Field Survey Procedure – Longitudinal Profile

Restoration Monitoring Guidance

8 April 2025

Document details	**An overview of a longitudinal stream survey, including a 1-page field method (Appendix A) and a field data form (Appendix B). This longitudinal profile can include water depth, pool residual depths, presence of fine sediment deposits, aquatic vegetation, and classification of mesohabitat units.**
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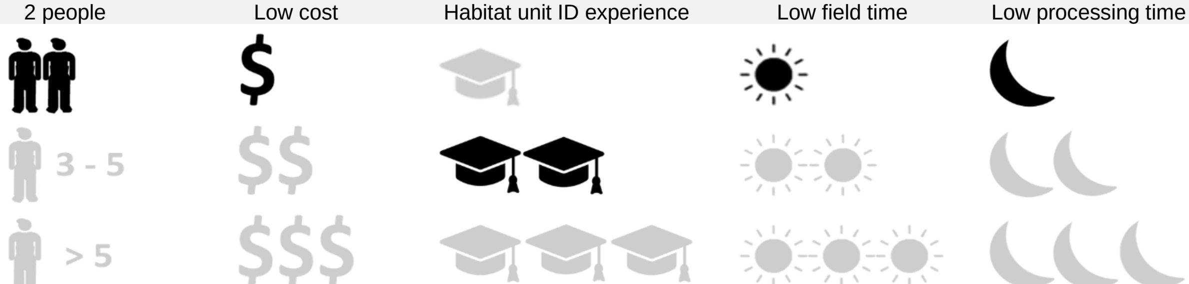
Draft	0.1	Oliver Franklin		31 July 2024	
Draft	0.2	Oliver Franklin		30 August 2024	Added references to more resources
Draft	0.3	Oliver Franklin		12 November 2024	Post pilot testing. Altered terminology, SWD, fines
Draft	0.4	Oliver Franklin		8 April 2025	Add slope measurement

Resource Commitments

2 people	Low cost	Habitat unit ID experience	Low field time	Low processing time



CONTENTS

1. OVERVIEW 4

1.1 Sampling Overview 5

1.2 Key Terminology 6

2. LONGITUDINAL PROFILE PROCEDURE 9

3. REFERENCES 12

APPENDIX A: LONGITUDINAL PROFILE 1-PAGER 13

APPENDIX B: LONGITUDINAL PROFILE FIELD FORM 14

APPENDIX C: CHARACTERISTICS OF SLOW-WATER CHANNEL UNITS 15

1. OVERVIEW

Please refer to 'APPENDIX A: Longitudinal Profile 1-Pager' for a concise step-by-step field method, intended for quick-reference in the field. The main body of this document provides further context and some relevant background.

This protocol characterises the variability of the channel along the length of the sampling reach. It records:

- Thalweg depth profile;
- Side-channel / node frequency;
- Habitat units classification;
- Presence/absence of fine sediment deposits; and
- Aquatic vegetation.

These variables were chosen to represent notable habitat features associated with many impacted streams, including those that have been channelised, that exist under altered flow regimes, that were constructed and function sub-optimally, or that are impacted by livestock grazing. The variables are anticipated to be responsive to both process-based and form-based restoration actions while representing biologically-meaningful aspects of salmon ecology. For example, a reach that does not receive natural channel-forming flows may accumulate sediment and rearing pools may infill, reducing the quality and quantity of salmon habitat and food resources, and reducing resilience to low-water and high temperatures. Livestock grazing may increase sedimentation, reduce shading, and result in nutrient loading, potentially leading to eutrophic conditions. Restoration that seeks to address these (and similar) impacts can be assessed by the degree to which these variables are altered. The focus of this protocol is habitat attributes, rather than invertebrate and/or fish abundances, as the former can be measured with fewer resources and has lower inherent variability.

While this protocol has been developed to provide simple assessments of changing reach conditions, it may also be beneficial to pair it with other methods to further explore the pathways of effects associated with your restoration project. For example flow, temperature, and/or dissolved oxygen loggers, measurement of shade at the water surface (e.g., with a spherical densiometer), cross-sectional channel variability, riparian vegetation, or LWD surveys may provide valuable information regarding how your actions resulted in changes to fish habitat. Longitudinal and planform heterogeneity is often associated with large woody debris (LWD), and this protocol can be conducted concurrently with a LWD Survey protocol. For example, one might combine the LWD, Longitudinal, and Fish Sampling protocols to explore the causal links between restoration action, increased LWD density, increased residual pool length, and increased salmon density (e.g., Mossop and Bradford 2006, Roni *et al.* 2015).

The application and interpretation of the variables within this protocol, and choice of other protocols, will be highly context-dependant. However, we recommend recording all variables included in this protocol due to the ease of their measurement and their potential to represent currently unforeseen habitat changes.

1.1 Sampling Overview

Typically a representative section of the focal reach is surveyed. The length of the reach surveyed is based on the measured bankfull width at a 'typical' location of the focal reach of the impact (restoration) site. It is recommended that three to five measurements of bankfull width are obtained and averaged while the reach is initially explored, to generate a reasonable estimate of bankfull width. The length of surveyed reach will then be:

a. 20 x bankfull width, if the bankfull width is 7.5 m or greater; or
b. 150 m, if the bankfull width is < 7.5 m; or
c. The full reach, if the reach is < 150 m in length.

This focal reach length, based on the impact (restoration) reach, will also be applied to the control/reference sites and kept consistent for any future surveys. In general, the assessed focal reach will be centred on the location of the restoration action, and the centre of an equivalent control/reference reach, and will not feature (or will note) any atypical features.

Longitudinal protocol samples are taken at predetermined intervals *and* upon each encounter with local shallow (pool outlet) and local deep points (pool maximum depths). This allows derivation of a number of useful metrics, including residual pool depths (depth at lowest flow), length in residual pool, proportions of reach occupied by fines, aquatic vegetation, or focal mesohabitats, and longitudinal and planform heterogeneity metrics. Habitat unit classification is also valuable for further analyses, including for identifying target mesohabitats for more detailed sediment sampling, e.g., Hilton and Lisle (1993) and Heitke et al. (2010).

Note that metrics derived from predetermined intervals can have lower resolution than metrics based on identified transitions between mesohabitats. Predetermined intervals were favoured as a less time-consuming and less subjective approach. In this protocol, the measurement intervals are related to the bankfull width of the focal stream, and features identified on this scale are anticipated to represent those that are geomorphically significant (i.e., would comprise a significant portion of the channel at bankfull flow).

This protocol surveys only the focal channel, and does not extend to characteristics of subordinate channels. Should subordinate channels be of interest, the protocol can be modified by (e.g.,) adding surveys of all encountered side-channel bifurcations that convey 16-50% of the flow.

A summary of the required equipment for this longitudinal survey is provided in Table 1.

Table 1: Equipment Checklist – Longitudinal Profiles

Item	
Field forms (waterproof) / Tablet	☐
Camera	☐
GPS	☐
Stadia rod	☐
Tape measure	☐
Clinometer	☐

Note: This list includes only equipment necessary for performing the survey and does not include items required for remote work, wildlife safety, or equipment cleaning/decontamination.

1.2 Key Terminology

Fast Water vs Slow Water

Describes current velocities at low-to-moderate flows *relative* to other channel units in the same stream. Typically, slow-water units are deeper at a given discharge than fast-water units.

Rough vs Smooth

Rough fast water is typically associated with higher gradient, higher velocity, higher bed roughness, greater step development, and supercritical flow. Rough water entrains more air bubbles and creates patches of white water, whereas smooth fast water flows appear more uniform.

Rough Fast Habitat Units:

Falls

Vertical or near-vertical drops of water. Commonly found in bedrock, cascade, and step-pool reaches.

Cascade

Highly turbulent series of short falls and small scour basins. Commonly associated with very large sediment sizes and a stepped longitudinal profile. Typically features of bedrock and cascade reaches.

Chute

Typically narrow, steep slots laterally confined in bedrock. Common in bedrock reaches but may also occur in cascade and step-pool reaches.

Rapids

Moderately steep channel units with coarse substrata and somewhat planar longitudinal profile (vs. the stepped longitudinal profile of cascades).

Riffles

Most common rough fast water unit in low-gradient (<3%) alluvial channels, and may be found in plane-bed, pool-riffle, dune-ripple, and braided reaches. Finer sediment sizes than other rough fast water units due to the shallower depth and lower force to mobilise the bed. When found in riffle-pool reaches, the riffle will have the steepest slopes and shallowest depths, and the thalweg may appear less defined.

Smooth Fast Habitat Units:

Sheet

Rare, but may be locally common in valley segments dominated by bedrock. Shallow water flows uniformly over smooth bedrock of variable gradient.

Run

Shallow gradient units typically with substrata ranging from sand to cobbles. Deeper than riffles with little if any supercritical flow. Common in pool-riffle, dune-ripple, and braided stream reaches. When found in riffle-pool reaches, the slope of the bed is less than the riffles and the thalweg may appear more defined.

Scour Pools:

Depressions formed when discharge mobilises substrates at a rate exceeding the sediment supply. See ‘APPENDIX C: Characteristics of Slow-Water Channel Units’ for habitat unit comparisons.

Eddy

Large flow obstructions along the stream edge cause the formation of pools downstream of the obstruction. Eddy pools are often associated with large wood deposits, boulders, and rock outcrops.

Trench

Usually in tightly-constrained bedrock-dominated reaches. U-shaped in cross sectional profile with highly resistant near-vertical banks. Often deep, but may still possess relatively high velocity currents.

Mid-channel

Formed by flow constrictions that focus scour along the main axis of flow in the middle of the stream; water movement is *not* diverted toward the bank. Deepest near the head (upstream). The flow constriction may be caused by laterally confined, hardened banks (e.g., bridge abutments) or large obstructions such as LWD or boulders.

Convergence

Result from the confluence of two channels of similar size. Resemble mid-channel pools but with two water entry points, which can result in fine sediment deposition upstream of the head of the pool, between the two inflows. Common in braided reaches.

Lateral

Formed where the channel encounters a resistant streambank or flow obstruction near the edge of the stream, such as bedrock outcrops, gravel bars, boulders, LWD. Additionally, they form at the outside of meander bends even without large roughness elements. This type is found alongside riprap-armoured banks, and is deepest closest to the bank with the flow obstruction or hardening. Contrast with eddy pools, which form downstream of obstructions, rather than alongside them.

Plunge

The vertical fall of water over a full-spanning obstruction scours a pool through the force of the fall. Abundant in small, steep headwater streams, especially those with bedrock, cascade, and step-pool reaches, and also common in forested riffle-pool channels where logs create plunge-pool steps.

Dammed Pools:

Water impounded by an obstruction to flow, can form under any flow condition. Typically containing more surface fines than scoured pools, and typically less abundant in the landscape due to their infill of sediment and the temporary nature of most dams. Dammed pools are distinguished by the material causing the impoundment and the location relative to the thalweg. See ‘APPENDIX C: Characteristics of Slow-Water Channel Units’ for habitat unit comparisons.

Debris

Form at the terminus of a debris flow or where large wood lodges at a channel constriction. Typically contains one or several large pieces of debris (framework) infilled by smaller wood and sediment (matrix). Note that debris flows differ from landslides: the former are typically more liquid, following existing gullies or channels, and comprise complex unconsolidated materials; landslides involve bulk earth movements often incorporating consolidated rock, and can form a longer-lived obstruction to flow.

Beaver

Usually composed of tightly woven smaller wood sealed with fine sediment on the upstream surface. If actively maintained, may breach and be rebuilt annually. Consider constructed beaver dam analogues (BDA) as a specific case of beaver dams that may contain pounded posts.

Landslide

A stream blockage comprising a mix of fine, coarse sediments, and woody debris from a mass wasting event. More abundant in confined reaches (step-pool, cascade) where hillslopes are directly coupled to the channel.

Backwater

Found primarily at low flows. Pools occurring along the bank of the main stream at the downstream end of a side-channel that is disconnected at its upstream end. Most often associated with pool-riffle, dune-ripple, and braided reaches. Also include in this unit alcoves or other laterally displaced pools that may not be associated with a scoured side-channel.

Abandoned Channel

Found primarily at low flows. Pools with no surface connection with the main channel. They are formed by bar deposits in secondary channels.

See Bisson *et al.* 2017 for a more comprehensive introduction to stream reaches and channel habitat units.

2. LONGITUDINAL PROFILE PROCEDURE

Progressing upstream, measurements will be obtained at predetermined intervals throughout the focal reach, with additional measurements taken at pool outlets and pool maximum depths.

1. Begin at the downstream end of the focal reach, and establish the ordinary interval distance between longitudinal measurements. Based on the initial bankfull width measurements that established the reach length, the interval distance will be:
   - 1 m for bankfull widths of <7.5 m, or
   - 1/5th of bankfull width where bankfull widths are 7.5 m or greater.
2. Locate the thalweg and record the following:
   a. Depth of water at the thalweg, taken from surface of substrate (i.e., do not allow rod to become buried in fine sediments). Measured in metres to 2 decimal places.
   - Where dense submerged vegetation is present, the transition from vegetation to fine sediment can be complex, and sediment may partially bury vegetation. The water depth should be measured to the point at which the fines become too dense for fish to swim

   b. The presence of fine sediment deposits that are perceptible through the rod / feet. Fine sediments is taken to mean substrates <2mm along their b-axis (intermediate axis) – that is, fine gravels and smaller. If, without applying downward pressure on the rod, coarse substrates remain perceptible beneath a shallow layer of fine sediments, the location is *not* considered a fine sediment deposit.

   c. The presence of any side-channel nodes (connections), noting whether it is a confluence or a bifurcation, whether it is flowing or dry, and whether on left or right bank. Record the presence of all nodes that are present from the current location upstream until the next interval.
      - Name each node encountered sequentially, following coding instructions on the datasheet. Each node is recorded only once (even if spanning multiple intervals).
      - It is recommended to include a sketch for reference.
      - Tributaries, spring brooks, or other features that discharge to the focal channel are not numbered but, if encountered, a note should be added to the datasheet.
      - Characterisation as side-channel is to be based on best judgement where potential side channels are extensive. It is not necessary to confirm the channel by following it until its bifurcation from the focal channel.
      - Note that nodes indicate a change in the number of distinct channels, where distinct channels are separated by islands that are higher than bankfull elevation / feature multi-year non-hydrophytic vegetation (i.e., nodes are not present at mid-channel bars).

   d. Presence and visual estimate of aquatic vegetation (exclude terrestrial vegetation that is rooted above bankfull, even if present within water). Specify lowest known taxonomic unit, and a % estimate of its extent across the wetted width in line with the current interval location.
      - Include floating, submerged, emergent vegetation, algal mats, biofilms on substrates
      - Include only vegetation that occupies either:
        - > 1m^2; or
        - a distance equivalent to >25% bankfull width in any one dimension.

e. The classification of the primary and, if present, secondary habitat unit present at - and laterally adjacent to - the thalweg measurement location. Habitat units are classified as per Figure 1, below, defined in Key Terminology (above) and with further details of slow water characterisations included as Appendix C.

- The primary habitat unit is the habitat unit that spans 50 – 100% of the wetted width. The secondary habitat unit is, where present, the unit that spans less than 50 % of the wetted width. Tertiary (and beyond) habitat units are rare but should be recorded in the notes section if encountered.

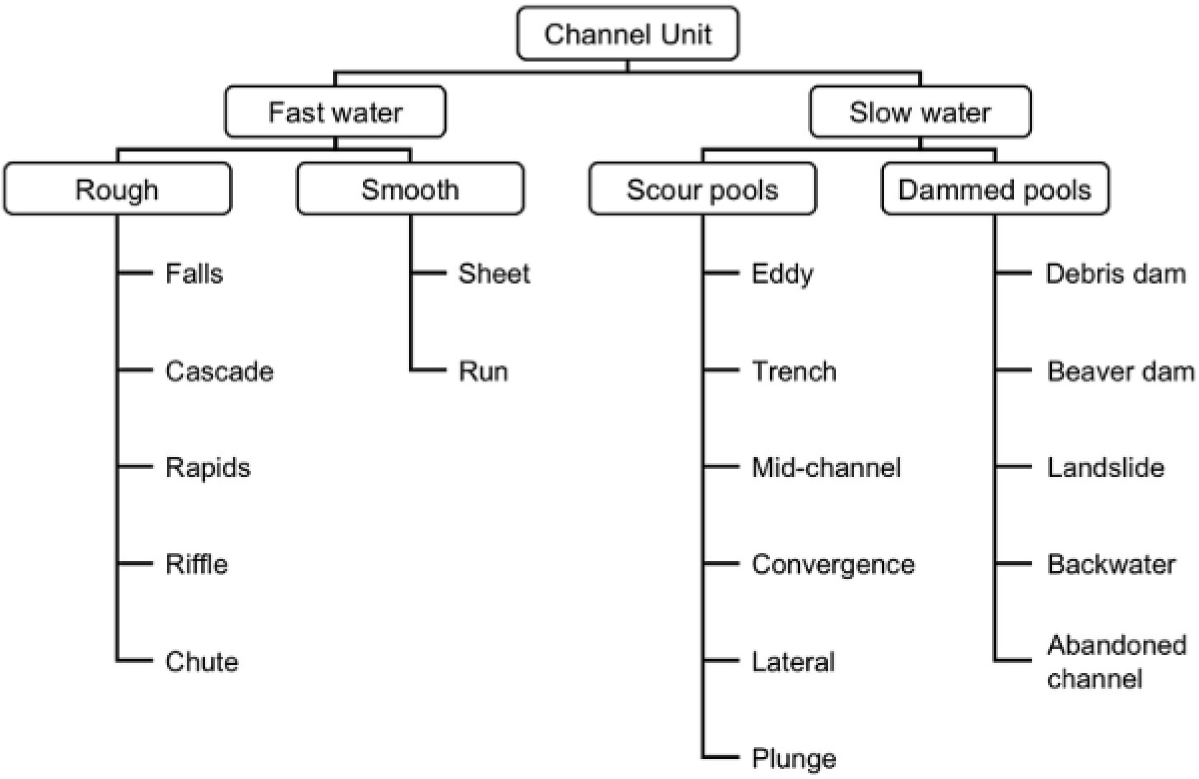


Figure 1 – Hierarchical subdivision of channel habitat units in streams. Bisson et al. 2017 after Hawkins et al. 1993. See 1.1 Key Terminology for brief descriptions of habitat units.

3. Proceed upstream along the thalweg the predetermined interval distance and repeat the measurements in Step 2, unless you encounter, along the thalweg, the following:

- The outlet of a pool; or
- The maximum depth of a pool.

a. Additional measures of thalweg depth and the presence of fine sediment deposits are to be taken at the pool outlet and the maximum depth, before returning to the next predetermined interval location (note that the interval does not reset at the pool outlet/maximum depth).

- The pool outlet (also referred to as a riffle crest) is the break in slope where water depth is at a local shallow point. Water depth typically decreases as you proceed upstream toward the pool outlet, then deepens as you pass the pool outlet. Ensure measurements are taken at the thalweg of the pool outlet.
- During periods of low flow the pool outlet is characterised by a transition from the slow and smooth water of the pool or pool tailout (glide) to the faster, rougher, and steeper water of

the riffle (see Figure 2). The outlet / riffle crest acts as a weir and is the location to which the pool would extend if streamflow dropped to zero.

- Where dammed pools are present (e.g., debris, small or large woody debris that create a pool), the pool outlet is the crest of the obstruction that forms the dam. Measure the depth at the deepest flow over the obstruction. If there is no overflow, record the depth as 0, noting if flow is observable passing under, through, or around the obstruction.

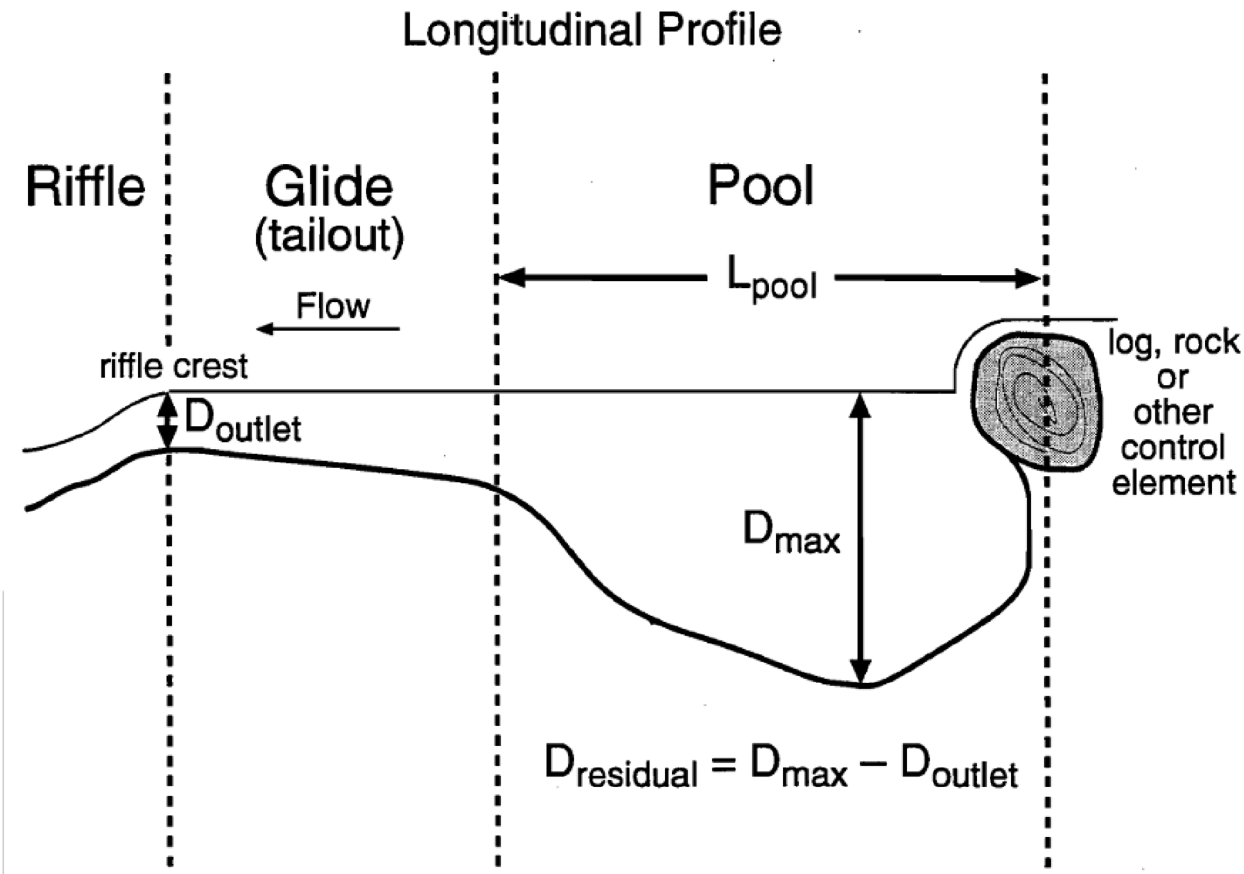


Figure 2 - Illustration of the pool maximum depth and pool outlet (riffle crest) locations at which measurements must be taken. Note that the pool outlet shown is *not* located at the downstream end of the concave component of the pool, rather it is downstream of the pool tailout. Image from Johnston and Slaney (1996), p. 102.

4. Repeat Steps 2 and 3 until the representative sample of the focal reach has been surveyed.
5. Slope: At three to four locations along the reach and using a clinometer, measure the slope of the water surface over a distance spanning approximately 10 times the interval spacing or as long as otherwise possible.
   - One person remains at the current interval with the clinometer, the second person flags the survey rod at the height of person one's eyes and proceeds upstream
   - With both people stood at the water surface, person one records the slope when the clinometer aligns with the flagging on the survey rod.
   - If measuring slope with another protocol (e.g. transects) this step can be omitted.

Special Cases

- If the thalweg is dry at any measurement location, such that no flowing water is visible above the bed, record the depth as 0 and note 'dry'. If there is an observable interruption in flow between the current and next measurement location, record 'dry upstream'.
- If the water is too deep to measure at the thalweg directly, extend a stadia rod at an angle, recording the depth and angle of the rod using a clinometer.
  - Note that obtaining a thalweg measurement at all intervals is critical for analysis. If encountering difficulties with measurement (e.g., deep beaver ponds), estimate the value to the best of your ability, and record on the datasheet that this is an estimate.

Transferable Information

- If information on targeted mesohabitats is required (riffle pebble counts, fine sediment proportion/V* in pools, etc.), the habitat units assigned here can be used to select suitable candidates. E.g., if riffle sediments are to be sampled, pebble counts could be conducted at a random selection of the riffle habitat units that span 3 or more measurement intervals, which corresponds to riffles that are longer than 60% of bankfull width (3 times 1/5th of bankfull).

3. REFERENCES

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APPENDIX A: LONGITUDINAL PROFILE 1-PAGER

1. **Establish ordinary interval distance,** based on initial estimates of reach bankfull width:
    a. 1 m for bankfull widths of <7.5 m, or
    b. 1/5th of bankfull width where bankfull widths are 7.5 m or greater.
2. **The first interval** is at the thalweg at the downstream extent of the focal reach. Record:
    a. **Depth of water** at the thalweg (m, 2dp), taken from surface of substrate
    b. Presence of **fine sediment deposits** at the interval location. Fine sediment deposits comprise particles < 2mm b-axis (sand or finer), through which coarse substrates are not readily perceptible underfoot.
    c. Presence of any **side-channel nodes** (confluences, bifurcations):
        i. Name each node sequentially, record node type, if flowing, left/right bank
        ii. Each node is recorded only once (even if spanning multiple intervals)
    d. Presence and visual estimate of aquatic vegetation (exclude terrestrial vegetation that is rooted above bankfull, even if present within water). Specify lowest known taxonomic unit, and a % estimate of its extent across the wetted width.
        i. Include floating, submerged, emergent vegetation, algal mats, biofilms
        ii. Include only vegetation that occupies either:
            - > $1m^2$; or
            - a distance equivalent to >25% bankfull width in any one dimension.
    e. **Habitat unit classification** (see Figure 1 or below coding) at - and laterally adjacent to - the interval location, including primary and secondary units where present.
3. **Proceed upstream along the thalweg** the predetermined interval distance (step 1) and repeat the measurements in Step 2, **unless you encounter**, along the thalweg, the following:
    - The outlet of a pool (riffle crest); or
    - The maximum depth of a pool.

    Additional measures are required at the pool outlet and pool max depth:
    - Thalweg depth (as step 2.a) and fine sediment deposits (as step 2.d)
    - Then return to the next predetermined interval location (the interval does not reset at the pool outlet/maximum depth).
4. **Repeat Step 3** until the representative sample of the focal reach has been surveyed.
5. **Slope**: At three to four locations along the reach and using a clinometer, measure the slope of the water surface over a distance spanning approximately 10 times the interval spacing.

Location Type Coding:
[blank] = predetermined interval, PO = pool outlet at predetermined interval, D = pool max depth at predetermined interval, XPO = pool outlet between predetermined intervals, XD = pool max depth between predetermined intervals

Habitat Unit Codes:
Fastwater: Falls = F; Cascade = CA; Rapids = RAP; Riffle = RIF; Chute = CH; Sheet = SH; Run = RUN
Scour Pools: Eddy = ED; Trench = TR; Mid-channel = MID; Convergence = CON; Lateral = LAT; Plunge = PL
Dammed Pools: Debris dam = DEB; Beaver dam = BEA; Landslide = LAN; Backwater = BAC; Abandoned Channel = AB

Node Coding:
List with number sequentially from downstream to upstream. Add suffixes: L/R for left/right bank, C for confluence or B for bifurcation, D if dry.
e.g. 6RBD = sixth node encountered, located right bank, bifurcation (branching from focal channel), currently dry

APPENDIX B: LONGITUDINAL PROFILE FIELD FORM

Longitudinal Profiles

Study Ref	Stream Name	Date
Start Waypoint Name/GPS		Staff
End Waypoint Name/GPS		Measurement Interval:
Reach Slope (%) Measurements		

Location Code	**thalweg depth (m)**	**Habitat unit (primary)**	**Habitat unit (secondary).** Blank = none	**Fines** (y = yes) Blank = none	**Nodes.** Blank = no new node encountered	**Aquatic Veg, Notes**

Location Type Coding:
[blank] = predetermined interval, PO = pool outlet at predetermined interval, D = pool max depth at predetermined interval, XPO = pool outlet between predetermined intervals, XD = pool max depth between predetermined intervals

Habitat Unit Codes:
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Node Coding:
List with number sequentially from downstream to upstream. Add suffixes: L/R for left/right bank, C for confluence or B for bifurcation, D if dry.

(print more forms than you think you need)

APPENDIX C: CHARACTERISTICS OF SLOW-WATER CHANNEL UNITS

Location denotes whether the unit is likely to be associated with the thalweg of the channel or adjacent to a bank. Longitudinal and cross-sectional profiles refer to the deepest point in the unit relative to the head, middle, or tail region of the unit. Substrate characteristics refer to the extent of particle sorting (i.e., particle uniformity) and resistance to scour. The channel unit-forming constraint describes the feature most likely to cause pooling, though others may be possible (e.g., a plunge pool formed by a partial obstruction). Table from Bisson et al. 2017 after Hawkins et al. 1993

	Location	Longitudinal Profile	Cross-Sectional Profile	Substrate Features	Forming Constraint
Scour Pools					
Eddy	Bank	Middle	Middle	Surface fines, not resistant to scour	Flow obstruction causing lateral deflection
Trench	Thalweg	Uniform	Uniform	Bedrock or sorted, resistant to scour	Bilateral resistance
Mid-channel	Thalweg	Middle	Middle	Sorted, variable resistance to scour	Constriction at upstream end
Convergence	Thalweg	Middle	Middle	Sorted, variable resistance to scour	Convergence of two channels
Lateral	Thalweg	Head or middle	Side	Sorted, variable resistance to scour	Flow obstruction causing lateral deflection
Plunge	Thalweg	Head	Upstream or middle	Sorted, variable resistance to scour	Full-spanning obstruction causing waterfall
Dammed Pools					
Debris dam	Thalweg	Tail	Highly variable	Usually sorted, not resistant to scour	Large woody debris dam of fluvial origin
Beaver dam	Thalweg	Tail	Highly variable	Surface fines, not resistant to scour	Beaver dam
Landslide dam	Thalweg	Tail	Highly variable	Often unsorted, variable resistance to scour	Organic and inorganic matter delivered by mass wasting from adjacent hillslope
Backwater	Bank	Tail	Highly variable	Unsorted with surface fines, not resistant to scour	Obstruction at tail impounding water along margin of main channel
Abandoned channel	Floodplain	Highly variable	Highly variable	Unsorted with surface fines, not resistant to scour	Lateral meander bars that isolate an overflow channel from the main channel