

<i>Title:</i> AOS Protocol and Procedure: Wadeable Stream Morphology		<i>Date:</i> 01/29/2018
<i>NEON Doc. #:</i> NEON.DOC.003162	<i>Author:</i> N. Harrison	<i>Revision:</i> C

AOS PROTOCOL AND PROCEDURE: WADEABLE STREAM MORPHOLOGY

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	02/29/2016	ECO-03668	Initial release, includes Rapid Habitat Assessment SOP
B	05/16/2017	ECO-04578	There is now only one type of survey implemented once every 5 years, or when a major channel altering event occurs. Added 13 cross-section (for a total of 15); Added a pebble count; Added a LWD tally; Set a maximum of 50 bankfull indicators collected; set a maximum of 50 floodprone width collected. With the exception of the 50 floodprone measurements collected at the transects, eliminated measuring any feature outside of the bankfull channel. Set minimum point amounts for features; wetted edge and thalweg. Changed the Total Station start of the project procedure; Changed the procedure for moving the Total Station; Updated Rapid Habitat to include gravelometer and detailed mapping survey. Changed the benchmark procedure to include – permeant benchmarks and trimble points.
C	01/29/2018	ECO-05292	Updated and revised all sections to reflect current practices.

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1 OVERVIEW

1.1 Background

Fluvial geomorphology is the study of the form and function of streams and the interaction between streams and the landscape around them. The morphology of a stream is dynamic over time - changes in water level and sediment supply shape the stream channel and dictate how the channel morphology response to perturbation. Glacier-fed streams may shift from a braided, unstable network to a single, stable channel as the glacier retreats up valley and sediment supply diminishes (Marren and Toomath 2014). In another example, if precipitation declines over time in an arid- or semi-arid region, stream channels will begin to incise and form deep canyons, leaving former floodplains perched high above the contemporary active stream channel (Leopold 1994). Physical attributes that comprise a stream (including in-stream channel structures, sinuosity, density of wood, and channel morphometrics) are collectively referred to as the geomorphic template.

The geomorphic template exerts a strong influence on ecological processes within fluvial systems. Attributes related to geomorphic features significantly influence the quantity and quality of habitat for virtually all aquatic organisms at multiple spatial scales, from the frequency of small features such as pools to the sinuosity of the entire channel (Frissell et al. 1986). Sediment supply, transport, and stability, (largely a reflection of the geomorphic template) may also directly affect the composition of biotic communities residing in the stream across spatiotemporal scales (Lamouroux et al. 2004). Although in-stream biota play a limited role in structuring the physical nature of stream channels, riparian and upland vegetation may strongly influence stream channel shapes by controlling erosive forces (Keeton et al. 2007). Woody debris within the stream channel plays an important role for aquatic organisms, as large woody debris (LWD) creates refugia and provides unique structural habitats on which many aquatic species depend (Lemly and Hilderbrand 2000).

Fluvial geomorphology is an important component of the ecological system and a metric for assessing biological and physical processes in streams. NEON will measure the geomorphic attributes of all NEON wadeable stream sites on a minimum rotation of every five years. Geomorphology surveys will be conducted using standard surveying equipment. A number of metrics will be drawn from data products derived from the surveys to quantitatively depict in-stream and riparian habitat in NEON wadeable stream sites.

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

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1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON’s Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON’s document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

CHaMP (Columbia Habitat Monitoring Program). 2014. Scientific protocol for salmonid habitat surveys within the Columbia Habitat Monitoring Program. Prepared by the Columbia Habitat Monitoring Program.

CHaMP Transformation tool, <http://ctt.joewheaton.org/>

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2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHSS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Performance QA/QC Plan

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Level 1, Level 2, Level 3 Data Products Catalogue
RD[04]	NEON.DOC.001271	NEON Protocol and Procedure: Manual Data Transcription
RD[05]	NEON.DOC.003224	Datasheets for AOS Protocol and Procedure: Wadeable Stream Morphology
RD[06]	NEON.DOC.001646	General AQU Field Metadata Sheet
RD[07]	NEON.DOC.001152	NEON Aquatic Sample Strategy Document
RD[08]	NEON.DOC.001717	TOS Protocol and Procedure: TruPulse Rangefinder Use and Calibration

2.3 Acronyms

Acronym	Definition
BFI	Bankfull Indicators
BM	Benchmark
COP	Control Point
DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Geographic Positioning System
HR	Height of Rod
LWD	Large Woody Debris
POC	Rugged hand held unit to record Total Station data.
STDev	Standard Deviation
TS	Total Station
TSOP	Total Station Operator
UTM	Universal Transverse Mercator Coordinate System
HD	Change in Horizontal Length
dH	Change in Height

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2.4 Definitions

Active channel: The natural waterway that contains all stream flow at and below bankfull stage

Assumed coordinate system: Localized coordinate system (i.e. not elevation, latitude, and longitude) of a survey established by attributing the first occupied point of a new site survey with the coordinates: 0 northing, 0 easting, 1000 elevation. All new surveys will be attributed an assumed coordinate system during the initial survey.

Bankfull Indicator: A physical marker created during the 1.5 to 2 year bankfull forming discharge used to identify the maximum channel height and width of the that discharge. Indicators used can be break in slope, change in soil type, the line where terrestrial vegetation starts, debris, and sand lines.

Bankfull Stage: the elevation of the water surface when rising water completely fills the channel and first begins to spill onto the floodplain.

Bankpin: Pins placed at bankfull locations on both sides of the stream

Benchmark: A permanent geographic marker of a known location; elevation, latitude, and longitude.

Control point: A permanent or temporary location used to set up or orient the surveying instrument.

Cross-Section Profile: A transect running perpendicular to the channel where channel features are mapped.

Datum: A frame of reference for measuring locations on the surface of the Earth (i.e. lines of latitude and longitude).

Deposition zone: Area where sediments settle and accumulate on the stream bottom. Usually areas where the current is slow moving.

Dry extent of reach: Hydrologically disconnected portions of the stream (i.e. surface water paths are discontinuous) within or across habitat units.

Established coordinate system: Spatially accurate coordinate system (UTM) established after the first survey of a site. All revisit site surveys must re-occupy the exact same established coordinate system as the first survey.

Floodplain: The relatively flat valley-floor surface that has been constructed during the present hydrologic regime.

Flood prone width: The valley floor outside of bankfull flood stage that is formed by floods two times the 1.5 to 2 year bankfull forming floods. Discharge level is defined as twice the bankfull depth.

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Geographic coordinate system: Data defined by a 3-dimensional surface and measured in meters or feet (i.e. latitude and longitude). Used interchangeably with datum.

Geographic Information System: A system designed to connect data to geography. The system is designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

Gradient: Is a value used to define the slope of a stream. This is expressed as the ratio of the amount a stream decreases in elevation over a selected horizontal unit length of stream. The resulting value is typically expressed as a number ranging from 0 – 1.0, or a percentage.

Habitat unit: A single habitat feature (e.g., a pool) within the stream reach.

Islands: Mounds of consolidated substrate that are surrounded by the stream. These features protrude above bankfull.

Large woody debris (LWD): Woody debris characterized by $\geq 0.15\text{m}$ diameter and $\geq 1\text{m}$ length.

Left bank: By standard convention, left bank is the left side of the channel from the perspective of an individual facing downstream.

Left edge water: The location in the stream where the water makes contact with the bank of streambed surface on the left side of the channel, looking downstream.

LWD jam: Considered 3 or more pieces of LWD that touch each other with at least 3 of the pieces meeting both a diameter criteria of $\geq 0.15\text{m}$ and a length criteria of $\geq 1\text{m}$.

Maximum pool depth: The deepest point of the pool unit.

Meander: A bend in a sinuous stream or river. Form when moving water erodes the outer banks and widens the channel, and the inner part with less energy deposits material. The result is a snaking pattern of the watercourse.

Mid-channel bar: Mounds of consolidated substrate that are surrounded by the stream. These features protrude above the streamflow but the maximum elevation is below bankfull.

POC: Rugged handheld tablet for controlling the robotic Total Station used to capture features during the survey.

POS: The Hilti POS 180 Robotic Head Total Station unit used during the geomorphology survey.

Pool: A river and stream aquatic habitat unit created by scour or impoundment and having a structural control. Pools are longer than they are wide and are 1.5 x deeper at their maximum depth than at their

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crest. Pools are deeper and have slower velocity than other stream habitat units. If all the running water in the stream was shut off, pools would still hold water. Fine sediments typically deposit in pools.

Prism: Mirrored flat surface that acts as a reflector to return the light pulse back to the Total Station to measure distance.

Prism pole: Graduated pole fixed with a prism on top used with the Total Station to measure the height of and mark survey points.

Projected coordinate system: Data defined by a flat 2-dimensional surface which is measured in meters or feet.

Riffle: A shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.

Right bank: By standard convention, the right bank is the right side of the channel from the perspective of an individual facing downstream.

Right edge water: The location in the stream where the water makes contact with the bank of streambed surface on the right side of the channel, looking downstream.

Run: A relatively shallow part of a stream with moderate velocity and little or no surface turbulence.

Sinuosity: A measure of the deviation of a line from the shortest path. Calculated by dividing the total length by the shortest possible path.

Step pool: Areas within high-gradient streams where water cascades over a series of rock ledges or woody snags, dropping into small pools that form between the features.

Temporary Points: A survey point that is not permanently benchmarked that can be removed once the survey and subsequent data processing has been completed. Magnetic nails are common and effective devices to serve as temporary points.

Thalweg: The line that connects deepest part of the active channel.

Total Station: (TS) The HILTI POS 180 Robotic Total Station is a high-resolution instrument used in surveying to measure distances and angles from horizontal points of interest. Total Stations utilize a laser pulse (light pulse) to determine distance and are equipped with a positioning system to determine the angle of rotation from a known datum to the point of interest.

Tributaries: Smaller order streams that feed into the mainstem of the monitoring reach. Tributaries may contain flowing water or be dry.

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Trimble Point: A marked point mapped with the total station and Trimble GPS with Tornado Antenna. If it is the first time a survey is done at a given location or previously installed benchmarks have been disturbed or removed, then the survey requires at least three Trimble points. Trimble points need to cover as much of the surveyed reach as possible, form as close as possible an equilateral triangle, and collect 1000 Trimble seconds using the Tornado antenna for each point. Benchmark 1 will serve as Trimble Point 1 while Trimble Points 2 and 3 will be temporary points. All Trimble Points must be mapped with the total station during the survey.

Waterfall: A feature that contains water falling at least 1.5m vertically, or very nearly so.

3 METHODS

3.1 Overview

The NEON wadeable streams morphology protocol provides methods to conduct a high resolution survey of the topographical aspects of a stream channel and the adjacent floodprone area. The survey captures the geometry of the stream channel within the NEON aquatic reach. Furthermore, it demarks the locations of biological habitats and stream channel features that are used for determining sample collection locations for other NEON aquatic protocols.

The survey covers the entire NEON aquatic reach, which, at most sites, is approximately 1000m in length. The location, or spatial position of points along the channel bed, water surface, floodplain, and the boundaries of in-channel habitats are recorded as Cartesian (X, Y, Z) coordinates using a the total station. Northing and Easting positions of each point are measured as X and Y coordinates and elevation is recorded as Z coordinates. All coordinates are recorded as the distance from the origin of the survey (e.g. 0, 0, 0 m). The origin of the survey is typically the first mapped benchmark point.

During the preliminary survey at a site, the first total station location is determined by using the survey technique “missing line workflow”, in which the missing line maps two points and establishes the total station location on the landscape based on the mapped points. During the missing line workflow one of the two points must a benchmark point. Benchmarks, using data derived from Trimble Points, will georeference the survey into the latitude and longitude coordinate system. Upon completion of the geomorphology survey, raw data collected with the total station will be post-processed and transformed into a geographic coordinate system. Data products derived from the geomorphology include georeferenced maps, shape and raster files that can be utilized by Arc GIS software, and a wide range of stream characterization metrics.

The geomorphology survey captures the fluvial geomorphic template of the reach by characterizing stream channel and floodplain topography (to a lesser extent), water surface elevation, and the location of channel features and biological habitats. Geomorphology mapping, used in concert with NEON’s Aerial Observation Platform (AOP), precipitation, groundwater, and turbidity data, enables researchers to obtain a complete picture of the stream fluvial geomorphology in time and space.

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NEON’s geomorphology mapping is comprised of four components: cross-sectional profile mapping, longitudinal channel mapping, pebble counts, and LWD tallies.

Cross-sectional profile maps capture floodplain width, bankfull width and height, and stream channel depth. Longitudinal profile mapping captures in-stream habitats, the location and position of in-channel LWD jams, mid-channel islands and bars, pool frequency and quality, changes in streambed elevation, and water level height. Pebble counts and LWD tallies quantify the quality of substrate and the quantity of wood in the channel, two extremely important components of stream structure.

Technicians mapping the stream will use a HILTI POS 180 robotic head total station and prism pole with an attached 360° mirrored prism. Survey points capture major slope breaks in the channel and floodplain, the edge of water along channel banks, mid-channel features, the position of thalweg along the streambed, and the location of habitat features. A unique survey code is associated with each mapped point. All survey data is stored on the POC datalogger, a handheld device that is used to enter and log survey data. Survey codes organize the survey data and allow for the creation of various GIS-derived topographic layers of the surveyed area during post-processing.

The methods described herein provide a unified guide to surveying geomorphic features and biological habitats in wadeable stream channels at aquatic sites within the NEON. This protocol and associated data products are designed to interface with other habitat and geomorphology monitoring programs currently operating in the United States and Canada. Standard Operating Procedures (SOPs), in Section 7 of this document, detail step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians must follow the protocol and associated SOPs, and use NEON’s problem reporting system to document and find resolution to any field issues associated with executing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON Domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document. In the event that local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in a trouble ticket. Quality assurance will be performed on data collected via these procedures according to the NEON Science Performance QA/QC Plan (AD[05]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

The NEON geomorphology protocol shall be conducted once every five years or following an event that results in significant alteration of the stream channel. With regards to the standard five-year rotation, it is strongly recommended that the geomorphology protocol is conducted during the baseflow regime as this period facilitates access to geomorphological features and provides repeatability in scheduling future mapping efforts. If scheduling conflicts negate the ability to schedule a survey during baseflow

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conditions it is recommended that Domains attempt to schedule the protocol during periods where streamflow and water depth are reasonably moderate. This is to say that streamflow is not so high to inhibit technicians to safely access required features, but not so low that geomorphic features discernable during baseflow conditions are absent. Following the initial survey, subsequent survey dates should be scheduled at a time that matches the seasonal and hydrologic conditions similar to that of the initial geomorphology survey.

Channel altering events have many impacts on stream channels and can be the result of debris flows, hyper-concentrated flows, or severe flooding. Stochastic events such as these play a major role in coarse woody debris delivery to fish-bearing streams and provide a mix of sediment to the higher order streams. Channel altering events can reduce (or even temporarily eliminate) riparian vegetation along the stream channel and create changes in the stream bed such as aggradation and scour (Bell and Mikulovsky, 2012). The NEON geomorphology survey is well-suited to assess the magnitude of such events by quantifying changes in channel geometry, particle-size distribution, and habitat. Thus, if conditions are warranted, the protocol should be immediately re-instituted once a channel-altering event has been deemed to have occurred. In these instances, Science will work with Domain staff in order to determine if a potential major channel altering event has occurred at a site. A significant and prolonged shift in the stage-discharge rating curve is typically a strong indication of streambed alteration as well as more casual observations of bank failures and evidence of flooding (i.e. high water marks) following a large storm or tectonic event. Damage to AIS infrastructure and established sampling transects should also be taken into account. If a channel-altering event is suspected to have occurred, domain staff shall write a trouble ticket explaining the situation and, if possible, provide pictures or videos to document any supporting evidence. Science will then work with the Domain staff to determine if an additional geomorphology survey is warranted.

NEON currently has five sets of survey equipment available for use across all Domains. Each set of equipment includes a total station, tripod, datalogger, stadia rod, and a prism rod with necessary attachments. Science staff will work with Domain managers and FOPs staff to coordinate the transfer of survey equipment across domains.

Rapid Habitat Assessment

The Rapid Habitat Assessment SOP is conducted once during site characterization at each wadeable stream site during a period when the stream is safely wadeable. The Rapid Habitat Assessment should be scheduled at a time when the stream level is relatively close to baseflow, but not during an abnormally dry part of the year (e.g., similar conditions or time of year as a biological sampling bout) and when leaves are on the trees if working in a deciduous forest (e.g., between Bio Bout 1 and Bio Bout 2 at the site). The Rapid Habitat Assessment SOP requires 4-8 hours of work for two highly skilled technicians.

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Following characterization, the Rapid Habitat Assessment SOP will be performed once per year around the same time of year, optimally between Bio Bout 1 and Bio Bout 2. Changes noted from the annual Rapid Habitat Assessment will trigger more frequent occurrences of the Stream Geomorphology SOPs.

4.2 Criteria for Determining Onset and Cessation of Sampling

The protocol may be initiated at any time during daylight conditions and may be executed during mildly inclement weather, such as very light rain, however efforts should be made to keep the total station and POC datalogger dry at all times. The protocol shall be temporarily ceased if hazardous conditions (e.g., lightning or flooding conditions) threaten personnel safety. The protocol may be resumed on a different day without compromising data quality. Geomorphology survey dates should also coincide with minimal planned biological or chemical sampling in the stream reach so as not to compromise other data collection efforts. For instance, if personnel have been wading in the stream and disturbing sediments to conduct the geomorphology surveys, water quality samples cannot be collected for at least 12 hours.

4.3 Timing for Laboratory Processing and Analysis

At the end of each survey day raw data must exported from the POC datalogger, saved on a domain network drive, and emailed to the appropriate Science support contact. Following the completion of the survey, all raw data (including Trimble data, if collected) must be saved and sent to Science. All data collected on the Fulcrum is synced daily and is automatically uploaded onto the network.

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4.4 Sampling Timing Contingencies

Table 1 Contingent Decisions.

Delay/Situation	Action	Outcome for Data Products
Nightfall	Measure and record 2-3 control points (COP) upstream of current total station (TS) location. Turn off instrument. Return to site and begin with a new total station setup using the COPs or BMs.	No change to the outcome of data products if COP's are shot correctly and the TS is level.
Heavy rainfall or rising water levels in the channel	If time allows, measure and record 2-3 COP's upstream of current total station location. Turn off instrument, cover with waterproof covering (e.g., heavy weight garbage bag), and move to higher ground. Once waters have receded, set up TS and orient to COP's.	Depending on the amount of rainfall received, wetted edge locations are likely to have changed and possibly thalweg elevations and bankfull widths (in more extreme scenarios). FOPs staff shall inform Science that this has occurred and, depending on the severity and timing of the storm event a decision will be made on whether/when to continue to survey.
Dead batteries in total station	Replace the dead battery with a fully charged one.	The survey should not be impacted by the TS battery running out of charge.
Accidental movement of tripod and total station	Re-level TS and continue survey. If this occurred while shooting in new COP's, re-shoot in COP's once the total station is level using new survey codes. If this occurred while orienting to previously mapped COP's, re-shoot in COP's as targets once total station is level to set new station.	Higher standard deviations may occur during total station setup and/or slight variability in topographic data may be present.
Wind	Keep prism pole at shortest height to avoid movement of the prism in wind. Halt survey if wind gusts are impacting the plumb line of the prism pole. If wind is so severe to instigate treefall, halt survey immediately and move to a safe location.	Variability in topographic data may be present if the prism and the point of the prism pole are not level.

4.5 Criteria for Permanent Reallocation of Sampling within a Site

Surveying is expected to occur within NEON aquatic sites with wadeable streams for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (relocatable sites). However, circumstances may arise requiring that sampling within a site be shifted from one particular location to another. In general, sampling is considered to be compromised when sampling at a location becomes so limited that data quality is significantly reduced. If sampling at a given site becomes compromised, a trouble ticket should be submitted.

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There are two main pathways by which sampling can be compromised. Sampling locations can become inappropriately suited to answer meaningful biological questions (e.g., a terrestrial sampling plot becomes permanently flooded or a stream moves after a flood and the location is no longer within the stream channel). Alternatively, sampling locations may be located in areas that are logistically impossible to sample on a schedule that that is biologically meaningful.

5 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

Personnel should wear clothing appropriate for weather conditions at the site. Both team members are required to wear hip waders and wading boots with no-slip soles. Technicians should consider wearing NEON approved personal flotation devices in high velocity streams or streams with pools and runs deeper than one meter. Activities in streams should only be performed when flow conditions are safe. Do not attempt to wade a stream where velocity x depth is $\geq 10 \text{ ft}^2/\text{s}$ ($0.93 \text{ m}^2/\text{s}$).

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6 PERSONNEL AND EQUIPMENT

6.1 Equipment

Table 2 Equipment list – [Total Station Survey]. R = Required Item; S = Suggested Item

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items								
MX109898	Hilti, Inc.	3522674	R	HILTI POS 180 Robotic Total Station and POC data collector	Measure and collect survey data	All	1	Y
MX107405	Tiger Supplies, Inc.	724200	R	Sokkia knob lock prism pole	Graduated pole that is attached to prism assembly and used for marking points and recording height of prism during surveys	All	1	N
MX107406	Tiger Supplies, Inc.	726132	R	HILTI POA 360° mirrored prism	Mirrored target for total station measurement shots	All	1	N
MX107407	Tiger Supplies, Inc.	724251	R	Sokkia heavy duty fiberglass tripod	Supports and orients total station	All	1	N

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
MX102549	Compass Tools Inc.	88180-04	R	Trimble® GEO XH 6000 GPS receiver or equivalent model.	Locate and mark benchmarks and Trimble Points	All	1	N
Part of MX109898	Hilti, Inc.	3522674	R	POA 84 Battery for the POS 180	Power for POS	All	2	N
Part of MX109898	Hilti, Inc.	3522674	R	POA 86 battery charger for the POC 180	Charge batteries for POC	All	2	N
Part of MX109898	Hilti, Inc.	3522674	R	Hilti application software USB key	Access HILTI updates	All	1	N
Part of MX109898	Hilti, Inc.	3522674	R	POC Controller with Stylus	Operate total station from prism pole	All	1	N

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Part of MX109898	Hilti, Inc.	3522674	R	POA battery for the POC 100	Power for POC	All	2	N
Part of MX109898	Hilti, Inc.	3522674	R	POA 81 AC adapter for POC 100	Charge battery for POC	All	1	N
Part of MX109898	Hilti, Inc.	3522674	R	POA 100 Accessories case (tools)	Change battery on POC	All	1	N
Part of MX109898	Hilti, Inc.	3522674	R	POA 76 Frame clamp	Attach POC to prism pole	All	1	N
MX107144	B&H Photo Corp	PADMCTS30BL	S	Waterproof camera	Photo document the reach and associated features	All	1	N

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
	ChrisNik	254MAGSPIKE	R	Magnetic nails	Used to mark locations of control points	All	25	N
MX104363	Ben Meadows Co., Inc.	223212OR	R	Pin flags	Used to mark locations of survey boundaries, bankfull delineation, etc.	All	25	N
MX100320	Ben Meadows Co., Inc. Forestry Suppliers, Inc.	213379 37184	R	Compass	Verify orientation of the survey	All	1	N
MX104369	Ben Meadows Co., Inc. Forestry Suppliers, Inc.	213379 37184	R	50m measuring tape	Measuring and laying out of transects	All	1	N
MX100324			R	Radios (preferably waterproof)	For communication between team members	All	1 per person	N
			R	Rain Cover (e.g., heavy duty plastic bag)	Protect total station from rain	Rain	1	N
	Amazon Capital Services Inc.	B00KVJKW5S	R	Foldable stadia rod	Measuring depth	All	1	N

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
MX100322	Forestry Suppliers, Inc.	91567	R	Laser rangefinder, laser level, or clinometer	Delineating floodprone areas	All	1	Y
MX110827	Ben Meadows Co., Inc.	138605	R	Gravelometer	Measuring particle sizes	All	1	N
MX106043 MX106199 MX104361	Amazon Capital Services Inc. McMaster-Carr Supply Co. Ben Meadows Co., Inc.	B001JYXXH8 50065A21 100952	R	Stakes, Clamps, & Chaining Pins	Secure meter tape during transect surveys	All	2 sets	N
MX111388	CDW-G	4452963	R	Tablet with AOS Pebble Count app	Recording data	Dry	1	Y
MX103220	Ben Meadows Co., Inc.	162090	R	Hammer or mini-sledge	Monument installation	All	1	N
			S	Map of site (Google Earth, AIS As-Built)	Monument installation, periodic QAQC	All	1	N

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
			R	Clamp with small square piece of wood	To assist in staff gauge survey shot	All	1	N
Consumable items								
MX102002	Grainger, W.W.	1JU51	R	Permanant marker	Recording data	All	3	N
MX103940	Grainger, W.W. Forestry Suppliers, Inc.	9WKP4 57880	R	Flagging tape, orange	Mark features and survey boundaries	All	1 roll per person	N

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Table 3 Equipment – Rapid Habitat Assessment.

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items								
MX102941 MX102942	Forestry Suppliers, Inc. Grainger	53190 1GEJ1	S	Clipboard	Recording data	All	1	N
MX100491 MX100494 MX107505	Ben Meadows Co., Inc. Grainger, W.W. Forestry Suppliers, Inc. Cabela's		R	Waders (hip or chest) or knee boots	Wading	All	1 pair/ person	N
MX102549	Compass Tools Inc.	88180-04	R	Trimble© GEO XH 6000 GPS receiver or equivalent model with Rapid Habitat Data Dictionary loaded	Record data	Habitat survey	1	Y

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
MX100722	Ben Meadows Co., Inc. Forestry Suppliers, Inc.	122731 39943	R	30 Meter tape	Measuring features	Habitat survey	2	N
MX105823	Forestry Suppliers, Inc.	71112	R	Meter stick or foldable meter stick	Measuring depth or pebble size	All	1	N
MX100322	Forestry Suppliers, Inc.	91567	S	Laser rangefinder	Measuring streams width	Habitat survey	1	N
MX110827			R	Gravelometer	Measuring pebble size	Pebble count	1	N
Consumable items								
MX103942	Ben Meadows Co., Inc. Forestry Suppliers, Inc.	010510-1 49247	R	Field data sheets (all-weather copier paper, write in pencil)	Recording data	All	1 set	N

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6.2 Training Requirements

All technicians must complete protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[04]). Field personnel shall be trained on how to: operate, troubleshoot, and retrieve data from robotic TS; proper use of a prism pole with prism; recognizing and how to properly survey in-channel and flood plain topographic points; fundamentals of basic surveying; QA/QC procedures for the survey; and safe working practices for stream field work.

All technicians must receive training in accordance with NEON EHSS Policy, Program and Management Plan (NEON. DOC.004300 AD[01]) and Field Operations Safety and Security Plan (NEON.DOC.004316 AD[02]). Technicians working in or near wadeable waterways shall be trained in Cold Water Safety Awareness and shall be competent in the use of waders.

6.3 Specialized Skills

Technicians must have the ability to conduct a total station survey in an accurate and efficient manner. Furthermore technicians must be able to identify geomorphological features and habitat boundaries in an accurate and timely manner.

6.4 Estimated Time

Total time spent to complete the geomorphology protocol will vary across sites depending on weather, travel time, and specific site conditions. Completing the survey should take four technicians anywhere between five and eight days. This estimate takes into account travel time and assumes technicians work standard eight hour shifts.

To complete the protocol in this timeframe crews should attempt to map approximately 200 meters of the aquatic reach per day. It is expected that the total reach length surveyed will be somewhat less than 200m on the first day as the initial orientation of the total station (which may include benchmark installation, the missing line workflow and Trimble point installation) can be time consuming. Foul weather and site-specific conditions such as thick brush, steep banks, and meandering channels will also inhibit the survey speed.

If after the third day of mapping, technicians are unable to meet the 200m rate of mapping, Domain staff must write a trouble ticket detailing survey rate and describe the issues contributing to the slowe-than-expected pace. At that time Science will work with the Domain staff to identify problems and present potential solutions. If it is determined that the sites conditions are such that the reach cannot be completely surveyed within the allotted time, Science will direct domain staff to adjust survey requirements in such a way that technicians are able to reach the top reach boundary within the allotted time.

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7 STANDARD OPERATING PROCEDURES

SOP A Equipment and Supply Overview

Check Equipment and Supplies Prior to the Start of the Survey

1. Check all surveying equipment to ensure it is ready for field use.
 - a. Inspect prism mirror for cracks or scratches.
 - b. Check and tighten all bolts on prism and prism pole.
 - c. Check prism pole knob lock to ensure it works properly and when locked holds the measurement rod securely in place.
 - d. Remove the total station (TS) from its case and check for signs of damage.
 - e. Ensure that primary and backup batteries for the TS and GPS are fully charged.
2. Prepare a field kit with all equipment listed in Table .
3. Be sure to bring adequate water and food as the morphology surveys will require a full day in the field. Polarized sunglasses will allow technicians to see below the water surface. Wearing them will reduce the risk of a fall and potentially submerging equipment such as the POC.

Hilti POS-180 Total Station Components

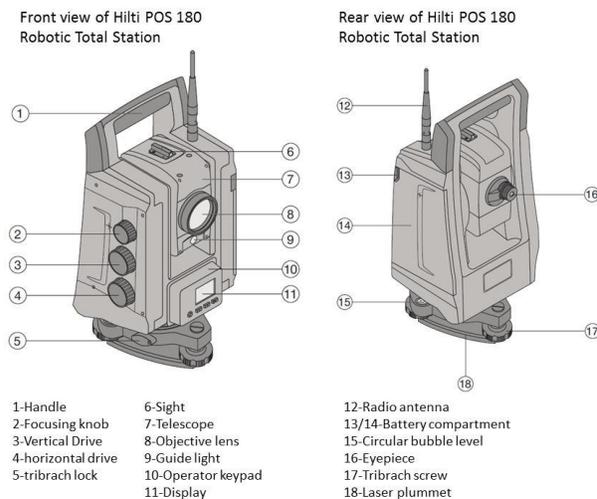


Figure 1. HILTI POS 180 Robotic Total Station. Photo from www.us.hilti.com.

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Hilti POS-180 Total Station Operator Keypad

The operator keypad is located on the front of the TS. The keypad is used to turn the TS on/off, laser plummet on/off, and confirming the selection on the display. The keypad and display screen are also used for the fine tune leveling of the TS prior to beginning a survey (Figure 2).

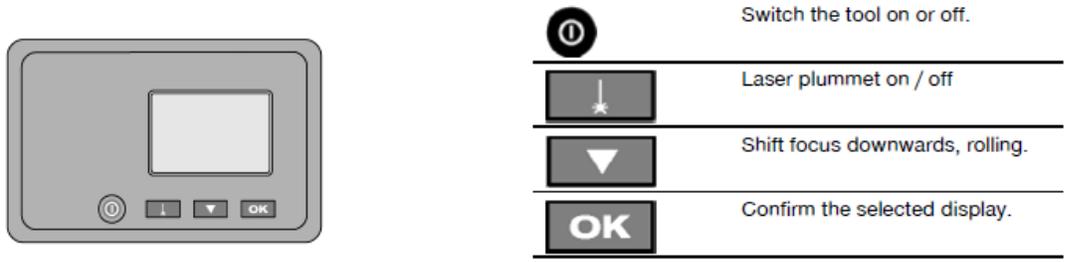


Figure 2. HILTI POS 180 keypad. Photo from www.us.hilti.com.

POC-100 Components

The POC is the data collection unit (Figure) that can be either attached and operated from the prism pole or operated as a hand-held device when removed from the prism pole.

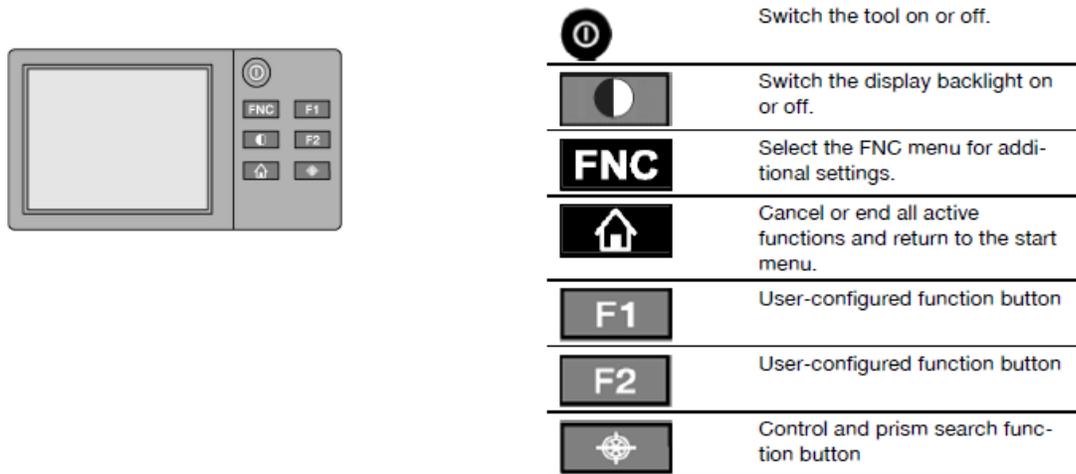


Figure 3. HILTI POC-100 unit keypad. Photo from www.us.hilti.com.

Transferring Relevant Data Files to the GPS Receiver

If Technicians desire data to help navigate in the field, such as coordinates for benchmark locations, they can be imported into the Trimble GPS unit so that they can be navigated to easily. Benchmarks may become covered with debris, rendering them

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difficult to locate in the field without navigation capabilities provided by a GPS unit, i.e. Trimble.

1. Connect the Trimble GPS to the computer with the supplied USB cable and power on the unit. Tap on the Windows icon at the bottom left side of the GPS screen.
2. Find the TerraSync icon and tap twice with the stylus.
3. Use the Windows Mobile Device Center (Window 10) to connect the device to Windows. If this is the first time connecting the GPS to the computer, the Windows Mobile Device Center may install automatically. If it does not, download it online from the windows software website.
4. Set the coordinate system in the Trimble TerraSync software to the corresponding coordinate system used for the site.
 - a. In the TerraSync software on the GPS, from the MDD tap **Setup** then click the **Coordinate System** box.
 - b. Match to the coordinate system of downloaded data, select: **System** = UTM, **Zone** = [appropriate zone and datum], then click **OK**. From the MDD, return to the **Map** screen.
5. Once the GPS unit is connected to the computer, within Pathfinder Office, use the  **Data Transfer** utility to transfer all desired files to the GPS receiver. You should at least import the data files with benchmark locations, though data depicting other landmarks such as sensor, or well locations may help find a benchmark in the field. Importing a background image or pertinent data dictionary may also help.

Leveling the Total Station

1. Fully unfold the tripod so the legs are spaced at even intervals.
 - a. If setting up the TS on penetrable surfaces, make sure that the tripod legs are secure by stepping on the foot pedals until they are pushed into the ground surface, stable, and secure.
 - b. If setting up the TS on impervious surfaces such as a flat boulder or a road, make sure the tripod is stable and secure. Wind or slippery surfaces can compromise the TS levability. The unit is top heavy so take care that it does not fall over on a smooth or uneven surfaces.

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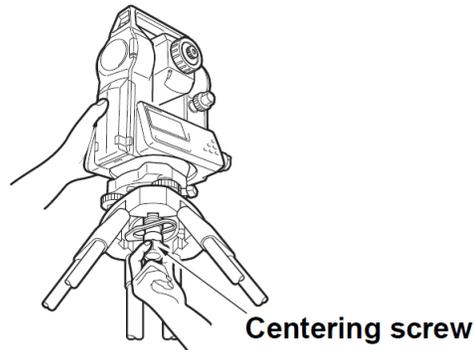


Figure 4. Attaching the Total Station head to the top of the tripod.

2. Place the TS head onto the tripod head and tighten the centering screw on the bottom of the unit. Ensure that it is properly secured to the tripod (Figure 4).
 - a. Always keep one hand on the top of the TS head while it is being secured.
3. Level the TS by adjusting the tripod legs until the level bubble on the bottom of the TS head is fixed completely in the center area (Figure 5).
4. Ensure that a battery is in the TS and turn the unit on.
5. View the TS keypad and screen to view the fine-tuning level of the TS (Figure 6).
6. Fine-tune the level of the TS using two of the three tribrach screw knobs until the display screen indicates the TS is level (Figure 6b).
7. Press [OK]. The TS is now level and ready for use.

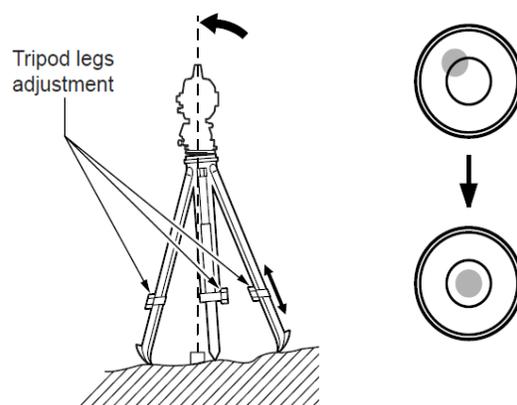


Figure 5. Leveling the tripod using the bubble level.

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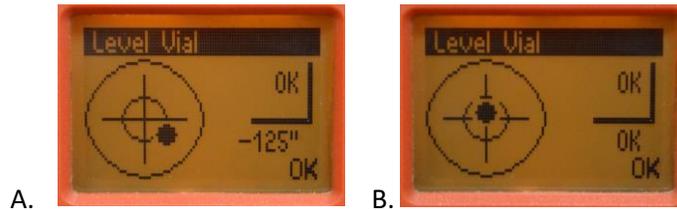


Figure 6. Total station fine-tuning leveling screen. A.) The total Station is not level. B.) The total station is level.

SOP B Total Station and POC Setup and Workflow

Important Notes Regarding Initializing the Geomorphology Survey

- If permanent benchmarks are not installed at the site prior to the survey they will need to be installed by FOPS. Trimble Points will also need to be installed and geo-referenced at this time. Complete Steps 1 and 2 to setup the total station and POC then proceed to Step 4 to permanently install benchmarks.
- If benchmarks are present at the site prior to the survey then FOPS staff will need to acquire each of the three benchmark coordinates from Science prior to beginning the survey. Installing and geo-referencing Trimble Points is not necessary under this scenario. Conducting the Missing Line workflow will also not be necessary. Complete Steps 1-3 to setup the total station and POC then proceed to Step 10 to begin the survey.

1. Setup and level the total station (TS) in an initial location (TS1).

- a. Level TS in a location where there is a clear line of site to all three benchmarks (See SOP A for leveling instructions). If benchmarks are not yet installed, level the TS in a location where you will be able to see them once they are installed.
- b. If possible, level the TS in a location where the bottom of the reach can also be mapped. Ideally you will be able to survey a portion of the monitoring reach from this location.

2. Setup the POC datalogger.

- a. Check POC settings.
 - i. Ensure units are set to metric.
 - On the Home Screen select “Config” tab.
 - Select “Settings”.
 - Check that Dist Units = Meters.
 - ii. Ensure Time and Date settings are correct.
 - On the Home Screen select “Config” tab.

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- Select “Time/Date”.
 - Update Time/Date settings as necessary.
- b. Start New Job.
- i. On the Home Screen select “Jobs” tab.
 - ii. Select “New” tab.
 - iii. Select ABC button by “Job” to name new Job file.
 - iv. Name the job file appropriately (i.e. SITE.YYYYMMDD.g) and select “OK”.
 - Set the date to be the first day of the survey.
 - v. Select “OK” to save job.
- c. Setup prism and ensure that it is linked to the POC/TS.
- i. Stand at least 5m from the TS holding the prism pole upright with the prism in direct line of sight of the station.
 - ii. Adjust your position until both colors (red/green) of the guide light are visible.
 - iii. Hold prism pole in place and press the prism search button  on the outside of the POC.
 - iv. Set “G’light” and “Prism” to “Auto”.
 - v. Select “Prism” tab.
 - vi. Select appropriate prism type. For geomorphology surveys this will be 360° Stand Prism.
 - vii. Select “OK”.
 - viii. You will hear a “ding” noise when the robotic head of the TS and the prism are linked up.
 - ix. Return to Home Screen.
- d. If benchmarks are installed, proceed to Step 3. If benchmarks are not installed, proceed to Step 4.

3. If three benchmarks (BM’s) were installed at the site prior to this survey, upload the benchmark coordinates into the POC datalogger.

- a. Prepare the .CSV file sent to FOPS from Science.
 - i. Create a folder on a USB flash drive called “Hilti Jobs”.
 - ii. Save the .CSV file in this location.
 - iii. In Excel, open the .CSV file.
 - iv. Ensure that the column names include ‘Name’, ‘E’, ‘N’, ‘H’, ‘Attr1’, ‘Attr2’, ‘Attr3’, ‘Attr4’, ‘Attr5’, ‘HA’, ‘VA’, ‘HD’, ‘hr’, ‘ppm’.
 - v. Note the names of the benchmarks in the “Name” column. They should be “BM1”, “BM2”, and “BM3”.
 - vi. If everything looks OK, close file and proceed to next step.
 - If all of the necessary data does not appear in the Excel file, submit a trouble ticket and contact Science.

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- b. Import the job file onto the POC.
 - i. Turn on POC datalogger.
 - ii. Insert USB drive into POC.
 - iii. On POC Home Screen, select “File”.
 - iv. Select “Import”.
 - v. Select “To Job” to designate the name of the job defined in Step 2 b iv.
 - vi. Ensure file units are set to Meters.
 - vii. Ensure Data Format is *.csv.
 - viii. Select the box next to “From File”.
 - Choose the .CSV file that you loaded onto the USB device.
 - If you get an error here make sure that the .CSV file is saved under the “Hilti Jobs” folder on the USB flash drive.
 - ix. Click “OK”.
 - x. On the ‘Import Design Points’ screen, click “OK”.
 - xi. The “Importing Points” screen will appear followed by “X points were imported”.
 - xii. Click “OK”.
 - xiii. On the ‘Select Task’ screen, click “OK”. The points should now be loaded into your job file.
- c. Shoot in each of the three benchmarks (BM’s).
 - i. Use bi-pod to level prism rod on the center of “O” in “NEON” engraved on benchmark #1 (BM1).
 - ii. Sight TS on the prism and ensure that prism and POC are linked up.
 - iii. Select “Meas Rec”.
 - iv. Select “New Station” tab.
 - v. Don’t change any data listed in the “Select Station Type” screen, leave these values as defaults and select “OK”.
 - vi. Click on the rectangle next to ‘Stat Pt ID’ and enter “TS1”, the code to be used for the first total station location.
 - Subsequent station codes should be “TS2”, “TS3”, etc.
 - vii. Set “HI” to equal 0.
 - viii. Select the “Targets” tab.
 - ix. Select the button to the right of “Pt ID” and choose “BM1” (the benchmark point at which the prism is located) and select “OK”.
 - x. Select the numbers to the right of “HR” to enter the height of the prism rod (two decimal places, i.e. 1.60).
 - xi. Select the “Meas” tab to shoot in BM1.
 - xii. Use bi-pod to level prism rod on the center of “O” in “NEON” engraved on benchmark #2 (BM2).

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- xiii. Select the button to the right of “Pt ID” and choose “BM2” (the benchmark point at which the prism is located) and select “OK”.
 - xiv. Enter “HR”, the height of the prism rod.
 - xv. Select the “Meas” tab to shoot in BM2.
 - xvi. Use bi-pod to level prism rod on the center of “O” in “NEON” engraved on benchmark #3 (BM3).
 - xvii. Select the button to the right of “Pt ID” and choose “BM3” (the benchmark point at which the prism is located) and select “OK”.
 - xviii. Enter “HR”, the height of the prism rod.
 - xix. Select the “Meas” tab to shoot in BM3.
 - xx. After each of the three benchmark points have been measured, select “OK”.
 - xxi. On the ‘Set Station’ screen, select “Calc”.
 - xxii. The error screen will then show standard deviation calculated between the known BM coordinates and those you just measured from TS1.
- d. The following standard deviation values will be listed:
- i. STDev(Pos): standard deviation of the location of head unit of the total station.
 - ii. STDev(HA): standard deviation of the horizontal angle.
 - iii. STDev(H): standard deviation of the height.
- e. Check that $STDev(Pos) \leq 0.002m$. If value is within error threshold, record all standard deviation values in the field datasheet and proceed to Step 10 to begin mapping cross-sections and geomorphology features.
- i. If SD’s are outside this threshold, repeat Steps 3d-3e up to five times.
 - Check the level on the TS and the prism rod prior to each benchmark shot.
 - Check the benchmarks to see if they are still stable in the ground. If they have moved since the last survey this would explain the high standard deviation.
 - ii. If, after five attempts, SD’s are not within the threshold:
 - 1. Stop work.
 - 2. Submit a trouble ticket and contact Science immediately (preferably from the field if possible).
 - Either the benchmarks have moved significantly, the incorrect coordinates were loaded onto the POC, or other problems have occurred with regards to the total station setup procedures.

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4. If benchmarks (BM's) are not installed at site, install 3 permanent benchmarks in a roughly equilateral triangle (make space between as large as possible).

- a. See the NEON.DOC.001025, SOP H (TOS Plot Establishment Protocol) for complete guidelines on how to install permanent benchmarks.
- b. The three benchmarks are to be named BM1, BM2, BM3, respectively.
- c. The geomorphology survey is to begin at the downstream extent of the monitoring reach and work upstream. As such, install the BM's near the downstream extent to prevent multiple total station moves prior to mapping.
- d. If possible, place large rocks or cobble around each BM and flag and label the location so that they can be easily found for future surveys.
- e. Take pictures of BM locations and record notes that describe where they are placed in relation to nearby landmarks. These pictures and notes should be saved at the local Domain office for future reference.

5. Begin Missing Line workflow if benchmarks were not previously installed.

- a. Note: If BM's were installed prior to this survey (and are all still in place), completing the Missing Line workflow is not necessary.
- b. This workflow requires two points in addition to TS1.
 - i. Benchmark #1 (BM1) will serve as the first point.
 - ii. Install one temporary point using a mag nail (spike driven securely into the ground so it will not move) to serve as the second point (label this point "PT2").
 - Try to place PT2 roughly the same distance as is between TS1 and BM1.
 - Attach flagging to this temporary point and label it with Sharpie so it can be easily found and identified.
 - iii. Attempt to form an equilateral triangle between BM1, PT2, and TS1.
- c. On the POC Home Screen:
 - i. Select "Applications".
 - ii. Select "Missing Line".
 - iii. Verify that the job listed is current job and select "OK".
 - iv. The "Measure 1st Pt" screen will appear.
- d. Use the bi-pod to level the prism rod on the center of "O" in "NEON" engraved on BM1.
- e. Sight TS on the prism and ensure that prism and POC are linked up.
- f. Select the numbers to the right of "HR" to enter the height of the prism rod.
- g. Check total station to ensure it is level.
- h. Select "Meas" to shoot in BM1.
- i. Select "Next". The "Measure 2nd Pt." screen will appear.

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- j. Use the bi-pod to level prism rod on the center of PT2.
- k. Sight TS on the prism and ensure that prism and POC are linked up.
- l. Select the numbers to the right of “HR” to enter the height of the prism rod.
- m. Select “Meas” to shoot in PT2.
- n. Select the “Results” tab
- o. Record HD (horizontal distance) and dH (vertical distance) values calculated by POC in a field datasheet.
 - i. Note that dH may be a positive or negative number depending on the gradient between the points and TS1.
 - ii. Record all significant figures for these values.
- p. Select “Save” to save results.
- q. Leave the prism rod level on PT2 and proceed to Step 6.

6. Begin Measure and Record Workflow.

- a. On the POC, hit the “Home” button to return to the home screen.
- b. Select “Meas Rec”.
- c. Select “New Sta” tab.
- d. Don’t change any data listed in the “Select Station Type” screen, leave these values as defaults and select “OK”.
- e. Under “Set Station” screen, select the ABC button to the right of “Stat Pt ID”
 - i. Enter Stat Pt ID as “TS1” (the name of the first total station location).
- f. Set HI = 0.000m.
- g. Select “Targets” tab.
- h. The “Meas Target Pt. 1” screen will appear.
- i. Ensure that the prism rod is still level on PT2.
- j. Select the button to the right of “Pt ID”.
- k. Select the “Man” tab.
- l. Select the ABC button to the right of Pt ID to name this point “PT2” (the name of the point the prism rod is currently on).
- m. Select the 123 button to the right of “E” (Easting).
 - i. Set Easting to equal to 0m.
- n. Select the 123 button to the right of “N” (Northing).
 - i. Set Northing to equal the HD value recorded in your notebook during Step 5n.
- o. Select the 123 button to the right of “H”.
 - i. Set Height to equal 1000 + the dH value recorded in your notebook during Step 5n

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- Note: Keep in mind that the dH can be a negative number which means you would be adding a negative number, or subtracting from 1000).
 - Example 1: dH = -0.007; H = 999.993
 - Example 2: dH = 0.008; H = 1000.008
- p. Select “OK” to save PT2.
- q. Enter HR, the height of the prism rod.
- r. Select the “Meas” tab to shoot in PT2.
- s. The “Meas Target Pt. 2” screen will appear.
- t. Use the bi-pod to level the prism rod on the center of “O” in “NEON” engraved on BM1.
- u. Select the button to the right of “Pt ID”.
- v. Select the “Man” tab.
- w. Select the ABC button to the right of Pt ID to name this point “BM1” (the name of the point the prism rod is currently on).
- x. Select the 123 button to the right of “E”.
 - i. Set Easting to equal to 0m.
- y. Select the 123 button to the right of “N”.
 - i. Set Northing to equal 0m.
- z. Select the 123 button to the right of “H”.
 - i. Set Height to equal 1000m.
- aa. Select “OK”.
- bb. Enter HR, the height of the prism rod.
- cc. Select “Meas” to shoot in BM1.
- dd. Check dHD (change in horizontal distance) and dH (change in height) values are both $\leq \text{abs}(0.005\text{m})$. If values are within acceptable error threshold, record them in the field datasheet and proceed to the next step.
 - i. If dHD and/or dH are $> \text{abs}(0.005\text{m})$, re-start Measure and Record workflow at Step 6.
 - ii. If, after another attempt, dHD and/or dH values remain $> \text{abs}(0.005\text{m})$, make note that this occurred, record dHD/dH values in the field notebook, and proceed to next step.
- ee. Select “OK” to save BM1.
- ff. Select “CALC”.
- gg. Check that StDev (H) is $< 0.005\text{m}$ (standard deviation for height). If value is within error threshold, record it in the field datasheet and proceed to Step 6gg.
 - i. If SD is $> 0.005\text{m}$, repeat Step 6 up to three times.
 - ii. If, after three attempts, StDev(H) remains $> 0.005\text{m}$, start Missing Line workflow over at Step 5 using BM1 and a new temporary point (PT3). Record in field notebook that this occurred.
- hh. ****Select “Set” to set station**.**

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- ii. Select “OK”. The “Measure Points” screen will appear.
 - i. ****VERY IMPORTANT****: If station is not set correctly, the survey will contain critical errors from this point forward and there are no real warnings to alert you that this is happening. Therefore it’s extremely important to make sure the station is set before you continue with the survey.
 - jj. **Verify you are at the correct station (TS1).**
 - i. Hit the “Home” button on the outside of the POC.
 - ii. Select the “Measure and Record” workflow.
 - iii. A screen appears that displays your station and backsight point. Verify both of these values are correct (note: the backsight value should be one of the points used in the missing line workflow, i.e. BM1).
 - If OK, leave the prism rod setup on BM1 and proceed to Step 7.
 - If station is not set correctly you must go back to Step 6b and repeat the set station process.

7. Install temporary Trimble points (TPs) using mag nails.

Note: installing Trimble Points is only necessary under the following scenarios:

1. If benchmarks were not installed at the site prior to the survey.
2. If benchmarks had previously been installed but two or more are missing or have been damaged or moved since that time.

If benchmarks have already been installed at the site prior to the survey and at least two are present and stable, temporary Trimble Points do not need to be re-installed and georeferenced and you can proceed to Step 10 once Steps 1-3 are complete. If Trimble Points need to be installed, proceed with the following steps:

- a. A total of three TP’s must be installed and georeferenced within the reach.
- b. BM1 will serve as TP1 (Trimble Point #1) in addition to being a benchmark.
- c. The three TP’s points must:
 - i. Enclose the entire reach.
 - ii. Form an equilateral triangle (or as close to one as possible given the morphology of the aquatic reach – some may be more of a rectangle).
 - iii. Be located in areas that contain minimal canopy cover.
- d. Level the Trimble monopole (with bipod legs) directly on the center of “O” in “NEON” engraved on BM1 (TP1).

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- e. Connect antennas and affix GPS unit to monopole. Ensure the setup is both level and stable.
 - f. Acquire a GPS location.
 - g. Search for “TP1” in the Trimble Data Dictionary and label point accordingly.
 - i. If “TP1” cannot be found in the data dictionary using the “Point Generic” feature is OK.
 - h. Begin GPS data collection.
 - i. Allow GPS to log positions for at least 300-1,000 logs.
 - i. 1,000 logs may not be possible in environments so a minimum of 300 will suffice. Collect up to 1,000 logs if possible at the greatest accuracy that can be reasonably achieved given the surroundings.
 - j. Once complete, select “Done” to store data.
 - k. TP2 should be located somewhere in the middle of the aquatic reach. If possible place this point on the opposite bank of TP1.
 - i. Drive a temporary mag nail flush into the ground, attach flagging, and label with a Sharpie so it can be easily found and identified.
 - ii. It may be possible to install and geo-reference TP2 from TS1 but it is likely that this will need to be done later in the survey from a TS location near the middle of the reach.
 - l. TP3 should be located near the upstream extent of the aquatic reach.
 - i. Drive a temporary mag nail flush into the ground, attach flagging, and label with a Sharpie so it can be easily found and identified.
 - ii. Install and geo-reference TP3 from the final TS location of the survey which will be located at the upstream aquatic reach boundary.
 - m. Leave TP2 and TP3 in place until the entire survey is completed and data are successfully transmitted to Science. TP1 will always remain in place as it is also BM1.
- 8. Survey the remaining two benchmarks (BM2 and BM3).**
- a. Use the bi-pod to level the prism rod on the center of “O” in “NEON” engraved on BM2.
 - b. Select the ABC button to the right of Pt ID to name this point “BM2” (the name of the point the prism rod is currently on).
 - c. Enter HR, the height of the prism rod.
 - d. Select the “M&R” tab to shoot in BM2.
 - e. Repeat Steps 8a-8d to shoot in BM3.
- 9. Survey all Trimble Points that are in view from total station location.**
- a. If installed Trimble Points are in view of TS1, shoot them into the survey at this time.

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- i. If the Trimble Points are not in view then at some point during the survey follow Step 10 to move TS in order to gain a new line of site to survey them in. In nearly all cases, TP2 and TP3 will need to be mapped later in the survey.
- b. TP1 (BM1) should be in view from TS1.
 - i. Note: although this point was already surveyed in as BM1 survey it in as “TP1” as well so that the Trimble Point ID will also be included in the geomorphology map point list.
- c. Use the bi-pod to level the prism rod on the center of “O” in “NEON” engraved on TP1 (BM1).
- d. Select the ABC button to the right of Pt ID to name this point “TP1” (the name of the point the prism rod is currently on).
- e. Enter HR, the height of the prism rod.
- f. Select the “M&R” tab to shoot in TP1.
- g. Repeat Steps 9c-9f to shoot in the remaining Trimble Points during the geomorphology survey. Again, TP3 should be surveyed from the final TS setup at the downstream extent of the reach.

10. From TS1, begin geomorphology survey (if possible).

- a. If possible, survey as much of the reach as you can from TS1 using the “Measure and Record” function on the POC.
- b. Record the first thalweg point ID shot from this TS location in the Fulcrum app.
- c. Once you have surveyed everything you can from TS1, enter the last thalweg point ID shot from this TS location in the Fulcrum app and prepare to move the TS following methods described in Step 11.
- d. If you cannot survey any of the monitoring reach from TS1, prepare to move the TS following methods described in Step 11.

11. Prepare to move the TS to another location.

- a. It is critical that the TS is not moved from TS1 until Steps 11b – 11d are complete.
- b. First, find an optimal location for the next total station location (TS2). Ensure that an adequate portion of the reach can be surveyed from this location.
- c. Install 2-3 temporary Control Points (COP’s) in a roughly equilateral triangle such that there are no overlapping sight lines. Use mag nails driven flush into the ground to mark location of each COP.
 - i. If lines of sight are difficult to establish, 2 COP’s will suffice. Installing 3 COP’s is ideal and should be utilized when possible.
 - ii. If forming an equilateral triangle is difficult, placing the COP’s in horizontal lines (relative to both TS location) will suffice. COP’s

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- cannot be arranged vertically relative to lines of sight from each TS location.
- iii. Ensure that lines of sight exists from each of the 2-3 COP's to both TS1 (current TS location) and TS2 (next TS location).
 - iv. Ensure that adequate spacing exists between each COP.
 - Ideally each COP would be spaced >5m apart but this is not always possible in some locations.
 - Maintain a minimum of 2m spacing between COPS's in locations where lines of site are difficult to establish.
 - v. Each COP should be consecutively labeled beginning with COP1 as the first COP established during the survey.
- d. Ensure the TS has remained level. If it has come out of level adjust accordingly prior to shooting in COP's.
 - e. From TS1, shoot in each of the COP's.
 - i. Use the bi-pod to level the prism rod on the center of COP1.
 - ii. Name point "COP1".
 - iii. Enter HR, the height of the prism rod.
 - iv. Select "M&R" tab to shoot in COP1.
 - v. Repeat above steps for COP2 and (if present) COP3.
 - vi. Make sure the TS is not disturbed between the COP shots and that it remains perfectly level. If the TS comes out of level between COP shots, re-level the TS and re-shoot each of the three COP's (note – you will like need to re-label these COP's with new point names. Make sure this is well-documented in the field notes and flagging).
 - f. After all Control Points have been shot in, move TS from TS1 and level instrument at TS2 location.
 - g. Using the POC identify the Control Points as new targets:
 - i. Navigate to the Home Screen.
 - ii. Select "Meas Rec" button.
 - iii. Select "NewSta" tab.
 - iv. Don't change any data listed in the "Select Station Type" screen, leave these values as defaults and select "OK".
 - v. Under "Set Station" screen, select the ABC button to the right of "Stat Pt ID" to enter Stat Pt ID as "TS2" (for the second total station location).
 - vi. Set HI = 0.000m.
 - vii. Select "Targets" tab.
 - viii. Under "Meas Target Pt 1" screen select the button next to Pt ID.
 - ix. Scroll down to select "COP1".
 - x. Select "OK".
 - xi. Use the bi- pod to level the prism rod on COP1.

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- xii. Enter HR.
- xiii. Check that total station is level.
 - If it has come out of level, re-level TS prior to shooting in COP1.
- xiv. Select “Meas Rec” to shoot in COP1.
- xv. Repeat above steps to shoot in COP2 and (if necessary) COP3.
 - Make sure the TS is not disturbed between the COP shots and that it remains perfectly level. If the TS comes out of level between COP shots, re-level the TS and start over from Step 11g.
- h. Once all three control points have been shot in Select “OK”.
- i. Select “CALC”. The error screen will then show standard deviation calculated between the COP shots taken from TS1 and TS2.
- j. The following standard deviation values will be listed:
 - i. STDev(Pos): standard deviation of the location of head unit of the total station.
 - Only given if 3 COP’s were used.
 - ii. STDev(HA): standard deviation of the horizontal angle.
 - Only given if 3 COP’s were used.
 - iii. STDev(H): standard deviation of the height.
 - Will be given whether 2 or 3 COP’s were used.
- k. If 3 COP’s were used:
 - i. Check that $STDev(Pos) \leq 0.005m$. If value is within error threshold, **record all standard deviation values in Fulcrum app and proceed to next Step 11m.**
 - ii. If $STDev(Pos) > 0.005m$, repeat Steps 11g-11j one more time.
 - Ensure that TS and prism rod on each COP are level.
 - iii. If after the second attempt the $STDev(Pos) > 0.005m$, record the SD value in the Fulcrum app after the second attempt and continue to next step.
- l. If 2 COP’s were used:
 - i. Check that $STDev(H) \leq 0.005m$. If value is within error threshold, **record the standard deviation value in the Fulcrum app and proceed to next Step 11m.**
 - ii. If $STDev(H) > 0.005m$, repeat Steps 11g-11j one more time.
 - Re-check that TS and prism rod at each COP are level.
 - iii. If after the second attempt the $STDev(H) > 0.005m$, record the SD value in the Fulcrum app after the second attempt and continue to next step.
- m. Select “Set” to set station (**this is a critical step**).
- n. Select “OK”. The “Measure Points” screen will appear.

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- i. ****VERY IMPORTANT****: If station is not set correctly, the survey will contain critical errors from this point forward and there are no real warnings to alert you that this is happening. Therefore it's extremely important to make sure you hit the "Set" button and that the station was set before you continue with the survey.
- o. ****Verify you are at the correct station****.
 - i. **This must be done every time after a station is set.**
 - ii. Hit the "Home" button on the outside of the POC.
 - iii. Select the "Measure and Record" workflow.
 - iv. A screen appears that displays your station and associated back sight. Verify both of these values are correct (note: the back sight value should be one of the COP's you just shot).
 - If OK then proceed to Step 11n.
 - If station is not set correctly then go back to Step 11f and repeat the set station process.
- p. Survey as much of the reach as you can from this total station location. Once you have surveyed everything in sight, prepare to move the TS by repeating the methods described in Step 11. Survey the entire extent of the monitoring reach in this manner following the workflow described below:

Survey everything possible from a given TS location -> Choose a new TS location -> Shoot in upstream COP's -> Move TS upstream -> Re-shoot in COP's to orient new TS location -> Set station -> Verify station is correct -> Repeat

- q. Leave all COP's labeled and in place until the survey is complete and the data is validated by Science. This way they can still be used if problems arise later in the survey and TS locations need to be re-established.
- r. If the survey is not complete by the end of the day, the most recent set of COP's will be used to continue the survey the following day.
 - i. At the end of the day, establish and shoot in new upstream COP's from the day's final TS location. At the beginning of the next day, set up the TS at the new location and back-shoot to COPs to orient the TS.

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Reference Guide for Survey Mapping

The following section provides information on the four main components of the NEON geomorphology survey:

1. Downstream and upstream reach boundaries
2. Cross-section surveys
3. Longitudinal profile
4. Pebble count surveys
5. LWD tallies

1. Downstream and Upstream Reach Boundaries

At the beginning of the survey (from TS1), map a point at the top of the permanent marker that monuments the downstream extent of the monitoring reach. Code this point “DSR”.

At the end of the survey (from the final TS location), map a point at the top of the permanent marker that delineates the upstream extent of the monitoring reach. Code this point “USR”.

2. Cross-section Surveys

A total of 15 cross-sections must be surveyed throughout the aquatic reach (Table 4).

Table 4 Cross-sections to be measured and mapped during the geomorphology survey.

Location	Count
Downstream extent of monitoring reach	1
Permanently marked aquatic plant transects	10
Stream discharge transect	1
S2 sensor transect	1
S1 sensor transect	1
Upstream extent of monitoring reach	1

At downstream/upstream extent, aquatic plant transect, and S1/S2 cross-section locations:

- a. Identify left bankfull (LBF) and right bankfull (RBF) indicators and mark with stakes.
- b. String meter tape taut from LBF to RBF stake.
- c. Measure bankfull width based on tape distance. Record bankfull width value in Fulcrum app.
- d. Divide BF width by 4 and mark 25%, 50%, 75% width locations on meter tape with flagging.

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- e. Identify the thalweg. This is typically the deepest point of the cross-section where stream velocity is highest.
- f. Measure depth at the thalweg from the middle of the meter tape down to the streambed surface with a stadia rod or other vertical measurement device. This value is considered the bankfull depth. Record value in Fulcrum app.
- g. Multiply bankfull depth by two. This value is considered the Floodprone Height. This value is calculated automatically in the Fulcrum app based on the Bankfull width.
- h. Level stadia rod at thalweg. Shoot laser level or sight inclinometer across Floodprone Height. Where the laser or inclinometer sightline intercepts the slope is the edge of the Floodprone Width. Mark LB (LFW) and RB (RFW) floodprone width boundaries with stakes.
- i. With the total station, survey in the following features:

Table 5 Cross-section features to survey.

XS Features to Survey	Code
Left bankfull	LBF
Right bankfull	RBF
25% bankfull depth*	25D
50% bankfull depth*	50D
75% bankfull depth*	75D
Thalweg	THL
Left bank floodprone width (if possible)**	LFW
Right bank floodprone width (if possible)**	RFW
Left edge water (if present)	LEW
Right edge water (if present)	REW
Top of Upstream and Downstream permanent marker	USR/DSR
Top of Aquatic Plant Transect permanent marker***	AP1, AP2...
Aquatic Plant Transect temporary marker****	AP1_TEMP
Base of S1 unistrut*****	S1_BASE
Base of S2 unistrut*****	S2_BASE

*If 25%, 50%, and/or 75% width markers are difficult to map due to obstructions or in-channel features it is permissible to move these shots towards the left or right bank and map them in an area with a better line of sight that is easier to shoot in.

**Floodprone widths may not be possible to survey in some areas as they may be too far from the stream and/or riparian vegetation may be present that prevents a line of site. If floodprone width shots require an additional TS setup or cannot be easily mapped from the current TS location these points can be skipped in the survey. Please add a note in the Fulcrum app that the shot was skipped and why. Map floodprone widths when feasible.

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***Permanent markers for Aquatic Plant Transects may not be accessible at some sites. Map a point at the center of the top of the marker if you can do so without making an extra TS move to do so. Code these (AP1, AP2, AP3, etc.) based on the Aquatic Plant Transect number that is associated with the location.

****Temporary markers for Aquatic Plant Transects may not be present at some sites. If they are present (typically plastic stakes), map a point at the center of both the top of the left bank and right bank marker if you can do so without making an extra TS move to do so. Code these (AP_TEMP1, AP_TEMP2, AP_TEMP3, etc.) based on the actual Aquatic Plant Transect number that is associated with the location.

*****Map the southernmost corner of the base of the S1 and S2 unistruts while surveying the two sensor transects. If instrumentation is not present in the aquatic reach at the time of the survey these shots can be skipped.

At the stream discharge cross-section:

- Complete all steps listed above for other cross-section locations **except** Step D (25D, 50D, and 75D locations).
- Survey from the left bank to the right bank.
- If possible, begin survey at the LB floodprone width and work your way down into the channel towards the right bank.
- Survey the top of the permanent marker(s) that delineates the discharge cross-section boundaries (label these points “DSC_LB/RB_PIN”).
- Survey and label the marked features listed in above table plus an additional 20-25 points (code “DSC”) along the cross-section with the total station.
 - i. The exact number of discharge cross-section survey points can vary relative to the width of the discharge cross-section.
 - ii. Space the discharge survey points in such a way that they are representative of the entire cross-section.
 - iii. Be sure to capture the thalweg and gradient changes. If possible, map points that begin on the LB floodprone width, extend across the left bank, into the channel and onto the right bank and right floodprone width.
 - iv. Taking more shots (rather than less) is preferred as this will produce a high density survey. Below is an example of a high density cross-section survey where each dot represents a TS shot.

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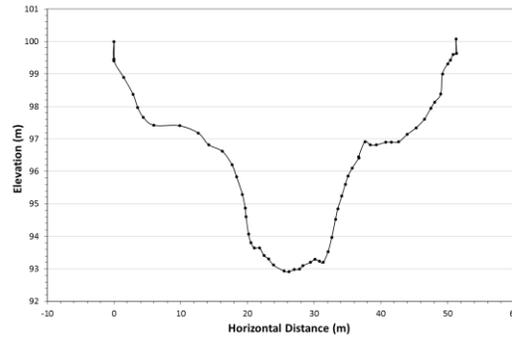


Figure 7. Example discharge cross-section survey data.

- At the stream discharge cross-section survey the staff gauge at a specific meter mark and indicate the meter mark where the tip of the prism rod is located in the survey code (see table below). For example if the rod is placed at the 1.00 meter mark, label this point “SP_1.00M”.
 - i. It may be difficult to level the prism rod at a fixed point on the staff gauge and/or the top of the staff gauge may be too high to reach. One strategy for obtaining an accurate and level staff gauge shot is to attach a clamp with a square piece of wood to the staff gauge as illustrated in the picture below. Note that the top of the small square piece of wood is placed exactly at 0.30 meter mark and held firm by the clamp. The prism rod is then leveled on the wood. The correct label for this shot would be “SP_0.30M”. Make sure the weight of the rod does not push the wood down while taking the shot. It may be helpful to have someone hold the clamp setup and tip of the rod in place while the shot is being taken.

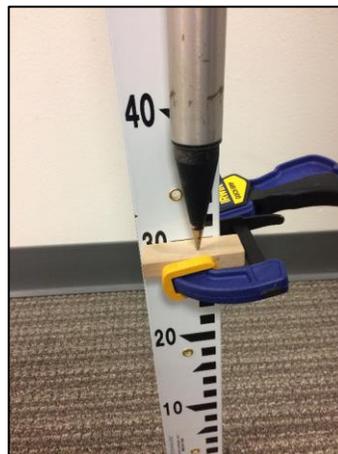


Figure 8. Mapping the staff gauge using a small block of wood and a clamp.

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Table 6 Features to survey at the stream discharge cross-section.

Stream Discharge XS Features to Survey	Code
25-30 points along discharge cross-section	DSC
Left bank permanent pin	DSC_LB_PIN
Right bank permanent pin	DSC_RB_PIN
Left bankfull	DSC_LBF
Right bankfull	DSC_RBF
Thalweg	DSC_THL
Left bank floodprone width (if possible)	DSC_LFW
Right bank floodprone width (if possible)	DSC_RFW
Left edge water (if present)	DSC_LEW
Right edge water (if present)	DSC_REW
Staff gauge at specific meter mark	SP_#.##M

3. Longitudinal Profile Survey

A longitudinal profile survey is to begin immediately upstream of the most downstream cross-section and end at the upstream extent of the monitoring reach. The entirety of the monitoring reach must be characterized using the five habitat unit categories described in the table and figures below. The downstream extent, or tail, of each habitat unit must be mapped. It is assumed that the same habitat unit is present between each mapped tail point. Each delineated habitat unit must be >50% of the wetted width and be longer than it is wide. When in doubt it is best practice to lump units together rather than split them apart in order to expedite the survey.

Table 7 Habitat unit types and descriptions.

Habitat Unit Type	Habitat Unit Description
Run	A relatively shallow part of a stream with moderate velocity and little or no surface turbulence.
Riffle	A shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.
Pool	A small part of the reach with little velocity, commonly with water deeper than surrounding areas.
Step-pool	Channel-spanning pools with boulder/cobble steps that cause subcritical flow (deep, slow flow) in the pool and supercritical flow (shallow, fast flow) over the steps. These features occur in gradients in the range of 5-20%.

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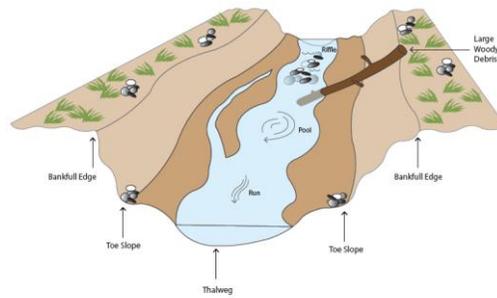
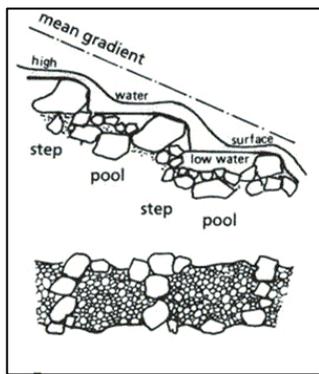
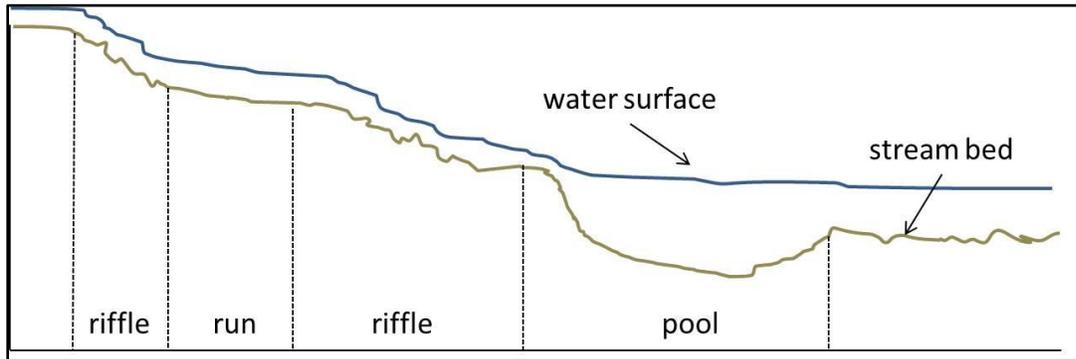


Figure 9. Above center: Long-profile illustration of riffle, runs, and pools. Bottom left: Illustration denoting step pools. Bottom right: Cross-section illustration denoting stream features.

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Within each habitat unit specific geomorphic features are to be surveyed with the total station throughout the longitudinal profile. These features are described in detail below as well as in the following table which provides a quick reference and specific and standardized survey codes that must be entered into the POC associated with each feature.

Right and Left Edge of Water (REW, LEW)

Map where water makes contact with the bank on both the right and left edges of the stream. Attempt to map at least one wetted edge point for the right and left side of each habitat unit but note that this may not be possible for pools that run long and are deep. Collect wetted edge shots that represent the average rather than the maximum or minimum wetted edge along the stream.

Thalweg (THL)

Map the line that connects the deepest part of the active channel. Collect a greater number of thalweg points along gradient changes and as the channel meanders and less thalweg points where the streambed appears flat and homogenous. In some instances the thalweg may become divided around geomorphic features such as mid-channel bars, islands, or large boulders/bedrock. In these instances (if time allows), attempt to map multiple thalweg networks. Be sure to connect thalweg points that branch off into multiple networks back to the main channel.

Maximum Pool Depth (MPD)

If possible, map the deepest part of the each pool unit. If a pool is too deep and it is unsafe to enter the deepest section, make a note in the Fulcrum app and skip mapping this point.

Mid-channel Bars (MCB)

Mid-channel bars are mounds of consolidated substrate that are surrounded by the stream. These features protrude above the streamflow but the maximum elevation is below bankfull. Map the upstream, downstream, left and right wetted edge of these features as well as the highest point of elevation (if possible) so that, in connecting the mapped points you would draw a polygon around the feature. Be sure to also survey in the thalweg network that surrounds these features – this also help to delineate them during post-processing.

Islands (ISL)

Islands are similar to mid-channel bars but contain a maximum elevation that rises above bankfull. Map the upstream, downstream, left and right wetted edge of these

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features as well as the highest point of elevation (if possible) in the same manner as mid-channel bars.

Tributaries (TRB)

Tributaries are smaller order streams feed into the mainstem of the monitoring reach. Tributaries may contain flowing water or be dry. At each tributary, map a single point one meter upstream from the confluence in the middle of the tributary.

Dry Extents of Reach (DDS/DUS)

If the stream becomes hydrologically disconnected (i.e. surface water paths are discontinuous) within a significant portion of the habitat unit, the downstream and upstream extent of these dry areas must be mapped. Continue to delineate habitat units between the upstream and downstream dry extents to the best of your ability (given that the reach is dry). Also continue to map thalweg shots and any geomorphic features that are present. Obviously no right or left edge water shots can be mapped within these segments.

Beaver Dams (BEA)

Map the upstream and downstream middle edge of every beaver dam that appears to actively alter streamflow within the monitoring reach.

Water Falls (WFB, WFT)

Consider a feature a “waterfall” if water is dropping at least 1.5m vertically, or very nearly so. Map two points at each waterfall, one at base and another at the top. The objective of these points is to identify the change in elevation of the stream caused by the waterfall.

Large Woody Debris Jams

Map all large woody debris jams using methods outlined in Section 4.

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Table 8 Survey codes and descriptions for the geomorphology survey.

Features to map within each habitat unit	Feature Description	Code
Run unit tail	Downstream extent of habitat run unit	RUT
Riffle unit tail	Downstream extent of habitat riffle unit	RIT
Pool unit tail	Downstream extent of habitat pool unit	POT
Step-pool unit tail	Downstream extent of habitat step-pool unit	SPT
Dry extent downstream*	Downstream extent of hydrologically disconnected area	DDS
Dry extent upstream*	Upstream extent of hydrologically disconnected area	DUS
Right edge of water	Right edge of wetted perimeter	REW
Left edge of water	Left edge of wetted perimeter	LEW
Thalweg	Line that connects deepest points of channel	THL
Maximum pool depth (pool habitats only)	The deepest part of the pool	MPD
Downstream mid-channel bar*	Downstream wetted edge of bar (in middle)	MCB_DS
Right edge mid-channel bar*	Right wetted edge extent of bar (in middle)	MCB_RB
Left edge mid-channel bar*	Left wetted edge extent of bar (in middle)	MCB_LB
Upstream mid-channel bar*	Upstream wetted edge of bar (in middle)	MCB_US
Top of mid-channel bar* (if feasible)	Highest point of mid-channel bar	MCB_TOP
Downstream island edge*	Downstream wetted edge of island (in middle)	ISL_DS
Upstream island edge*	Upstream wetted edge of island (in middle)	ISL_US
Left edge island*	Left wetted edge of island (in middle)	ISL_LB
Right edge island*	Right wetted edge of island (in middle)	ISL_RB
Top of island* (if feasible)	Highest point of island	ISL_TOP
Upstream culvert boundary	Center upstream edge of culvert	CUL_US
Downstream culvert boundary*	Center downstream edge of culvert	CUL_DS
Tributaries*	1m upstream in tributary thalweg	TRB
Base of waterfall*	If qualifying, center of the base of the waterfall	WFB
Top of waterfall*	If qualifying, top of the waterfall	WFT
Upstream edge of beaver dam*	Upstream wetted edge of dam (in middle on substrate)	BEA_US
Downstream edge of beaver dam*	Downstream wetted edge of dam (in middle on substrate)	BEA_DS
Upstream terminus of LWD jam*	If qualifying, upstream edge of LWD jam	LWD_US
Downstream terminus of LWD jam*	If qualifying, downstream edge of LWD jam	LWD_DS
Left edge of LWD jam*	If qualifying, left edge of LWD jam	LWD_LB
Right edge of LWD jam*	If qualifying, right edge of LWD jam	LWD_RB
Height of LWD jam* (if feasible)	If qualifying, highest point of LWD jam	LWD_TOP
Top (upstream) of monitoring reach	On marker that delineates upstream boundary	USR
Bottom (downstream) of monitoring reach	On marker that delineates downstream boundary	DSR

**feature may or may not be present in monitoring reach*

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4. Large Woody Debris Tallies

Throughout the entirety of the monitoring reach, observe all large woody debris (LWD) that enters or lies within bankfull margins. Record the number of pieces in Fulcrum app that meet both of the following criteria:

- Diameter: ≥ 0.15 m
AND
- Length: ≥ 1 m

In addition to the tally, all LWD jams must be surveyed. An LWD jam is considered 3 or more pieces of LWD that touch each other with at least 3 of the pieces meeting the above single piece criteria.

- At each LWD jam map the following points:
 - The upstream (LWD_US) and downstream (LWD_DS) terminus edge.
 - The left edge (LWD_LB) and right edge (LWD_RB).
 - The highest elevation point (LWD_TOP, if this can be safely accessed).
 - If an LWD jam is somewhat scattered, map a reasonable amount of points surrounding it so that it is well-defined in space.
- If a piece of the LWD jam is partially buried, map the location where the wood enters the substrate.
- If a piece of the LWD jam extends outside of the bankfull margin, map a point as far as you can outside the bankfull perimeter without having to move the total station.

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5. Pebble Count Surveys

Pebble count surveys are to be conducted at five aquatic plant transects characterized as riffle units. Attempt to select five transects that are well-distributed throughout the monitoring reach. If none of the aquatic plant transects are characterized as riffles, choose those that can be characterized as runs. If none can be characterized as runs, choose those that can be characterized as riffle/pools (where the stream is transitioning from a riffle to a pool). If none of these conditions are present at the aquatic plant transects, submit a trouble ticket prior to conducting pebble count surveys.

Conditions of pebble count surveys:

- Each survey should contain 40-counts resulting in a 200-count survey for the reach.
- Substrate is to be measured on the b-axis using a gravelometer as described in the figure below.

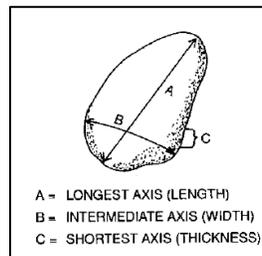


Figure 10. Illustrating denoting the different substrate axes.

Pebble count survey methods are as follows:

1. Utilize the meter tape extended across the cross-section survey transect.
 - a. Surveys are to be conducted from the right bank to the left bank. Avoid sampling in either bank (i.e. begin just inside bankfull indicator in the active channel zone).
2. To determine sample spacing, divide the bankfull width by 40 and sample at this increment along the meter tape.
 - a. Note: it may be helpful to clip a Sharpie to the meter tape to slide along the transect and help track sampling intervals.
3. Sample the substrate directly below each sampling interval on the meter tape. Close your eyes and select the first particle you make contact with at each interval. This may be done using a rod or finger to reduce surveyor bias towards certain size substrate. Be sure to be consistent in the method used to select the sample particle.

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4. Measure the b-axis (the intermediate axis) using a gravelometer. This is done by selecting the closest size hole on the gravelometer that the particle will fit through.
 - a. For example, a 60 mm particle would be classified in the 64 mm bin size class.
 - b. If the substratum is too large to pick up, measure *in situ*
 - c. If the substratum is so large that it encompasses more than one sampling location do not measure it more than once. Skip ahead to the next sampling location (where it is not present) and reduce sample spacing so that 40 measurements can be obtained.

5. Record data in the Fulcrum app to complete the pebble count survey.

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QAQC Techniques

QAQC can be performed at different stages of the survey to verify that mapped features are spatially aligned and that all necessary data is being collected. This section provides QAQC strategies for field technicians to implement to help ensure quality data is being collected during the geomorphology survey.

During the survey:

- If completing the Missing Line workflow (Section 1 Step 5), ensure that all standard deviations are within stated criteria.
- When moving total stations, ensure that standard deviations are within stated criteria once Control Points have been surveyed at the second total station location.
- Following each total station move:
 - Ensure that the total station was set to the proper location.
 - Map a few shots from the new TS location and use the map feature on the POC to verify that the new shots align with those from the previous TS location. To access the POC map function:
 1. Click the home button on the outside of the POC.
 2. Select “Info”.
 3. Select “Points”. This will bring up a map of the survey. Zoom in to where you are and check that the most recent mapped features are in correct alignment and that the stream morphology appears to be correct.

At the end of each day:

1. Download the survey data from the POC and view the .CSV file.
 1. Insert a USB flash drive into the POC.
 2. Select the “Home” button on the outside of the POC.
 3. Select “File”.
 4. Select “Export” to upload the appropriate job file (CSV) onto the flash drive.
2. Using the latest version of the MorphViewer R-script, load the raw survey data to view a scatterplot of Easting vs Northing data in your web browser. If something does not look right in this plot (i.e. the thalweg meanders right when you would expect it to stay straight), submit a trouble ticket immediately and discuss with Science before continuing survey. A readme file is available to help setup this script.

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3. Verify that all of the points you mapped that day are represented in the output .CSV.
4. Verify that all mapped points were coded correctly.
5. Note any points or features that were missed or mislabeled. If possible survey in missed points the next day. Save these notes in the Fulcrum app under the appropriate total station location table. **Do not delete or edit any points during the survey or while viewing the .CSV file.**
6. Send the .CSV file to Science at the end of each day.
7. If, by the second or third day of the survey, you are struggling to complete approximately 200 meters of mapping, contact Science immediately for a discussion.

At the end of the survey:

1. Verify that all necessary points and features have been mapped using the lists provided in Section 2.
2. For example, each cross-section should contain 8-10 feature points. As such there should be 15 points labeled “LBF” points, 15 points labeled “RBF”, etc.
3. Verify the minimum number of right edge water points (50), left edge water points (50), and thalweg points (20) were collected during survey.
4. Note any points or features that were missed or mislabeled. Ensure that these notes were entered into the Fulcrum app. Provide the final survey .CSV file from the POS and the Trimble file (if collected) to Science.

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SOP C Tips for Best Practices

The following section provides tips to facilitate best practices during the geomorphology survey.

- It is critical that there is clear communication between the person holding the prism rod and the POC operator. Always enter the height of rod (HR) in meters with two decimal places, i.e. 1.60. When the HR changes it is imperative that the person operating the POC is made aware of the new height. In the instance of a HR error, record in the “Mapped Points that Contain Errors” table of the Fulcrum app:
 - The HR value entered in the POC (the incorrect value).
 - The correct HR value (what it should be changed to during post-processing).
- Avoid using the 1.50m mark on the prism rod. Depending on the setup, it can be difficult to place the rod height at precisely 1.50m due to the assembly of the prism head. Instead, use 1.60m for the lowest rod height. High precision can be achieved at this rod height.
- The prism pole must be level while points are being mapped. If the substrate is soft avoid pushing the point at the bottom of the pole into the ground, instead gently set it on top of the substrate.
- Use the level bubble on the prism pole to ensure the rod is level before shooting the point with the TS. When leveling the prism rod by hand sometimes it is useful to balance the rod between the tips of your fingers. Exhale just before the shot is taken from the TS – this helps still yourself and keeps the rod level. This approach may not always be possible in every rod placement situation. Use the bipod when leveling the prism rod on benchmarks and control points.
- When setting up the TS, choose a location where the ground surface is fairly solid. Push the legs into the ground so that the TS will not move when you walk around the tripod perimeter. If the TS location is unstable the instrument can become un-level simply by people walking nearby. In that instance it will be difficult to maintain desired standard deviations while back-shooting COP’s.
- Once the total station has been leveled, spin both the robotic head and the lens around 360°. Check the TS level after these rotations have been performed and adjust the TS level accordingly, if necessary. Once the TS

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remains level after each of these spins the instrument can be considered truly level.

- Always hold the TS robotic head by the handle at the top when transporting the instrument or affixing it to the tripod. Follow the “one hand rule” – always have one hand on the robotic head handle whenever it is either not secured to the tripod or in the carrying case.
- Never set the POC datalogger down on an unstable surface where it may slip and fall to the ground. The POC screen is fragile and if it is damaged the survey cannot continue until it is repaired by the manufacturer.
- Prior to the survey, print out a map of the site (Google Earth, AIS as-built maps, etc.). This can help determining Trimble Points and benchmark installation locations as well as potential total station placement locations. It can also be used as a QAQC supplement during the survey – periodically compare the stream morphology patterns observed on this map to what is being produced on the POC map. Thalweg shots mapped during the geomorphology should be consistent with the direction of the stream that is depicted on the map.
- A workflow involving 4 people is the most efficient way to complete the geomorphology protocol. The total station should always be taking shots – i.e. avoid significant mapping lag time other than when the TS is being moved or set up in a new location. Divide work between the four crew members as follows:
 - 1 person: Holds POC and entering data into app. This person should be standing next to the TS in order to sight the prism in manually when connection gets lost.
 - To sight the TS in manually use the knobs on the side of the robotic head to focus, move the head vertically, and move the head horizontally. Note: sometime the TS sight can be very out of focus so you might have to turn the focus knob many times.
 - 1 person: Holds the rod and maps points up and down the stream.
 - Have the person holding the rod begin with one feature (i.e. LEW) and map as far upstream as you can see from the TS. Mark the position where you left off with flagging so that, following the TS move, you can begin mapping from this point. Next map the next feature downstream of this position (i.e. THL) until you get back to the total station. Then map the third feature (REW) back upstream to the flagged location. Along the way take shots at habitat boundaries and map any

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geomorphic features. This way you can reduce confusion regarding what you have mapped from each TS location. Use radios to communicate between the person at the total station and the person holding the prism rod.

- 2 people: Scout the next TS location, install the next Control Points, set up transects and record applicable measurements in the Fulcrum app, conduct pebble counts, be available to move brush and clear line of site for surveyors.
- Don't spend too much time mapping an overabundance of edge water shots. If the edge of water is reasonably straight, 3-4 edge water shots (per side) will probably suffice for a single total station setup. Think of it as a line connecting the shots you take. Prioritize mapping changes in thalweg elevation and direction. A roughly 2:1 ratio of thalweg to edge water shots should not be uncommon at the end of the survey.
- Don't spend too much time on shots that are far away from the TS. It is likely that you will be able to easily obtain these shots from the next TS location.
- Re-shooting "bad" shots:
 - It is a common occurrence to need to re-shoot points for a variety of reasons (the prism rod may have been un-level or slipped out of placement, the HR may have been entered wrong in the POC, etc.)
 - In these instances it is always advised to re-shoot the point in question.
 - Use the "Mapped points that contain errors" function in the Fulcrum app to track points that are in error, need to be re-labeled, etc.
 - During post-processing Science will use these notes to delete and/or re-label points within the survey job file.
- Avoid prolonged exposure of the POC and the TS robotic head to direct and intense sunlight. In extreme cases, the LED screen of the POC can be damaged and the TS can have difficulty taking shots. Use an umbrella to shield both the POC and the TS head during particularly hot and sunny days.
- Keep the POC and TS dry at all times. Take care when transporting instrumentation in the stream and avoid the equipment getting rained on.

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SOP D RAPID HABITAT ASSESSMENT

The Rapid Habitat Assessment SOP is performed once during AOS site characterization to define which habitats and samplers to target for stream biological sampling efforts. During Operations, this SOP will be performed annually to document channel changes and trigger more frequent occurrences of the stream morphology SOPs. Data must be entered using the Trimble data dictionary.

D.1 Habitat Survey: Annual

1. Navigate to the downstream boundary of the 1000 m sampling reach using reach boundary coordinates found in the Domain-specific Sampling Design (BOT plot marker).
 - a. This point may be different from the bottom of the permitted reach.
2. Record the waypoint using the Trimble (latitude, longitude) and coordinate uncertainty (GPS accuracy) at the downstream boundary using the Trimble data dictionary.
3. Determine and record the habitat type of the habitat unit directly upstream of the boundary (Figure 9).
 - a. Tips for determining discrete habitat units:
 - i. If the habitat is shorter than it is wide, do not consider it to be its own habitat unit. Consider it a part of the next habitat unit, or as part of a complex of the same unit.
 - ii. If there is a small, embedded habitat within the main habitat unit (e.g., a small pool to the side of a riffle), consider it a unique habitat unit only if it accounts for >50% of the stream width.
 - b. Habitat types
 - i. Riffle
 - ii. Run
 - iii. Pool
 - iv. Step pool
 - v. Other (define)
4. Measure and record the length (to nearest 0.1 meter) of the habitat unit along the thalweg, and enter in the Trimble data dictionary.
 - a. If a significant obstruction (e.g., deep pool, debris dam) exists so that you cannot follow the thalweg, estimate the length along the shore instead.
 - b. If the stream branches, follow and measure the branch that appears to have the most flow. Note the existence of the branch in the remarks of the Trimble data dictionary.
5. Measure and record the maximum wetted width of the habitat unit and enter in the Trimble data dictionary. You may use either the laser rangefinder (RD[08]) or a meter tape.
6. Measure and record the depth of the habitat unit to nearest 0.01 meter and enter in the Trimble data dictionary.
 - a. Pools: measure depth at the deepest point
 - i. If too deep to wade, measure the deepest location that you can safely reach

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- b. Riffles, runs: measure depth in the thalweg
7. Estimate and record the percentage of submerged large woody debris (LWD%) for that habitat type to the nearest 5%. Think of this as debris that might be used as habitat for algae, macroinvertebrates, or fish. Enter in the Trimble data dictionary.
 - a. This is a relatively subjective rating, so the same technician should make the final decision for each habitat unit during the survey.
 - b. Technicians should break the habitat into visual sections to estimate percent cover more easily (**Error! Reference source not found.**). Figure 11).
 - c. Calibrate percent cover against other technicians, even though one technician will make the final decisions.



Figure 11. Example of habitat division

8. Estimate and record the size classes of the dominant substrata within the habitat unit. Substrata type classifications are used to determine sampling locations and sampler types for macroinvertebrate and periphyton sampling. Enter in the Trimble data dictionary.
 - a. You may record one or multiple size classes per habitat unit.
 - b. Substratum size classes
 - i. Bedrock
 - ii. Boulder: >256 mm
 - iii. Cobble: 64.0 – 256 mm
 - iv. Pebble 2.0 – 64.0 mm
 - v. Sand: 0.062 – 2.0 mm
 - vi. Silt: 0.004 – 0.062 mm
 - vii. Clay: 0.001 - 0.004 mm
9. Estimate and record the percent riparian cover over the channel at the habitat unit. This is a coarse visual estimate (no densiometer) of how much of the water's surface is shaded throughout the day, which has been shown to directly affects algal growth on the stream bed (Lowe et al. 2006).

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- a. This number may change dramatically depending on the time of year of the survey, but current conditions should be recorded. If the canopy is primarily deciduous and the survey is taking place when leaves are off the trees (due to scheduling during characterization), make a note on the field datasheet.
- b. Use the same estimating techniques and calibration between technicians as presented for LWD% above. This is a relatively subjective rating, so the same technician should make the final decision for each habitat unit.
10. When all measurements have been recorded for the present habitat unit, move upstream to the next habitat unit and repeat the steps above.
11. Habitat units may be linked together if they occur multiple times in a row.
 - a. For example, in streams where there are multiple short step pools, you may measure a series of step pools together rather than splitting them up to save time. Call this example a “step pool complex” provided there are no other habitat types in the middle.
12. Long habitat units may be split apart to make measurements easier.
 - a. For example, a 100-m long riffle may be split into two units, each called “riffle” if it makes measurements easier.
13. Continue until the entire sampling reach (approximately 1000 m) has been surveyed. Record a waypoint and coordinate uncertainty at the upstream end of the survey (TOP plot marker).

D.2 Pebble Count

1. Start in the most common habitat type (as determined above). Choose a location that appears representative of the reach (i.e., did not appear to be an outlier in the habitat survey).
2. Step into the stream perpendicular to flow.
3. While averting your eyes from the substratum, bend down and pick up the first pebble you touch next to the big toe of your boot (either foot). If the substratum is too large to pick up, measure *in situ*.
 - a. This step removes bias from the measuring process.
4. Measure B-axis (intermediate axis) using a gravelometer to group particles to the nearest size bin (Figure 12).
 - a. Measure B-axis by determining the closest size hole that the particle fits through in the gravelometer and record the bin size (size of gravelometer hole), record in mobile application.
 - b. Bin sizes are as follows:
 - i. silt/clay
 - ii. sand
 - iii. 2.8 mm
 - iv. 4.0 mm
 - v. 5.6 mm
 - vi. 8.0 mm
 - vii. 11.0 mm
 - viii. 16.0 mm
 - ix. 22.6 mm

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- x. 32.0 mm
- xi. 45.0 mm
- xii. 64.0 mm
- xiii. 90.0 mm
- xiv. 128 mm
- xv. 180 mm
- xvi. < 265 mm
- xvii. > 256 mm
- xviii. Bedrock

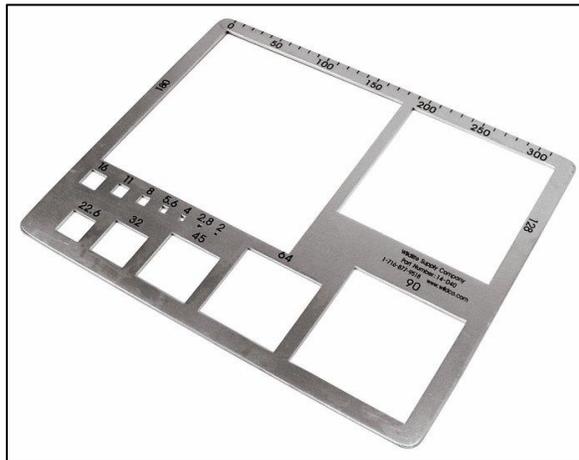


Figure 12. Use a gravelometer to determine which size bin/hole the particle fits through.

Site (4-letter code): HOPB		Recorded by: sparker@neoninc.org									
Date (YYYY-MM-DD): 2016-09-15		Collected by: critz@neoninc.org									
Local time (HH:MM): 14:00		Sampling protocol: NEON.DOC.003162 Rev: B									
Habitat types: riffle, run, pool											
		Record length of B-axis in mm by size bin									
		1	2	3	4	5	6	7	8	9	10
1-10		11	11	16	>256	5.6	32	>256	>256	16	22.6
11-20	sand	sand	22.6	4	>256	2.8	>256	16	45	90	
21-30	>256	bedrock	3	18	>256	boulder	15	>256	>256	sand	
31-40	8	>256	silt/clay	>256	11	11	bedrock	<256	8	22.6	
41-50	sand	<256	2.8	22.6	5.6	8	sand	sand	<256	sand	
51-60	sand	sand	8	>256	5.6	>256	22.6	11	8	>256	
61-70	22.6	sand	32	45	16	2.8	sand	>256	2.8	4	
71-80	sand	22.6	11	>256	32	sand	11	22.6	128	180	
81-90	>256	90	4	22.6	16	32	45	180	22.6	sand	
91-100	11	sand	>256	22.6	>256	>256	22.6	16	16	32	

Figure 13. Example pebble count datasheet. Data should be entered in the mobile application if available.

5. Take another step into the stream channel and repeat the steps above.
6. Move upstream systematically in a zigzag pattern (from bank to bank) until 100 measurements have been recorded (Figure 14). Measurements are taken while passing

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through multiple habitat units as you move upstream, but at a minimum the most common habitat is captured. A very small portion of the entire sampling reach will be surveyed for pebble count.

- Record all habitat types encountered across the 100 particles in the mobile application.

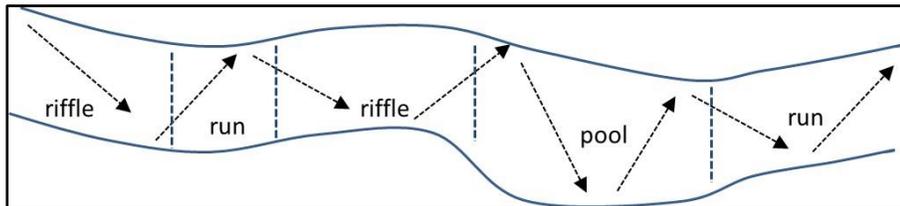


Figure 14. Zigzag pattern through multiple habitats for pebble count measurements.

SOP E Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible; alternatively, devices should be synced immediately upon return to the Domain Support Facility.

Given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times. As a best practice, field data collected on paper datasheets should be digitally transcribed within 7 days of collection or the end of a sampling bout (where applicable). However, given logistical constraints, the maximum timeline for entering data is within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

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