New Mexico Environment Department
Surface Water Quality Bureau

Standard Operating Procedure (SOP)

for

PHYSICAL HABITAT MEASUREMENTS

Approval Signatures

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1.0 PURPOSE AND SCOPE

The purpose of this procedure is to describe the process for measuring the physical habitat attributes and geomorphic characteristics relating to the dimension, pattern, and profile of wadeable streams. Measurements may include a reach-wide pebble count, thalweg profile, large woody debris tally, cross section survey, slope, percent canopy cover, and streamflow. If biological collections such as periphyton, benthic macroinvertebrates, or fish are needed, refer to appropriate SOP for data collection methods.

In order to understand the current condition and predict the future condition of a flowing waterbody, it is necessary to determine certain characteristics relating to dimension, pattern, and profile. The hydraulic geometry (also known as river morphology or geomorphology) of a stream is important when investigating sediment transport and relative channel stability. According to Rosgen (1996), "For a stream to be stable it must be able to consistently transport its sediment load, both in size and type, associated with local deposition and scour." Similarly, riparian characterization and density are important because they significantly impact water temperature and will influence whether a stream will meet the temperature standard for its aquatic life use.

SWQB's habitat and geomorphology monitoring may include data collection for the following activities:

- assess the general narrative standards for sedimentation/siltation, plant nutrients, and biological integrity using the SWQB assessment protocol (NMED/SWQB 2013);
- evaluate quality of habitat and channel stability, aid in identification of stressors in impaired reaches, and supply data for TMDL development;
- provide baseline data to refine water quality standards, classify waterbodies and define reference conditions;

- monitor differences above and below a perturbation, point source, best management practice (BMP), and/or non-point source disturbance; and
- review plans or proposals submitted for in-stream construction activity (CWA §404/§401 certification).

2.0 RESPONSIBILITIES

Personnel who conduct physical habitat sampling and data validation and verification activities or who supervise those who do must be familiar with this SOP.

Technical staff should have experience collecting geomorphic, hydrological, and biological data in New Mexico streams. All new employees will receive training and perform each of the field measurements described in this SOP under the supervision of a senior technical staff member at least once before being permitted to make these measurements without a senior technical staff member present.

3.0 BACKGROUND AND PRECAUTIONS

This SOP is designed to be used in wadeable perennial streams and is not appropriate for large river systems, intermittent or ephemeral streams, lakes and reservoirs, or wetlands.

Field measurements should be conducted on at least one site in every wadeable assessment unit that is monitored during SWQB's water quality surveys. The survey site will be located at the established water quality station, when possible, and as close to the bottom of the assessment unit while best representing the entire reach. If the habitat or biological sampling is not done at an established water quality station then the location and distance from the established station will be documented on the appropriate field sheets. If the work is done more than 1 kilometer from the water quality station, then a new station will be established.

If fish or benthic macroinvertebrates are scheduled to be collected at a particular site, both physical habitat and biological field measurements will be collected during the biomonitoring index period and *at least six weeks after a scouring flow event*. (Biggs & Kilroy 2000). The occurrence of recent scouring of the course substrate can be determined with an evidence based approach. Note recent depositional features, incisions, downcuts, wrack lines at or above assessed bankfull, absence of periphyton growth, folded in-channel vegetation, folded vegetation on the floodplain, and translocation of the current year leaf litter on active floodplain. If nearby gage data ares available, note any high flows with gage height 3x the previous week average. The occurrence of four or more of these factors is considered a scour event. Attempt to pin down the timing of the event with gage data or new vegetation emergence. If timing cannot be determined, assume that the event occurred the previous day and plan resampling accordingly.

The biomonitoring index period is defined as **August 15 to October 15** for Mountain sites and **August 15 to November 15** for Foothills and Xeric sites. If <u>no</u> biological monitoring is planned or needed at a particular site, physical habitat measurements may be taken during baseflow conditions post snowmelt runoff and prior to the monsoon season (generally mid-May through early-July or late-fall to early-winter depending on location and weather patterns). If a site is dry or has shallow isolated pools the visit will be recorded as such and no measurements associated with this SOP will be taken.

All monitoring locations utilized during field investigations will be referenced in such a manner that the locations are firmly established and documented with global positioning system (GPS) for latitude, longitude, and elevation. All physical measurements will be traceable to the actual person making the measurement and to the actual piece of field equipment utilized to make the measurements. All equipment maintenance, calibration, and field records will be kept so that all such procedures are traceable. All time records will utilize local time and will be recorded to the nearest five minutes, unless more discrete timing is required by the study. Standard field sheets will be used to log data for each level of survey and all data will then be stored in the SQUID database or other electronic means (e.g. Excel) (see Section 5.0 (Equipment and Tools) for a list of any forms that are required by this SOP).

3.1 Sampling During or After Rain Events

Do not sample during high flow rainstorm events. For one, it is often unsafe to be in the water during such times. In addition, biological and chemical conditions during and after high flows are often quite different from those during baseflows. Some compromise is necessary regarding whether to sample a given stream because of storm events. This decision is based on the following guidelines to help determine the influence of rain events:

1. If the stream is running at or above bankfull flow or the water seems much more turbid than typical for the class of stream do not sample that day.
2. Do not sample a stream if it is unsafe to wade the majority of the stream reach.
3. Keep an eye on the weather reports and rainfall patterns. Do not sample a stream during periods of prolonged heavy rains.
4. If the stream seems to be close to normal summer flows and does not seem to be unduly influenced by recent storm events, go ahead and sample it even if it has recently rained or is raining, making comment of the sampling conditions.

If you decide a site is unduly influenced by a storm event, do not sample the site that day and document the site conditions on the field forms so the stream can be rescheduled for another visit.

3.2 “Rule of 10”

Wading across a stream bed can be very dangerous depending on flow and substrate conditions. Do not attempt to wade into a stream if the depth (in ft) multiplied by the velocity (in ft/s) equals or exceeds 10 square feet per second (ft^2/s). For example, a stream that is 2 ft deep, and has velocities of 5 ft/s or more, should be considered too dangerous to wade. If you unknowingly start to take measurements and discover part of the way across that you are/will violate the rule of ten, return to the nearest bank and note “too fast/deep to measure” on the field form. Refer to SWQB’s JHA (Job Hazard Analysis) for further safety precautions when conducting field work.

3.3 Streambed Concerns and Obstacles

Some channels have quicksand-like areas, deep holes, sharp rocks, excessive fallen logs, etc., that can lead to foot entrapment, injury, or falls. A wading rod, surveyor’s rod, ski pole, or stick can be gently used for stabilization and to probe the streambed when conditions are uncertain. Staff should use best professional judgment to assess risks involved with data collection. Refer to SWQB’s JHA (Job Hazard Analysis) for further safety precautions when conducting field work.

4.0 DEFINITIONS

The following habitat type definitions may be utilized in any aspect of physical habitat monitoring, especially in field notes, documentation of transect type, and descriptions of habitat diversity.

Pools - Still water, low velocity, smooth, glassy surface, usually deep compared to other parts of the channel.
Run - Water moving slowly, with a smooth, unbroken surface. Relatively shallow and low turbulence.
Riffle - Turbulent, shallow flow; Water moving, with small ripples, waves and eddies -- waves not breaking, surface tension not (or barely) broken. Sound: "babbling", "gurgling".
Dry Channel - No water in the channel.
Off-Channel Areas - Side-channels, sloughs, backwaters, and alcoves that are separated from the main channel.

Assessment Units (AUs) are river or stream reaches defined by various factors such as hydrologic or watershed boundaries, geology, topography, incoming tributaries, surrounding land use/land management, water quality standards, etc. AUs are designed to represent waters with assumed homogeneous water quality (WERF 2007). Stream or river AUs in New Mexico are typically no more than 25 miles in length unless there are no tributaries or land use changes to consider along the reach (NMED/SWQB 2010).

5.0 EQUIPMENT AND TOOLS

- Field forms printed on rain proof paper
- Bank pins
- Measuring tape (with both standard and metric units)
- Metric ruler
- 2 telescoping surveyor's rods (round profile, metric scale, 7.5 m extended)
- 1 meter stick (alternatively, a short (1-2 m) rod or pole (e.g. ski pole) calibrated with cm markings for thalweg measurements, or the PVC pipe described for slope determinations can be marked in cm and used)
- Densiometer modified with taped "V"
- Clinometer or Hand level with PVC "tripod"
- GPS unit
- 5 – 10 flags to mark transects
- 1 or 2 fisherman's vest with lots of pockets and snap fittings (used at least by person conducting the in-channel measurements to hold the various measurement equipment (densiometer, clinometer, etc.); useful for both team members involved with physical habitat characterization)
- Chest waders; hip waders can be used in shallower streams
- Clipboards (lightweight, with strap or lanyard to hang around neck)
- Soft lead (#2) pencils
- Laminated SOP and/or quick reference guides for physical habitat
- Digital camera

6.0 STEP-BY-STEP PROCESS DESCRIPTION

6.1 Office Procedures (prior to field work)

For planning and scheduling purposes, complete the following assessments prior to collecting any geomorphic or biological data.

1. Collect and Assess Nutrient Level 1 data
2. Preliminary Turbidity Assessment

3. Initial Temperature Assessment

Use the most recent version of the Assessment Protocol for the preliminary assessments. These assessments determine what types of data are collected during field work. **Figure 6-1** details the decision process to determine what types of data need to be collected. *Refer to appropriate SOP if biological collections such as periphyton, macroinvertebrates, or fish are needed.*

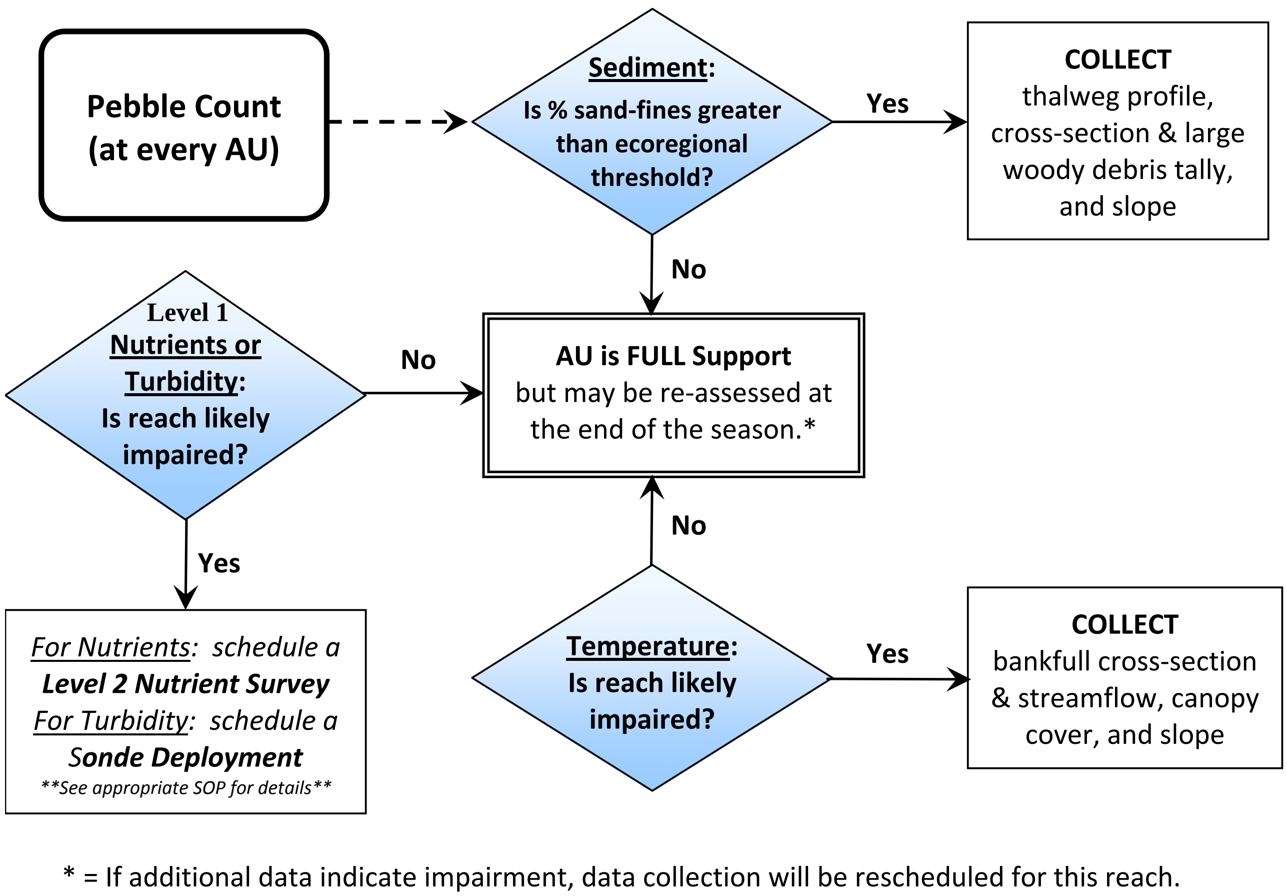

Figure 6-1: Decision tree for habitat collection.

6.2 Field Procedures

6.2.1 *Reach Selection*

The reach selection is a critical decision that can greatly influence the outcome of subsequent field procedures. Before selecting a location for the survey, note the character of the stream while driving to the site, viewing aerial/satellite imagery, and by conducting a site walk to ensure that the reach is representative of the AU being characterized. Take time to walk upstream and downstream of the monitoring station to observe the occurrence of riffle-run-pool sequences and isolated features such as culverts or other human disturbances. Keep these factors in mind to ensure the proportion of geomorphic and disturbance features are represented in the selected reach.

While conducting the site walk, note the wetted width of the stream at six or more locations. The wetted width is used to determine the length of the study reach. For streams with an average wetted width less than or equal to 3.5 m, a representative reach is 160 meters. For streams with widths greater than 3.5 m, the length of the study reach is 40 times the average wetted width. Data collection must not be made at one point without first walking up and down the channel for at least 250 meters.

6.2.2 PHOTODOCUMENTATION

It is essential to take several photos of the reach condition and any disturbances or modifications that are relevant to data collection and assessment. Include a detailed description of each photo on the *Field Form* including date and time the photos were taken.

6.2.3 LOGISTICS AND WORK FLOW

The seven components of physical habitat measurements are organized into four grouped activities:

1. Substrate Size (Section 6.2.4)
2. Channel Dimensions, Thalweg Profile and Large Woody Debris Tally (Section 6.2.5)
3. Bankfull Cross-Section, Stream Flow, and Percent Canopy Cover (Section 6.2.6)
4. Slope (Section 6.2.7)

Level 1 Sedimentation (pebble counts) and Level 2 Sedimentation Surveys as necessary (based on the results of the pebble count) need to be performed within 24 hours of each other. Do not separate these two activities as data are pulled from both for assessment calculations. The Level 1 pebble count data is used in the Level 2 Relative Bed Stability calculation. When these two field activities are separated in time, there could be high flow events, releases, etc., between them that change the character of the channel.

6.1.3.1 Reach Layout

Measure the wetted width in at least five different locations. Calculate the average wetted width to determine the length of the study reach. For streams with an average wetted width less than or equal to 3.5 m, a representative reach is 160 meters. For streams with widths greater than 3.5 m, the length of the study reach is 40 times the average wetted width. Each of the four grouped activites are performed at specific locations along the study reach (**Figure 6-2**). Since the pebble count (Substrate Size classification) is the first activity to be performed and is also performed at every AU, the transects for the other measurements (e.g., channel dimensions, streamflow, etc) can be established as the pebble count is being conducted (**Table 6-1**).

Table 6-1. Location of transects for grouped activities.

	SMALL STREAMS (average wetted width ≤ 3.5 m)	**LARGE STREAMS** (average wetted width > 3.5 m)
Pebble Count (Section 6.2.4)	**21 Transects spaced 8 meters apart** Transect A (1st transect) = 0 meters Transect E (21st transect) = 160 meters	**21 transects at 2X average wetted width** Example: Average wetted width = 6m Distance between transects = 12m Total reach length = 6 × 40 = 240m

Cross-Section & LWD Tally (Section 6.2.5) Canopy Cover (Section 6.2.6)	**5 Transects spaced 40 meters apart** Transect A (1^{st} transect) = 0 meters Transect E (5^{th} transect) = 160 meters	**5 transects at 10X average wetted width** Example: Average wetted width = 6m Distance between transects = 60m Total reach length = 6 × 40 = 240m
Thalweg Profile (Section 6.2.5)	*For widths < 2.5 m*, measure thalweg depth every 1.0 m (**150 total measurements**) *For widths > 2.5 and ≤ 3.5 m*, measure thalweg depth every 1.5 m (**100 total measurements**)	Measure thalweg depth at intervals equal to 0.01 times the study reach length (**100 total measurements**)
Bankfull Cross-Section and Streamflow (Section 6.2.6)	**One Transect** Try to measure at Transect C (mid-reach), but try to locate at a cross-section that has most of the following qualities: – segment is straight; – no pools; – "U" shaped channel; – flow is relatively uniform.	**One Transect** Try to measure at Transect C (mid-reach), but try to locate at a cross-section that has most of the following qualities: – segment is straight; – no pools; – "U" shaped channel; – flow is relatively uniform.

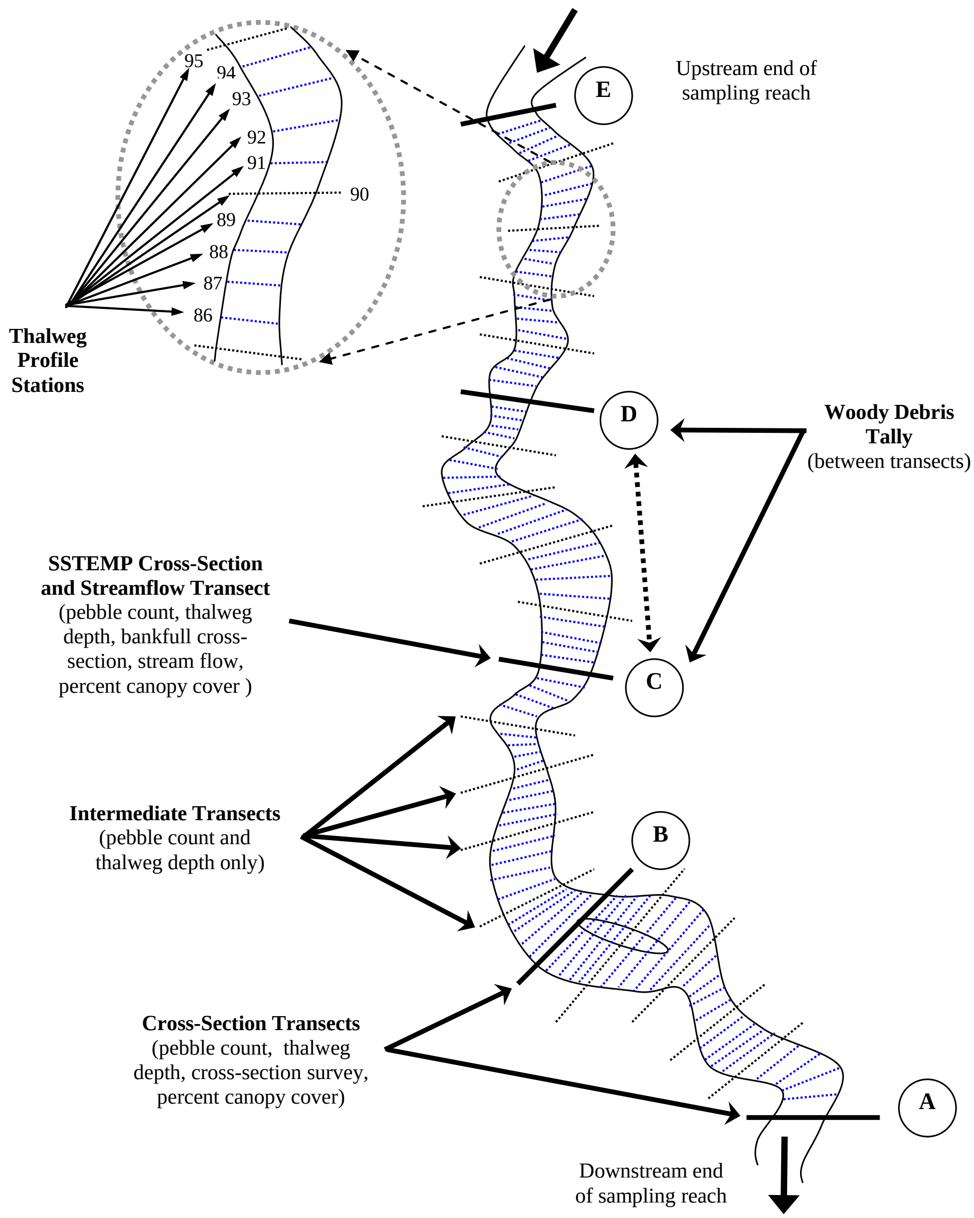

Figure 6-2. Reach layout for physical habitat measurements.

6.2.4 ***Substrate Size***

Substrate size is one of the most important determinants of habitat character for fish and macroinvertebrates in streams. The term *substrate size* is used to describe the size of streambed surface particles. Substrate size is evaluated at each of 21 equally-spaced transects (refer to **Figure 6-2 and Table 6-1**) using modified EMAP methods (Peck, et al. 2006). The basis of this protocol is a systematic selection of 5 substrate particles from each of 21 cross-section transects. The substrate sampling points along the cross-section are located at 0, 25, 50, 75, and 100 percent of the measured wetted width, with the first and last points at the water's edge just within the left and right banks (**Figure 6-3**).

If the channel is split by a mid-channel bar, the five substrate points are centered between the wetted width boundaries regardless of the mid-channel bar in between. Consequently, substrate particles selected in some cross-sections may be "high and dry." *For cross-sections that are entirely dry, make measurements across the* ***unvegetated portion*** *of the channel. Be sure to note the occurrence of dry mid-channel bars on the field form.*

The procedure for obtaining substrate measurements (a.k.a. pebble count) is described in **Table 6-2**. Record measurements in the *PEBBLE COUNT* section of the **Pebble Count Field Form**. To minimize bias in selecting a substrate particle for size classification, it is important to concentrate on correct placement of the your foot along the cross-section and to select the particle right off the tip of your big toe (not, for example, a more noticeable large particle that is just to the side of your foot). It is also important that bare hands are used, so that the subtle differences in FINES and SAND are observed.

When differentiating between SAND and FINES, follow these steps:

- If the selected point is possibly ≤2mm, pinch a small pea-sized amount of material and remove it from the stream.
- First confirm that the sample is ≤2mm.
- If less, rub the material between the forefinger and thumb. Any feeling of grittiness or the feeling of single grains rolling between your fingers is SAND.
- A slick or sticky feeling, or a lack of grittiness is FINES.

  *ANY feeling of grittiness should be recorded as SAND. Sand particles are much larger than fine particles and therefore comprise a large portion of a mixture of sand and fine particles

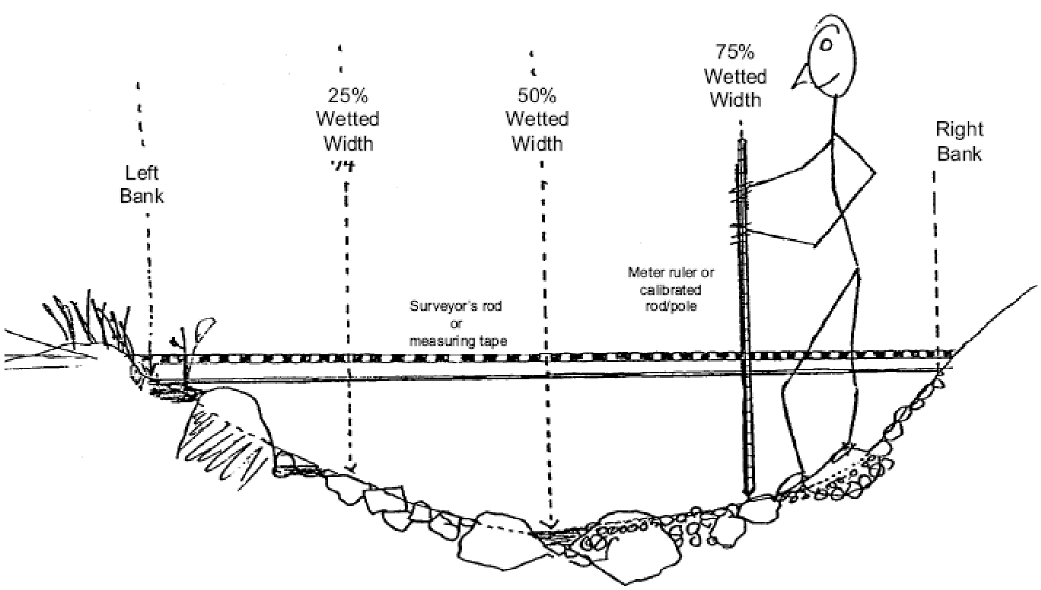

Figure 6-3. Substrate Sampling Cross-Section.

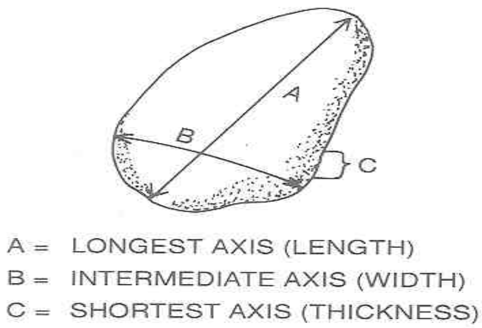

Figure 6-4. Substrate particle showing its 3 main axes of measurement. (Harrelson, et al. 1994).

Table 6-2. Pebble Count Procedure

1. Starting at the bottom of the reach (Transect A), divide the **WETTED WIDTH** channel by 4 to locate the substrate measurement points along the transect (Left Edge, 25%, 50%, 75%, and Right Edge).

2. Place your foot at each measurement point along the transect. Avert gaze (do not look down), slide your index finger straight down off of your big toe, and pick up the first particle touched by the tip of your index finger. Measure the intermediate axis with a metric ruler (refer to **Figure 6-4**). Record the intermediate axis in millimeters (pebble width) in the *PEBBLE COUNT* section of the field form corresponding to the transect and location along transect (Left Edge, 25%, 50%, 75%, Right Edge).

   <u>NOTE</u>: If the particle is too small to measure, classify it using a sand-gauge card. If the particle is immovable embedded substrate or substrate too large to lift evaluate the particle in-stream by measuring the smaller of the two exposed axes. If a detritus layer or vegetation is encountered, push your finger through the layer to reach the substrate. If woody debris is encountered, avert gaze and re-place your finger to resample.

3. Record particles that have an intermediate axis larger than 2mm as a whole number in the field sheet. “Gritty” particles with an intermediate axis less than 2mm are recorded as **SAND.** “Smooth” particles less than 2mm are recorded as **FINES.** Bedrock and consolidated substrates are recorded as **BEDROCK.** Streams with a calcified substrate cementing individual particles into a consolidated layer is also recorded as **BEDROCK.**

   <u>NOTE</u>: SQUID only recognizes whole numbers, and the words: SAND, FINES, BEDROCK. Any other entries will not be accepted or cause errors in reporting.

4. Move successively to the next location along the transect. Repeat step 2 at each transect location.

5. Proceed upstream to the next transect and repeat steps 1 – 3.

6. Collect substrate measurements at each of the 21 transects for a total of 105 individual pebble counts. Tally the total number of pebbles that are considered fine sediment (i.e. particles ≤ 2 mm) and calculate the percent sand/fines by dividing the number of fine particles by the total number of particles (105). Compare the percent sand/fines for your study reach to the site class threshold value to determine if more data are needed for analysis of relative bed stability (see **Table 6-3A and Table 6-3B** for site class thresholds and definitions).

Table 6-3A. Fine Sediment Thresholds based on Biological Responses

Mountain Site Class	< 20% Sand & Fines	< 21 particles *
Foothill Site Class	< 37% Sand & Fines	< 39 particles *
Xeric Site Class	< 74% Sand & Fines	< 78 particles *

NOTES: * Number of particles ≤ 2mm diameter based on a 105 particle count.

Table 6-3B. New Mexico Site Class Definitions

Site Class	Definition
Mountains	Ecoregions 21 and 23, **except** 21d, 23a, 23b and 23e
Foothills	Ecoregions 21d, 22a, 22b, 22f, 23a, 23b, 23e and 79
Xeric	Ecoregions 20, 24, 25, 26, and 22, **except** 22a, 22b, 22f

Ecoregion Number	Ecoregion Name	Ecoregion Number	Ecoregion Name
20	Colorado Plateau	23a	Chihuahuan Desert Slopes
21	Southern Rockies	23b	Madrean Lower Montane Woodlands
21d	Foothill Woodlands and Shrublands	23e	Conifer Woodlands and Savannas
22	Arizona/New Mexico Plateau	24	Chihuahuan Deserts
22a	San Luis Shrublands and Hills	25	High Plains
22b	San Luis Alluvial Flats and Wetlands	26	Southwestern Tablelands
22f	Taos Plateau	79	Madrean Archipelago
23	Arizona/New Mexico Mountains		

NOTES: * Additional written descriptions of ecoregions in New Mexico are available at: http://www.eoearth.org/article/Ecoregions_of_New_Mexico_(EPA).

6.2.5 CHANNEL DIMENSIONS, THALWEG PROFILE AND LARGE WOODY DEBRIS TALLY (RELATIVE BED STABILITY)

6.2.5.1 Channel Dimensions

Measurements of channel dimensions including substrate size, residual pool depths, volume and numbers, large woody debris tallies, and slope are necessary for calculating relative bed stability (Kaufmann et al. 1999). The procedure for obtaining channel dimensions is described in **Table 6-4**. Data are recorded in the **Cross Sectional Profile Field Form**. Features measured include wetted width, depth of water, bankfull width, and bankfull height. Bankfull height is measured relative to the present water surface. In other words, bankfull height is measured up from the level of the wetted edge of the stream.

6.2.5.2 Thalweg (longitudinal) Profile

Thalweg refers to the flow path of the deepest water joining the lowest points in a stream channel. The thalweg profile is a longitudinal survey of maximum flow path depth at 100 or 150 evenly spaced intervals over the length of the study reach measured along the centerline of the channel. One person walks upstream carrying a survey rod and a 1-m metric ruler (or calibrated rod or pole such as a ski pole, shovel handle, or wooden dowel). A second person carries a clipboard with copies of the field sheets to record data.

The procedure for obtaining thalweg profile measurements is modified from Peck et al. (2006) and presented in **Table 6-5**. Record data on the **Thalweg Profile and Large Woody Debris Field Form**. Use the survey rod and a metric ruler or calibrated rod or pole to make the required depth measurements at each interval and to measure off the distance between stations as you proceed upstream. The first thalweg measurement is taken at the most downstream station in the study reach (station *1 – Transect A*).

6.2.5.3 Large Woody Debris Tally

The large woody debris (LWD) tally should be performed concurrent with the thalweg profile such that the recorder of the depth measurements also estimates the percent aerial coverage of woody material within the bankfull channel. This component of habitat characterization allows a semi-quantitative estimate of the number, volume and distribution of wood within the study reach which is used to adjust relative bed stability for sediment assessments. LWD is defined as woody material with a small end diameter of at least 10 cm (4 in.) and a length of at least 1.5 m (5 ft).

The procedure for estimating large woody debris is presented in **Table 6-6**. The estimate includes all pieces throughout the entire reach that are at least partially within the bankfull channel (Zone 1 or 2 in **Figure 6-5**) or bridging above it (Zone 3 in **Figure 6-5**). The active (or bankfull) channel is defined as the channel that is filled by moderate sized flood events that typically recur every one to two years. Pieces of LWD that are not at least partially in Zones 1, 2, or 3 are not counted. Record estimates on the **Thalweg Profile and Large Woody Debris Field Form**.

Table 6-4. Cross Sectional Profile Procedure

1. Starting at the bottom of the reach (Transect A), lay a surveyor's rod or stretch a measuring tape (tag line) tight across the stream with the "zero" end at left bankfull, as viewed when looking downstream. Adjust the rod or tape, as needed, to ensure that it is level. Record the bankfull width and bankfull height in the *TRANSECT A* section of the **Cross Sectional Profile Field Form**.

Determining Bankfull Width:

Bankfull stage is defined as the point of incipient flooding or the elevation where flows overtop the active channel and spread across an adjacent active floodplain as constructed by the present stream in the present climate, and frequently inundated (Dunne and Leopold, 1978) at intervals of 1 to 2 years. The bankfull flow is equivalent to the "effective discharge"; the flow which transports the greatest volume of sediment over time. Evidence from a large number of streams suggests that these flows are frequent, moderate sized flows with a typical return interval of 1-2 years and that they represent the channel forming or maintenance flows.

There is no single, absolute and definitive line for bankfull stage. Instead, the strategy is to build a case for identification of bankfull based on physical evidence at the site. The best evidence of bankfull stage is a series of features that are depositional, containing similar substrate and vegetation components, and lying at a consistent elevation, such as:

- topographic breaks in slope
- tops of point bars
- changes in vegetation
- changes in size of bank or bar materials
- evidence of an inundation feature such as small benches
- the presence of a floodplain
- exposed root hairs below an intact soil layer indicating exposure to erosive flow
- bank undercuts

If the stream or river has incised it may have abandoned the floodplain, which will make the former floodplain a low terrace. It is critical to distinguish the active floodplain from low terraces in the identification of bankfull stage. Remember that in many New Mexico incised channels the most evident flat valley surface may actually be an abandoned terrace. Use common sense and local knowledge in deciding whether it is realistic that a particular elevation is inundated nearly every year. Where channels have incised and evolved to the point where a new depositional feature is redeveloping as an active floodplain, the determination of bankfull is less problematic and unambiguous. In other highly incised channels where bank erosion and bed scour are prominent, lack of consistent and unambiguous bankfull indicators may preclude any reliable determination of bankfull dimensions. In these situations, use best professional judgment in estimating bankfull dimensions and note the lack of consistent and reliable indicators on the fieldsheet.

Determining Bankfull Height:
Bankfull height is the distance from the water's surface to the bankfull tagline (leveled surveyor's rod or tape).

2. Divide the wetted width channel by 4 to locate the measurement points along the transect. Record the distances corresponding to Left Bank (0%), LCtr (25%), Ctr (50%), RCtr (75%), and Right Bank (100%) of the measured wetted width.

   NOTE: Record these distances only at regular Transects A – E.

3. Place your sharp-ended meter stick or calibrated pole at a random point along the wetted edge on the left bank. Measure depth and record it in the *Depth* field of the field form.

   NOTE: Cross-section depths are only measured at regular Transects A – E.

4. Move successively to the next location along the transect. Repeat step 3 at each location.
5. Proceed upstream to the next lettered transect and repeat steps 1 – 4.

Table 6-5. Thalweg Profile Procedure

1. Determine the interval length between thalweg measurements based on the wetted width used to determine the length of the study reach.
   - For widths less than 2.5 m, measure thalweg depth every 1.0 m (150 total measurements).
   - For widths greater than 2.5 and less than or equal to 3.5 m, measure thalweg depth every 1.5 m (100 total measurements).
   - For widths greater than 3.5 m, measure thalweg depth at intervals equal to 0.01 times the study reach length (100 total measurements).

2. Complete the header information on the field form. Record the interval distance determined in Step 1 in the *Interval Length* field on the **Thalweg Profile and Large Woody Debris Field Form**.

3. Begin at the downstream end (Station *1 – Transect A*) of the reach. Locate the flow path that connects the deepest points within the channel (*the thalweg*). This may not always be found at mid-channel and may not always be a point within the greatest flow path in every channel cross-section. Measure thalweg depth to the nearest centimeter and record it in the *Thalweg Depth* field on the field form. Read the depth on the **side** of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

   NOTE: For streams with interrupted flow, where no water is in the channel at the station, record zeros for depth.

   NOTE: It is critical to obtain thalweg depths at **all** stations. *If the thalweg is too deep to measure while wading*, stand in shallower water and extend the rod or pole at an angle to reach the thalweg. Determine the rod angle by resting a clinometer on the upper surface of the rod and reading the angle on the external scale of the clinometer. Leave the depth reading for the station blank, but flag the measurement to indicate a non-standard procedure was used. Record the water level on the rod and the rod angle (vertical = 90°) in the comments section of the field form. When you return to the office, calculate the thalweg depth as the measured depth (length of rod that was under water) multiplied by the trigonometric *sine* of the rod angle. (For example, if 3 meters of the rod are under water when the rod was held at 30 degrees (*sine* = 0.5), the actual thalweg depth is 1.5 meters.) *If a direct measurement cannot be obtained*, make the best estimate you can of the thalweg depth and flag the data point to indicate that it is an estimated depth.

4. Proceed upstream to next station (determined by interval length) and repeat step 3 until all measurements are complete.

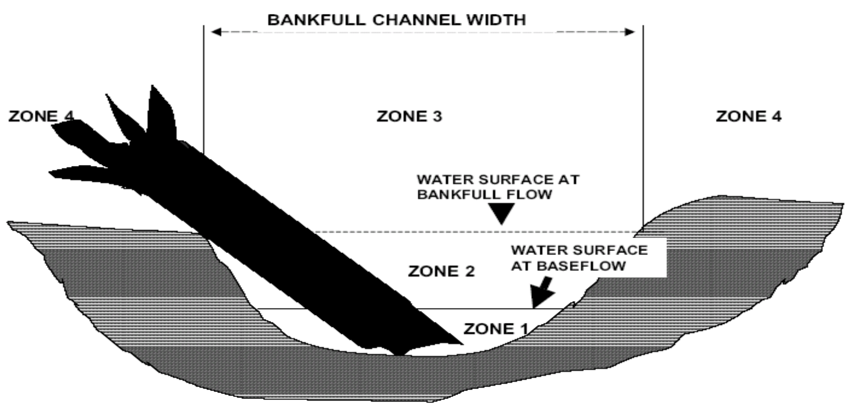

Figure 6-5. Large woody debris in bankfull channel

Table 6-6. Procedure for Estimating Large Woody Debris

NOTE: Estimate pieces of large woody debris (LWD) within each segment of stream while the thalweg profile is being determined. Include all pieces in the estimate whose large end is found within the segment.

1. The LWD tallies are estimated between all lettered transects within the study reach (i.e., between A-B, B-C, C-D, and D-E).

2. Scan the stream segment (A-B, B-C, etc.) for LWD and estimate the amount of LWD that are at least partially within the bankfull channel or are at least partially bridging the bankfull channel (Zones 1, 2, and/or 3 in **Figure 6-5**).

3. Check the appropriate box (dense, abundant, common, rare, absent) in the *Large Woody Debris* section of the field form. *Dense* is defined as greater than 75% of the reach has LWD within or bridging the bankfull channel; *Abundant* signifies 40-75% of the reach has LWD; *Common* refers to 10-40% of the reach has LWD; and *Rare* indicates that less than 10% of the reach has LWD.

4. Repeat steps 2 and 3 for the next stream segment and record estimate on the field form.

*6.2.6 **BANKFULL CROSS-SECTION, STREAM FLOW, AND PERCENT CANOPY COVER***

6.2.6.1 Bankfull Cross-Section and Stream Flow

Bankfull cross-section and stream flow data, in conjunction with other sampling, are essential to almost all SWQB activities. Activities such as water quality surveys, NPDES permit compliance monitoring, TMDL development, nonpoint source monitoring, assessment of fluvial geomorphological conditions, planning, and research rely on accurate flow measurement data.

Take stream flow measurements at a single, suitable location within the study reach to characterize conditions at the sampling point. The preferred location is as close as possible to the location where chemical samples are collected (typically the mid-point of the reach; Transect C), but the location can be moved as necessary to get a better measurement of stream flow. Flow measurements are usually taken after collecting water chemistry samples. Record all flow measurements in English units.

No single method for measuring stream flow is applicable to all types of stream channels. The preferred procedure for obtaining flow data is based on "velocity-area" methods. *For streams that are too small or too shallow to use the equipment required for the velocity-area procedure, refer to the appropriate SOP for alternative procedures.*

Velocity-Area Procedure

Because velocity and depth typically vary greatly across a stream, accuracy in field measurements is achieved by measuring the mean velocity and flow cross-sectional area of many increments across a channel (**Figure 6-6**). Each increment gives a subtotal of the stream flow and the whole is calculated as the sum of these parts. Bankfull cross-section and flow measurements are made ***at only one*** *carefully chosen transect within the study reach, typically Transect C*. It is important to choose a channel cross section that is as much like a canal as possible. A glide area with a U-shaped channel cross section that is free of obstructions provides the best conditions for measuring flow by the velocity-area method. The procedure for obtaining bankfull cross-section and stream flow measurements is outlined in **Table 6-7**.

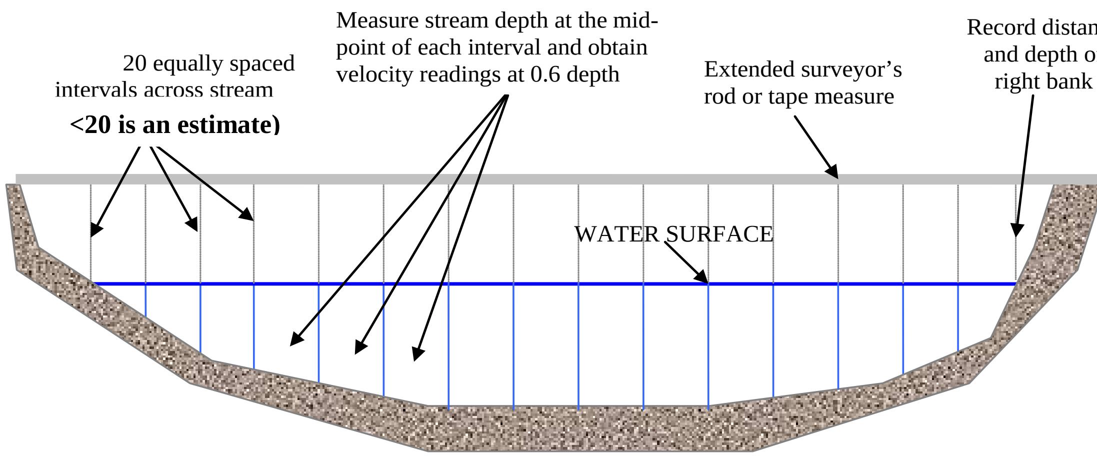

Figure 6-6. Layout of channel for obtaining bankfull cross-section and stream flow data

Table 6-7. Bankfull Cross-Section and Stream Flow Procedure

1. Locate a cross-section of the stream channel for stream flow measurements that has most of the following qualities:
    - Segment of stream above and below cross-section is straight.
    - Depths mostly greater than 0.2 ft and preferably velocities greater than 0.49 ft/s – no pools!
    - "U" shaped channel with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.

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

Place an *X* in the *TRANSECT* box on the **Bankfull Cross-Section and Stream Flow Field Form** to indicate the transect that was chosen for channel dimensions and flow measurements.

2. Insert the bank pins just beyond bankfull indicators. Lay a surveyor's rod or stretch a measuring tape (tag line) tight across the stream at the chosen cross-section (usually Transect C) with the "zero" end at left bankfull, as viewed when looking downstream. Adjust the tape height and bank pins, as needed, to ensure that the tape is level and perpendicular to the direction of flow. Record the bankfull width and height on the field form.

Determining Bankfull Width:
Bankfull stage is defined as the point of incipient flooding or the elevation where flows overtop the active channel and spread across an adjacent active floodplain as constructed by the present stream in the present climate, and frequently inundated (Dunne and Leopold, 1978) at intervals of 1 to 2 years. The bankfull flow is equivalent to the "effective discharge"; the flow which transports the greatest volume of sediment over time. Evidence from a large number of streams suggests that these flows are frequent, moderate sized flows with a typical return interval of 1-2 years and that they represent the channel forming or maintenance flows.

There is no single, absolute and definitive line for bankfull stage. Instead, the strategy is to build a case for identification of bankfull based on physical evidence at the site. The best evidence of bankfull stage is a series of features that are depositional, containing similar substrate and vegetation components, and lying at a consistent elevation, such as:

- topographic breaks in slope
- tops of point bars
- changes in vegetation
- changes in size of bank or bar materials
- evidence of an inundation feature such as small benches
- the presence of a floodplain
- exposed root hairs below an intact soil layer indicating exposure to erosive flow
- bank undercuts.

If the stream or river has incised it may have abandoned the floodplain, which will make the former floodplain a low terrace. It is critical to distinguish the active floodplain from low terraces in the identification of bankfull stage. Remember that in many New Mexico incised channels the most evident flat valley surface may actually be an abandoned terrace. Use common sense and local knowledge in deciding whether it is realistic that a particular elevation is inundated nearly every year. Where channels have incised and evolved to the point where a new depositional feature is redeveloping as an active floodplain, the determination of bankfull is less problematic and unambiguous. In other highly incised channels where bank erosion and bed scour are prominent, lack of consistent and unambiguous bankfull indicators may preclude any reliable determination of bankfull dimensions. In these situations, use best professional judgment in estimating bankfull dimensions and note the lack of consistent and reliable indicators on the fieldsheet.

Determining Bankfull Height:
Bankfull height is the distance from the water's surface to the bankfull tagline (leveled surveyor's rod or tape).

3. Attach the velocity meter probe to the wading rod. Check the meter to verify the probe is functioning properly and the correct calibration value is displayed. Fill out the top of the field form indicating the method and units used.

4. Divide the total wetted stream width into at least 20 equal-sized intervals (windows). To determine window width, divide the total width by 20 and round to a convenient number. Windows should not be less than 0.4ft wide even if this results in less than 20 windows. If the channel is too narrow to establish 20 windows, then flow may be estimated using fewer windows, however flag these data as "estimated flow". The first measurement is located at the left margin of the stream (left when looking downstream) and the last measurement is located at the right margin of the stream (right when looking downstream).

5. Stand downstream of the rod or tape and to the side of the first measurement point at the left edge of water (LEW). Record the tag line distance from left bankfull and the depth indicated on the wading rod on the field form noting that the measurements are at the left edge of water (LEW).

   NOTE: In many cases, the first and last depth measurements (LEW and REW) may equal 0..

6. Take the next measurement in the center of the window standing downstream of the probe to avoid disrupting streamflow. Record the tag line distance and depth of water on the field form. If the depth is <2.5ft, adjust the position of the probe on the wading rod so it is 0.6 of the measured depth below the surface of the water. Depths ≥2.5ft require velocity measurements at 0.2 and 0.8 depths, and the average is recorded as the window velocity. Face the probe into the direction of flow.

   To find the center of the window at the first measurement location, add the tag line distance recorded at the LEW to one-half of the window width determined in Step 4. For example, if the tag line distance at the LEW is 3 ft and the window width determined in Step 4 is 2 ft, the first velocity-depth measurement should be at a tag line distance of 4 ft (3 + (½ x 2)).

   To find the center the window at each subsequent location, add the window width determined in Step 4 to the previous tag line distance. In the example above, the previous tag line distance is 4 ft, so the next velocity-depth measurement location would be at a tag line distance of 6 ft. (2 + 4 = 6 ft).

7. Refer to SOP 7.0 Flow for operation instructions specific to the various flow meter models.

8. Move to the next window and repeat steps 6 and 7. Continue until velocity-depth measurements have been recorded for all windows. Note for the last measurement (at REW), depth and velocity values may equal 0.

9. Note on the field form the locations of left bankfull (LBNKFULL) and right bankfull (RBNKFULL), left edge of water and right edge of water (LEW and REW), and the thalweg (TWG). From this cross-section profile, a number of variables can be determined including the floodprone width, bankfull width, and wetted width and depth. Percent Canopy Cover (see section 6.2.6.2) will also be determined at the bankfull transect.

6.2.6.2 Percent Canopy Cover

The amount of riparian vegetation intercepting solar radiation may be quantified as the average percent canopy density. Average percent canopy density is used for SSTEMP Total Maximum Daily Load (TMDL) stream temperature modeling when a temperature impairment is determined through the use of seasonal thermograph deployments.

Canopy cover over the stream is determined at each of the 5 cross-section transects (Transects A – E). A convex, spherical densiometer is used (Lemmon 1957). Mark the densiometer with a permanent marker or tape exactly as shown in **Figure 6-7** to limit the number of square grid intersections to 17. Densiometer readings can range from 0 (no canopy cover) to 17 (maximum canopy cover). Six measurements are obtained at each cross-section transect (four measurements in each of the four directions at mid-channel and one at each bank).

The procedure for obtaining canopy cover data are presented in **Table 6-8**. Densiometer measurements are taken at 0.3 m (1 ft) above the water surface, rather than at waist level, to (1) avoid errors because people differ in height; (2) avoid errors from standing in water of varying depths; and (3) include low overhanging vegetation more consistently in the estimates of cover. Hold the densiometer level (using the bubble level) 1 foot above the water surface with your face reflected just below the apex of the taped "V", as shown in **Figure 6-7**. Concentrate on the 17 points of grid intersection on the densiometer that lie within the taped "V". If the reflection of a tree, branch, or leaf overlies any of the intersection points, that particular intersection is counted as having cover. For each of the six measurement points, record the number of intersection points (0 to 17) that have vegetation covering them in the appropriate section of the **Percent Canopy Cover Field Form**. To convert the measurements to percent canopy cover, the readings are summed and divided by the total possible points (Fitzpatrick, et al. 1998).

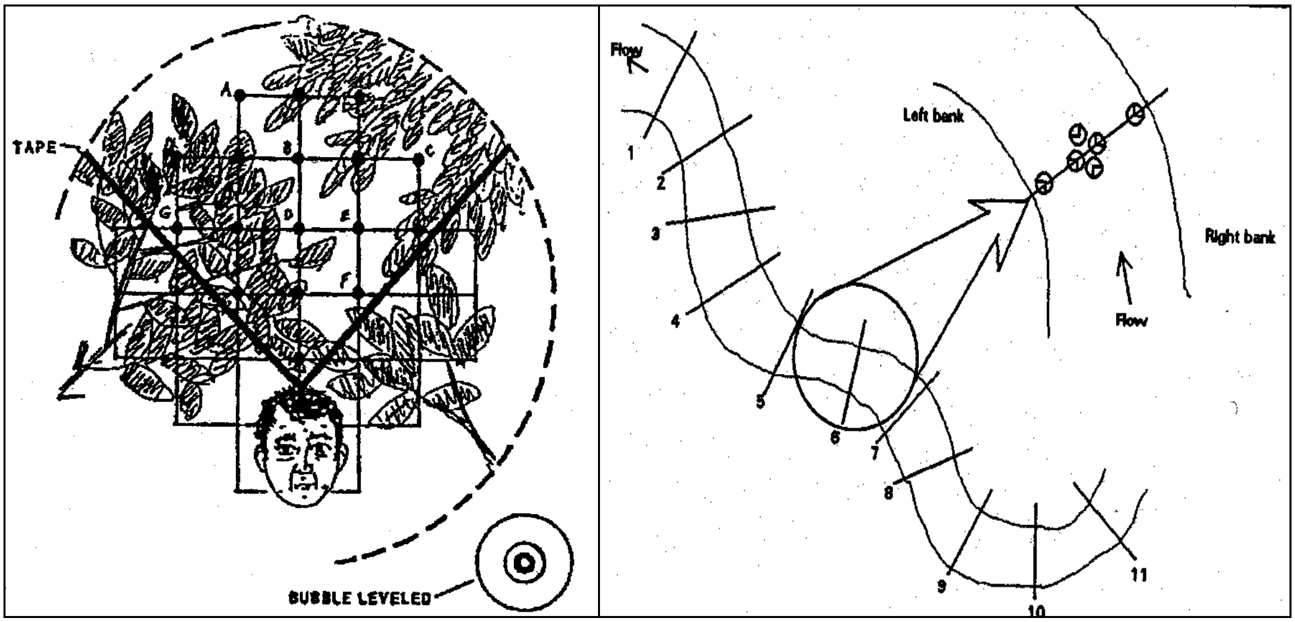

Figure 6-7. Proper use of densiometer and measurement locations within each transect (Mulvey et. al. 1992).

Table 6-8. Procedure for Canopy Cover Measurements

1. At each cross-section transect (Transects A – E), stand in the stream at mid-channel and face upstream.

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

3. Count the number of grid intersection points within the "V" that are covered by either a tree, a leaf, or a branch. Record the value (0 to 17) in the *CENUP* field of the canopy cover measurement section of the **Percent Canopy Cover Field Form**.

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

5. Repeat Steps 2 and 3 facing downstream, and again while facing the right bank (right as you look

downstream). Record the values in the *CENDWN* and *CENR* fields of the field data form.

6. Move to the water's edge (either the left or right bank). Repeat steps 2 and 3 again, this time facing the bank. Record the value in the *LEW* or *REW* field of the field data form. Move to the opposite bank and repeat.

7. Repeat Steps 1 through 6 at each regular cross-section transect (Transects A – E) including any additional side channel transects established when islands are present.

6.2.7 SLOPE

The slope, or gradient, of the stream reach in conjunction with the multiple depth and width measurements taken in the thalweg profile (Section 6.2.5.2) is used to compute residual pool depths, volumes, and numbers (Robison and Kaufmann 1994). Additionally, slope in combination with measurements of channel dimensions, wood, and substrate particle size is necessary for calculating relative bed stability (Kaufmann, et al. 1999), an important characteristic when assessing streams for sediment impairment.

Slope is typically measured by two people each having a pole that is marked at the same height. Alternatively (but much less precise), the second person can be marked at the eye level of the person doing the backsighting. *Be sure that you mark your eye level on the other person or on a separate pole beforehand while standing on level ground.* Sight to **your eye level** when backsighting on your co-worker. *It is recommended that field crews use poles marked with **exactly the same height** for sighting slope, particularly in streams with slopes **less than 3%**.* When two poles are used, sight from the mark on one pole to the mark on the other pole. Also, be sure that the second person is standing (or holding the marked pole) at the water's edge or in the same depth of water as you are. The intent is to get a measure of the *water surface slope*, which may not necessarily be the same as the bottom slope.

Clinometers and hand levels may read both percent slope and degrees of the slope angle; be careful to read and record percent slope. Verify this by comparing the two scales. Percent slope is always a higher number than degrees of slope angle (e.g., 100% slope = 45° angle). For slopes > 2%, read the percent slope to the nearest 0.5%. For slopes < 2%, read to the nearest 0.25%. If the reading is 0% but the water is moving, record the slope as 0.1%. If the reading is 0% but the water is not moving, record the slope as 0%. *If you would have to sight across land to measure slope then you need to make additional measurements* (i.e., do not "short-circuit" a meander bend). Record each slope measurement taken including the length of the stream segment used for the sighting. The procedure for measuring slope using a clinometer or hand level is presented in **Table 6-9**.

Table 6-9. Procedure for Obtaining Slope Data using a Clinometer or Hand Level

Use this procedure if you are standing at the **upstream transect** (E) after completing the thalweg profile and other cross-section measurements.

1. Stand in the center of the channel at the upstream cross-section transect. Determine how far you can see the center of the channel without sighting across land.

2. Mark a surveyor's rod and a calibrated rod (or meter ruler) at the same height. If a shorter pole or ruler is used measure the height from the ground to the opening of the clinometer or hand level

when it is resting on top. Mark the method used on the **Slope Field Form**. If using some other method besides a clinometer or hand level, describe in comments section.

3. Have one person take the marked surveyor's rod downstream to the furthest point where you can stand in the center of the channel and still see the center of the channel at the upstream location. Measure the distance between the upstream and downstream locations and record this distance on the field form. Report distance in Meters.

4. At the downstream location, hold the surveyor's rod vertical with the base at the same level as the water surface. If no suitable location is available at the stream margin, position the rod in the water and note the depth.

5. At the upstream location, place the base of the calibrated rod/ruler at the same level as the surveyor's rod (either at the water surface or at the same depth in the water).

6. Place the clinometer or hand level on the calibrated rod/ruler at the height determined in Step 2. With the instrument, sight back downstream to the flagged height on the surveyor's rod at the downstream location. Record % slope.

7. Proceed to the next downstream, line-of-sight location and repeat Steps 3 through 6 until the entire study reach has been "sighted".

6.2.7.1 Hydrostatic Leveling

Hydrostatic leveling is an inexpensive, light, and accurate method of slope measurement. In comparing slopes measured with a manometer (water-tube level) to measurements with a surveyor's level and stadia rod, LaPerriere and Martin (1986) reported agreement within 2%. In fact, EPA is now recommending using hydrostatic levels for measuring water surface slopes in streams with slopes less than 2.1% as part of the EMAP physical habitat field protocols for wadeable streams (Kaufmann, pers. comm.).

A manometer is simply a clear, flexible plastic ("Tygon") tube about 1cm (10 mm) in diameter and about 10 to 20 meters long. At the site to be measured, the hose is extended over the length of the slope. The hose is filled with water making sure no air bubbles remain. After the water level stabilizes in the tube the height of the water column in the downstream end of the tube is measured from the bottom of the meniscus to the top of the water's surface. This measurement determines the vertical drop. Horizontal distance can be measured by pulling the hose taut and measuring the length. The procedure for measuring slope using a hydrostatic level is presented in **Table 6-10**.

Table 6-10. Procedure for Obtaining Slope using a Hydrostatic Level (Water Tube)

1. Mark the method used on the **Slope Field Form**. Place the tube in the stream and submerge to fill the tube with water. Ensure that all air bubbles are removed from the tube.

2. Place the UPSTREAM end of tube open to the water surface at Transect E (**Figure 6-8**).

3. Hold the DOWNSTREAM end of tube with open end at an elevation higher than the upstream water surface (**Figure 6-8**).

4. Measure the height of the water column in the downstream end of the tube (H) to the nearest millimeter. Measure from the bottom of the meniscus to the water's surface. This is the elevation loss between the upstream and downstream water surfaces. Record this difference on the **Slope Field Form**.

5. Measure the distance between the two ends of the tube (L) along the centerline of the stream. Record this length on the **Slope Field Form**.

6. Proceed downstream such that the upstream end of the tube is now located at the previously downstream location. Repeat Steps 1 through 6, measuring the elevation loss along the length of the study reach until the entire reach has been evaluated.

7. Stream surface slope is calculated as the elevation difference (H) divided by the distance (L) along the centerline of the stream. Slope = H / L.

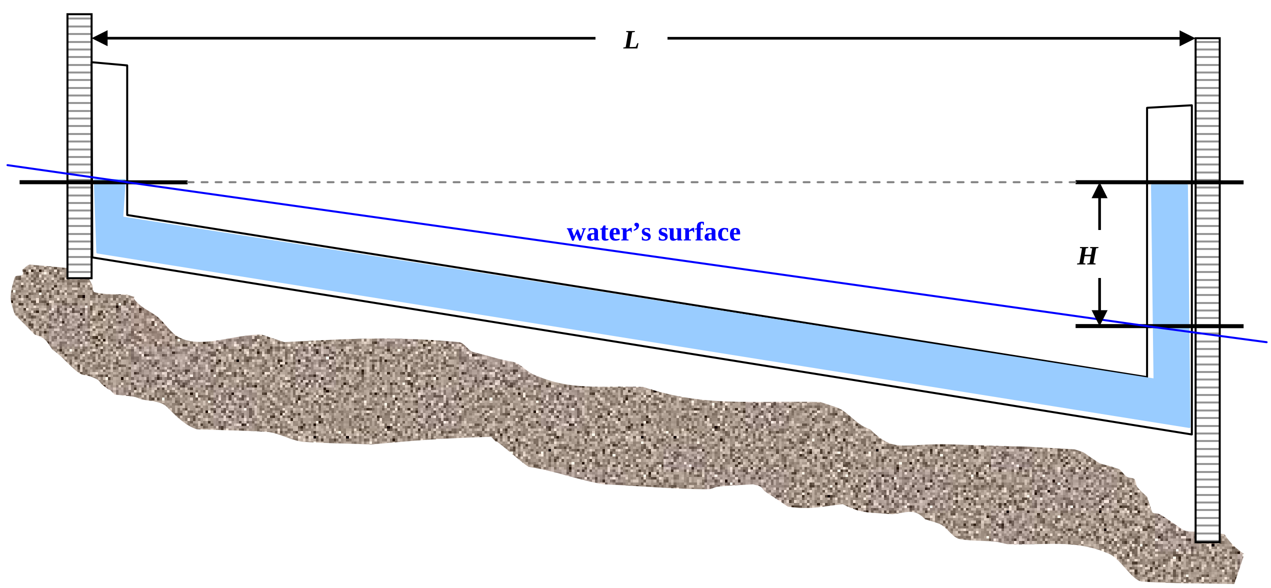

Figure 6-8. Hydrostatic leveling. Slope of the water surface is the difference in height of the water's surface (H) divided by the length (L), with all measurements in meters.

7.0 REVISION HISTORY

Revision 1: August 8, 2012- Minor edits and clarification of language.
Revision 2: Updated references. Updated SQUID upload procedures. Clarified pebble count, flow, slope, thalweg, and logistics protocols. Scouring event defined. Field forms clarified.
Revision 3: Updated index period guidelines

8.0 ATTACHMENTS

Field Equipment Checklist
Habitat Field Forms:
- Cover Sheet for Field Work
- Pebble Count Field Form
- Cross Sectional Profile Field Form

- Thalweg Profile and Large Woody Debris Field Form
- Bankfull Cross Section and Stream Flow Field Form
- Percent Canopy Cover Field Form
- Slope Field Form

Laminated SOP and/or quick reference guides for physical habitat (Tables 6-1 through 6-10)

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