DEPARTMENT OF ECOLOGY
State of Washington

Standard Operating Procedure EAP114, Version 1.4

Estimating Substrate Sizes and Embeddedness at Major Transects

December 2021
Publication 22-03-203
[Approved or Recertified 2021]

Purpose of this Document

The Washington State Department of Ecology develops Standard Operating Procedures (SOPs) to document agency practices related to sampling, field and laboratory analysis, and other aspects of the agency's technical operations.

Publication Information

This SOP is available on the Department of Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2203203.html.

Ecology's Activity Tracker Code for this SOP is 18-042.

***Recommended citation*:**
Merritt, Glenn. 2022. Standard Operating Procedure EAP114, Version 1.4: Estimating Substrate Sizes and Embeddedness at Major Transect for Watershed Health Monitoring. Publication 22-03-203. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2203203.html. (Approved or Recertified 2021.)

Contact Information

Publications Coordinator
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6764

Washington State Department of Ecology – https://ecology.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Original Author – Jill Lemmon and Glenn Merritt
Date – December, 2017

Original Reviewer – Dan Lantz (King County), Jenny Wolfe and Meghan Rosewood-Thurman
Date – December 11, 2017

Current Author – Glenn Merritt
Date – November 30, 2021

Current Reviewer – Meghan Rosewood-Thurman, Brian Engeness, and Jeff Robbins
Date – November 30, 2021

QA Approval – Arati Kaza, Ecology Quality Assurance Officer

Recertification Date – December 7, 2021

Signatures Available Upon Request

The Washington State Department of Ecology's (Ecology's) Standard Operating Procedures (SOPs) are adapted from published methods, or developed by in-house technical and administrative experts. Their primary purpose is for internal Ecology use, although sampling and administrative SOPs may have a wider utility. Our SOPs do not supplant official published methods. Distribution of these SOPs does not constitute an endorsement of a particular procedure or method.

Any reference to specific equipment, manufacturer, or supplies is for descriptive purposes only and does not constitute an endorsement of a particular product or service by the author or by Ecology.

Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process.

SOP Revision History

Revision Date	Revision History	Summary of Changes	Sections	Reviser(s)
5/10/17	1.0	Updated reviewers, added footers, updated glossary, general formatting, added references, updated figure #'s	All	Meghan Rosewood-Thurman
5/16/17	1.1	General spelling and punctuation	All	George Onwumere
5/16/17	1.2	Accepted George Onwumere' s edits	All	Meghan Rosewood-Thurman
5/17/17	1.2	QA Review and Approval	All	Bill Kammin
12/11/17	1.3	Edited error in Table 1.	6.0	Meghan Rosewood-Thurman
11/30/18	1.3	Publication and accessibility updates.	All	Ruth Froese
11/30/2021	1.4	Edited for Recertification	All	Meghan Rosewood-Thurman

1.0 Purpose and Scope

1.1 This document is the Environmental Assessment Program (EAP) Standard Operating Procedure (SOP) for estimating substrate and embeddedness in rivers and streams for the Watershed Health Monitoring program (WHM) or related studies during a Data Collection Event (DCE).

1.2 This SOP includes procedures for sites sampled with the Narrow and Wide protocols. See SOP EAP106 (Merritt, 2020), which describes the site verification and layout procedures for the WHM Narrow Protocol and SOP EAP105 (Hartman, 2020) which describes site layout for the Wide Protocol. It is also used by the Ambient Biological Monitoring Program. Substrate measurements at minor transects are discussed separately, in SOP EAP119 (Merritt, 2017) for the Narrow Protocol.

2.0 Applicability

2.1 This SOP was adapted from field methods of the Environmental Protection Agency's Environmental Monitoring and Assessment Program (Peck et al., 2005 and 2006).

2.2 This SOP is used in combination with other SOPs to complete a DCE for the WHM program. This method explains how to assess substrate and embeddedness across the main channel at 11 major transects. Follow the method outlined in this SOP only after the site verification and layout procedures have been completed (Merritt, 2020, and Hartman, 2020).

2.3 Data collected with the methods outlined in this SOP are used to calculate metrics that quantify bed stability and substrate at a site (Janisch, 2013).

3.0 Definitions

3.1 Bankfull depth: the vertical distance in cm between the channel bed substrate and bankfull elevation.

3.2 Bankfull height: the vertical distance between surface of water and bankfull stage. For WHM, this is measured in centimeters.

3.3 Bankfull Stage: This stage is delineated by the elevation point of incipient flooding, indicated by deposits of sand or silt at the active scour mark, break in stream bank slope, perennial vegetation limit, rock discoloration, and root hair exposure (Endreny, 2003).

3.4 Bankfull width: Horizontal distance between the bankfull stage on the left bank and the bankfull stage on the right bank. For WHM, this is measured to the nearest tenth of a meter.

3.5 Bar: Dry or exposed portions of the streambed. For this method, we are only counting bars that have water on both sides. Figures 1a &1b below provide examples. Bars are lower in elevation than the bankfull stage (islands are higher).

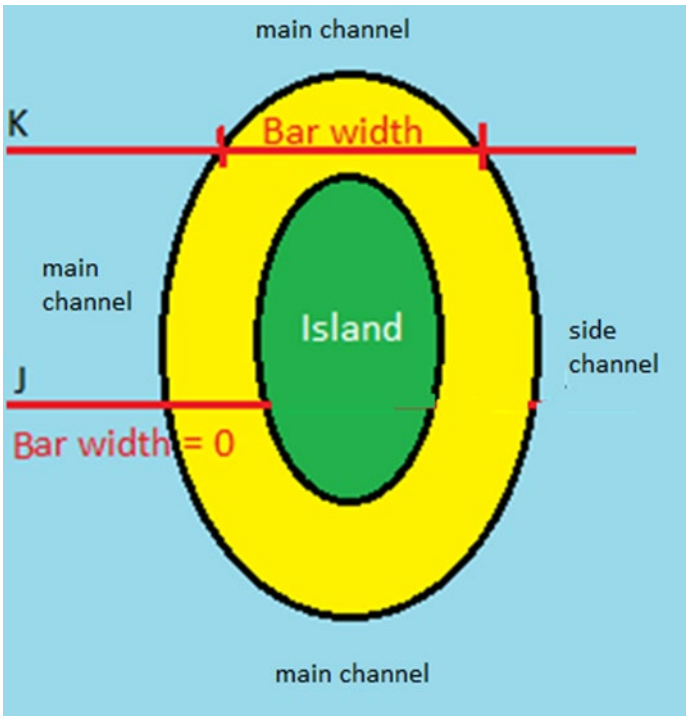

Figure 1. Example transects for recording bars. J has no bar. K does.

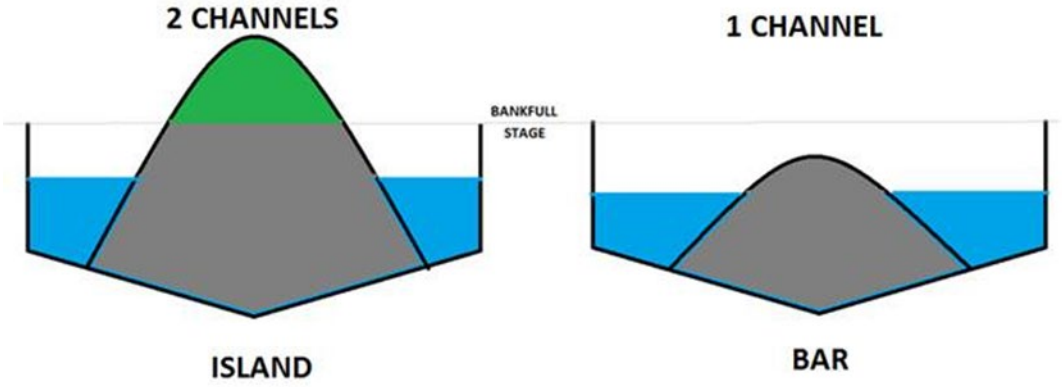

Figure 2. Example of an island (extends vertically above bankfull height) vs a bar (is NOT higher in elevation that bankfull height). All measurements are taken in the main channel

Note: Single boulders that rise above the water surface are **not** recorded as bars.

3.6 cm: centimeter

3.7 Concrete: Man-made material (e.g., in culverts), typically as a mixture of broken stone or gravel, sand, cement, and water, that that forms a stone-like mass on hardening. For WHM, concrete material is coded as RC if it is man-made construction material larger than 4 m in diameter along an intermediate axis; it is coded as OT if smaller.

3.8 DCE: The Data Collection Event is the sampling event for the given protocol. Data for a DCE are indexed using a code which includes the site ID followed by the year, month, day, and the time (military) for the start time of the sampling event. For example: WHM06600-000222-DCE-YYYY-MMDD-HH:MM. One DCE should be completed within one working day, lasting 4 - 6 hours, on average.

3.9 EAP: Environmental Assessment Program

3.10 Ecology: The Washington State Department of Ecology

3.11 Embeddedness: The percent of a particle's surface area that is surrounded by sand or smaller (< 2 mm) substrate.

3.12 Hardpan: A layer of earth that has become relatively hard and impermeable, usually through mineral deposits. A chemically hardened layer where soil particles are cemented together with organic matter of SiO_2, sesquioxides, or $CaCO_3$ (Armantrout, 1998). Hardpan is not intentionally made by humans. For WHM, material of this nature is coded as HP if it is larger than 4 m in diameter along an intermediate axis; it is coded as a rock of whatever size it comprises if smaller (e.g. XB, SB).

3.13 Index station: The distinct point location mapped by the site coordinates obtained from the Washington Master Sample 2020 (Larson, in prog.) list. The index station is called "X" and is generally located at major transect F; however, the point may occur at any elevation in the stream between transects A and K.

3.14 Intermediate Axis: The diameter of a particle that is neither the longest nor the shortest of mutually perpendicular axes (Bain 1999, Harrelson et al., 1994). See Figure 3 for a diagram from Endreny (2003).

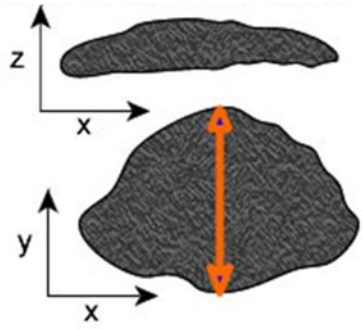

Figure 3. Diagram of intermediate axis from Endreny (2003). Note the orange "y" axis; this is the intermediate axis.

3.15 Left bank: For WHM, a person facing downstream will have the left bank on their left side.

3.16 m: meter

3.17 Main Channel: Channels in a stream are divided by islands (dry ground that rises above bankfull stage). Main channels contain the greatest proportion of flow.

3.18 Major transect: One of 11 equidistant transects across the length of a site. These transects run perpendicular to the thalweg and are labeled as follows: A (furthest downstream), B, C, D, E, F, G, H, I, J, and K (furthest upstream).

3.19 Narrow protocol: The set of WHM SOPs that describe data collection at wadeable sites with an average bankfull width of less than 25 m at the index station.

3.20 Narrow protocol: The set of WHM SOPs that describe data collection at wadeable sites with an average bankfull width of less than 25 m at the index station.

3.21 QAMP: Quality Assurance Monitoring Plan. The QAMP for WHM is Cusimano et al. (2006). An updated version will be released in 2020.

3.22 Right bank: For WHM, a person facing downstream will have the right bank on their right side.

3.23 Site: A site is defined by the coordinates provided to a sampling crew and the boundaries established by the protocol's site layout method (Hartman, 2020 (SOP EAP105) for the Wide Protocol; Merritt, 2020 (SOP EAP106) for the Narrow Protocol). Typically, a site is centered on the index station and equal in length to 20 times the average of 5 bankfull width measurements. Sites cannot be longer than 2 km nor shorter than 150 m. Narrow protocol sites range from 150 m to 500 m long. Wide Protocol sites are up to 2 km long and most-frequently longer than 500 m. The most downstream end of a site coincides with major transect A; the most upstream end coincides with major transect K.

3.24 Station: Any location within the site where an observation is made or part of a sample is collected.

3.25 Transect: A straight line along which observations are made or measurements are taken. This line spans the stream channel and is perpendicular to the direction of flow.

3.26 Wetted width: Farthest horizontal distance between water edge on the left and right sides of a channel. Do not subtract mid-channel bars.

3.27 WHM: Watershed Health Monitoring, a status and trends monitoring program within the Environmental Assessment Program at the Washington State Department of Ecology.

3.28 Wide protocol: The set of WHM SOPs that describes the sample and data collection at non-wadeable sites or sites wider than 25 m bankfull width. It is an abbreviated version of the Narrow Protocol and is typically accomplished by use of rafts.

4.0 Personnel Qualifications/Responsibilities

4.1 This SOP pertains to all Ecology staff in EAP and any other technicians collecting and entering data for the WHM program.

4.2 All field staff must comply with the requirements of the EA Safety Manual (Ecology, 2019). A full working knowledge of the procedures in Chapter 1 "General Field Work," especially the sections "Working in Rivers and Streams," and "Fall Protection," is expected. Sampling from a boat requires one person onboard to be a qualified boat operator as defined by the EAP Boating Plan in Chapter 3 of the EA Safety Manual. All persons onboard must be familiar with Chapter 3 of the EA Safety Manual, "Boating."

4.3 All field staff must have completed the annual WHM program field training and be familiar with the WHM protocol to be used for the given DCE. All field staff must be familiar with the electronic data recording tablet and web-based field forms that one uses to record and submit data for the WHM program. Contact the WHM Data Coordinator for further information.

4.4 The field crew leaders must be knowledgeable of all aspects of the project's Quality Assurance Monitoring Plan (QAMP) to ensure that credible and useable data are collected. All field staff should be briefed by the field crew leader or project manager on the sampling goals and objectives prior to arriving to the site.

4.5 All field staff must be familiar with the electronic data recording tablet and web-based field forms that one uses to record and submit data for the WHM program.

4.6 Field staff must be annually trained to minimize the spread of invasive species. See SOP EAP070: https://www.ecology.wa.gov/quality.

5.0 Equipment, Reagents, and Supplies

5.1 Field tablet (charged), electronic field forms

5.2 Clip board with blank paper data forms and pencils (contingency)

5.3 Measuring devices (measuring rod, 50m tape, laser rangefinder)

5.4 Laser level

5.5 Calipers

5.6 10 cm diameter PVC ring

5.7 Wading/rafting gear (pre-cleaned of organisms)

5.8 Disinfection solutions, brushes, or other equipment necessary to minimize the spread of invasive species from site to site. See SOP EAP070 for more information.

6.0 Summary of Procedure

6.1 Pre-sampling Preparation

6.1.1 Establish the 11 major transects and determine the appropriate protocol to use (narrow vs wide) before measuring channel dimensions. Follow the method outlined in this SOP only after completing site verification and layout procedures SOP EAP106 (Merritt, 2020) or SOP EAP105 (Hartman, 2020).

6.2 Narrow Protocol Method for Measuring Substrate and Embeddedness

6.2.1 At all major transects, make observations of bankfull or wetted depth, substrate particle size, and percent embeddedness at each of 121 stations. This includes 11 equidistant stations on each of 11 major transects. Record observations in the electronic data form.

Note: This SOP is limited to observations at major transects. For additional substrate observations at minor transects (110) see SOP EAP119 (Merritt, 2017).

6.2.1.1 At each transect, measure bankfull width according to SOP EAP113 (Lemmon, 2020). Divide the bankfull channel distance equally by 10 to identify 11 sampling stations.

The eleven stations along each transect are:

1. **Left bank** – at the left bankfull stage
2. **.1** – 10% distance across the channel
3. **.2** – 20% distance across the channel
4. **.3** – 30% distance across the channel
5. **.4** – 40% distance across the channel
6. **.5** – half way across the channel
7. **.6** – 60% distance across the channel
8. **.7** – 70% distance across the channel
9. **.8** – 80% distance across the channel
10. **.9** – 90% distance across the channel
11. **Right bank** – at the right bankfull stage

6.2.1.2 In the eforms, use the Navigation Page (Figure 4) to locate the transect that is being measured. Transect A is the first transect encountered when walking up the stream. Therefore, if you are starting here, click on “A”.

6.2.1.3 On the Major Transect Page, click on the Substrate tab to open the Substrate Field Form (Figure 5).

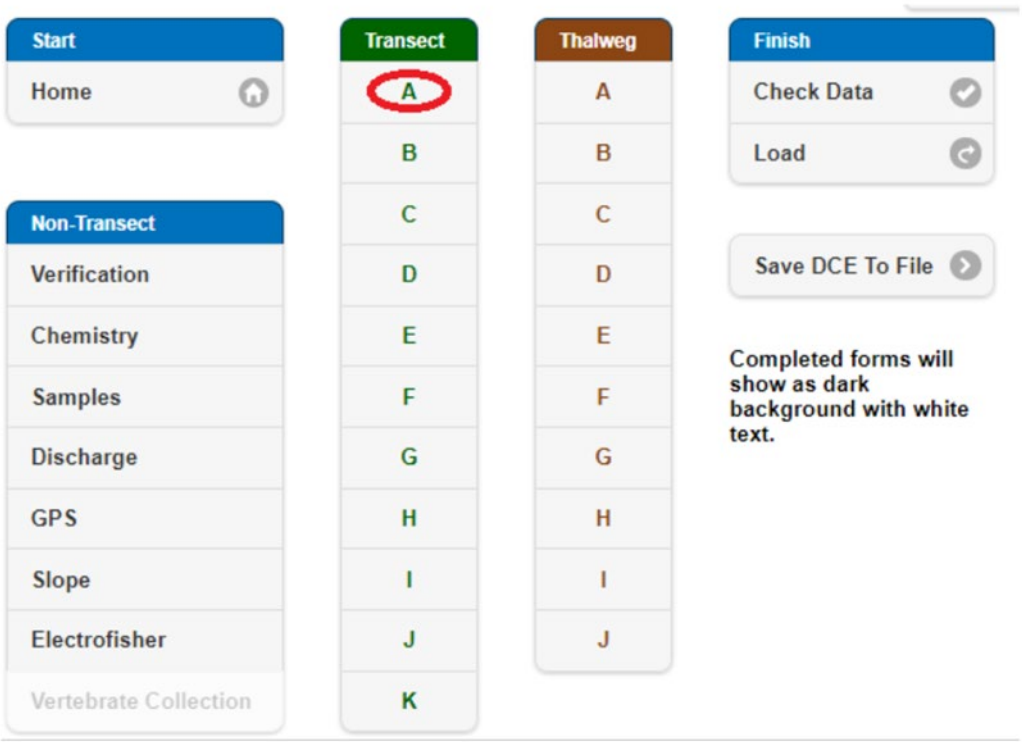

Figure 4. Navigation pane of the electronic WHM field forms

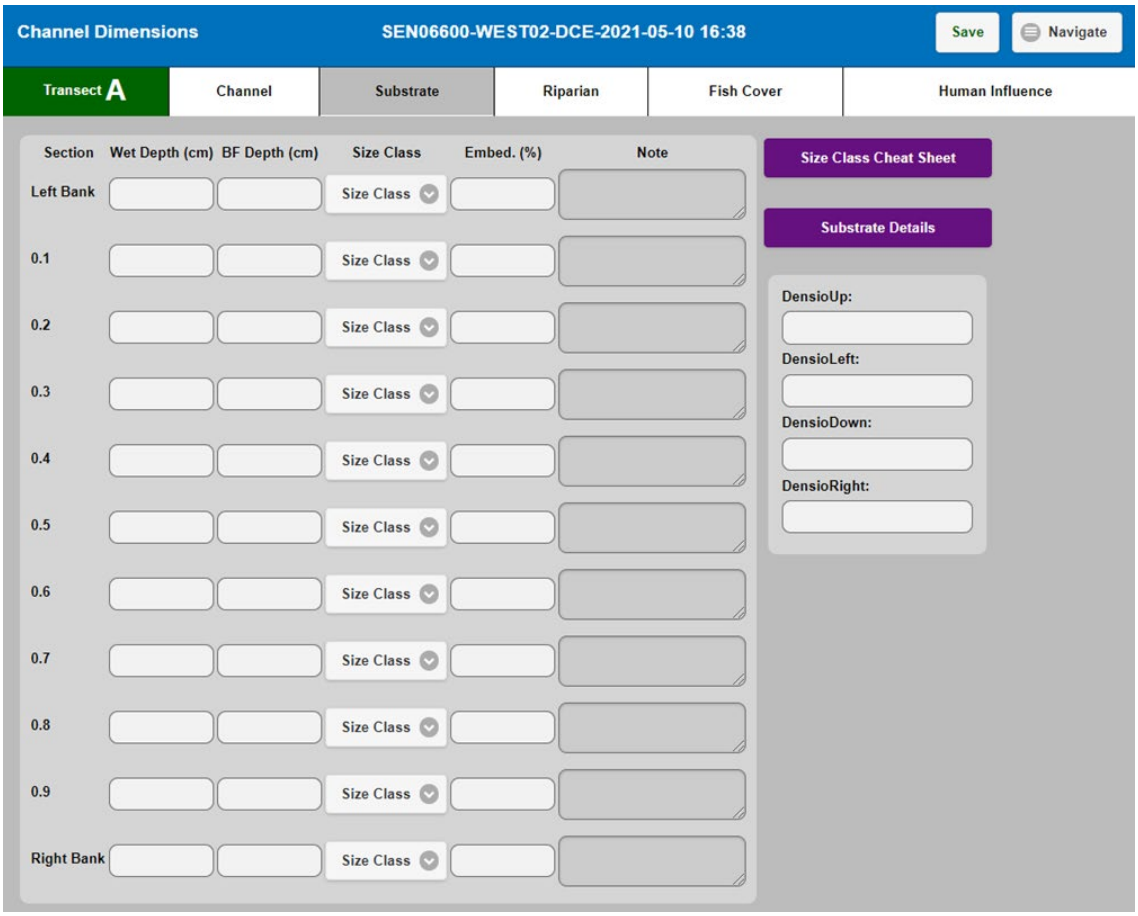

Figure 5. Major Transect Page (A), open to the Substrate Field Form.

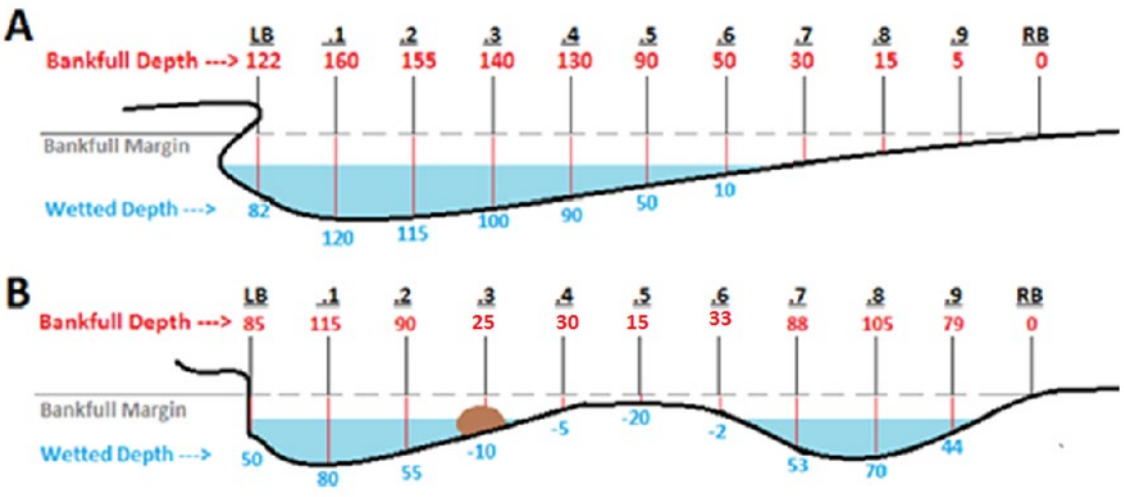

Figure 6. Example data for two transects, with undercut or vertical banks. Transect B illustrates negative wet depth (-10 cm) at station .3.

6.2.2 Measure and record channel depth (whole cm) at each 11 equidistant transect stations. Depths can be measured as positive or negative, depending upon situation (e.g., see negative wetted depth in Figure 6, B Station .3). Perform this task concurrently with substrate type (6.2.3) and with embeddedness estimates (6.2.4) at the same stations.

Note: Our objective is to determine bankfull depth, but field staff can measure and record either wetted depth (left column) or bankfull depth (right column), depending on which is easier to measure. Bankfull depths will get calculated from wet depths by addition to bankfull height.

6.2.2.1 Measure bankfull depth at the left bank station. For gradual banks, bankfull depth is zero (see Figure 6, right banks). For undercut (overhanging) banks, and vertical banks, bankfull depth is greater than zero (Figure 6, left banks).

6.2.2.2 Record bankfull depth for the left bank station on the Substrate Field Form, top row (Figure 5).

6.2.2.3 6.2.2.3 Measure depth (either wetted or bankfull) for stations 0.1 through 0.9. For stations where the stream bed is above water (e.g., bar, boulder) wet depth is measured as a negative value. For stations where a boulder rises above the bankfull stage, bankfull depth is measured as a negative value. Depths are to the bed surface on which LWD pieces lay.

Note: If a station falls within the wetted portion of the channel, it is likely easier to measure the wet depth.

6.2.2.4 Record depths (either wetted or bankfull) for stations 0.1 through 0.9 on the Substrate Field Form, rows 2-10 (Figure 5). Scroll the page to reach bottom rows.

6.2.2.5 Measure bankfull depth on the right bank and record in the eforms (Figure 5).

6.2.3 Identify and record substrate type for particles occurring at each of the 11 equidistant stations along each major transect. Perform this task concurrently with depth measurements (6.2.2) and with embeddedness estimates (6.2.4) at the same stations.

NOTE: We seek an unbiased selection of particles. Chose each particle based on the location of the depth station, rather than by looking first and choosing. Humans tend to pick larger particles that they can see.

6.2.3.1 Locate a substrate particle for observation at each of the 11 equidistant transect stations. Without looking, place your finger down into the substrate at the upstream edge of the base of the measuring rod.

6.2.3.2 Estimate the size class and type of that particle based on the intermediate axis length (Figure 3). Codes are based on material AND size. For example, see definitions of concrete and hardpan in section 3.

Note: If unsure of the size class, measure the particle using a measuring rod (for boulders), ruler, or calipers (for cobble or gravel). Be careful when deciding between cobble and coarse gravel or between coarse gravel and fine gravel.

6.2.3.2.1 Identify the appropriate code by referring to Table 1, or to the Substrate Size Class and Substrate Details Cheat Sheets (see the purple buttons on the field form in figure 5). See Figure 7 for deciding on particles that are larger than a car.

6.2.3.2.2 Wood pieces that are large enough to be considered LWD are not evaluated as substrate. Instead, evaluate the substrate beneath the piece of LWD. The minimum sizes for LWD are different, depending upon location east or west of the Cascade Crest. See SOP EAP121 (Wolfe, 2020).

Table 1. Substrate codes, types, size ranges, gauging cues, and embeddedness.

Code	Type	Size Range	Size Gauge	Embeddedness
RS	Bedrock (smooth)	> 4 m	Larger than a car	0%
RR	Bedrock (rough)	> 4 m	Larger than a car	0%
RC	Concrete/Asphalt/Culvert	> 4 m	Larger than a car	0%
XB	Boulder (large)	> 1 m to 4 m	Meter stick to car	Observe particle
SB	Boulder (small)	> 0.25 m to 1 m	Basketball to meter stick	Observe particle
CB	Cobble	64 mm to 250 mm	Tennis ball to basketball	Observe particle
GC	Gravel (coarse)	> 16 mm to 64 mm	Marble to tennis ball	Observe 10 cm ring
GF	Gravel (fine)	> 2 mm to 16 mm	Ladybug to marble	Observe 10 cm ring
SA	Sand	> 0.06 mm to 2 mm	Gritty to ladybug	100%
FN	Fines (silt, clay, muck)	≤ 0.06 mm	Not gritty	100%
HP	Hardpan	> 4 m	Larger than a car	0%
WD	Wood (smaller than LWD)	< LWD	See SOP EAP121 (Wolfe, 2020) for smallest LWD	Observe
OT	Other (doesn't fit above)	Any size	Includes unnatural items smaller than a car	Observe

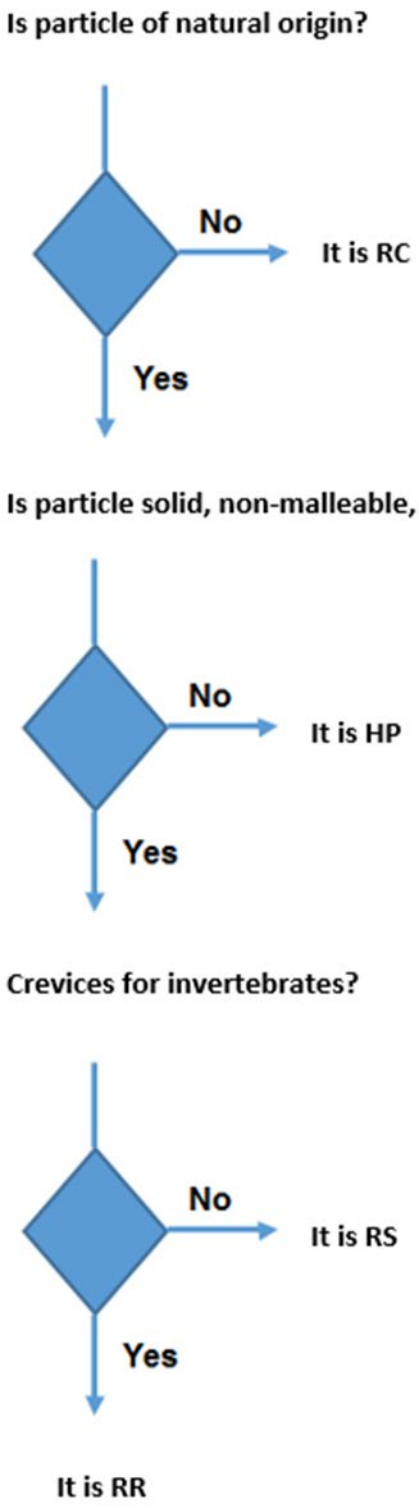

Figure 7 Decision tree for particles larger that 4m in diameter (larger than a car).

6.2.3.3 Record the code in the Size Class column of the Field Form (Figure 5). If you identify substrate as other (OT), provide a description in the "Note: column.

6.2.4 Estimate percent embeddedness and record your estimate for particles occurring at each of the 11 equidistant transect stations. Percent embeddedness is the percent surface area in which the particle is embedded (surrounded by) sand or smaller (≤ 2 mm) substrate. Perform this task concurrently with depth measurements (6.2.2) and with substrate identifications (6.2.3) at the same stations.

6.2.4.1 Estimate embeddedness (%) for each particle that you identified in 6.2.2.

6.2.4.1.1 For particles larger than 4 m, such as bedrock or hardpan (coded as RS, RR, HP, RC), the field form automatically assigns 0%. RC includes culverts larger than 4m, regardless of human-made material.

6.2.4.1.2 For sand or fines (coded as SA or FN), the field form automatically assigns 100% embeddedness.

6.2.4.1.3 For boulders or cobble (coded as XB, SB, or CB) field crews make an estimate of embeddedness for the lone particle.

Note: For cobble or boulders, use cues such as stain lines if the rock can be moved from the streambed. Place your fingers at the point where the substrate meets the streambed before picking it up to visually estimate the area covered by sand or fines. If the substrate cannot be moved, estimate the area you think is covered by sand or fines.

6.2.4.1.4 For coarse and fine gravel (coded as GC or GF) field crews make an estimate of dominant embeddedness using a 10 cm ring that surrounds the particle (Figure 8). Estimate the typical embeddedness for particles in the ring that are of similar size to the one that was coded as GC or GF.

Note: Embeddedness only refers to the sand or fines (muck) surrounding particles. Do NOT include algae or periphyton growth in your estimate.

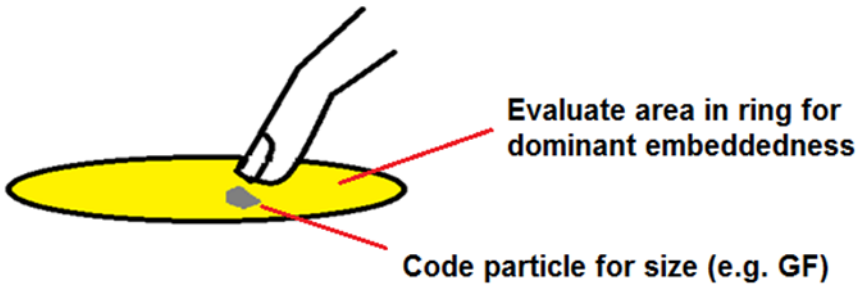

Figure 8 Using a 10 cm diameter ring (78.5 cm^2) to determine embeddedness of gravel or other small particles.

6.2.4.1.5 For small particles (< 64 mm) coded OT or WD, estimate embeddedness using the 10 cm ring (Figure 8). Larger particles of OT are estimated for embeddedness based on individual particles. Particles of wood larger than 64 mm are estimated for embeddedness based on the individual particle, but if the piece of wood is large enough to be considered large woody debris, we do not assess embeddedness because we select the substrate particle underneath the large woody debris instead.

6.2.4.2 Record embeddedness (%) in fourth column on the Substrate field form (Figure 5).

6.3 Wide Protocol Method for Measuring Substrate and Embeddedness.

6.3.1 For the Wide Protocol, make observations of channel depth, substrate particle size, and percent embeddedness at each of 11 major transects. The station count per transect is variable and includes real observations for dry stations on one bank per transect and estimated observations for a wetted littoral plot on the same side of the channel. Record observations in the electronic data form (Figure 4).

6.3.1.1 Travel to the correct side of the river for the given transect. This is based on the site layout procedure in SOP EAP105 (Hartman, 2020).

6.3.1.2 Measure bankfull width according to SOP EAP113 (Lemmon, 2020).

6.3.1.3 Define the dry transect stations and a littoral plot. Measurements at each transect are restricted to one dry station at the bankfull margin, adjacent dry stations at equidistant points (10% of bankfull width apart), and a littoral, wetted plot (Figure 9). The littoral plot starts at the wetted margin, extends 10 meters into the river (in most cases), 10 meters upstream, and 10 meters downstream. In rare circumstances, the water will not extend 10 meters into the river. In such cases, the plot extends as far as the water.

Note: The number of dry stations will vary at each transect, depending upon how much of the transect, between the littoral plot and bankfull margin, is above water.

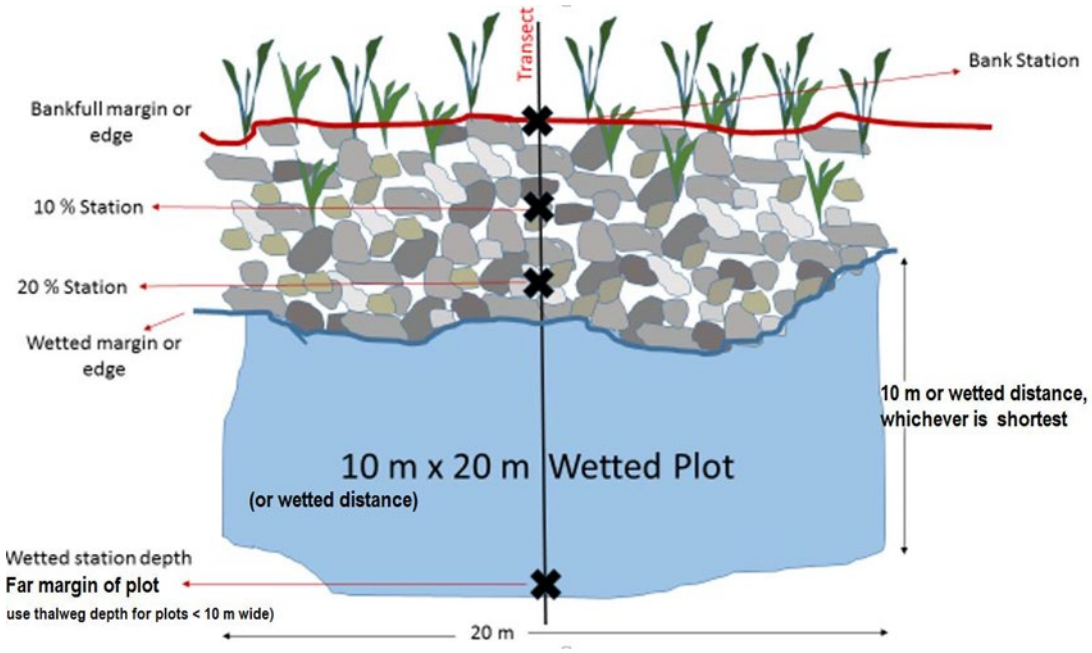

Figure 9 Example transect stations and the littoral plot for the Wide Protocol.

6.3.1.4 Make measurements/estimates at dry stations (see the Narrow Protocol transect stations; Section 6.2).

6.3.1.4.1 Measure bankfull depth (cm) at each dry station.

6.3.1.4.2 Estimate the particle size class/type at each dry station.

6.3.1.4.3 Estimate embeddedness at each dry station.

6.3.1.4.4 Record measurements/estimates on the Substrate Field Form (Figure 5).

6.3.1.5 Make estimates/measurements for the littoral plot (Figure 9).

6.3.1.5.1 Measure the wetted depth (cm) at the edge of the plot, on the river side. This depth measurement should be made at a distance of 10 meters from the wetted margin. In cases where there is a wetted plot less than 10 meters wide, measure wetted depth at the deepest location in the plot, the thalweg.

6.3.1.5.2 Estimate the mean (typical) size class/type for all substrate in the 10 m x 20 m littoral plot.

6.3.1.5.3 Estimate the mean (typical) embeddedness for the whole plot.

6.3.1.5.4 Record estimates and depth measurement on the Substrate Field Form (Figure 5). Littoral plot data are entered as a single transect station.

7.0 Records Management

7.1 Contact the Watershed Health Monitoring Data Coordinator for the latest guidance document describing how to validate, complete, and load WHM field forms to the WHM database.

8.0 Quality Control and Quality Assurance

8.1 PROJECT QA/QC procedures are discussed in the Quality Assurance Monitoring Plan (Cusimano et al., 2006); a new version will be available 2020.

9.0 Safety

9.1 All field staff must comply with the requirements of the EAP Safety Manual (Ecology, 2019).

10.0 References

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

10.2 Bain, M.B. 1999. Substrate. Pages 95 to 103 in M.B. Bain and N.J. Stevenson, editors. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

10.3 Cusimano, R., G. Merritt, R. Plotnikoff, C. Wiseman, C. Smith, and WDFW. 2006. Status and Trends Monitoring for Watershed Health and Salmon Recovery: Quality Assurance Monitoring Plan. https://apps.ecology.wa.gov/publications/SummaryPages/0603203.html

10.4 Ecology, 2019. Environmental Assessment Program Safety Manual. Washington State Department of Ecology. Olympia.

10.5 Endreny 2003. Fluvial Geomorphology Module, UCAR COMET Program and NOAA River Forecast Center, Syracuse, NY.
http://www.fgmorph.com

10.6 Harrelson, C.C, C.L. Rawlins, and J.P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.
http://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf

10.7 Hartman, C. 2020. Watershed Health Monitoring: Standard Operating Procedures for GIS-Based Verification, Layout, and Data Collection (Wide Protocol). SOP EAP105. Washington State Department of Ecology, Environmental Assessment Program, Olympia.
https://ecology.wa.gov/Quality

10.8 Janisch, J. 2013. Dictionary of Metrics for Physical Habitat: Definitions and Calculations Used for Watershed Health Monitoring and Related Studies. Washington State Department of Ecology.
https://apps.ecology.wa.gov/publications/SummaryPages/1303033.html

10.9 Lemmon, J. 2020. Watershed Health Monitoring: Standard Operating Procedures for Measuring Channel Dimensions. SOP EAP113. Washington State Department of Ecology, Environmental Assessment Program, Olympia.
https://ecology.wa.gov/Quality

10.10 Merritt, G. 2020. Watershed Health Monitoring: Standard Operating Procedures for Verification and Layout of Sites (Narrow Protocol) SOP EAP106. Washington State Department of Ecology, Environmental Assessment Program, Olympia.
https://ecology.wa.gov/Quality

10.11 Merritt, G. 2017. Watershed Health Monitoring: Standard Operating Procedures for Thalweg Profiling SOP EAP119. Washington State Department of Ecology, Environmental Assessment Program, Olympia.
https://ecology.wa.gov/Quality

10.12 Parsons, J., D. Hallock, K. Seiders, B. Ward, C. Coffin, E. Newell, C. Deligeannis, and K. Welch 2018. *Standard Operating Procedures to Minimize the Spread of Invasive Species*, EAP 070 Version 2.2.
https://ecology.wa.gov/Quality

10.13 Peck, D. V., Averill, D. K., Herlihy, A. T., Hughes, R. M., Kaufmann, P. R., Klemm, D. J., Lazorchak, J. M., McCormick, F. H., Peterson, S. A., Cappaert, M. R., Magee, T. & Monaco, P. A. 2005. Environmental Monitoring and Assessment Program - Surface Waters Western Pilot Study: Field Operations Manual for Non-Wadeable Rivers and Streams. EPA Report EPA 600/R-05/xxx, U.S. Environmental Protection Agency, Washington, DC.

10.14 Peck, D.V., Herlihy, A.T., Hill, B.H., Hughes, R.M., Kaufmann, P.R., Klemm, D.J., Lazorchak, J.M., McCormick, F.H., Peterson, S.A., Ringold, P.L., Magee, T., and Cappaert, M.R. 2006. Environmental Monitoring and Assessment Program-Surface Waters, Western Pilot Study, Field Operations Manual for Wadeable Streams. EPA/620/R-06/003. U.S. Environmental Protection Agency, Washington, D.C. https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NHEERL&dirEntryID=161489

10.15 Wolfe, J. 2020. Watershed Health Monitoring: Standard Operating Procedures for Counting Large Woody Debris. SOP EAP121. Washington State Department of Ecology, Environmental Assessment Program, Olympia. https://ecology.wa.gov/Quality