect change in channel morphology and location then transect monuments above active flood plain is necessary. As remote sensing techniques become more available many of the width measurements may be calculated in the office. Tests of the relationship between remote versus field measurements should be continued.
Category Reviewed	Substrate
Metric(s) Reviewed	%Fines, Embeddedness, Pebble Distribution
Critical function of the attribute	• Fish Habitat - interstitial spaces for rearing, food, cover, and quality/availability of spawning gravel • Stream Character - roughness, potential bed load, sediment budget
Protocols reviewed	• AREMP, PIBO, EMAP, CDFG, NIFC, ODFW, UC … all use version of Wolman pebble count or visual estimation into size classes for pebble distribution. Transects are used to systematically select particles (usually 5-10 particles per transect). Transects can be located in specific habitats (usually riffles) or systematically throughout the reach. Wide variety of measures for Embeddedness but most measure or visually estimate depth of cobble substrate within finer material. % Fines are either calculated from pebble counts or surveyed separately, usually in pool tails. Definition of fines seems to range from 1 - 10 mm with the most common 2 mm.
Measurement limitations from the literature	• %Fines - tend to under estimate % fines; measurements taken in inappropriate habitat; • Embeddedness - critical flaw in measurement technique (increased fines can = decreased % embeddedness); also no agreed upon definition; • Pebble distribution - ability of observer to select and measure particles without bias; number of particles may not be adequate; usually conducted in riffles or random sites and not by channel unit
Do metrics capture the critical function?	• %Fines - Gives an idea of spawning habitat impairment if measured at pool tail (i.e., PIBO and AREMP); however, no protocols measure interstitial space in other channel units where juveniles rear and/or overwinter • Embeddedness - Too subjective and not able to assess water flow, DO^2 levels, and other critical elements of interstitial space; poorly defined and typically not measured in all habitat types
If current protocol inadequate, what should be adopted (short term & long-term)	• % Fines - the PIBO/AREMP use of 3 grids (50 pts/grid) in first 10 pools counting number of 2 mm and 6 mm particles provides a maximum of 1500 particles per reach. Protocol reviews suggest this technique has moderate precision, ability to detect differences between stream types, and is related to more intensive measurements (i.e., the TRUTH). • Embeddedness - no technique currently available. If this is a real concern and focus of the study; suggest a detailed literature review and more hydrological approach (i.e., sediment cores/sieves, etc.) • Pebble count - Wolman pebble count in riffles (min 100 particles) is adequate

	minimum. However, recent reviews suggest that several improvements are needed. Most current rapid protocols use heel-toe selection method of each particle and visual estimate or ruler for measuring. Bunte et al (2009) suggest using a grid to select particles at each transect, use of gravelometer to measure each particle into ¼ phi size classes, sampling away from bank/water's edge (as per PIBO), and conducting counts of >100 in all habitat types within the study reach.
Category Reviewed	Water Quality
Metric(s) Reviewed	Sampling methods reviewed for water temperature, conductivity, alkalinity, pH, dissolved oxygen, nutrients, turbidity
Critical function of the attribute	• temperature related to many physical habitat conditions, such as geomorphology, climate conditions, riparian vegetation, etc. and also has physiological significance for fish (e.g., behavioral responses, survival thresholds for multiple life stages) • conductivity and alkalinity related to invertebrate metrics. Also related to site geology, soils, and ion availability. • dissolved oxygen and related metrics measured for primary production estimates • nutrients (N and P) commonly limiting in streams and related to primary production, geology, soils and vegetation. • turbidity measured as survey condition for spawning surveys and fine sediment transport.
Protocols reviewed	AREMP, PIBO, EMAP, NPS, ODFW, ODEQ, WDOE, CNCA
Measurement limitations from the literature	• Temperature: handheld field measurements at time of sampling not sufficient for analysis and trend detection with fish or environmental variables. Handheld measurements only useful for determining if fish sampling allowed (permitting reasons). • Alkalinity/conductivity – Handheld field measurements sufficient for site sampling. Less useful as direct environmental variable influencing fish, more commonly relates to fish habitat variables, such as macroinvertebrates. • Nutrients-sampling scenarios expensive for monitoring projects and usually a low priority because other factors more directly related to fish metrics • Turbidity: handheld measurements and methods highly variable when used to quantify water clarity and visibility. Meters preferred method of measure for turbidity, but are expensive.
Do metrics capture the critical function?	• Temperature-. Can be directly related to fish metrics at small and large spatial scales. • Alkalinity/conductivity- Can explain variation in invertebrate metrics. • Nutrients-. Can explain variation in riparian vegetation and correlation to soils and geology. Not directly related to fish (non-pollution sources).
If current protocol inadequate, what should be adopted (short term & long-term)	• In both short and long term deployment of temperature loggers to collect continuous (hourly) data for the entire year at all status and trend monitoring sites. Collection of alkalinity and conductivity using field meter at all status and trend monitoring sites. Nutrient sampling expensive and only relevant when nutrients of primary concern.

Appendix D: Monitoring Design Review

D.1 Spatial Designs

Spatial designs describe how sampling effort is to be allocated across a study area. The most appropriate spatial design depends on monitoring program requirements and constraints. In general, the following types of spatial designs are available:

Census

The census spatial design describes the location of all the sites comprising the domain of interest. In some cases, a single site might be used to estimate the total number of fish in a population, by the establishment of a counting facility located strategically where all fish will pass and be counted. In other cases, the census might consist of counting fish throughout the population's domain occupied (or potentially occupied),for example, at all reaches where the species occurs. In any case, a census implies that all elements will be enumerated.

Model-based

A model-based spatial design relies on selection of sites based on the need to estimate parameters or coefficients of a model that will be used to make the indicator estimates. Such models typically include one or more independent variables or covariates such as environmental conditions or geomorphic setting. Sites are generally selected along the important gradients governing the model parameters. A simple model might be a relationship between a population's growth rate and temperature. Sites might be selected at locations covering a thermal gradient over the range of the population's thermal tolerance. Then the model would be used to estimate productivity across all sites in the domain. A restricted model-based spatial design refers to situations in which the selection of locations in part of the domain is guided by the candidate model, and locations in other parts are selected by other methods.

Survey

The term survey in the current context implies the use of a randomization rule in the selection of locations across the domain of interest and the caveat that all locations have a positive chance of being selected. Approaches available to achieve these criteria for monitoring natural resources include: simple random sampling, systematic sampling, and GRTS (Stevens and Olsen, 2004) based sampling. A restricted survey design implies that part of the domain will be sampled by application of a survey, and other parts by application of one of the other spatial designs.

Opportunistic

An opportunistic-based design is where you will only be able to sample at sites that are selected based on ease of access or other subjective criteria.

In some instances, categories may be combined to produce hybrid designs. For example, part of a domain may be sampled by counting fish as they pass over a weir (census), and the remaining portion of the domain may be best monitored by a survey.

Each of these spatial designs has strengths and weaknesses. In general, the chance of making poor inferences is highest for opportunistic spatial designs and lowest for census designs. Conversely, opportunistic spatial designs will generally be less expensive to implement than census designs.

Temporal

Temporal designs describe how sampling effort is to be allocated across time. The most appropriate temporal design depends on the monitoring programs requirements and constraints. When developing the temporal design there are two basic units of time to consider:

Study period*:* The entire length of time the study will be operated. For example, the monitoring objectives of the study may include determining the long-term trend in annual abundance over 20 years so the *study period* would be 20 years.

Temporal unit: The unit of time for which a metric or indicator is reported. For most long monitoring studies "year" is a temporal unit. Studies may also have more frequent temporal units that might range from seasonally to hourly. For convenience, in the following discussion, we refer to a year as the temporal unit.

Most long-term monitoring objectives ask questions about patterns of change across years, sometimes decades or longer. These questions might be specific to a single location, or might cover broad regions and include many locations. The basic question for temporal designs is: what is the best allocation of sampling effort across years? Do we need to sample every site every year? Similar questions can be raised if the objectives concern a single site: does meeting your objectives require you to conduct field measurements every year (or every temporal unit if your temporal unit differs from a year)?

In some instances, categories may be combined to produce hybrid designs. For example, part of the domain might be sampled every year, while the remaining portion of the domain may be best monitored by surveys that are not implemented every year.

The temporal design choice is a little easier to think about when the monitoring objectives require sampling a set of sites during the study period. Again, thinking about year as the temporal unit, we could sample all sites every year. However, for some objectives, it might be just as efficient to sample some sites annually and some sites on a periodic cycle, like every "n" years (where n could by 2, 3, 4...years). These *panel designs* allow the opportunity to investigate a greater number of sites during the study period than might be possible with a "sample every site every year" design without a loss of precision for status estimates (e.g., population abundance estimates). In addition, panel designs afford approximately the same mean trend detection power after three monitoring cycles have passed (Urquhart and Kincaid, 1999). For example, a design that includes an annual panel (25 sites), along with three 3-year panels (25 sites each panel, beginning in year 1, year 2, and year 3) will achieve very closely the same power after nine years, as a design with the same 50 sites visited every year. The advantage of the multi-panel design is that a total of 100 sites will have been sampled, compared with 50 for the every site-every year design (see Urquhart and Kincaid, 1999).

Allowing flexibility in the choice of sampling patterns over years offers a variety of possibilities when your monitoring program includes multiple sites. However, a thorough evaluation of selecting a temporal sampling pattern cannot be done without simultaneously considering both the spatial and response designs. This optimization process will require a knowledge about the spatial, temporal, and "residual" variation (including how well the response design estimates the site's metric score), and costs for collecting the relevant data at a site (including travel cost between sites). Unlike the availability of single site trend detection tools, we are unaware of analogous "off the shelf" tools for multiple site trend detection. However, with an estimate of the important components of variation, the use of simulation tools (along with the computational power of current desktop computers) allows an evaluation the relative merit of different design choices. Several recent publications describe a variety of simulation examples that illustrate how this problem can be addressed (see Wagner et al. 2007; Dauwalter et al. 2009, Jacobs et al. 2009).

D.2 Response Design

Once the spatial and temporal designs are established, we need to determine exactly what, how, where and when to measure the attributes of interest. The response design includes a finer scale spatial and temporal description than that covered by the spatial and temporal design components. For example, you might be able to measure your attribute (such as water temperature) at a point in a stream network. However, for other attributes, such as characterizing the density of redds, or the amount of wood, or the density of pools, it will be necessary to make measurements along the reach. In these cases, calculating a metric, such as spawner abundance using an area under the curve method, requires sampling at multiple times during the spawning season. Documenting when and how data is collected at a site is part of the response design. Descriptions of any laboratory procedures are also part of the response design. Finally, response designs include the methods used to calculate site metric (e.g., the analytical procedure to estimate abundance using an area-under-the-curve method). Field operations manuals and quality control procedures are examples of kinds of documents that describe some parts of a response design. The following is a list of what should be covered in a description of a response design:

- What will be measured or collected in the field.
- How will it be measured or collected.
- Where the measurements be made within each of the sites comprising the sample.
- How sampling will be distributed within the temporal unit (e.g., year).
- Laboratory methods.
- Analytical procedures to calculate the metrics from the measurements.

In many ways the process of developing a response design is similar to selecting tools from a toolbox. There are many tools to choose from but some work better for the job at hand than others. Developing an appropriate response design to meet the objectives will depend on a variety of factors including attributes of interest and how well they can be measured or estimated given costs of making the measurements.

In many cases, sampling must occur during an “index” window, such as the summer low flow period, because all sites cannot be sampled simultaneously. In these cases, it is useful to sample some sites more than once to estimate this “index window” component of variation. An index window should be chosen so that:

- It is as short as possible within field operational constraints,
- The variation in the measurements is as small as possible within the window, and
- It is ecologically based.

The procedures used to calculate the metrics from the measurements comprise an analytical component of a response design. In some cases, the metric of interest might come directly from the measurement, e.g., maximum temperature during the June – Aug. interval (no calculation needed, except to read logger's maximum temperature). In most cases, a set of measurements is combined to calculate the metric of interest for each site in the sample. For example, an area-under-the-curve method is used to calculate the number of spawning salmon from the measurements taken during each of many visits to the site. Alternatively, the mean width of a stream is calculated from a set of width measurements taken at many locations across the stream's "plot" (e.g., mean of 10 width measurements taken systematically across 500 meters centered on the site, or 40 times the wetted channel width). Some metrics require complex calculations derived from measurements of a variety of attributes at a site. Documentation of these aspects of data collection and metric calculation is part of the response design.

D.3 Inference Design

The inference design describes the process used to estimate indicators for the target population(s) based on information (metrics) collected at the sample sites. This may occur for a single time period and the result is a status estimate for the indicator, or it may involve making estimates across multiple time periods when trends are of interest.

If the study involves only a single site, the inference design is simple since the metric values for the site are the population indicators of interest. Inference for trends at the single site does require choosing a statistical procedure to estimate the trend. The only uncertainty in the status estimate is from the metric measurement error.

If the spatial design is a census, the inference design will require defining the procedures used to calculate indicators for the target population based on the metric values from all the sites in the census. The only uncertainty in indicator estimate is from the metric measurement error.

If the spatial design is a survey, the inference design will require knowing the properties of the survey design, such as stratification and unequal probability weighting. When a temporal design is present, an inference design for trends must also be specified.

If the spatial design is an opportunistic site design, the inference design for estimating status requires defining the procedures used to summarize metrics across all the sites. Extreme care should be made in making inferences to any areas other than the sites sampled since we do not know how representative the handpicked sites are to anywhere other than the locals sampled.

The options available for an inference design are closely linked to the design used to select sites for status and trend monitoring and for mechanism monitoring. Mechanisms designs, in general, have specific statistical analysis procedures associated with them (e.g., Before-After-Control-Impact BACI designs). The inference design is the statistical analysis procedure. Many of the statistical analysis procedures utilize standard analysis of variance, regression or analysis of covariance. The validity of the inference depends on how well the assumptions of the analysis procedures.

For status and trend monitoring designs, the inference design depends on the site selection procedures. For a census design, no inference design is required since all sites are included and calculation of descriptive summary statistics is all that is necessary.

Inference designs for model-based spatial designs require the selection of a spatial stochastic model appropriate for the variables of interest. For example, a geostatistical model such as kriging may be appropriate. Typically, several models may be available and the selection of which one to use depends on the assumptions required for the model and whether those assumptions are met.

Design-based spatial survey design statistical inferences rely on the randomization procedures used to select the sites. Horwitz-Thompson estimators and variance estimators are available for all common survey designs (e.g., Lohr 1999). In addition to design-based inferences, model-based inference designs such as spatial stochastic models may be used. Since spatial survey designs provide (in most cases) a representative sample, an analysis for the spatial stochastic model is more likely to provide unbiased estimates. Another advantage of using spatial survey designs is that both design-based and model-based inference designs can be used.

D.4 Overall Design Considerations

In designing a monitoring program, we need to optimize the allocation of sampling effort across the potential set of spatial and temporal units during the study period. This balancing requires consideration of the cost of sampling (response design per site and transportation between sites) as well as the variability between sites within and across the study period and the temporal unit.

The following considerations are important for optimizing this allocation of sampling effort:

Degree of certainty - The level of confidence in the results of the monitoring program plays a significant role in determining the appropriate design. In general, the degree of certainty in monitoring results is lowest for opportunistic designs, intermediate for model-based and survey designs, and highest for census designs. It is lowest for opportunistic designs because it is difficult or often impossible to assess how well the chosen sample sites represent the domain for which inferences are intended. Because of the non-statistical nature of sample site selection, it is often impossible to assess the degree of certainty of results from opportunistic sample sites because you cannot determine the precision or bias associated with inferences to entire populations obtained from data collected at opportunistic sample sites. The degree of certainty is intermediate for model and survey based spatial designs because they depend on a statistical sample with its associated uncertainty. In addition, model-based designs can be subject to unknown uncertainties associated with model assumptions. The degree of certainty is highest for census designs because all members of the target population are sampled (either via a fixed counting station or by sampling at all sites in the domain) resulting in no sampling uncertainty or faulty assumptions about the representativeness of selected sites.

Cost - The cost of designs generally varies directly in relation to their degree of certainty. While the high degree of certainty provided by a complete census may be attractive, in many cases the cost associated with conducting a census over a large geographic area or for the entire study period will be prohibitive.

Feasibility - Adopting a design that achieves the desired degree of certainty and that is within the budget may result in a design that is not feasible due to extenuating circumstances. For example, being denied access to a significant portion of private lands in the study area will result in a need to revise the monitoring goals and objectives to recognize that restriction.

Existence of a verified model - Choosing a model-based design will obviously not be an option if currently no models exist that can guide the site selection process.

Flexibility - It is a common occurrence that over the life of a monitoring program, there may be changes in the goals and objectives, monitoring technologies, allocated budgets, or other constraints. Some designs are more amenable than others to the modification that may be necessary to meet these new challenges. For example, an initial objective that requires an abundance estimate over a prescribed monitoring region might be changed to an objective that requires abundance estimates for specific populations within that region. A spatial/temporal design that allows the addition or subtraction of sites without biasing results is more desirable than one that requires an entirely new design.

A framework that can be used to balance the various competing choices in designing a monitoring program consists of:

- understanding the influence of spatial and temporal components of variability in the data
- evaluating the accuracy of the estimates
- the statistical power of the design (i.e., the chance of correctly detecting some situation)
- costs.

Appendix E: Glossary

Term	Definition
Active Channel	A channel at current and recent discharges which contain a continuously defined streambed and developed streambanks, beyond which permanent features such as terrestrial vegetation begin to dominate.
Aerial Cover	Stream shading from riparian vegetation.
Alkalinity	A measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate.
Anadromous	Fish that migrate from salt water to breed in freshwater.
ASCII	The American Standard Code for Information Interchange is a character-encoding scheme based on the ordering of the English alphabet.
Backsight	A point taken looking backwards to a previously occupied point.
Backsight Check	Comparing the results from the foresight to the backsight for the same point to establish accuracy of a traverse.
Bankfull Elevation	see bankfull stage.
Bankfull Indicator	Physical indicators left behind from bankfull flow events such as bar elevations, undercut banks, stain lines, etc. (See Section 4.1)
Bankfull Stage	The height of the water surface at which a stream first overflows its natural banks during high flow events. The bankfull stage and its attendant discharge serve as consistent morphological indices which can be related to the formation, maintenance and dimensions of the channel as it exists under the modern climatic regime.
B-Axis	The middle axis of an irregular shaped object such as a rock. It is equal to the sieve size substrate will fit through.
Bearing	The direction one object is from another object, measured in degrees.
Bedform	Refers to the lateral (cross-section) and longitudinal (upstream to downstream) profile of the stream channel. A depositional feature on the bed of a river (fluvial processes) or other body of flowing water that is formed by the movement of the bed material due to the flow. Bedforms are characteristic to the flow parameters and are particularly to flow depth and velocity, and therefore the Froude number.
Benchmark	Permanent control points outside of the active channel. Benchmark locations are established by taking a gps coordinate. Benchmarks are used to 'tie' surveys into 'real' world coordinates and to re-establish surveys into an existing coordinate system for site revisits. Three benchmarks are established with rebar in a equilateral triangle.
Braided Stream	A stream segment that consists of a network of small channels separated by small and often temporary islands called braid bars. Braided streams occur in rivers with high slope and/or large sediment load (Schumm and Kahn 1972). Braided channels are also typical of environments that dramatically decrease channel depth, and consequently channel velocity, such as river deltas, alluvial fans and peneplains.
Breaklines	A linear surveyed feature that defines and controls the topographic surface behavior of a TIN in terms of smoothness and continuity.
Channel Segment	A linear portion of channel that is separated from other portions of the channel by an island with an elevation that equals or exceeds the bankfull elevation for a distance greater than the site width category. Channel segment 1 is always the main channel, channel segment 2 is the first side channel separated from the main channel by a qualifying island.
Channel Segment Number	Sequentially numbering system uniquely identifying the main channel and all side channels.
Channel Type	Classification of channels following the Montgomery and Buffington (1998) system of classification.
Channel Unit	Areas of relatively homogeneous depth and flow that are bounded by changes in depth and flow (Hawkins et al. 1993).
Charismatic Megaboulders	Large, visually obvious, unique boulders that are stable during high flows and easily described and relocated at future visits.

Constrained Stream	Stream with no depositional floodplain that is usually constrained by valley walls.
Control Point	A point occupied by the total station.
Cross-section	A transect of a stream where depth and velocity measurements are taken to estimate the discharge. Also used to describe locations used to collect substrate measurements.
Data Logger	An electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors. Usually based on a computer. Generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors. Can interface with a personal computer and utilize software to activate the data logger and view and analyze the collected data. Others have a local interface device (keypad, LCD) and can be used as a stand-alone device.
Declination	The difference between the north geographic pole and the north magnetic pole. Depending on where you are on the earth, the angle of declination will be different - from some locations, the geographic and magnetic poles are aligned so declination is minimal, but from other spots, the angle between the two poles is pretty big.
Depositional Feature	Floodplain and levees; a floodplain is a low-lying plain on both sides of a river that has repeatedly overflowed its banks and flooded the surrounding areas. When the floods subside, alluvium is deposited on the floodplain. The larger materials, being heavier, are deposited at the river banks while the finer materials are carried and deposited further away from the river. The larger materials at the river banks build up into embankment called levees.
Digital Elevation Model (DEM)	Data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. The intervals between each of the grid points will always be referenced to some geographical coordinate system. This is usually either latitude-longitude or UTM (Universal Transverse Mercator) coordinate systems.
Flagging	Colored ribbon used to identify transects, monuments, channel units, or other features during the course of a survey.
Flow Characteristics	The presence or absence of turbulent or laminar flow. Controlled by the interaction of channel unit gradient and substrate.
Fluvial processes	Processes associated with rivers and streams and the deposits and landforms created by them.
Geomorphic Reach	A length of stream with relatively homogenous geomorphic characteristics including discharge, gradient, and confinement.
GIS	A geographic information system (GIS) is any system that captures, stores, analyzes, manages, and presents data that are linked to location.
GPS Positions	Global Positioning System provides location coordinates by triangulating position information from orbiting satellites.
Gradient (bed surface)	The rate of change in bed surface elevation over a given distance.
Gradient (water surface)	The rate of change in water surface elevation over a given distance.
Horizontal Error	The X and Y value difference from a foresight to a backsight at a control point.
Human Influence	Impacts on the riparian corridor caused by humans.
Inflexion Points	The point of significant change in angle along a concave or convex surface.
Island	Areas within a channel that are at or above the bankfull elevation.
Large Side Channel	A side channel containing between 16 and 49 percent of the stream flow.
Large Woody Debris (LWD)	Wood in the active channel that is larger than the minimum criteria of 10 cm diameter and 1 meter in length.
Longitudinal Profile	The two dimensional view of a stream moving up the thalweg of the stream.
Magnetic North	The direction the red arrow points on a compass.
Maximum Pool Depth	The deepest part of a pool.

Mid-Channel Bar	An area above the wetted elevation but below the bankfull elevation that is surrounded by water on all sides.
Non-constrained Stream	Stream that can access a floodplain.
Non-Qualifying Side Channel	Side channel outside the active bankfull channel (see Section 6.1).
Orientation	Location relative to a compass.
Particle	A substrate such as course gravel, cobble, etc.
Particle Embeddedness	The percentage a cobble that is buried by sand and finer substrate.
Planform View	The two dimensional view of the stream looking down from above.
Pool Tail Depth	Water depth at the point where water would first begin to exit the pool.
Primary Channel	The channel with the most flow (main channel).
Prism	The reflector on top of the survey rod used to reflect the signal from the total station.
PVC Cuff	A piece of PVC fit around the arm with surgical tubing used to collect data in wet environments.
Reach	See geomorphic reach.
Resident	Fish that do not migrate to the ocean.
Rip-rap	Large rock placed by man in a river or stream.
Scour	The fluvial process by which the stream flow erodes and deposits sediment.
Site	The specific point, location or length of stream where measurements are taken and metrics derived. Represents a single sample unit within a monitoring program's study design.
Site Map	A map drawn by the surveyors showing the planform view of the site and indicating the relative position of benchmarks, monuments, channel units, etc.
Site Marker	A permanent maker that denotes the location of the bottom and top of the site. Usually a tag nailed to a tree or rebar driven into the ground in line with the top or bottom transect. Rebar monuments should not be used in designated wilderness areas.
Site Monument	A naturally unique object used to locate benchmarks. A bearing and distance is recorded from the monument to the nearest benchmark.
Site Width Category	A measurement of width based on binning the average bankfull width. Used in site layout to establish 20 equal spaced intervals along the length of the center of the channel and establish the site length.
Small Side Channel	A side channel with less than 16 percent of the streams flow and within the active bankfull channel.
Substrate	The natural environment in which an organism lives, or the surface or medium on which an organism grows.
SunEye	A piece of equipment manufactured for the purpose of capturing the solar input of a site.
Thalweg	The line that connects the lowest points along the length of a river bed where there is active flow, and thus the line of deepest, continuous flow.
Total Station	An electronic/optical instrument used in modern surveying. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read slope distances from the instrument to a particular point.
Transect	An imaginary line, perpendicular to the bankfull channel that runs through the center of the bankfull channel and intersects the bank.
Triangulated Irregular Network (TIN)	A vector based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three dimensional coordinates (x, y, and z) that are arranged in a network of non-overlapping triangles.
Qualifying Side Channel	Side channel within the active bankfull channel. See Section 6.1 for more detail.

Quality Control	Data quality constrains that limit what values can be entered into the data system.
Quality Assurance	Data quality procedures that are implemented to verify information quality after data has been entered into the data system.
UTM Coordinate	The Universal Transverse Mercator (UTM) geographic coordinate system is a grid-based method of specifying locations on the surface of the Earth that is a practical application of a 2-dimensional Cartesian coordinate system. It is a horizontal position representation, i.e., it is used to identify locations on the earth independently of vertical position, but differs from the traditional method of latitude and longitude in several respects.
Valley Type	Valley type is used to mean the same concept as “valley segment” as defined in Montgomery and Buffington (1993) and includes colluvial, alluvial, and bedrock valley types.
Vertical Error	The Z value difference from a foresight to a backsight of a control point.

Appendix F: Solmetric SunEye Operating Instructions

The Solmetric SunEye device is used to measure solar radiation at the center of the wetted channel as outlined in Section 9.3. This section outlines specific operating procedures for the SunEye. For more specific instructions, the user's manual can be resourced at: http://resources.solmetric.com/get/Solmetric%20SunEye%20200%20Series%20Users%20Guide_en.pdf

Step 1. Turn on the SunEye by pushing the yellow power button on the upper left side of the device.

Step 2. Begin a new session for the site by tapping the "New session…" button on the left side of the screen. Name the session using SiteID – Date-Organization (e.g., CBW05583-457806-20140710-ODFW), then tap "Next".

Step 3. Select the location for the session using the "SunEye GPS" option. Do NOT check the box that says "Get new GPS location for each skyline". After the coordinates have been obtained, tap "Done" in the upper right corner.

Step 4. A total of 11 images (skylines) will be captured for each site. Tap the yellow circle in the lower left corner of the screen, then tap "Skyline". Next tap "New". Alternatively, push the blue button with the star icon  to start a new skyline. Ensure that the settings read as follows: Type = Fixed, Azim = 180°, Tilt = 0°. Tap "OK".

Step 5. The SunEye has different camera settings which allow it to more accurately differentiate between open sky, and vegetation or other structures. The three setting options are "Clouds and Blue Sky", "Normal", and "Shaded". For our purposes, the shaded option is generally preferred because it provides the best delineation between vegetation and open sky. To select the camera setting, tap the ► icon in the upper left corner, then tap the drop down button next to "Sky" and select "Shaded". Tap "Close".

Step 6. While standing on the north side of device to ensure that your body is not blocking the sun, hold the SunEye 30 cm above the wetted or dry surface, align the SunEye compass so the heading is centered on true South, and ensure that the level indicator is centered. Push the round green button on the keypad or tap "Snap" to capture the skyline. Hold the SunEye steady until the skyline is successfully captured.

Step 7. After the skyline is captured, an image of the skyline that was just captured will appear. Review the image to ensure that it is not blurry and that your head is not blocking the sun path. If the image looks good, tap the link "Tap here to add a note" at the top of the screen and record the transect number (T1, T3, T5,…, T11). Also, record the skyline number in the data logger for the appropriate transect. If the skyline image is of low quality, it can be deleted by tapping the yellow circle in the lower left corner of the screen, then tapping “Skyline”, then “Browse”. Scroll down to the skyline you want to delete, highlight the skyline, then tap “Delete”.

Step 8. Proceed to the next transect, and push the blue button with the star symbol  to start a new skyline, or tap the yellow circle in the lower left corner of the screen and then tap “Skyline”, then “New”. The SunEye can be set to standby mode by pushing the power button between transects to conserve battery life.

Step 9. After skyline images have been captured for all 11 transects, simply press the power button to shut down the device. All data is automatically saved until it is transferred off of the device.

1	Digital camera with fisheye lens	6	Built-in stylus
2	Touchscreen VGA display	7	Reset button, DC Power, USB Port
3	Standard camera tri-pod mount (backside)	8	Home/Main Menu button
4	Power On/Off button	9	Five-way navigation buttons
5	Wrist strap attachment point	10	Quick Launch set-up buttons

Appendix G: Onset HOBO Shuttle Field Downloading Instructions

The Onset HOBO waterproof shuttle is used to download water temperature data from stream temperature loggers (TidbiTs) in the field. More detailed instructions on shuttle use can be found at: http://www.onsetcomp.com/files/manual_pdfs/10264-F-MAN-U-DTW-1.pdf

Step 1. Make sure the shuttle's large cap and center cap are closed securely. Tighten the center cap until it is just flush with the large cap, or until the O-ring is no longer visible.

Step 2. Make sure the communication end of the shuttle is clean. Attach the correct coupler for the logger, and ensure that it is seated properly.

Step 3. Insert the logger (TidbiT) into the coupler.

Step 4. Momentarily hold down the coupler lever and release. Readout should begin immediately. The amber LED blinks continuously while readout and relaunch are in progress. Do not remove the logger when the amber LED is blinking.

Step 5. After reading out the logger, the shuttle synchronizes the logger's clock to the shuttle's internal clock and relaunches the logger to start recording data.

Step 6. When the relaunch has completed, the green LED blinks for 15 minutes or until you momentarily press the coupler lever to stop it. If the red LED blinks instead, there was an error, and the logger may have stopped. If this occurs, make sure that the logger is secure in the coupler (as close to shuttle as possible) and clean off any residue on the glass nodes of the logger. Retry. If repeated attempts fail, remove logger and replace it with new logger. Notify watershed lead about downloading error.

Step 7. Remove the logger from the coupler and return it to the stream.

Checking Shuttle Status in the Field

The shuttle's memory has 63 "banks." One logger readout can be stored in each bank. To check the shuttle's memory and batteries in the field, remove the logger and press the coupler's lever for at least three seconds. When you release the lever, the green LED blinks once for each unoccupied bank in the shuttle's memory. (Press the lever momentarily to stop the blinking).

If the shuttle's batteries are running low, all of the shuttle banks are full, or the clock has not been set, the red LED blinks (press the lever momentarily to stop the blinking). Use HOBOware software to check the shuttle's battery level, available memory, and clock. You may need to change the batteries, or offload the data files to the host computer and delete them from the shuttle to free up memory before you can continue reading out loggers.

Appendix H: Revising the Protocol

As new information becomes available and monitoring efforts are refined, the protocol will be revised. Effectively tracking past and current protocol versions are important for data summaries and analyses that utilize data collected under different protocol versions. Protocol Editor will house previous and current protocol versions and the dates of their implementation. Reviews will be performed for all proposed changes to the protocol and the project coordinator will be notified so that the version number can be recorded in project metadata and any necessary changes can be made to database structure (Peitz et al. 2002).

Consistent with the recommendations of Oakley et al. (2003) this protocol includes a log of its revision history. The revision history log (adapted from Peitz et al. 2002) will track the protocol version number, revision dates, changes made, the rationale for the changes, and the author that made the changes. Revisions or additions to existing methods will be reviewed by CHaMP staff prior to implementation. Major revisions such as a complete change in methods will necessitate a broader review by outside technical experts. When the protocol warrants significant changes the protocol version and date on the title page should be updated to reflect the new version. Version numbers should increase incrementally by hundredths (e.g., Version 1.01, 1.02 etc.) for minor changes and by the next whole number (e.g., version 2.0, 3.0 etc.) for major changes (Peitz et al. 2002).

Some protocols from the “Field Manual of Scientific Protocols for Habitat Surveys within the Upper Columbia Monitoring Strategy” (Moberg 2010) have been incorporated into the CHaMP protocol. Revisions to the Upper Columbia protocol have been tracked in a revision log and can be referenced to inform future decisions. As development of the CHaMP protocol proceeds, those revisions will be tracked in the CHaMP log.

Protocol Revision History Log

Previous Version Number	**New Version Number**	**Revision Date**	**Method**	**Changes made**	**Reason**
1.1	1.2	2012	Site Layout	Deleted the table of reasons for rejecting a site.	The reasons for rejecting a site will be recorded in CHaMP monitoring site evaluation instead of in the data logger.
1.1	1.2	2012	Site Layout	While laying out transects, changed from stretching the tape in the middle of the bankfull channel to the middle of the wetted channel.	Repeatability among crews is higher when identifying the middle of the wetted channel vs. the bankfull channel.
1.1	1.2	2012	Site Layout	Deleted bearing readings from benchmarks to other benchmark locations.	Distance and angle location information is contained within the topographic survey, negating the need for bearing readings.

Previous Version Number	New Version Number	Revision Date	Method	Changes made	Reason
1.1	1.2	2012	Site Layout	Added site layout for revisits.	2012 is the first year of revisiting annual sites.
1.1	1.2	2012	Site Revisit	Added for all methods where revisit information is needed.	2012 is the first year CHaMP will be revisiting sites and needed to add to the protocol.
1.1	1.2	2012	Channel Units	Added a dichotomous key for channel units.	This was added to help crews work through keying out channel units in order to establish a more systematic approach to classifying channel units.
1.1	1.2	2012	Point Collection Method	Added Water Surface (ws), Mid Channel Island (mw), Inflow Point (in), Outflow Point (out), and Discharge (q) codes.	These codes were added to help the RBT develop a water surface DEM, determine the top and bottom of the topographic survey, and identify where discharge was measured.
1.1	1.2	2012	LWD Jams	Added proportion of jams in individual units.	This allows for a better spatial allocation of LWD volume per channel unit.
1.1	1.2	2012	Large Wood	Adjusted diameter and length categories.	To allow for more precise estimates of larger wood pieces and conform to PNAMP standards.
1.1	1.2	2012	Fish Cover	Deleted undercut bank fish cover estimates and moved the undercut method to be stand alone.	Capturing undercut bank areas, volumes, and locations which allows for more powerful metric calculations.
1.1	1.2	2012	Particle Embeddedness	Added percent fines surrounding cobbles.	Estimating embeddedness is now the product of the rank value for percent buried and percent fines surrounding the cobble in an attempt to reduce observer variability in estimating percent embeddedness.
1.1	1.2	2012	Particle Size Distribution	Particle size will be placed in size categories using a gravelometer instead of using discrete measurements.	Using a gravelometer will reduce observer variability and stratify particle sizes into size classes.

Previous Version Number	New Version Number	Revision Date	Method	Changes made	Reason
1.1	1.2	2012	Pool Tail Fines	Changed size categories to be mutually exclusive. <2 is no longer counted in the <6 category.	There was confusion among crew members in the previous method and keeping the size categories separate will help alleviate confusion.
1.1	1.2	2012	Chanel Segment	Percent flow is no longer recorded for channel segments.	Percent flow is not used for any metric calculation and is not needed. It created confusion amongst the crews.
1.1	1.2	2012	Solar Input	Increased the number of transects where solar input is collected to all odd transects for a total of 11 transect readings vs. 5 transect readings in 2011. Also changed equipment from Solar Pathfinder to Solmetric SunEye	Increased the amount of solar input data readings taken at a site to better represent solar input distribution throughout the site.
1.1	1.2	2012	Stream Temperature	Added a temperature logger maintenance record that assesses the sensor condition. Also added an instant temperature reading at the same location as the temp logger.	To better understand the fluctuations of temperature data and whether values are valid, adding meta data in regards to sensor state/condition will be useful for quality control purposes. The instant temperature reading provides a quick calibration assessment of the stream temperature logger that has been at the site for an extended period of time.
1.1	1.2	2012	Photos	Added a site overview photo with GPS reading, and compass bearing, and established a rebar location.	The site overview photo will be used for a repeat photo location that will be used to help evaluate and detect change through time of the site.
1.1	1.2	2012	Photos	Added text for repeat photos at transects 1, 11, and 21.	Repeat photos can provide context for understanding change over time.
1.1	1.2	2012	Fish Cover	Added category for aquatic vegetation and algae.	Need to describe fish cover from aquatic vegetation.
1.1	1.2	2012	Fish Cover	Clarified that restoration LWD is counted as	Eliminate confusion regarding what category

Previous Version Number	New Version Number	Revision Date	Method	Changes made	Reason
				woody debris, not as an artificial structure.	restoration wood is a part of.
1.1	1.2	2012	Air Temperature	Added a temperature logger maintenance record that assesses the sensor condition.	For quality control purposes and to better understand whether our temperature loggers are recording valid information.
1.1	1.2	2012	Drift	Added a depth measurement when removing the nets.	An attempt to get more precise flow estimate at the time sample.
1.1	1.2	2012	Riparian	Added standing dead woody vegetation to canopy layer and understory layer	Added to account for additional shade influences on the stream.
1.1	1.2	2012	Riparian	Separated duff, bare dirt and rock	Needed to separate pervious from impervious surfaces.
1.2	1.3	2013	Point Collection Method	Eliminated “q” code.	Method was not implemented consistently and the desired use of data point was unknown
1.2	1.3	2013	Fish Cover	Included boulders and undercuts in estimation of Total NO fish cover.	Including boulders and undercuts provides a better estimation of total no fish cover and allows interpretation of those elements that may overlap.
1.2	1.3	2013	Ocular Substrate Composition	Changed Bedrock size class from >4000mm to n/a	Bedrock will be classified based on its characteristic, not its size.
1.2	1.3	2013	Large Woody Debris	Removed “Jam” classification	Difficult to assess in the field based on rules of touching pieces. Utility of data not known.
1.2	1.3	2013	Large Woody Debris	Extended qualifying pieces to those within bankfull prism that are supported by other qualifying pieces.	By removing jams, this eliminated pieces that were above bankfull elevation but supported by qualifying pieces. Clarification will continue these pieces to be counted.
1.2	1.3	2013	Undercut Banks	Associate each unique undercut to a channel	Focusing on undercuts within channel units allows for unit

Previous Version Number	**New Version Number**	**Revision Date**	**Method**	**Changes made**	**Reason**
				unit.	level metric calculations and reduces the crew members area of inquiry.
1.2	1.3	2013	Undercut Banks	Eliminated depth measurements.	Depth was measured inconsistently among crew members and the utility of the data is unknown.
1.2	1.3	2013	Undercut Banks	Eliminated distance to upstream or downstream channel unit boundary.	Not necessary since undercuts are now linked directly to a channel unit.
1.2	1.3	2013	Undercut Banks	Changed vertical limit from bankfull to 1m above water surface.	Designate a vertical limit that is more consistent with other fish cover elements.
1.2	1.3	2013	Undercut Banks	Increased minimum qualifying width from 10 cm to 20cm.	Increase the repeatability of identifying qualifying undercuts in the field.
1.2	1.3	2013	Undercut Banks	Required three width measurements at predefined locations along undercut length.	Average width measurements were inconsistent among crew members. Having defined locations where measures are taken eliminates field judgment calls.
1.2	1.3	2013	Particle Size Distribution	Reduced number of counts to 110 pebbles (11 pebbles at 10 cross-sections)	To increase the efficiency of data collection.
1.2	1.3	2013	Particle Size Distribution	Prioritized measurements to be done in riffles.	Uncertainties regarding where to place cross-sections. Lead to more consistent measurements among crews.
1.2	1.3	2013	Particle Size Distribution	Changed Bedrock measurements from particles >4000 mm to "bedrock"	Bedrock will be identified when encountered in the field. Creates distinction between bedrock and very large boulders >4000 mm.
1.2	1.3	2013	Particle Size Distribution	Added unique size classes >512 mm.	Increase resolution of data stemming from medium sized to mega boulders.
1.2	1.3	2013	Air Temperature	Eliminated methodology.	Utility of data is unknown.
1.2	1.3	2013	Macroinvertebrate	Eliminated methodology.	In previous years, all crews collected drift using two nets.

Previous Version Number	New Version Number	Revision Date	Method	Changes made	Reason
			Drift		In 2013, a new methodology was implemented in four test watersheds to improve data quality. Sampling protocol available as separate document.
1.3	1.4	2014	Channel Units	Added Small Side Channel as a Tier 1 unit. Detach them from channel unit they flow into.	Added to help account for small side channels in area and side channel metric calculations. Increase data quality and repeatability.
1.3	1.4	2014	Channel Segment Numbers	Identify 2013 Type I non-qualifying side channels with segment and channel unit number.	Unique segment and channel unit number will improve consistency of side channel metric calculations.
1.3	1.4	2014	Large Woody Debris	Eliminated size classes to collect discreet length and diameter estimates. Included pieces to measure.	Discreet length and diameter measurements will provide more accurate LWD volume estimates. Measuring some pieces will help crew members calibrate their eyes.
1.3	1.4	2014	Water Chemistry	Included instantaneous water temperature.	Temperature will be collected at the same time as other water quality measurements for analysis purposes.
1.3	1.4	2014	Macroinvertebrates	Reintroduced macroinvertebrate drift sampling.	Tested differing methods of collection in 2013 which resulted in improved collection techniques and results.
1.4	1.5	2015	n/a	No methodological changes were made to the 2015 protocol.	
1.5	1.6	2016	n/a	No methodological changes were made to the 2016 protocol.	

(adapted from Peitz et al. 2002)

Appendix I: Survey Control Network Strategy

A stable, survey control network that can be reoccupied is the foundation for repeat topographic surveys and facilitating trend monitoring. If snapshot status monitoring is all CHaMP did, a temporary survey control network would suffice. However, as CHaMP is interested in tracking trends through time, there are a much richer range of spatially-explicit analyses (e.g. geomorphic change detection) that can only be done if a permanent survey control network is in place. That control network consists of a series of fixed points with known coordinates. The integrity of the control network through time depends first and foremost on those fixed points being recoverable and re-occupiable with survey equipment (e.g., total station or rtkGPS). For example, for a total-station survey to take place in the coordinate system of the control network, the crew needs to be able to set up over a known fixed point and backsight to another known fixed point. If at least two inter-visible points do not exist the total station survey cannot proceed without using more complicated surveying methods that are susceptible to large errors. There are many possible strategies one can employ to maintain the integrity of a survey control network. The purpose of this document is to spell out the strategy CHaMP crews shall employ to insure a quality survey control network is maintained through time.

TERMINOLOGY

Benchmark: A permanent control point (typically capped rebar) established at new site surveys and used to re-occupy an existing control network at revisit surveys. Additional benchmarks can also be used to supplement the original benchmarks at revisit sites. A unique x, y, and z coordinate is established for each benchmark.
Control Point: A permanent or temporary location used to set up and orient the surveying instrument.
Fixed Point: a control point or benchmark with known coordinates.
Survey Control Network: Multiple control points or benchmarks surveyed to obtain coordinates and whenever possible arranged in a configuration to envelop the site.
Coordinate System: A system which uses one or more numbers, or coordinates, to uniquely determine the position of a point.
Assumed Coordinate System: Independently created coordinate system. Not relative to other objects on the earth.
Real World Coordinate System: A coordinate system relative to other objects on the earth. UTM.

BENCHMARKS

In the initial visit during the New Site survey the crew establishes an assumed coordinate system as each benchmark is surveyed to calculate a coordinate for the benchmark. The coordinate assigned to each benchmark is transformed to a real world UTM coordinate system during post-processing that is used in subsequent revisit surveys. The benchmarks are required for comparison of all data within CHaMP that has a spatial component. The geomorphic change detection requires properly set benchmarks that can be resurveyed many times in a repeatable manner. The auxiliary data is tied to the channel units which are surveyed during the topographic data collection. Good benchmarks equal good data.

The first priority of a survey crew at a new site is to properly establish benchmarks and then proceed with collecting topo data. The first priority of a survey crew at a revisit site is to reoccupy the UTM coordinate system, check benchmarks, and if necessary set new benchmarks and then proceed with collecting topo data.

Benchmarks should meet the following criteria: stability, geometric arrangement, extension along the length of the site, and intervisibility (at least three must be intervisible). There is no maximum number of benchmarks. The significance of an increased number of benchmarks is they enable the crews to conduct more checks to evaluate survey data integrity using the Stake Point function. Strategically adding more benchmarks will provide better data quality for current or future surveys. More benchmarks provide more checks of survey integrity and support data quality analysis.

Additionally, in some cases where intervisible benchmarks are lost, an increased number of non-intervisible benchmarks may allow for alternative, less desirable means of rotating and translating revisit data to the UTM coordinate system. These are high risk methods of data transformation that should only be used as a last resort.

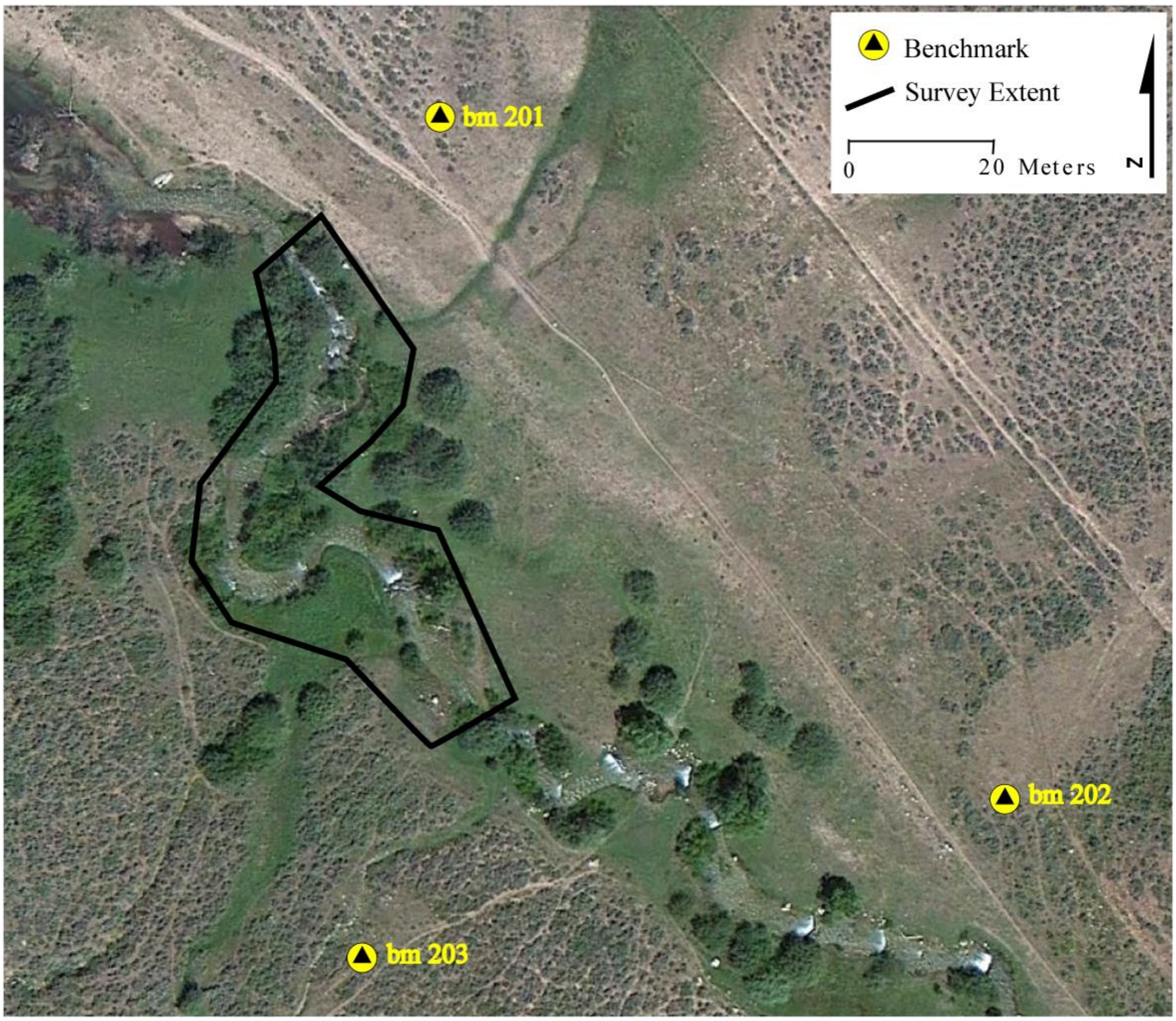
Benchmark strategies to employ:

1) Large benchmark spacing relative to the size of the site.
2) Benchmarks near both ends of the site (bottom and top of site/transect1 and 21) and when possible, along the entire length of the site.
3) Increase benchmark geometry (Triangle) size whenever possible.
4) When possible, set benchmarks far outside of survey extent on side-hills or ridges adjacent to the stream. Look for holes in vegetation that will allow line of sight to the stream from side-hills or ridges.
5) If a stream has open space on one side, utilize it to the fullest extent. A benchmark triangle that extends the entire site length on one side of the stream is better than a ¼ site length triangle on both sides of the stream.

THE PERFECT BENCHMARK SCENARIO

At this site the crew met the protocol requirements for three benchmarks with stability, geometry and intervisibilty. The benchmarks are spaced widely relative to the size of site, there are benchmarks near both ends of the site, the benchmarks are in a nearly equilateral triangle (good geometry), and the benchmarks are set outside the survey extent and stream corridor on nearby side-hills.

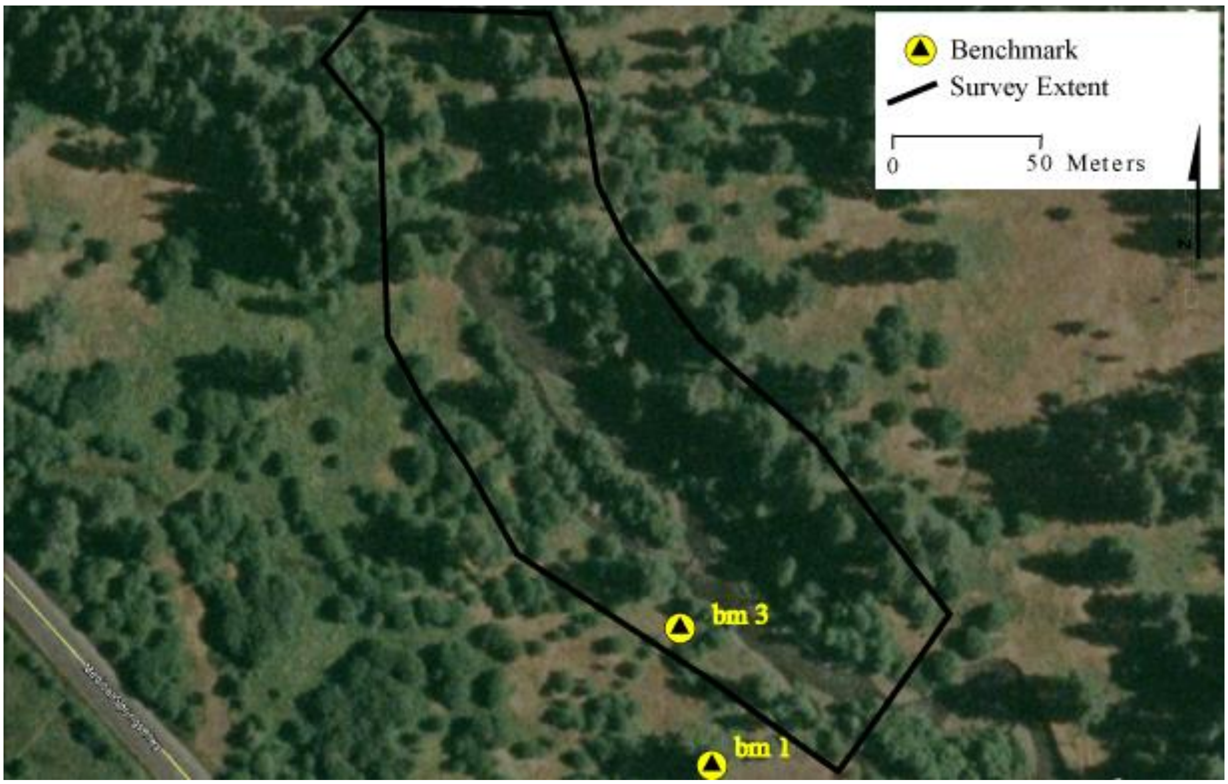
Many CHaMP sites may not fit into the perfect scenario. When encountering these imperfect situations, look to employ as many of the strategies as possible and during revisit surveys look for opportunities to improve the benchmark layout.



EXAMPLE 1: REVISIT SURVEY, CATHERINE CREEK SITE 10

A crew conducting a revisit survey in 2012 found bm1 and bm3. The crew was unable to locate bm2. Bm1 and bm3 were about 40 meters apart on a site of 280 meters. This situation presents the possibility for survey errors between bm1 and bm2 to propagate vastly as multiple traverses are conducted throughout the site.

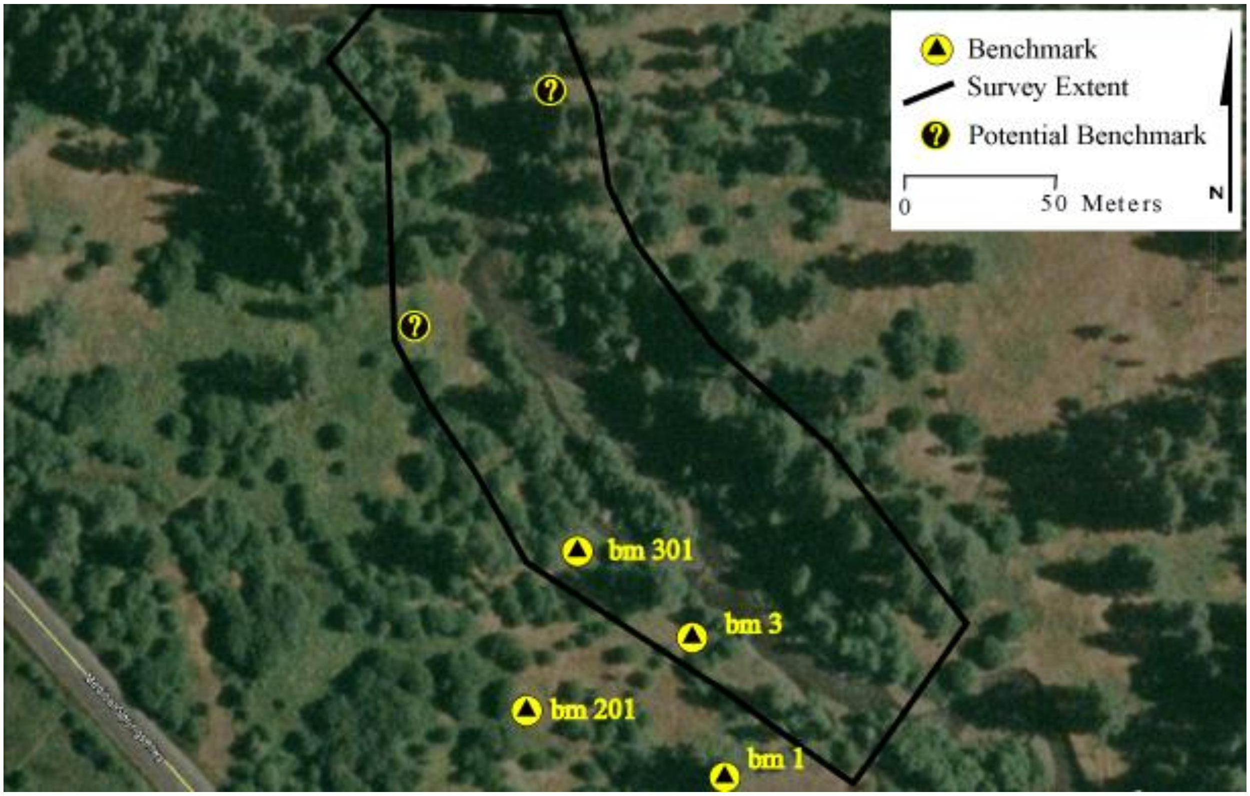
In this example there are two strategies which can be employed: increase benchmark spacing relative to the size of the site and increase benchmark geometry.



EXAMPLE 1: BENCHMARK SUPPLEMENTATION, CATHERINE CREEK SITE 10

In 2012 the crew added bm201 to obtain three intervisible benchmarks. In 2013 a crew returned to the site and noticed that another benchmark could be easily added to improve benchmark geometry size relative to the length of the site and added bm301.

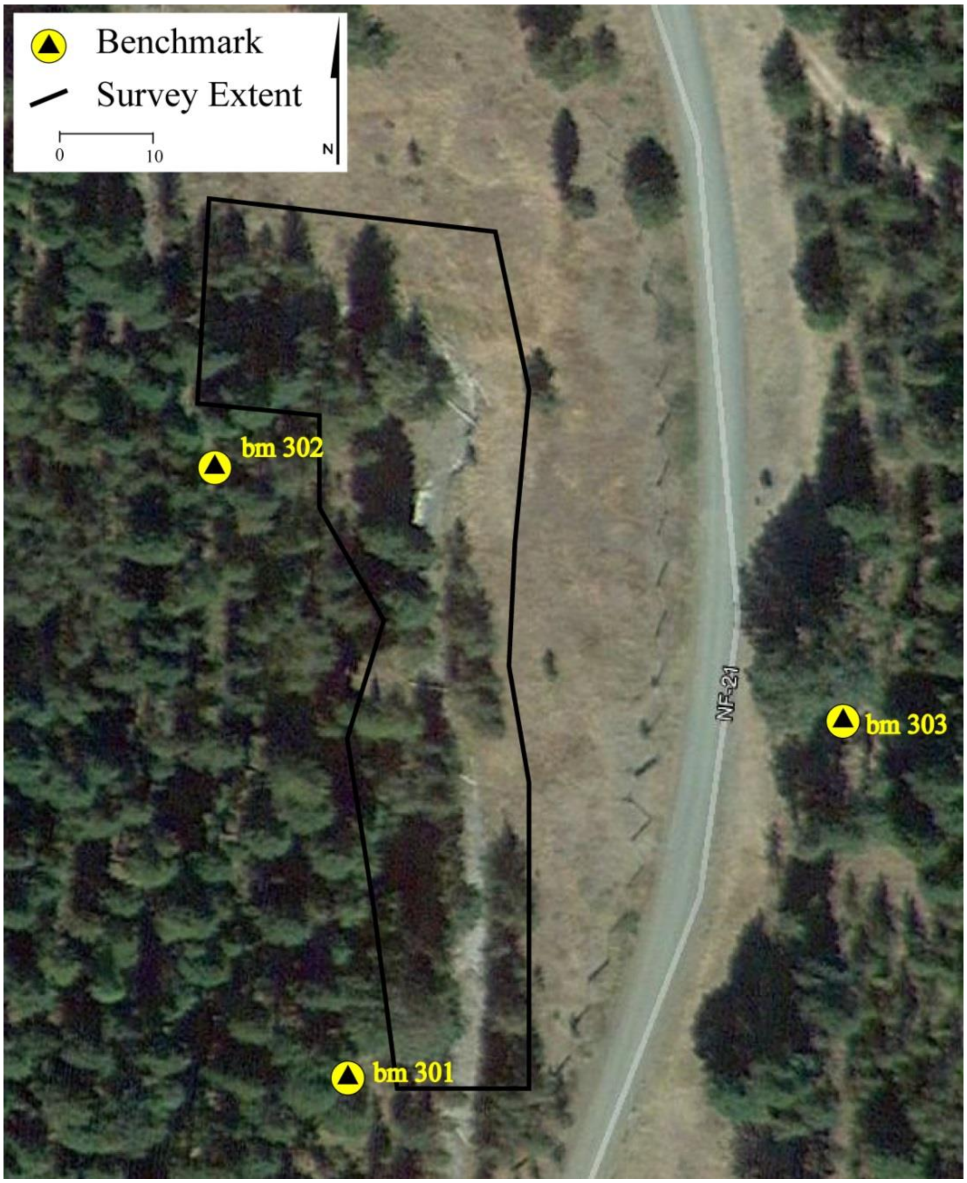
To further supplement this site a crew should investigate the potential to set more benchmarks on the site. The potential benchmark locations may not meet the intervisibilty criteria, but they can be staked out on every revisit to evaluate progress of the current survey relative to the previous survey.



EXAMPLE 2: REVISIT SURVEY, SPRING CREEK

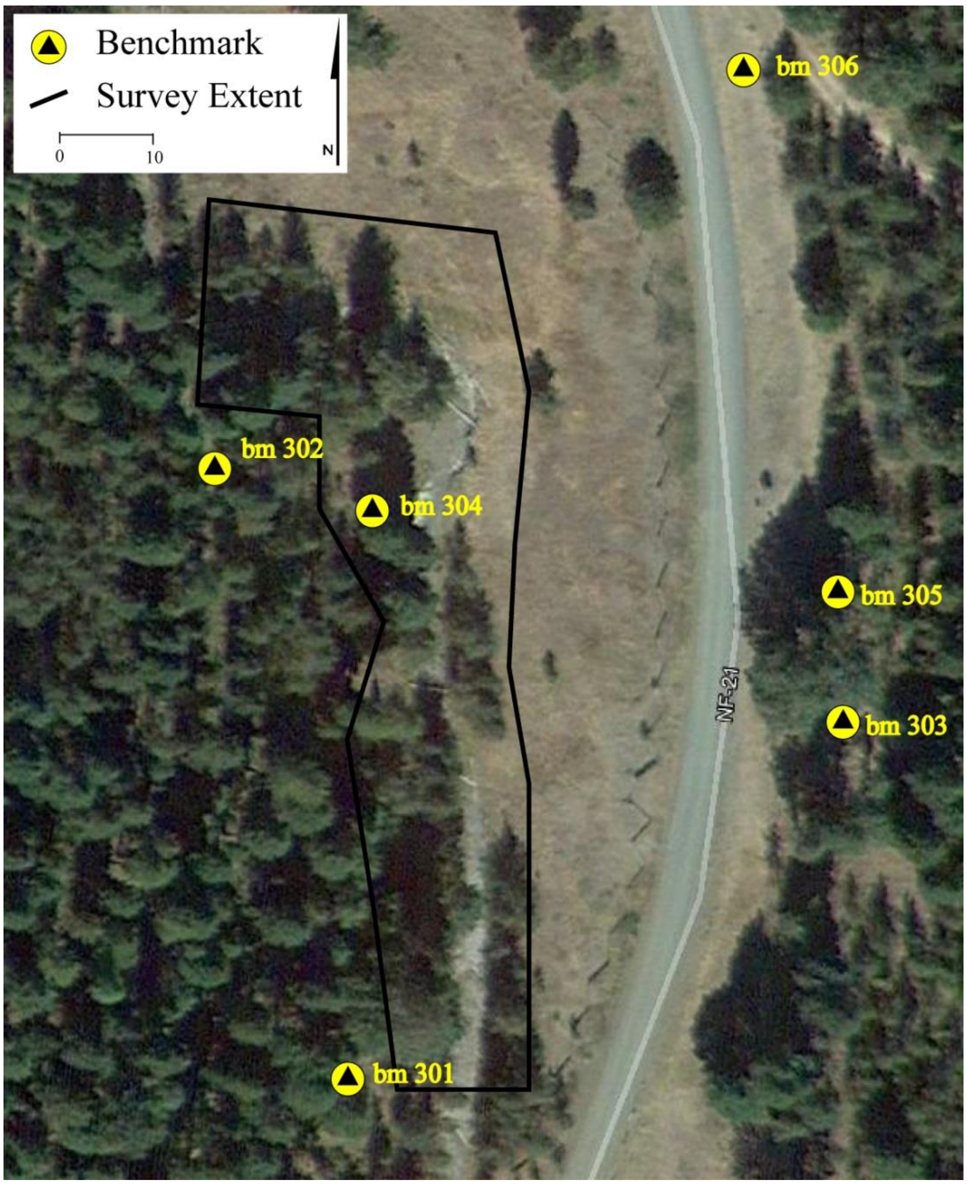
Benchmark scenario with No intervisibilty: This site was surveyed and benchmarks were set but there was no visibility from bm301 to bm302 and no visibility from bm302 to bm303.

In this example the strategy to employ is to set new intervisible benchmarks.



EXAMPLE 2: BENCHMARK SUPPLEMENTATION, SPRING CREEK

Benchmark scenario with No intervisibilty: With some strategy and effort a revisit crew was able to obtain visibility from bm301 to bm303 which enabled the crew to reoccupy the original coordinate system and set new benchmarks. The revisit crew set new intervisible benchmarks in the adjacent field: bm304, bm305 and bm306. The significance to this site is there is a large open field adjacent to the site which very easily could have been utilized. The first priority of a survey crew at a new site is to properly set benchmarks and then proceed with collecting topo data. A first priority of a survey crew at a revisit site is to reoccupy the original coordinate system, check benchmarks and if necessary set new benchmarks and then proceed with collecting topo data.



EXAMPLE 3: REVISIT OPPORTUNITIES, TEN MILE RIVER CA.

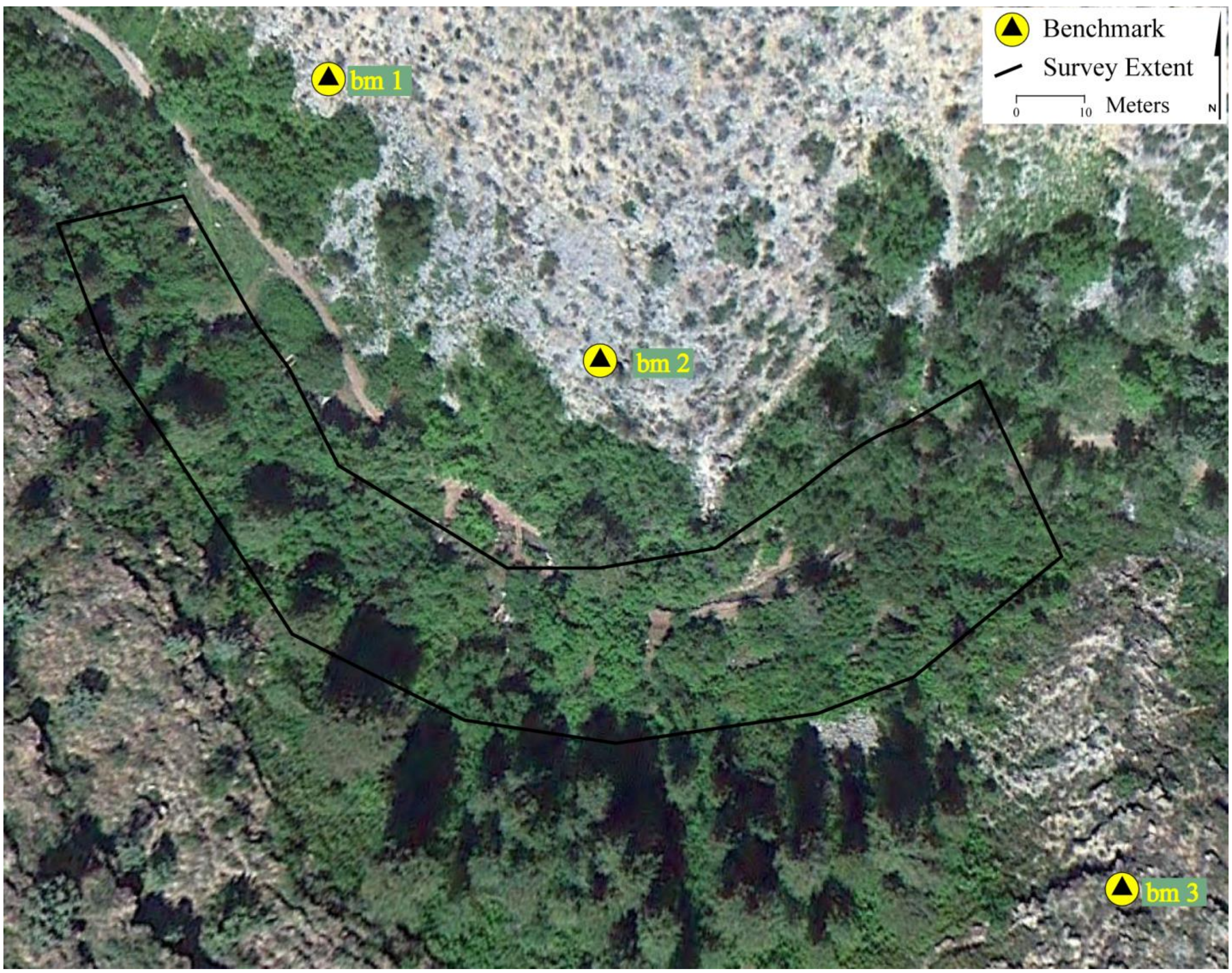
Heavily forested sites can be a challenge but crews need to look for opportunities to improve benchmark locations when encountering these sites. Opportunities to look for are: 1) clearings nearby that will allow for the placement of additional intervisible benchmarks, 2) gaps in trees along the site that allow benchmark placement throughout the site, and 3) gaps in the tress that allows benchmarks at both ends of a site.

On the North Fork of the Ten Mile River in California, a crew set benchmarks at a site that is heavily forested and presents a challenge. The crew was able to set three benchmarks with a spacing of 18 to 27 meters at one end of the site. As the image indicates there is a clearing parallel to the site, 17 meters from the centerline of the stream and about 50 meters long, Look for opportunities like this clearing which could provide a larger benchmark spacing relative to the size of a site and provide benchmarks at both ends of a site. The additional benchmarks will allow revisit survey crews to use the Stake Point function to evaluate the current survey relative to the original survey and may allow for a transformation if two of the three intervisible benchmarks are lost.

EXAMPLE 4: NEW SITE SURVEY, RIGHT HAND FORK LOGAN RIVER

The strategy at this site was to set the benchmarks to allow for intervisibility and access to the stream thru vegetation. Look for holes in vegetation that will allow line of sight to the stream from side-hills or ridges.

This site on the Right Hand Fork of the Logan River has a floodplain with thick vegetation, and steep canyon slopes with sporadic vegetation. The crew elected to climb the steep slopes and set three intervisible benchmarks that provide reasonable access to the thickly vegetated floodplain below. The benchmarks are vertically 20-30 meters above the valley floor. The strategy being employed at this site is the benchmarks geometry size relative to site size are equal, and benchmark locations allow line of site to the top, middle, and bottom of the site. Notice the three benchmarks are in a line which has poor geometry, but at this site, setting the benchmarks in an equilateral triangle was not possible.



MAXIMUM ALLOWABLE ERROR APPLICATION INSTRUCTIONS

When to apply revisit or initial visit error values for benchmarks and control points.

For the 2016 season:

1) When occupying a newly established 2016 bm/cp: For any bm/cp set in 2016, apply Initial survey error value.

2) When occupying a bm/cp set in previous years (2011-2015): For any bm/cp established in previous years, apply revisit survey error value.

Maximum Acceptable Error

Initial survey H=±.030m and V=±.015m

Revisit survey H=±.050m and V=±.030m

Appendix J: LaMotte Alkalinity Test Kit Instructions

LaMotte

ALKALINITY TEST KIT

DIRECT READING TITRATOR METHOD

MODEL WAT-DR • CODE 4491-DR

QUANTITY	CONTENTS	CODE
50	BCG-MR Indicator Tablets	T-2311-H
60 mL	*Alkalinity Titration Reagent B	*4493DR-H
1	Test Tube, 5-10-15 mL, w/cap	0778
1	Direct Reading Titrator, 0-200 Range	0382
1	Alkalinity Endpoint Color Chart	4491-CC
1	Acid Demand Index	1546

*WARNING: Reagents marked with an * are considered to be potential health hazards. To view or print a Material Safety Data Sheet (MSDS) for these reagents go to www.lamotte.com. To obtain a printed copy, contact LaMotte by e-mail, phone or fax.

To order individual reagents or test kit components, use the specified code number.

This test set provides total alkalinity readings only.

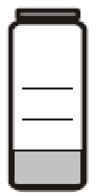
Read LaMotte Direct Reading Titrator Manual before proceeding. The Titrator is calibrated in terms of total alkalinity expressed as parts per million (ppm) Calcium Carbonate ($CaCO_3$). Each minor division on the Titrator scale equals 4 ppm $CaCO_3$.

NOTE: When testing swimming pool water, consult an Acid Demand Index to determine if the total alkalinity is too high. The Index will indicate the recommended amount of acid required to offset high alkalinity content.

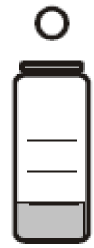
WARNING! This set contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision

ALKALINITY TEST PROCEDURE

1. Fill the titration tube (0778) to the 5 mL line with the sample water.



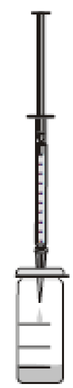
2. Add one BCG-MR Indicator Tablet (T-2311).



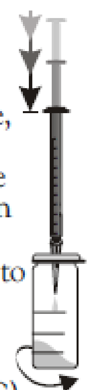
3. Cap and swirl to mix until tablet dissolves. Solution will turn blue-green.

4. Fill Direct Reading Titrator (0382) with *Alkalinity Titration Reagent B (4493).

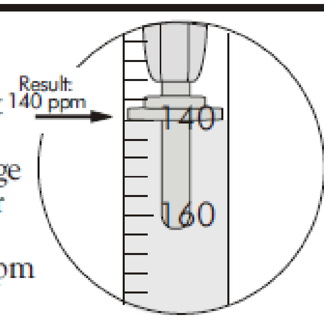
5. Insert the Titrator into the center hole of the test tube cap.



6. While gently swirling the tube, slowly press the plunger to titrate until the solution color changes from blue-green to purple. Consult Alkalinity Endpoint Color Chart (4491-CC).



7. Read the test result directly from the scale where the large ring on the Titrator meets the Titrator barrel. Record as ppm Total Alkalinity in ppm Calcium Carbonate ($CaCO_3$).



NOTE:

If the plunger tip reaches the bottom line on the scale (200 ppm) before the endpoint color change occurs, refill the Titrator and continue the titration.

When recording the test result, be sure to include the value of the original amount of reagent dispensed (200 ppm).

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Appendix K: Benchmark Evaluation Dichotomous Key