



Environmental Analysis Program

Pomona College
Biogeochemistry Laboratory

SOP-F304

Stream Physical Habitat Assessment – SWAMP Protocol

Standard Operating Procedure

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1. Purpose

This SOP describes procedures for characterizing the physical habitat of wadeable streams using the quantitative transect-based protocol developed by the California State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP). Physical habitat data document the structural condition of streams – channel dimensions, substrate composition, bank stability, riparian vegetation, instream cover, and human influence – and are essential for interpreting bioassessment results and diagnosing the causes of biological impairment (Barbour et al., 1999; Ode et al., 2016).

The protocol produces data compatible with the California Index of Physical-habitat Integrity (IPI), the California Stream Condition Index (CSCI), and the Algal Stream Condition Index (ASCI), enabling direct comparison with statewide reference data (Mazor et al., 2016; Rehn et al., 2018).

2. Scope

- **Applies to:** Wadeable perennial and intermittent streams and rivers where personnel can safely wade (generally depths less than approximately 1 m and velocities less than approximately 1.2 m/s)
- **Does not apply to:** Non-wadeable rivers requiring boat-based protocols; estuarine or tidal reaches; depressional wetlands (use CRAM instead); lake or reservoir shorelines
- **Location:** All EA Program stream monitoring sites, including tributaries to the Santa Ana River watershed and other southern California waterbodies

3. Responsibilities

Role	Responsibility
PI / Project Lead	Approve site selection and sampling design
Field Lead	Coordinate logistics, lead reach delineation, verify equipment
Trained Personnel	Collect physical habitat data per this SOP

Role	Responsibility
New Students	Complete training before participating in field crews

4. Definitions

- **b-axis (intermediate axis):** The intermediate dimension of a sediment particle (not the longest or shortest axis); the standard measurement used to classify particle size in pebble counts; measured with a metric ruler to the nearest mm (Ode et al., 2016).
- **Bankfull channel:** The stage at which water just begins to overflow the channel banks into the floodplain; the reference condition for channel geometry measurements in SWAMP; typically evidenced by a change in bank slope, a break in vegetation, or the top of the point bar (Ode et al., 2016; Peck et al., 2006).
- **Cobble embeddedness:** The percentage of the surface area of gravel, cobble, and boulder particles that is surrounded and buried by fine sediment (sand, silt, clay); an indicator of fine sediment loading and hyporheic connectivity (Ode et al., 2016).
- **CPOM (coarse particulate organic matter):** Organic material (leaves, needles, twigs, bark) with a largest dimension between 1 mm and 10 cm; recorded at substrate measurement points as an indicator of allochthonous organic input to the stream.
- **D16, D50, D84:** Percentile statistics of the particle-size distribution from a pebble count; the particle size at which 16%, 50%, or 84% of particles are smaller; used to characterize substrate texture; D50 is the median particle diameter.
- **Embeddedness:** See cobble embeddedness.
- **IPI (Index of Physical-habitat Integrity):** The California statewide index of stream physical condition calculated from SWAMP physical habitat data; scores from 0 (most disturbed) to 1 (least disturbed); used alongside the CSCI for reach-level condition assessment (Rehn et al., 2018).
- **Inter-transect:** A transect located halfway between two main transects; used for substrate, embeddedness, and organic matter measurements but not for cross-section geometry; see Appendix B for inter-transect locations (Ode et al., 2016).
- **Main transect:** One of 11 equally spaced transects (A through K) across the full sampling reach; the primary sampling unit for all SWAMP physical habitat modules including cross-section geometry, bankfull identification, substrate, canopy cover, bank stability, human influence, and riparian vegetation.
- **OHW (ordinary high-water mark):** The line on the bank formed by the action of water in its ordinary course; used as an alternative bankfull indicator where clear geomorphic evidence is absent.
- **Pebble count:** A randomized survey of substrate particle sizes at systematically distributed points along transects; each particle is measured at the toe of the measurer's boot or wading rod tip to ensure objectivity; produces the particle-size distribution used to calculate IPI substrate metrics (Ode et al., 2016; Peck et al., 2006).
- **Reach:** A representative stream segment typically 150 m in length (or $37.5\times$ the mean wetted width for wider streams), within which all SWAMP physical habitat measurements are collected; selected to encompass representative channel features and minimize confounding influences of point sources or major confluences (Ode et al., 2016).
- **Riparian zone:** The terrestrial area adjacent to the stream channel that is influenced by

periodic flooding and that contributes organic material, shade, and bank stability to the aquatic system; assessed in SWAMP modules I (riparian vegetation) and G (bank stability).

- **Sinuosity:** The ratio of the actual stream channel length to the straight-line valley length over the reach; values greater than 1.5 indicate a meandering channel; a component of the SWAMP reach characterization.
- **Thalweg:** The line of deepest flow along the channel axis; followed during the longitudinal profile module to characterize channel bed elevation changes.
- **Wetted width:** The horizontal distance across the stream from water's edge to water's edge at a transect; used to determine reach length ($37.5 \times$ mean wetted width) and to scale substrate sampling interval.

5. Safety and Hazards

Hazards

- **Drowning and swift water:** Do not wade in flows deeper than approximately waist height or where footing is unstable. Always face upstream. Use a wading rod for support.
- **Slippery substrates:** Algae-covered cobble and bedrock are extremely slippery. Wear felt-soled or studded wading boots.
- **Biological:** Waterborne pathogens, poison oak, ticks, snakes, and stinging insects. Check for ticks after every field day.
- **Heat:** Southern California field sites can exceed 40 °C during summer. Carry adequate water and take shade breaks.
- **Sensitive species:** California red-legged frog, arroyo toad, southwestern willow flycatcher, and steelhead may be present at some sites. Consult permit requirements before sampling (see [SOP-F004](#)).

5.1. Required PPE

- ☐ Chest or hip waders (neoprene or breathable)
- ☐ Wading boots with felt or studded soles
- ☐ Sun protection (hat, sunscreen, long sleeves)
- ☐ Nitrile gloves (when handling samples)

5.2. Permits

Sampling in or near habitat for listed species may require a CDFW Scientific Collecting Permit and/or a USFWS Section 10 permit. The PI must confirm permit status before fieldwork at any new site.

5.3. Invasive Species Prevention

Decontaminate all wading gear between sites per [SOP-F007](#).

5.4. Emergency Procedures

A minimum of two people must be present for any in-stream work. Refer to [SOP-F001 Field Safety](#).

6. Equipment and Materials

Item	Notes
Fiberglass measuring tape (50 m)	For establishing transect tag lines
Surveyor's rod or stadia rod	For measuring depth at cross-sections
Metric ruler (30 cm, mm gradations)	For pebble count (b-axis measurement)
Convex spherical densiometer	For canopy cover measurements
Clinometer (Suunto or equivalent)	For channel slope
Compass	For bearing and sinuosity
GPS unit or smartphone	For recording coordinates at each transect
Wading rod	For support and depth reference
SWAMP Physical Habitat Field Data Sheets	See Appendix A; print on waterproof paper
Clipboard and mechanical pencils	
Camera (waterproof or in dry bag)	Photo-document each transect
Flagging tape	For marking transect locations

7. Estimated Time

Task	Time (2-person crew)
Reach delineation and transect setup	20–30 minutes
Full physical habitat assessment (Modules C–M)	1.5–2.5 hours
Slope and sinuosity (Module L)	20–40 minutes
Photographs (Module M)	10–15 minutes
Total	2–3.5 hours per reach

8. Procedure

8.1. Reach Delineation

The sampling reach defines the stream segment over which all measurements are collected (Ode et al., 2016).

1. Select a representative reach of appropriate length (150 m for streams with mean wetted width 10 m; 250 m for wider streams).
2. Walk the reach before beginning measurements to identify the thalweg, bankfull indicators, and any safety hazards.

3. Mark the downstream boundary (Transect A) and record GPS coordinates.
4. Stretch the measuring tape upstream along the thalweg (not the bank) to the upstream boundary (Transect K).
5. Set transect locations at equal intervals (e.g., every 15 m for a 150 m reach), placing chaining pins or flagging at each transect.

 Tip

Select reaches that are representative of the stream segment. Avoid reaches with immediate upstream or downstream disturbances (bridges, dam tailwaters, outfalls) unless those features are the sampling target (Ode et al., 2016).

8.2. Module A: Reach-Level Information

Record at the start of each visit:

- GPS coordinates at Transects A (downstream) and K (upstream)
- Date, time, crew members
- General weather and flow conditions (normal, high, low, dry)
- Any unusual conditions (algal blooms, trash accumulation, visible pollutants, recent disturbance)

8.3. Module B: Bankfull Identification Calibration

Before beginning measurements, the full crew must agree on bankfull indicators (Ode et al., 2016):

1. Identify at least two independent lines of evidence for bankfull (e.g., break in bank slope, top of point bar, change in vegetation, flood debris line).
2. Walk the first 2–3 transects together and calibrate agreement on bankfull height.
3. Differences in bankfull identification between crew members are the largest source of inter-observer variability in SWAMP physical habitat data.

8.4. Module C: Cross-Section Geometry (Main Transects)

At each main transect (A through K) (Ode et al., 2016; Peck et al., 2006):

1. Stretch the measuring tape across the channel from left to right bank at the bankfull boundary (looking downstream).
2. Record the total bankfull width to the nearest 0.1 m.
3. Record the wetted width to the nearest 0.1 m.
4. At 5 equally spaced points across the wetted channel, measure water depth to the nearest cm using the surveyor's rod.
5. Record the thalweg depth (deepest point).
6. Estimate the dominant bank angle (undercut, vertical, steep, gradual, flat) for left and right banks.

8.5. Module D: Substrate (Pebble Count)

At each of the 21 transects (main and inter-transects), at 5 equally spaced points across the wetted channel (Ode et al., 2016):

1. Measure **water depth** to the nearest cm.
2. Pick up the particle at the toe of your boot (or wading rod tip) and measure the **b-axis** to the nearest mm. Record on the field form.
3. If the particle cannot be picked up (bedrock, hardpan), record the appropriate size class code (see Appendix C).
4. Record presence or absence of **CPOM** at each point.

This produces 105 substrate measurements per reach.

8.6. Module E: Cobble Embeddedness

At each substrate measurement point on main transects, if the particle is gravel, cobble, or boulder:

1. Estimate the **percentage of the particle surface buried** by fine sediment to the nearest 5% or 10%.
2. Record sand and finer substrate as 100% embedded by convention.
3. Do not assess embeddedness for bedrock.

8.7. Module F: Algal and Macrophyte Cover

At each of the five substrate measurement points (main and inter-transects):

1. Record presence/absence of **macroalgae** on the substrate particle.
2. Record presence/absence of **macrophytes** (rooted vascular aquatic plants; mosses excluded).
3. At main transects, estimate percent cover within a 1 m radius.

8.8. Module G: Bank Stability

At each main transect, for both left and right banks (Ode et al., 2016):

1. Estimate the **percent of bank covered by erosion** (exposed bare soil, slumping, undercutting) to the nearest 5%.
2. Estimate the **angle of the bank** (undercut, vertical, steep, gradual, flat).

8.9. Module H: Human Influence

At each main transect, record the proximity of human influences within a 5 m upstream/downstream window and 10 m from each bank. Record each feature as 0 (absent), P (present > 10 m), C (within 10 m), or B (on bank). Features include: walls/rip-rap/dams, buildings, pavement, roads/railroads, pipes, landfill/trash, park/lawn, row crops, pasture/hay, logging, and mining.

8.10. Module I: Riparian Vegetation

At each main transect, for both left and right banks, estimate areal cover (0–4 scale: 0 absent, 1 < 10%, 2 = 10–40%, 3 = 40–75%, 4 > 75%) in three layers:

- Canopy (> 5 m)
- Understory (0.5–5 m)
- Ground cover (< 0.5 m)

Record the dominant vegetation type for each layer.

8.11. Module J: Instream Cover

At each main transect, estimate percent cover of instream features within one channel width upstream and downstream of the transect line:

Feature	Definition
Boulder (> 25 cm)	Visual estimate of surface coverage
Cobble (6.4–25 cm)	Visual estimate
Wood (snag, rootwad)	Visual estimate
Overhanging vegetation	Bank overhang within 0.5 m of water surface
Undercut bank	Bank extending over water
Macroalgae	Attached filamentous or mat-forming algae
Macrophytes	Rooted vascular aquatic plants

8.12. Module L: Channel Slope and Sinuosity

Measure channel slope using a clinometer at a minimum of three measurement intervals along the reach (between Transects A–C, E–G, and I–K) or more frequently if slope is variable.

Measure sinuosity by comparing total thalweg length (measured with the tape along the thalweg) to the straight-line valley distance (measured with a compass and tape) (Ode et al., 2016).

8.13. Module M: Photographs

At each main transect, take the following photographs:

1. Looking upstream along the thalweg
2. Looking downstream along the thalweg
3. Left bank at the transect line
4. Right bank at the transect line

At Transects A and K, also photograph the downstream and upstream reach boundaries. All photographs should include the transect label (flagging or field data sheet) in the frame for orientation.

Record photo file names in the field data sheet.

9. Quality Control

9.1. Inter-Observer Variability

For substrate measurements, the precision targets are (Ode et al., 2016):

- Median substrate size class (D50): agreement within one Wentworth size class between independent observers
- Embeddedness: agreement within 15 percentage points

9.2. Repeat Measurements

For periodic quality assurance, conduct a repeat measurement by an independent crew within 48 hours. Both crews must achieve agreement within the precision targets above.

9.3. Common Errors to Avoid

- Measuring transects out of sequence (always work upstream)
- Inconsistent bankfull identification between crew members (calibrate at the first transect)
- Forgetting to record GPS coordinates at Transects A and K
- Omitting inter-transect measurements (required for full IPI calculation)
- Failing to record the measurement units (mm vs. size class code) for substrate

10. References

- Ode et al. (2016)
- Rehn et al. (2018)
- Peck et al. (2006)
- Barbour et al. (1999)
- Mazor et al. (2016)

Barbour, M. T., Gerritsen, J., Snyder, B. D., & Stribling, J. B. (1999). *Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish* (2nd ed.). U.S. Environmental Protection Agency, Office of Water. <https://www.epa.gov/cwa-methods/rapid-bioassessment>

Mazor, R. D., Rehn, A. C., Ode, P. R., Engeln, M., Schiff, K. C., Stein, E. D., Gillett, D. J., Herbst, D. B., & Hawkins, C. P. (2016). A revised framework for modeling and implementing bioassessment in California: The California Stream Condition Index (CSCI). *Ecological Indicators*, 69, 653–669. <https://doi.org/10.1016/j.ecolind.2016.04.029>

Ode, P. R., Fetscher, A. E., & Busse, L. B. (2016). *Standard operating procedures for the collection of field data for bioassessments of california wadeable streams: Benthic macroinvertebrates, algae, and physical habitat*. California State Water Resources Control Board, Surface Water Ambient Monitoring Program. https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/sops.html

- 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., & Cappaert, M. (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, Office of Research; Development.
- Rehn, A. C., Mazor, R. D., & Ode, P. R. (2018). *An index to measure the quality of physical habitat in California wadeable streams* (SWAMP Technical Memorandum SWAMP-TM-2018-0005). California State Water Resources Control Board, Surface Water Ambient Monitoring Program. https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/physical_habitat_index_technical_memo.pdf

11. Related SOPs

SOP	Title	Relationship
F001	Field Safety	Required prerequisite
F004	Site Access and Permits	Permits for listed species
F007	Field Decontamination	Between-site decontamination
F301	Stream Discharge	Concurrent discharge measurement
F606	Canopy Cover	Densimeter technique
F610	BMI Sampling	Co-collected bioassessment data

12. Training Record

Before conducting physical habitat assessments independently, personnel must:

1. Read this SOP, [SOP-F001](#), and the SWAMP Supplemental Guidance Document (Ode et al., 2016) in full
2. Review the SWAMP physical habitat field data sheets (Appendix A)
3. Participate in a calibration exercise for bankfull identification and substrate measurement with an experienced crew leader
4. Complete at least one full reach assessment under supervision, with substrate and embeddedness estimates agreeing with the trainer within the precision targets in §9
5. Demonstrate proper densimeter technique and slope measurement
6. Be signed off by the PI or field lead

13. Appendix A: Field Data Sheets

SWAMP Bioassessment Field Data Sheets (including physical habitat forms) are available from SWAMP@waterboards.ca.gov or at: https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/sops.html

Print on waterproof paper (Rite in the Rain) for field use. Forms needed:

1. Station Information and Notable Field Conditions
2. Channel/Riparian Cross-Section and Thalweg Profile (one per transect)
3. Slope and Bearing
4. Post-Sampling Qualitative Observations
5. Discharge Measurement (if applicable)

14. Appendix B: Quick Reference – Transect Layout

For a 150 m reach (average wetted width = 10 m):

Transect	Station (m)	Type
A	0	Main
AB	7.5	Inter
B	15	Main
BC	22.5	Inter
C	30	Main
...	...	...
K	150	Main

For a 250 m reach, multiply all station distances by 250/150.

15. Appendix C: Substrate Size Class Quick Reference

Code	Class	Size Range (mm)
RS	Bedrock smooth	Continuous
RR	Bedrock rough	Continuous
HP	Hardpan	Continuous
BL	Boulder	> 250
CB	Cobble	64–250
GC	Coarse gravel	16–64
GF	Fine gravel	2–16
SA	Sand	0.06–2
FN	Fines	< 0.06
WD	Wood	–
OT	Other	–

Always measure the **b-axis** (intermediate axis) of the particle.