AOS PROTOCOL AND PROCEDURE: WADEABLE STREAM MORPHOLOGY

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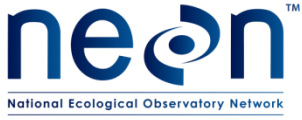
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A	02/29/2016	ECO-03668	Initial release, includes Rapid Habitat Assessment SOP

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1 OVERVIEW

1.1 Background

Streams exhibit a massive degree of physical diversity and geomorphic character. The geomorphic character of a stream channel is driven by current and past geologic, climatic, and biological conditions present in the terrestrial environment immediately adjacent to the channel and in the upland contributing area of the watershed. The morphology of a stream is dynamic over time. Changes in water level and sediment supply play a major role in shaping the channel and dictate how the channel morphology will change in response to perturbation. Glacier-fed streams may shift from a braided, unstable channel 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). The collective physical attributes in a stream, including in-stream channel structures, sinuosity, density of wood, and channel morphometrics, is known as the geomorphic template.

The geomorphic templates strongly influence ecological processes in streams. Attributes related to geomorphic features significantly influence the quantity and quality 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).

The geomorphic template 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 annually. 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. One particularly important data product that will be derived from the geomorphic surveys is a geomorphic map, which will inform many other NEON data products ranging from biological collections to the impact morphology plays on nutrients and food web dynamics.

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.

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/

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, Program and Management Plan 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.014051	Field Audit Plan
AD[06]	NEON.DOC.000824	Data and Data Product Quality Assurance and Control 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.005003	NEON Scientific Data Products Catalog
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

2.3   Acronyms

Acronym	Definition
BFI	Bankfull Indicators
BM	Bench Marker
CP	Control Point
DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Geographic Positioning System
SI	International System
TSOP	Total Station Operator
UTM	Universal Transverse Mercator Coordinate System

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: 3000 northing, 2000 easting, 1000 elevation. All new surveys will be attributed an assumed coordinate system during the initial survey.

Backsight: survey routine to establish a basic for horizontal, vertical, or angular measurements within the surveying instrument. Backsight checks are used to assure the continued accuracy of a survey.

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 geographic marker of a point of known elevation, latitude, and longitude.

Coarse woody debris (CWD): Downed woody debris submerged in the stream that is ≥0.15 m (6 inches) in diameter.

Control point: A permanent or temporary location used to set up or orient the surveying instrument. Includes any station setup, benchmark, and backsight locations**.**

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.

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 stream width at a discharge level defined as twice the bankfull depth.

Foresight: A control point that will be used for a future station setup location

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.

Glide: Stream habitat feature located at the downstream end of a pool, where the stream bed slopes gradually upwards, which causes a narrowing of the depth of water flowing over this feature. Similar to a run, the water surface is smooth with relatively uniform flow. If unsure about this classification, use 'run'.

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 unitless number ranging from 0 – 1.0, or a percentage.

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

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

Log Jam: grouping of three of more pieces of wood that are touching and lie within bankfull. Log jams that are oriented laterally across the stream channel tend to create pools upstream of them due to the retardation of stream flow through the obstacle.

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.

Pool: An aquatic habitat unit in a river or stream created by local scour or impoundment and having a structural control. Pool water depth is above average, if all the running water in the stream was shut off, areas in the stream that would still hold water are pools. Pool water velocity is below average for the reach and because of that fine sediments deposit in pools. Pools are generally longer than they are wide (unless they are plunge pools), and are 1.5 x deeper at their maximum depth than they are at their crest.

Prism: mirrored flat surface that acts as a reflector to return light pulse back to the total station to measure distance.

Prism pole: graduated pole used to determine height of prism and mark survey points

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

Riffle: Shallow reaches flowing over rough bed material such as boulders and cobbles, creating ripples, waves, and eddies on the water surface.

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

Run: An aquatic habitat with swiftly flowing water but no surface water agitation, with relatively uniform flow.

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: High-gradient streams (steep) where water cascades over a rock or woody snag, dropping into a pool. Due to the gradient and surrounding geology, this pattern continues down the stream: step (drop)—pool—step—pool—etc.

Thalweg: the portion of the stream channel through which the majority of the stream flow is transported. This is typically identified as the deepest portion of the flowing channel.

Total station: a high resolution instrument used in surveying to measure distances and angles from horizontal of points of interest. Totals stations utilize a laser pulse (light pulse) to determine distance, and are equipped with a positioning system to determine the angle of rotation of the total station from a known datum to the points of interest.

Traverse: the process of moving the total station from one control point or benchmark to a new foresight.

Woody Debris: wood located within bankfull that has a DBH of >10 cm and is longer than 1m

3   METHOD

3.1   Overview

The NEON wadeable streams morphology protocol provides methods to conduct an engineering-grade survey of the topographical aspects of a stream channel and the adjacent floodplain. The survey captures the geometry of the stream channel and floodplain of the NEON aquatic reach and 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 that is ≤1000 m. The location, or spatial position of points along the channel bed, water surface, floodplain, and at the boundaries of in-channel habitats are recorded as Cartesian (X, Y, Z) coordinates using a total station. Northing and Easting positions of each point are measured as X and Y coordinates. Elevation is recorded as Z coordinates. The coordinates are measured in the SI unit meter (m) and recorded by the total station. All coordinates recorded by the total station are recorded as a distance from the origin of the survey (e.g. 0,0,0 m). The origin of the survey is the first station location. The first station location is determined by surveying three benchmarked points at the downstream end of the aquatic reach. The benchmarks shall form a near-equilateral triangle with the total station. Proper triangulation of the total station with benchmark and control points that are GPS located are necessary for the total station to track its position in the survey area and for the total station data to be transformed into a geographic coordinate system in order to create a map. **The raw x,y, and z coordinates recorded by the total station are in a local coordinate system. The total station does not know where it is with respect to geographic coordinates on Earth (e.g., lat/long or UTM). In order to convert the total station data to a geographic coordinate system a**

series of benchmarked locations with known UTM coordinates and elevation are surveyed prior to and during each survey. The survey data is transformed using benchmark and control point locations into a geographic coordinate system using ArcGIS.

The survey shall capture topographic attributes of the stream channel and floodplain, water surface elevation, and the location of channel features/biological habitats. Habitats include the location and position of in-channel woody debris, mid-channel islands, pools, and riffles. A robotic total station is used for the survey. The operation of the total station and data collection may be completed by one technician. However, it is important that the second technician on site be available to aid in the initial instrument set-up (layout/surveying of benchmarks) and to help with maintaining the progress of the survey by marking features, planning control points for new station locations, and holding back vegetation to maintain line of sight between the total station and the prism.

The total station operator, herein referred to as the TSOP, operates the total station using the remote data collector called the POC. The TSOP places the point of the prism pole with an attached 360° mirrored prism on a point to be surveyed (e.g., points of topography or elevation of water surface). Survey points shall capture major slope breaks in the channel and floodplain, edge of water (i.e., wetted edges) along channel banks, mid-channel features, position of thalweg, and location of habitat features. Contour lines, a series of consecutive survey points, of a specific feature (e.g., bankfull indicators, top of bank, toe of bank) are used only when the feature is present. Point data are individually coded by specific feature when entered into the total station. The codes aid in post processing of the data and the creation of different GIS derived topographic layers of the surveyed area.

The methods described here provide a single, unified guide to surveying geomorphic features and biological habitats in stream channels at all sites within the NEON program. The data collected from the surveys will be used to generate GIS -based digital elevation model (DEM) layers that display topography of the channel and flood plain, create habitat maps to guide biological sampling, and investigate long-term trends and changes in channel morphology and habitat area. The protocol and 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, provide detailed 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. Use NEON's problem reporting system JIRA to document and resolve 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 JIRA.

The procedures described in this protocol will be audited according to the Field Audit Plan (AD[05]). Additional quality assurance checks will be performed on data collected via these procedures according to the NEON Data and Data Product Quality Assurance and Control Plan (AD[06]).

3.2   Survey Workflow

1. Place (if this is the first survey at this site) or locate site benchmarks BEN001, BEN002, BEN003 which will be at the end of the aquatic reach closest to the auxiliary portal. At some sites this will be closer to the downstream end of the reach (e.g. D04 Rio Cupeyes) and at other sites it'll be closer to the upstream end of the reach (e.g. D10 Arikaree).
2. Set up the total station in a location near all three benchmarks with clear line of sight to all 3 benchmarks. If possible, the selected location of the total station should be able to see to one of the ends of the aquatic reach. If this is not possible, it's ok and will require a transit of the total station to get to one of the ends of the stream reach (defined below) to begin collecting stream feature **data (also known as "points" and used interchangeably)**.
3. Survey BEN001, BEN002, and BEN003
4. Place pin flags at the furthest downstream and upstream location that is in line of sight with the total station location that is within the permitted reach. This demarks the sub-survey area.
5. If required to clearly see the full stream channel (likely the case), perform a transit of the total station to a location with better visibility of the stream channel (i.e. up on one bank of the stream near the edge). Moving the total station is detailed in section SOP D.
6. Stretch a measuring tape across the stream bankfull width at the reach boundary. Use the tape to conduct the first cross-section profile of the channel and floodplain.
7. Measure thalweg depth and determine flood prone width
8. Survey points along the measuring tape starting at right bank flood prone width and finish at left bank flood prone width
9. Work upstream to conduct the longitudinal survey beginning at the right flood prone width. Stop at pin flags that mark the end of sub-survey area.
10. Work back downstream collecting points for right floodplain. Walk in a zig-zag pattern and collect data every ~5 m. Stop at downstream pin flag.
11. Work back upstream collecting points for the top of the bank and other right bank features. Stop at upstream pin flag
12. Work downstream collecting points along the toe of the bank
13. Work upstream collecting points along the right edge of water
14. Work downstream collecting data for thalweg (Note: 'right' is on your 'right' side when looking downstream). The thalweg is more obvious when walking downstream)
15. Work upstream collecting data for left edge of water
16. Work downstream collecting data for left bank features
17. Work upstream collecting left floodplain points
18. Work downstream collecting left flood prone points. Stop at end of sub-survey area.

19. Return to the stream and survey physical features and habitats
20. Survey two new control points upstream of the sub-survey area and use these points to re-locate total station to a new location and continue the survey upstream.
21. Repeat steps 4-20 until the entire survey (≤1000 m NEON aquatic reach) is completed.
22. When in the portions of the reach that has the Riparian Transects 1 and 10, repeat steps 6-8.
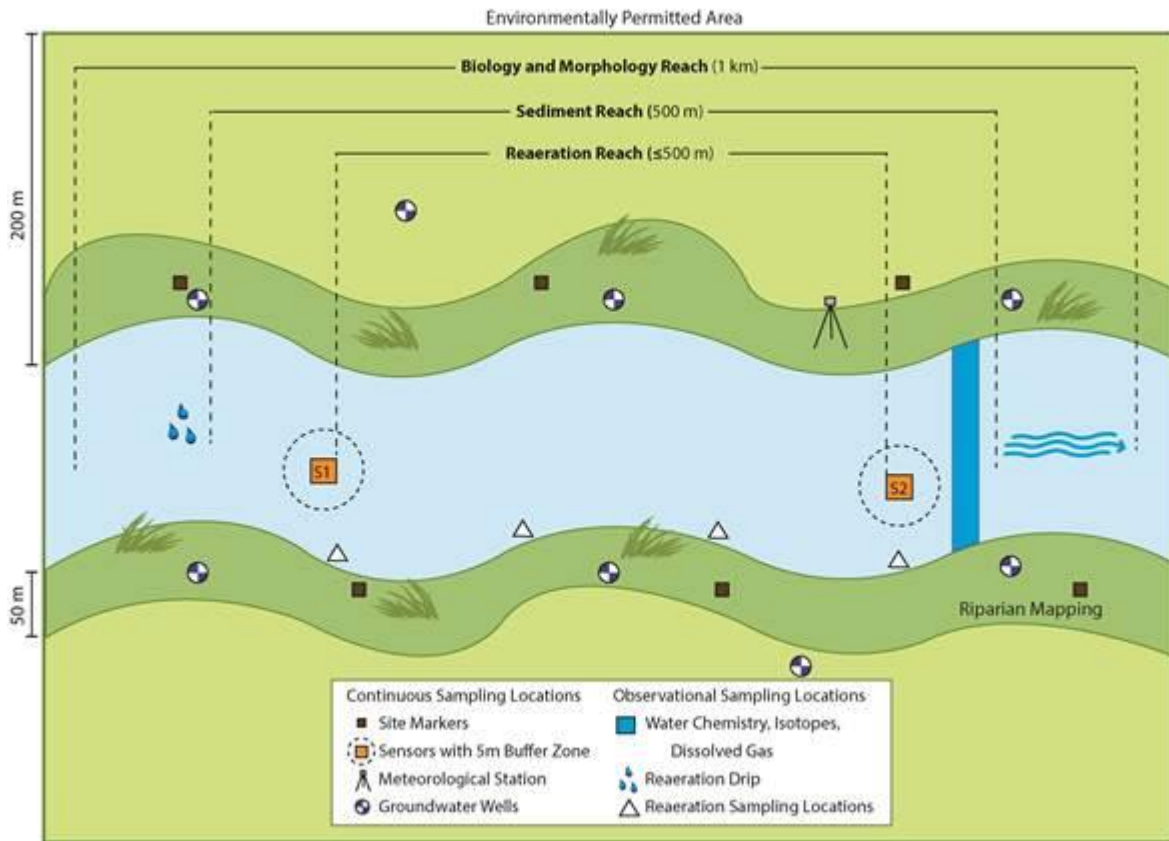
Figure 1. A generic site layout example

4   SAMPLING SCHEDULE

4.1   Sampling Frequency and Timing

The wadeable streams morphology protocol is executed once per year at NEON wadeable stream sites. Morphology survey bout dates will be selected several weeks ahead of time and will coincide with periods of expected baseflow conditions, as personnel must be able to safely cross the wetted portions of the channel.

NEON has five total stations available for use between all domains. Survey dates will need to be coordinated between Domains to coincide with availability of the survey equipment. The units will be shipped between Domains or from HQ to Domain offices

Baseline vs. Monitoring Sampling Schedule:

Two versions of the protocol will be executed during site operations. A comprehensive survey of the entire reach and all attributes, referred to as the "*baseline survey*" shall be conducted during site characterization or within the first year of Operations. Subsequent baseline surveys shall be conducted every five years after. An abbreviated version of the protocol, referred to as the *"monitoring survey"* shall be executed during the interim years.

Rapid Habitat Assessment

The rapid habitat assessment SOP is done once during 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 two technicians for 4-8 hours of work per site on one day during characterization.

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 Morphology SOPs.

4.1.1   Baseline Survey
The baseline survey consists of a series of cross-section and longitudinal profiles of the reach. The baseline survey shall capture the following data:

- Cross-section profile at the downstream aquatic reach boundary
- Cross-section profile at the AIS discharge transect
- Cross-section profile at the upstream aquatic reach boundary
- Thalweg position along the entire reach
- Elevation of the water surface and bank boundary (wetted edges/edge of water)
- Bankfull Indicators (BFI). The exact location of BFI's from the previous year shall be located using the POC and resurveyed each year.
- Location of the top, toe, and slope breaks along the channel bank
- Floodplain topography
- Extent of floodprone width
- Locations of all NEON infrastructure including groundwater wells, power boxes, met station, and AIS sensors
- Locations of woody debris, pools, riffles, and other notable in stream features
- Location of biology markers (plant transect location markers P01-P10, Fish reach markers (F01-F11)

4.1.2 Monitoring Survey

The monitoring survey is an abbreviated version of the baseline survey that consists of cross-section profiles and longitudinal profiles of the reach. The monitoring survey shall capture the following data:

- Cross-section profile at the upstream and downstream aquatic reach boundaries
- Cross-section profile at the Riparian Transects 1 and 10
- Cross-section profile at the AOS discharge transect

- Thalweg position along the entire reach
- Bankfull Indicators. The exact location of BFI's surveyed during the previous year shall be uploaded prior to the survey and located using the POC. This will ensures the position of BFI's are tracked annually.
- Locations of woody debris, pools, riffles, and other notable in stream features
- Locations of all NEON infrastructure and AIS sensors, if applicable

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 light rain. However, the protocol shall be temporarily ceased if hazardous conditions (e.g., lightning or flooding conditions) threaten the safety of the personnel. The protocol may be halted and resumed on a different day without compromising data quality. Morphology survey dates should also coincide with minimal planned biological or chemical sampling in the stream reach so as not to compromise data involving other protocols. 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.

At sites with heavily vegetated riparian zones consisting of trees or shrubs growing above 1.5 m tall, selecting periods in the spring or fall before leaf-out will enhance the ease of execution for the wadeable streams geomorphology protocol. The survey method requires a direct line of site between the total station and the points being surveyed. Therefore, surveys conducted during vegetation senescence are far easier to conduct relative to periods of leaf-out.

4.3 Timing for Laboratory Processing and Analysis

All raw survey data points and associated data files shall be downloaded from the total station POC to an external drive (e.g., USB key supplied with the total station) and uploaded to a network drive at the Domain support facility within 12 hours of the completion of the survey.

4.4 Sampling Timing Contingencies

Table 1 Contingent decisions

Delay/Situation	Action	Outcome for Data Products
Nightfall	Measure and record two control points (CP) or	No change to the outcome of data products if COP and BEN points are

	benchmarks (BM). Turn off instrument. Return to site and begin with a New Station (NewSta) setup using the CPs or BMs	shot correctly and the total station is level.
Heavy rainfall or rising water levels in the channel	Survey two CP or BM's. Turn off instrument, cover with waterproof covering (e.g., heavy weight clear garbage bag), then move to higher ground. Once waters have receded begin with New Station set-up and resume the survey.	The re-orientation of the survey will not be impacted. However, there may be changes in wetted edge depths. The survey shall be continued when water is back to near baseflow conditions.
Dead batteries in total station	Do not move or disturb the tripod or total station. Change the battery, turn on, check level, establish communication with the POC, and continue with the survey	No expected change in data products is expected. After changing batteries the crew should re-shoot the nearest benchmark and verify that the instrument was not disturbed. If disturbed, see "Accidental movement of tripod and total station" below
Accidental movement of tripod and total station	Reset total station into proper place. Perform new station setup (NewSta). Ensure tripod and total station are level, establish communication with POC, shoot the two nearest COPs or BMs that have been previously surveyed prior to the station being disturbed, set new station location and continue with survey from the new station location. If the station was slightly bumped, check level, and take a backsight shot to a COP or BEN and verify the measurements are the within the error range.	Misaligned coordinate system and skewed survey points
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 the prism and the point of the prism pole are not plumb (i.e., the prism pole is offset from the normal line to the feature) results in an incorrect measurement of x,y, and z coordinates.

4.5   Quality Control and Quality Assurance

The procedures associated with this protocol will be audited according to the Field Audit Plan (RD[05]). Additional quality assurance will be performed on data collected via these procedures according to the NEON Data and Data Product Quality Assurance and Control Plan (RD[06]).

Collection of previous control point locations following the move of the total station to a new location are useful to estimate the error associated with the new data resulting from the relocation of the total station. When the total station is moved to the new location following SOP D and the new station is accepted by the total station; re-survey the previous two control points of the previous section surveyed.

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 ≥ 10 ft^2/s (0.93 m^2/s).

6 PERSONNEL AND EQUIPMENT

6.1 Equipment

Table 2 Equipment list – [Total Station Survey]

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items						
MX109898	R	HILTI POS 180 Robotic Total Station and POC data collector	Measure and collect survey data	All	1	Y
MX107405	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	R	HILTI POA 360° mirrored prism	Mirrored target for total station measurement shots	All	1	N
MX107407	R	Sokkia heavy duty fiberglass tripod	Supports and orients total station	All	1	N
MX102549	R	Trimble$^{©}$ GEO XH 6000 GPS receiver	Locate and mark benchmarks and	All	1	N

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
			control points			
Part of MX109898	R	POA 84 Battery for the POS 180	Power for POS	All	2	Y
Part of MX109898	R	POA 86 battery charger for the POC 180	Charge batteries for POC	All	2	Y
Part of MX109898	R	Hilti application software USB key	Access HILTI updates	All	1	N
Part of MX109898	R	POC Controller with Stylus	Operate total station from pole	All	1	N
Part of MX109898	R	POA battery for the POC 100	Power for POC	All	2	N

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Part of MX109898	R	POA 81 AC adapter for POC 100	Charge battery for POC	All	1	N
Part of MX109898	R	POA 100 Accessories case (tools)	Change battery on POC	All	1	N
Part of MX109898	R	POA 76 Frame clamp	Attach POC to prism pole	All	1	N
	S	Camera	Photo document the reach and associated features	All	1	N
	R	Pin flags	Used to mark locations of control points, benchmarks, and survey boundaries	All	25	N
	R	Compass	Verify orientation of the survey	All	1	N

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
	R	50m measuring tape	Measure and layout	ALL	1	N
	S	Radios	For communication between team members	All	1 per person	N
	R	Rain Cover (e.g., heavy duty plastic bag)	Rain Cover for Total Station	Rain	1	N
Consumable items						
	R	Flagging tape, orange	Mark features	All	1 ROLL	N

R/S=Required/Suggested

Table 3 Equipment – Rapid Habitat Assessment

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
			Durable items			
	S	Clipboard	Recording data	All	1	N
	R	Waders (hip or chest) or knee boots	Wading	All	1 pair/ person	N
	R	Handheld GPS unit (recreational or Trimble)	Record waypoint	Habitat survey	1	N
	R	Meter tape	Measuring features	Habitat survey	1	N
	R	Meter stick or foldable meter stick	Measuring depth or pebble size	All	1	N
	S	Metric ruler	Measuring pebble size	Pebble count	1	N
			Consumable items			

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
	R	Field data sheets (all-weather copier paper, write in pencil)	Recording data	All	1 set	N

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 total station; 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; and 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

The POC operator must have the ability to distinguish between red and green colors emitted by the total station during connection and communication with the POC unit; and also be able to hear a single three-bell ring that confirm connection between the total station and the POC.

6.4 Estimated Time

The time required to complete the baseline or monitoring survey will vary depending on a number of factors, such as skill level, system complexity, environmental conditions, and reach length. Other factors that reduce the ability to maintain line of sight between the total station prism (e.g., vegetation, water depth, and gradient/steepness of the channel) will also impact the time it takes to complete the survey. A skilled two person team is capable of surveying 600-800 m (800-1000 individual points) of a complex reach in two 8-hour work days. This includes site preparation time, surveying of benchmarks, and completion of pre-survey QA/QC tasks. The completion of the baseline survey is expected to take between 20-40 hours depending on the factors listed above. The abbreviated monitoring survey is expected to take 12-16 hours due to the reduction in data points collected. The timeframe provided is an estimate based on completion of all tasks by a skilled two-person team. Use this estimate as a guide for assessing progress. If technicians feel a task is taking significantly longer than the estimated time, a problem ticket should be submitted.

7 STANDARD OPERATING PROCEDURES

SOP A Preparation for Sampling

Preparation for executing the wadeable stream geomorphology survey primarily involves ensuring that all necessary equipment is functioning properly and ready for use in the field.

A.1   Equipment and Supplies

23. 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 from its case and check for signs of damage.
    e. Ensure that primary and backup batteries for the total station and GPS are fully charged.
24. Print a list of benchmark location coordinates and/or a site map that depicts the location of benchmark locations on weatherproof paper.
25. Load benchmark location files into the Trimble GEO XH 6000 receiver (see section A.1)
26. Prepare a field kit with all equipment listed in Table 2.
27. Be sure to bring adequate water and food, as the morphology surveys will require a full day in the field.

A.2   Total Station Components

Front view of Hilti POS 180 Robotic Total Station

Rear view of Hilti POS 180 Robotic Total Station

1-Handle
2-Focusing knob
3-Vertical Drive
4-horizontal drive
5-tribrach lock

6-Sight
7-Telescope
8-Objective lens
9-Guide light
10-Operator keypad
11-Display

12-Radio antenna
13/14-Battery compartment
15-Circular bubble level
16-Eyepiece
17-Tribrach screw
18-Laser plummet

Figure 2. HILTI POS 180 Robotic Total Station. Photo from www.us.hilti.com

A.3   Total Station Operator Keypad

The operator keypad is located on the front of the total station (**Figure 2**). The keypad is used to turn the total station 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 total station prior to beginning a survey (**Figure 3**).
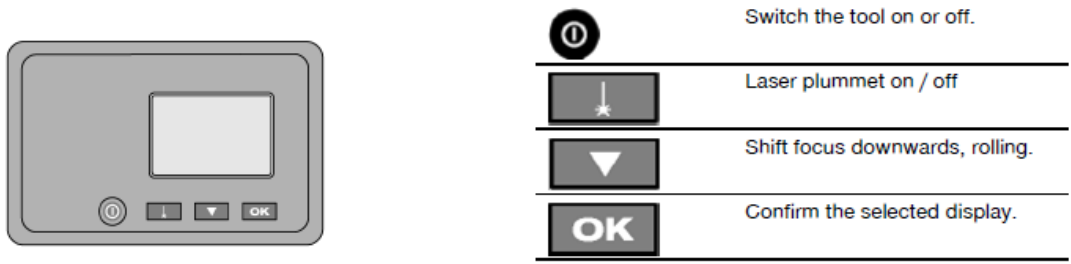
Figure 3. HILTI POS 180 keypad. Photo from www.us.hilti.com

A.4 POC Components

The POC is the data collection unit (**Figure 4**) that can be attached and operated from the prism pole. The POC may also be operated as a hand-held device when removed from the prism pole.
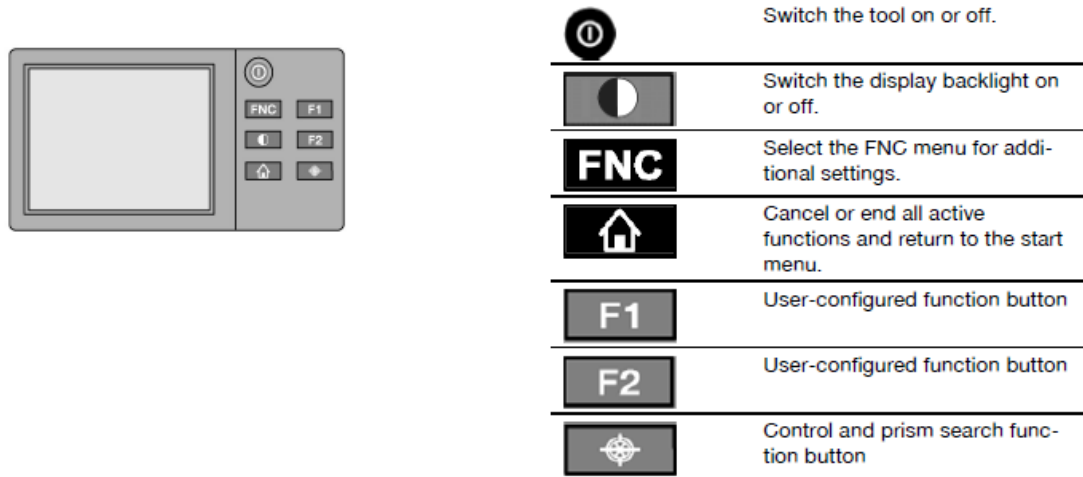

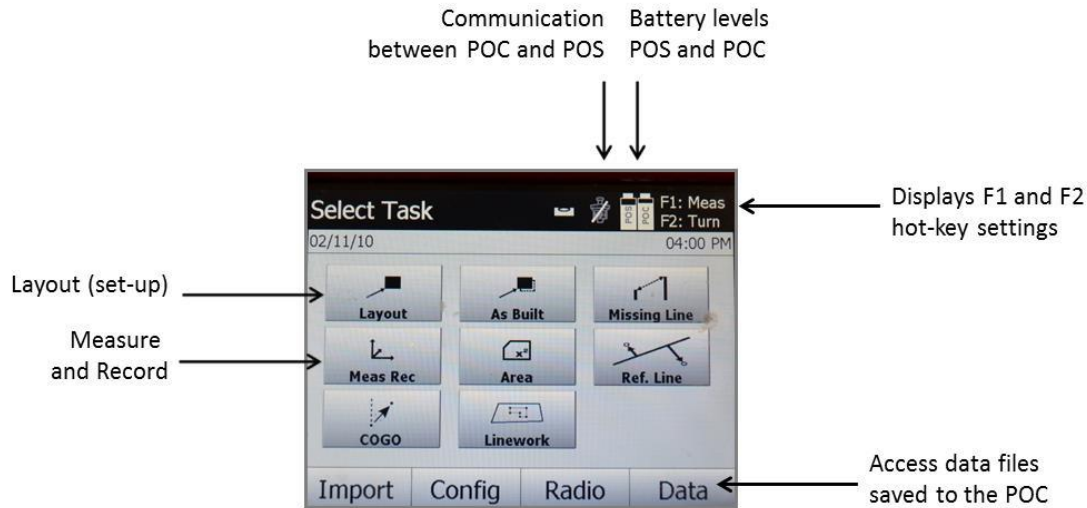**Figure 4.** HILTI POC unit keypad. Photo from www.us.hilti.com

Figure 5. Home Screen on Hilti POC for the total station.

A.5 Transferring Relevant Data Files to the GPS Receiver

Data to help you navigate in the field, such as coordinates for benchmark locations, should be imported into the GPS unit so that they can be navigated to easily. Benchmarks may become covered with debris, rendering them difficult to locate in the field without navigation capabilities in a GPS receiver.

1. Connect the 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 (Win7 or Vista) 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.

a. To import a benchmark location data file, go to **Utilities → Data Transfer…** and in the window that appears, click the **Send** tab followed by **Add…** and select **Data File** from the list. Select the desired data file(s) and click **OK**.

b. If a specific data dictionary is desired, click **Add** and select **Data Dictionary**, browse for the appropriate GPS data dictionary location in the shared drive, select all applicable data dictionaries and click **Open**.

c. If a background is desired, once more click **Add** and select **Background**, browse for the desired background and click **Open**.

d. After selecting all file types to transfer to the GPS click **Transfer All.**

6. In the TerraSync software on the GPS, select the transferred image(s) as the background.

a. Use MDD and tap on **Map,** from this pane go to the **Layers** SDD and click **Background Files…**

b. In the list of files, select which image file(s) you would like to use as background and click **OK**.

c. To temporarily turn off the background image (to reduce software wait times) go to the **Layers** SDD and un-check **Background**.

7. When transfer is complete, eject the GPS drive (if needed) and disconnect USB cord from both PC and GPS.

a. Make sure the GPS is fully charged before heading to the field.

A.6   Survey Site Preparation and Layout

1. Ensure the General AQU Field Metadata Sheet (RD[06]) is completed. Be sure to record any weather conditions at the start of the survey

2. Record the stage height of the stream in datasheet (RD[05])

3. Locate benchmark points using waypoints stored in the Trimble GEO XH 6000 GPS receiver

4. Flag all benchmark and initial control point locations

A.7   Robotic Total Station Set-up

1. Set up tripod and total station at a point close to all three benchmark points.

2. Fully unfold the tripod so the legs are spaced at even intervals (**Figure 6**) and position the tripod head directly over the benchmark location.

a. Make sure that the tripod shoes are firmly fixed into the ground by stepping on the foot pedals until they are flush with the ground.

b. Alternatively, the tripod may be set up on a large flat boulder, road or other fixed structure

3. While the tripod and total station are being set up, the other technician should locate the first two benchmark points to be shot for orientation of the total station.

4. Place pin flags that mark the sub-section of the reach to be surveyed. The distance for the survey sub-section is determined by the line of sight between the TS and prism. **NOTE: it is important to mark and abide by the flagged sub-sections in order to avoid repeating survey points or missing sections.**

5. Place the HILTI POS 180 Robotic Total Station onto the tripod head. Support the total station with one hand while tightening the centering screw (#18) on the bottom of the unit to ensure it is secured to the tripod (**Figure 6**).

6. Turn on laser plummet and set station directly over the center of the benchmark cap on the ground.

7. Level the total station by adjusting the tripod legs until the bubble is completely in the center area (**Figure 7**).
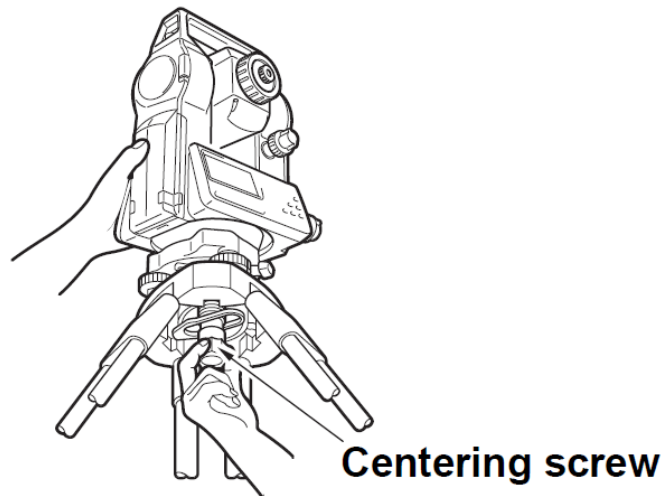
Figure 6. Attaching the total station to the tripod

8. Turn on the total station
9. Use total station keypad and screen to view level of the total station (**Figure 8a**)
10. Fine adjust the level of the total station using the tribrach screw knobs (**Figure 2 #17**) until the display screen indicates the total station is level (**Figure 8b**)
11. Press [OK]. The total station is now leveled and ready for use.
12. Establish communication (via Bluetooth wireless) between the total station and the prism pole/POC unit. See section A.8.
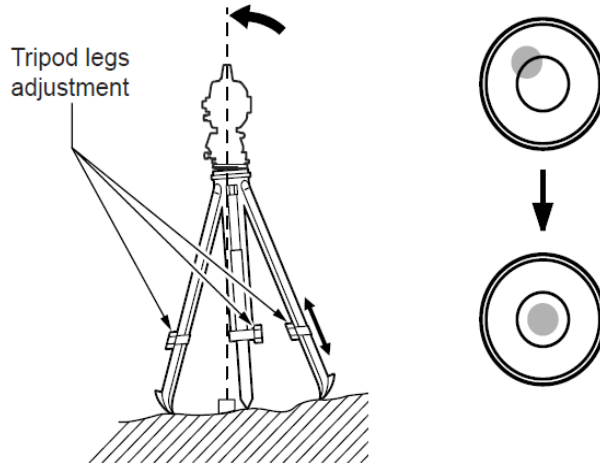
Figure 7. Leveling the tripod using the bubble level
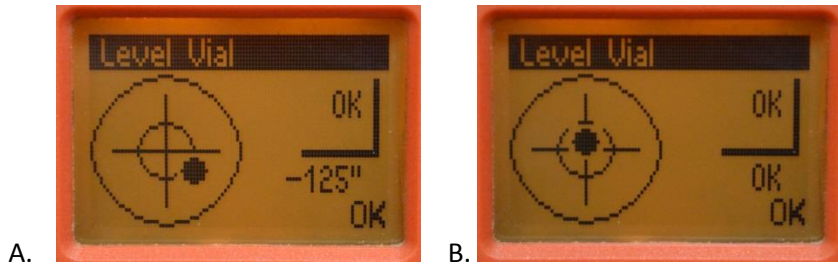
Figure 8. POS 180 display screen leveling application. A.) Total Station not level. B.) Total Station is level.

A.8 Establishing Connection between the Total Station and Prism

1. Press the search button on the POC (**Figure 4**).
2. Press [G'light:ON] button (**Figure 9**)
   a. Setting options for the guide light
      1) OFF
      2) Flashing frequency-slow
      3) Flashing frequency-fast
      4) **Flashing frequency-AUTO (with this setting, the light flashes only if there is a loss of connection to the prism pole.**
3. Set guide light option to "Flashing frequency-auto"
   a. **If the flashing red/green light is in the activated state, a person can see either a green or red light depending on which side of the sighting line the person is located.**

   b. **A person (i.e., the prism) is in the sighting line if both colors can be seen at the same time.**

4. Stand at least 5 m from the total station holding the prism pole upright with the prism in direct line of sight of the station.

5. Adjust your position until both colors (red/green) of the guide light are visible.

6. Hold prism pole in place and press the prism search button ⊕ on the POC (**Figure 4**).

7. Remain still until you hear a single three-bell ring, meaning the total station has connected with the POC controller and is in view of the prism.

8. If the prism and total station are NOT in contact a red line will display through the prism icon on the POC. **When communication is lost the POC will beep a three-ring tone. NOTE: WALK WITH PRISM POLE UPRIGHT (90° TO GROUND) WHEN MOVING. THIS WILL ALLOW THE TOTAL STATION TO FOLLOW THE PRISM AND MAINTAIN COMMUNICATION.**

   a. If there is an obstruction in the line of the site and communication is lost, return to the point where the communication was lost, align with the red/green guide lights and press the prism search button on the POC.

9. Once communication between the total station and the prism is established, continue to SOP B (Survey layout and Benchmarks).
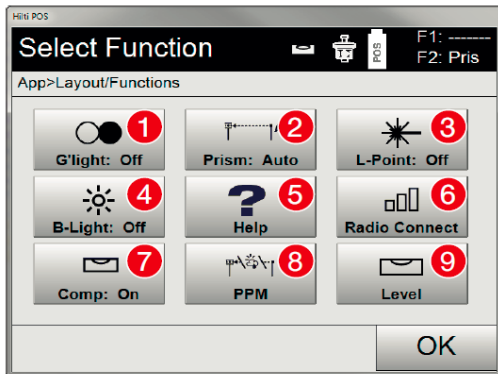
Figure 9. Layout applications functions screen on the HILTI POC

SOP B   SURVEY LAYOUT AND BENCHMARKS

Each survey must include the proper measurement of the survey location and GPS coordinates of a series of benchmark and control points that span the survey area. The locations and coordinates of benchmarks [code: BEN] and control points [code COP] are necessary a) to convert the total station data to a geographic coordinate system, b) to add base layer imagery to the map, and c) for proper re-orientation of the survey coordinates during repeat surveys.
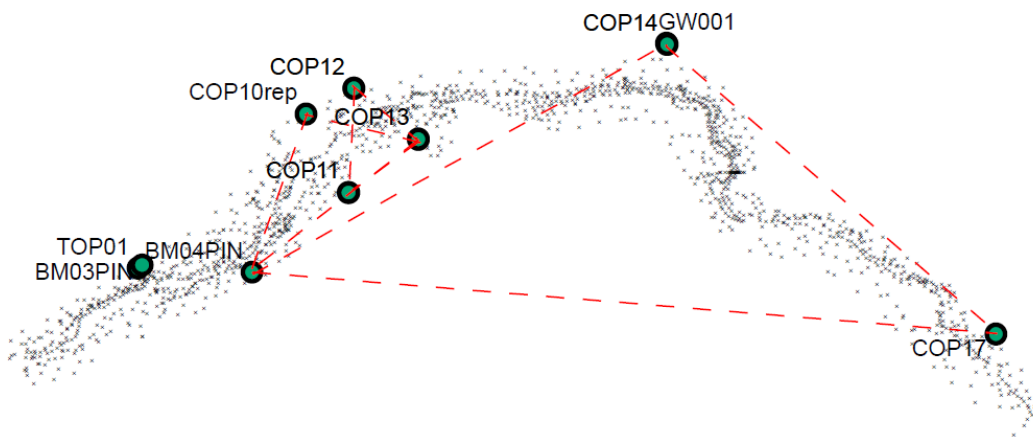
Figure 10. Benchmark layout scenarios. Green circles are benchmarks or control points distributed along the reach. BEN or COP's that lie in an equilateral triangle are used for converting the total station data to a geographic coordinate system. The triangle formed by BM04PIN, COP14GW001, and COP17 provided the best results during transformation of the total station data.

1. Verify that the tripod (bubble level) and total station (display keyboard function or check from the POC) are level.
2. Turn on the laser plummet and measure the height of the instrument over the first benchmark point. **Record the benchmark identification number by benchmark number and year of benchmark survey (e.g., BEN0012015), height of the instrument over benchmark, and the GPS coordinates into the datasheet.**
3. Turn on POC
4. Establish communication with total station
5. Go to [MEAS REC]
6. [NEW JOB]
7. [NEW]
8. Click box for Job and enter Job Name using the format SITE ID-YYYY-MM-DAY (e.g., ARIK-2015-04-15)
9. [OK]
10. [NEW STATION]

    a.   HEIGHTS ON

    b.   POINT SYSTEM- BLDG LINE-3pt

11. [OK]
12. Enter the height of the prism under [HR]
13. Put prism over 1st benchmark (BEN001) and Measure
14. Put prism over 2nd benchmark (BEN002) and Measure
15. Put prism over 3rd benchmark (BEN003) and Measure

16. [STAT H]
17. [MAN H]
18. Set the height of the total station in the POC. Select [HI] and enter the height of the total station (measure from ground surface to the horizontal line of the "+" on the side of the total station to the nearest 1cm).
19. Place prism pole on the benchmark, assign the BEN elevation as 1000m, and measure this point. Be sure the height is saved as 1000m in the POC prior to taking the shot.
    a. 1000 m is an arbitrary number that is used as a placeholder for the z coordinate origin. When the data is transferred to ArcGIS the elevation will be adjusted to the actual value.
20. [OK]
21. [SET]
22. [OK]
23. The station location is set and can now measure and record new data
24. Go to first point you want to record and start the survey (SOP C)

SOP C   DATA COLLECTION METHODS

The collection methods for the geomorphic survey require precision and accuracy. The survey method uses a "point cloud" system to capture changes in topography of the channel; inflections of the thalweg, wetted edges, location of mid-channel features, etc. A complete list of all features that shall be surveyed is found in the next section. The complexity of stream channels varies at every site. For this reason, the amount and distribution of survey points will also vary. The amount and distribution of survey points is solely dependent on the complexity of the area being surveyed. **There is no "set" number of points for a reach. It is important to consider how the data that is being collected will be used. The geospatial analysis of the survey data will result in spatial smoothed data that represents a digital elevation model (DEM) of the stream channel and floodplain. Typically, the DEM will have a resolution of >1 m.** Keep this in mind when collecting data for changes in topography or locations of features. For example, a "complex" channel morphology with a 10-15 m long meander bend will require greater coverage (i.e., collection of data at points that are close enough to capture the true form of the channel), whereas a section of the channel that is a straight "simple" morphology may only require 2-3 points to capture the geometry. See **Figure 11** for a schematic of point distribution between a "complex" and "simple" reach.

The overarching goal of the protocol is to conduct a survey that is geometrically representative of the stream channel and floodplain. The survey data shall be used to generate morphology maps that capture changes in the geometry of the stream channel and floodplain over time. When conducting a survey of a particular reach, be aware of the site layout and overall geometry of the landscape. **Collect survey points at inflections, or changes in slope.** When surveying streambed topography avoid capturing aspects of bed roughness (e.g., boulder substrate) and **focus on the overall changes in the topography of the bed.**
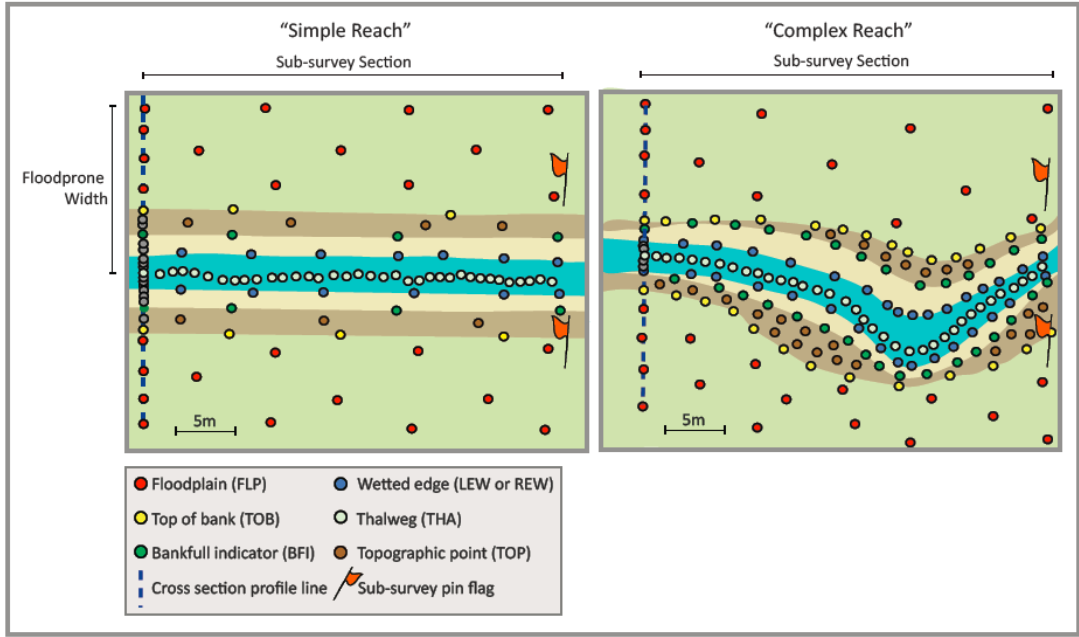
Figure 11. Schematic of point distribution between a simple and complex reach

C.1   Survey Codes

Table 4. Survey codes for data input into total station

Feature Description	Code
WATER CODES	
Left edge of water (looking downstream)	LEW
Right edge of water (looking downstream)	REW
Mid-channel edge of water	MEW
Wood/Log Jam edge of water	WEW
Side channel edge of water	SEW
CHANNEL FEATURE CODES	
Bankfull indicator	BFI
Thalweg	THA
Topographic point (e.g., change in elevation, slope or line of inflection along the channel bed)	TOP
Top of Bank	TOB
Toe of Bank	TOE
FLOODPLAIN CODES	
Flood Prone	FLP
Topographic point (e.g., slope breaks, abandoned channels)	TOP
CHANNEL HABITAT CODES	
Pool Head	POH
Pool tail	POT
Pool max depth	POM
Riffle Head	RIH
Riffle Tail	RIT
Large Boulders	BLD
Individual Woody Debris	WOD
Log Jam	JAM
Wood in Floodplain	WFP
Other small woody debris Jam (e.g., snag, beaver dam)	OWD
MISCELLANEOUS CODES	
NEON Sensor Sets (1 – upstream, 2- downstream)	SS1, SS2
NEON Met Station	MET
Groundwater Wells (GW)	GW1-GW8
Plant Transect Locations	P01-P10
Fish Reach Locations	F01-F11
Foresight	FOS
Backsight	BAS
Benchmark	BEN
Control Point	COP
Break Line	BRK

C.2   Collecting Data Points using the Total Station-POC and Prism pole with 360° Mirrored Prism

1. Place the prism pole with mirrored prism on top of the point of which you want to measure the elevation and survey the position. **If the substrate is soft do not push the pole into the ground. This will give a false reading of the elevation. Gently rest the pole on the substrate, prevent it from sinking by holding it at the correct level.**

   a) The prism pole must remain in the plumb position. Plumb meaning that the rod is held vertical and is not tipped to the side. Use the plumb level on the prism pole to ensure the rod is set correctly before shooting the point with the total station. **If the rod moves during the shot, reset the prism pole and re-shoot the point. If you believe there was an error it is always better to re-shoot the point.**

2. When the rod is plumb (use bubble level on rod) press [Meas Rec] button on POC

   a. Alternatively, The F1 hot key on the POC is set to the [Meas Rec] function

3. Name point by selecting [Pt ID] and use the keypad to enter point identification. See **Table 4** for codes. Use format TOP01…TOP02…TOP03

4. Press [OK]

5. Select [HR] and enter in the rod height, i.e., the height of the prism. HR is read from the numeric graduations on the prism pole.

   a. **All HR's are reported in meters (m) with two decimal places, e.g., 2.55, or 2.00. It is advised to set the rod height at a workable distance and do not adjust unless absolutely necessary. When the HR changes it must be changed in the total station using the POC prior to taking the survey shot. If the HR changes and it is not changed on the POC then the shots must be retaken. The best advice is to change the HR as few times as possible. During windy conditions, chose a HR that is as low as possible to avoid wiggling of the prism during data collection.**

6. Press [OK], and this returns you to the measure points screen

7. On the Measure Points screen press [M&R] or hotkey F1

8. The POC screen will show "measuring distance" and when data collection is complete "Point 'TOP01' was saved"

   a. To check if the data was collected return to the home screen on the POC (**Figure 5**) and select [Data] and all points will be available to view as a text or map file. Use the POC screen to navigate to the proper job name and data file.

9. Move the prism pole and prism to the next point

10. If the next point is in the same code (e.g., TOP) then press F1. The point will be named using the next numeric number in the series

    a. The alpha code for each point will be entered in the POC. Subsequent times the POC will auto fill a numeric values (e.g., TOP01, TOP02, TOP03) during

consecutive shots of points with the same code. **It is advised to take advantage of this feature by shooting points with the same code consecutively up or down the survey sub-section area to reduce time typing in new numbers. If you return to a feature code that was previously shot the numbering will pick up where it last left off.**

1) When returning to a feature code type in the code identifier and default numeric value 01 (e.g., TOP01), a message on the POC screen will appear "TOP01 is already in use, Use TOP02**".**

2) Select OK. You can now continue to collect data in series for the same code by simply pressing F1 (measure and record).

C.3   Collecting Cross-section Profile Data Points

1. Ensure the total station is at a location that has full line of sight across channel and floodplain at the cross-sectional transect location. **When setting up the total station for the first time at a site be sure that the entire cross-section is in unobstructed view from the total station location.**

    a. Cross-section profiles shall be completed at the following locations:

    1) Downstream aquatic reach boundary

    2) Upstream aquatic reach boundary

    3) AIS Discharge transect

2. Place pins (hereafter known as bankpin(s)) at bankfull on both sides of the stream at the cross-section location.

3. Stretch a measuring tape across the stream and parallel to flow.

4. Record the bankfull width and location on the field data sheet.

5. Place the prism pole (to the stream bed) where the thalweg crosses the measuring tape.

6. Measure the depth of water at the thalweg point; this is the max bankfull depth.

7. Record the max bankfull depth and distance along the tape to the nearest bankpin on the field datasheet. **Be sure to record which bankpin (L or R edge) the measurement references**.

8. Multiply the max bankfull depth by 2 to determine the 2x max depth.

9. Use the prism pole and prism (set prism pole height to the 2x max bankfull depth) find the corresponding bank locations that are in direct horizontal alignment with the prism
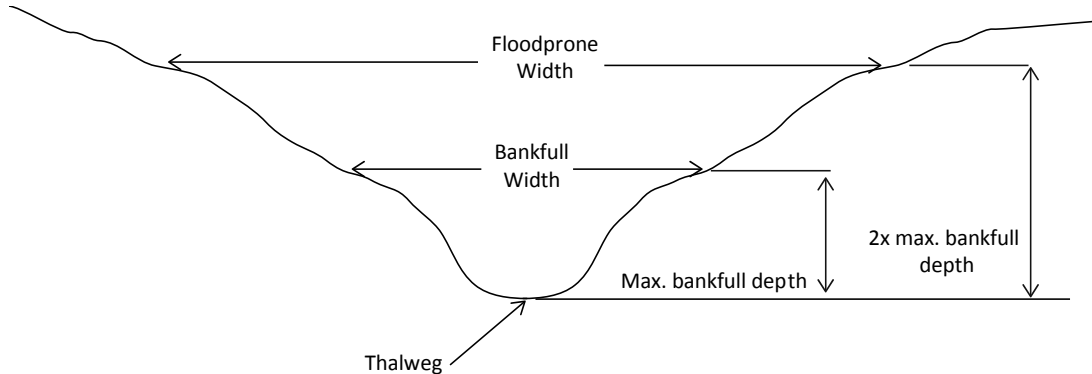
Figure 12. Channel cross-section widths and flood prone width.

10. Spot the locations on each bank and place pin flags. **Complete this step with two people: one holding the prism pole and the other places the flags.**
    a. The flag marks the flood prone width, and extent of the floodplain survey for the reach**. Keep in mind that the actual distance from the stream to the flood prone extent may change as you move up the stream. Use vegetation type or other features (i.e., trees, sand deposits, etc.) to spot the flood prone width between measured cross-sections.**
11. Start the cross-section profile survey at the right bank flood prone width flag. **If the extent of the flood prone area is wider than the permitted area, survey only to the permitted boundary and denote a stop in survey using the BRK code**.
12. Survey points on the floodplain [FLP]. **Take no less than 4 FLP data points between the flood prone width and the bankfull tape.**
    a. If the area is flat take points at close to equal spacing.
    b. If the area contains changes in topography be sure to capture the points of change in elevation between the flood prone width and bankfull.
    c. Be sure to stay in line with the bankfull tape when shooting flood plain points. If necessary extend the tape out to the flood prone width to guide you.
13. Continue collecting surveying points across the channel along the measuring tape (e.g., a straight-line that connects the two benchmarks and is perpendicular to the stream flow).
14. Collect survey data at the bankfull pin (code BFI) and again at an increment equal to bankfull width (m) divided by 20. For example the increment for a 10 m reach would be 0.5 m (10 divided by 20). Do not use increments less than 0.1 m.
    a. Collect data at right and left edge of water [REW or LEW], top of bank [TOB], toe of bank [TOE], thalweg [THA], and at breaks in slope along the bank [TOP].

15. While technician 1 (T1) is completing the cross-section profile, technician 2 (T2) shall determine the percent composition of the wetted channel substrate at the transect as a percentage of each size class
    a. Bedrock (smooth bedrock surface)
    b. Boulder (basketball size or larger)
    c. Cobble (basketball to baseball sized)
    d. Gravel (baseball sized to marble sized)
    e. Sand (individual grains that are gritty when rubbed between fingers)
    f. Silt (individual grains that are smooth when rubbed between the fingers)
16. Record location and substrate classification on the field datasheet

C.4   Collecting Longitudinal Profile Data Points

The longitudinal profile consists of a series of points that map wetted edges/edge of water, thalweg position, bank geometry, and floodplain topography. Collection of longitudinal data shall occur along the entire aquatic reach. The survey will have to be broken up into workable sections called sub-survey sections, which will be marked using pin flags. The sub-survey section shall be delineated prior to beginning the longitudinal profile and each time the total station is moved upstream. The sub-survey section shall be marked out and extend as far as possible from the total station and in complete line of sight of the total station. The total station (in prism mode) can reliably measure distances up to 2000 m. However, under field conditions this is not the case. Obstructions (e.g., vegetation, boulders, entrenchment, and abrupt changes in channel direction or elevation) in the line of sight between the total station and the prism limit the achievable working distance during the collection of longitudinal profile data points. The use of sub-survey sections breaks the work into smaller, more manageable parcels and ensures that sections of the reach are not missed or excessively overlapped when the total station is moved to a new location. The longitudinal survey shall be conducted by two technicians. Technician 1 (T1) is the POC/POS operator and technician 2 (T2) places pin flags and assists T1 with the survey.

As a general guide, take a minimum of 20 and maximum of 100 measurements of each code (e.g., FLP, TOB, TOE, BFI, THA), when present, per 100 m of reach while conducting the longitudinal profile survey.

The following illustrations show examples of the suggested locations of survey points and codes for features that shall be surveyed while executing the protocol.

A.
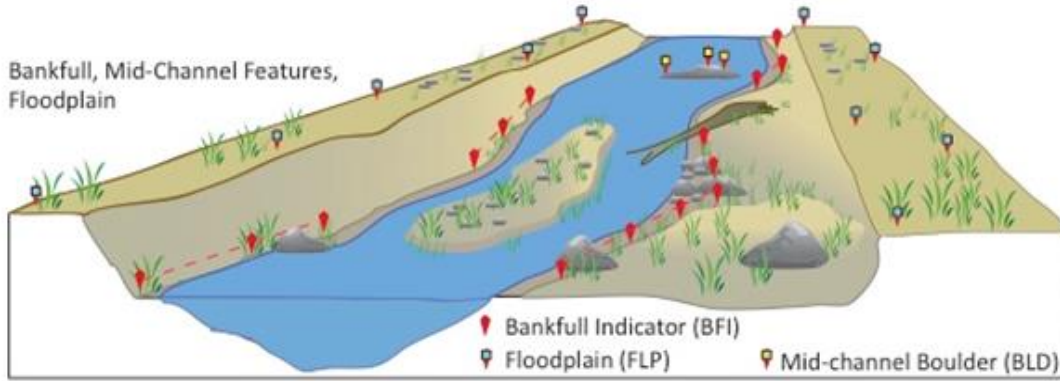
Bankfull, Mid-Channel Features, Floodplain
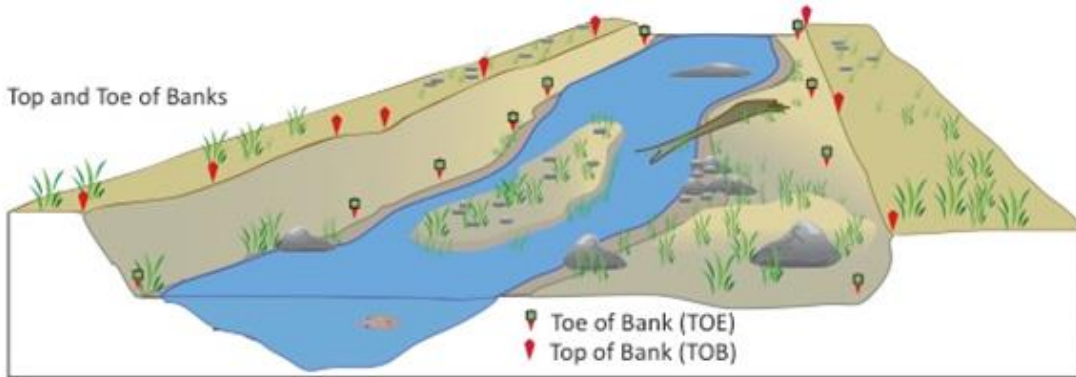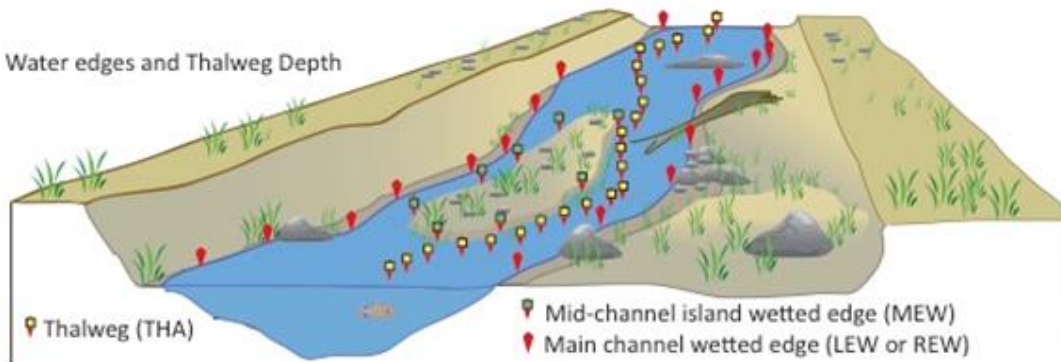
- Bankfull Indicator (BFI)
- Floodplain (FLP)
- Mid-channel Boulder (BLD)

B.

Top and Toe of Banks

- Toe of Bank (TOE)
- Top of Bank (TOB)

C.

Water edges and Thalweg Depth

- Thalweg (THA)
- Mid-channel island wetted edge (MEW)
- Main channel wetted edge (LEW or REW)

D.
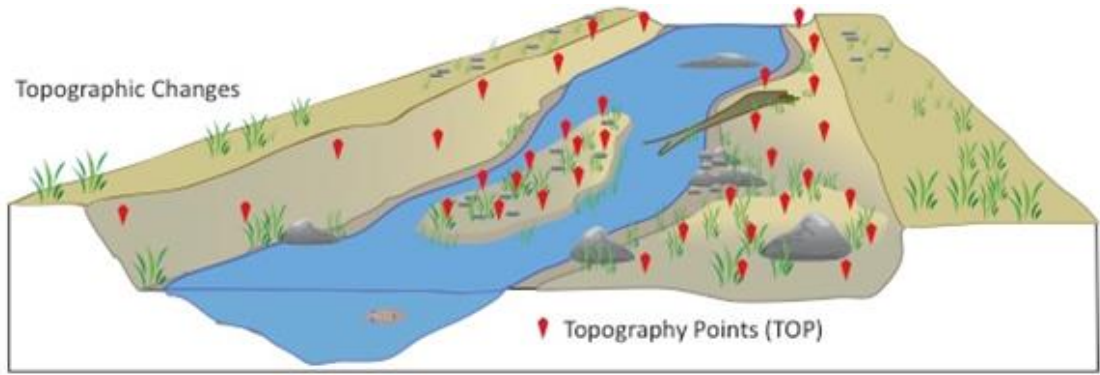
E.

Figure 13. Examples of suggested locations for data collection and codes associated with features surveyed during execution of the protocol.

1. Place new pin flags at the furthest upstream location that is in full line of sight with the total station. The flags are used to demark the boundary of the "sub-survey section" and prevent sections from being missed or overlapped when moving the total station to a new point upstream.

2. Place pin flags along the bank to identify features within bankfull that need to be surveyed including:
   a. Woody Debris, wood jams, mid-channel features (e.g., large boulders), islands, and bars.

3. T1 shall begin to collect total station data in the sub-survey section beginning at the right bank flood prone width point that was determined during the cross-section survey.
   a. **At this point T1 may work independently while T2 executes other protocols. T1 and T2 may also work cooperatively on the survey (preferred method, when possible).**

4. Collect data at a point every 10 m along the flood prone width location [code: FLP] while walking upstream. When you reach the pin flag denoting the end of the sub-survey section, turn around and collect data for the flood plain [code: FLP]. See **Figure 11A and Figure 13A.**

5. Collect data on the flood plain code [code: FLP] by walking in a zigzag pattern downstream collecting at least one data point, approximately every 5 m, work back to the start of the sub-survey area. See **Figure 11A** for point layout**.**

6. When surveying the floodplain capture the location of all groundwater wells [code: GWW] and other NEON infrastructure on the floodplain. See **Table 4** for applicable codes.

7. Work upstream surveying points on the right bank [code: TOB] (**Figure 13B)** until you reach the end of the sub-survey area.

8. Work downstream surveying points along the toe or slope breaks along the right bank [codes: TOE or TOP]. Survey right bankfull indicators [code: BFI], when present.
   a. Pay special attention to areas along the bank with visible topographic relief. A general rule of thumb for capturing bank geometry is to focus on areas of inflection or points of maximum and minimum elevation for a given area.
   b. Survey slope breaks and other topographic features using the code [TOP]. See **Figure 13B-D** for examples of the proper usage of survey codes when entering data into the total station.
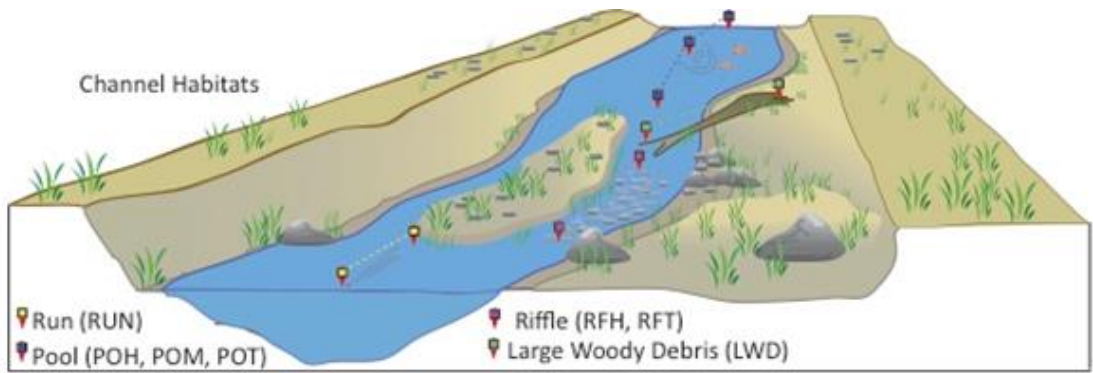   c. **Bankfull edge** is defined as the edge or line along the bank that denotes the elevation of the water surface associated with a peak flow that occurs every 1-2 years (the bankfull discharge). Finding the location of the bankfull discharge can be difficult and is sometimes subjective: see **Figure 13**A for the location of

an idealized bankfull edge, for some guidelines on approximating the bankfull edge, and for examples of bankfull edges in streams.

    d. Take bankfull indicator shots as lines, when the feature is present

    e. Best practice is to survey bankfull indicators (BFI) as short segments. In some cases BFIs are not always obvious. **Pay special attention to sections of the stream where BFIs are likely to be found (e.g., along the outer edge of bends in the stream or along the tops of bars)**

9. Work upstream and survey the <u>right edge of water</u> [code
10. : REW] (**Figure 13C**)
11. Work back downstream and collect data at thalweg points [code; THA] (**Figure 13**C).

    a. THA point measurements shall be taken along the entire path of the wetted channel.

    b. **Be sure to capture inflections and changes in thalweg position that are ≥1.0 m (x,y, or z directions).**

12. While surveying THA measurements, **ALSO** survey other features in the wetted channel including woody debris [code: WOD], wood jams [code: JAM], mid-channel features (e.g., large boulders [code: BLD], islands [code: TOP], and bars [code: TOP]). Each of these features, if present in the channel, **must** be surveyed. Label the features in the total station using the nomenclature from **Table 4**.

    1) If a sensor set is encountered, survey in the position of the sensor sets (code: SS1 or SS2).

    2) If a tributary enters the stream, survey 5 meters up the tributary channel along the thalweg and the top of the bank using the appropriate codes (**Table 4**).

13. Survey <u>topographic features</u> [code: TOP], such as abandoned or secondary channels, depressions, raised areas such as islands or point bars, or any other feature that reflects a notable change in elevation as a result of substrate deposition or removal.

14. Survey <u>woody debris</u> including naturally fallen or artificial (i.e., cut end or manmade structure) wood that lies within bankfull and is in contact with the stream bed at any point. **Wood that spans the channel and does not make contact with the bed is not surveyed**.

    a. Survey the location of the wood by taking a measurement in the middle of the piece (i.e, placing the prism pole on top of the wood in the approximate center of the piece) and on each end. Use the code "WOD" and a numeric value (01.1 for the center of first piece encountered, 1.2 for the first end of the first piece surveyed, 1.3 for the second end of the first piece surveyed, and continue with

WOD02, WOD03, etc. for each subsequent piece encountered as you move upstream.

b. If a wood jam (3 or more pieces of wood are present this is a jam [code:JAM]) is encountered survey a point that lies at the middle of the jam and one on the downstream end. Number as above- first log jam encountered is JAM.01.1 for center, JAM01.2 for end, etc.

   1) Survey the middle of the Jam on the downstream end Use the code JAM01 for the first jam encountered and continue with JAM02, JAM03, etc. for each subsequent piece encountered as you move upstream. Be sure to capture the extent of the jam with respect to the dimensions of the channel.

c. Survey any mid-channel edge of water, when present (code: MEW). This is likely to occur in large jams that divert the flow of the stream.

d. If the wood or log jam extends from the bankfull channel area onto the floodplain survey the edge of the jam that is in floodplain (code: WFP). **This is the only case the location of wood on the floodplain is included in the total station survey.**

15. Work upstream collecting data points along the <u>left edge of water</u>.

16. Work downstream and collect points on the left bank [code: TOB, TOE, TOP], left bankfull indicators [code: BFI], if present. Pay special attention to areas with visible topographic relief. Survey points of inflection and points of maximum and minimum elevation for a given area [code: TOP]. Continue upstream to pin flags. .

17. Work back upstream and collect data at points along the left floodplain using codes [code: FLP] following a 5 m zigzag pattern.

18. Work downstream and collect data at points at ~10 m intervals along the flood prone width

19. Return to the stream and survey the following habitat features, if present

   a. <u>Pools</u>: survey a point along the thalweg that denotes the pool head [code: POH], pool max depth [POM], and pool tail [POT].

      1) **The "head' is the upstream location and the "tail" is the downstream location**

      2) **Be sure that pool feature labels POHXX, POMXX, POTXX for the same pool have the same numeric code, e.g., POH01, POM01, POT01 points are in the same pool.**

   b. <u>Riffles</u>: survey two points along the thalweg that mark the upstream [code: RIH] and downstream [code:RIT] extent of the riffle.

      1) **Be sure that the head and tail of the riffle have the same numeric code, e.g., RIH01-RIF01 is the same riffle.**

   c. <u>Large Boulders:</u> [BLD]

    d. <u>Mid-channel islands:</u> [MEW] and [TOP]

20. The sub-section survey is complete when the survey of habitat locations and physical features are surveyed.

21. If necessary, fill in additional streambed changes using the code TOP. **ADD ADDITIONAL TOP POINTS FOR THE CHANNEL BED IF THE STREAM IS WIDER THAN 2 METERS. This step should be done in streams with complex bed topography and incised beds. The main goal is to collect data points at topographic changes in slope to assist in capturing the complex morphology.**

22. Upon completion of the sub-survey section:

    a. Shoot a backsight to a control point. Record the data for the [code: COP] backsight in the datasheet.

    b. Collect (or have collected prior survey data points) **two** control points [code: COP]. These can be control points that were used for the last sub-section, new ones placed upstream, or a combination of both. COPs used to move the station should be chosen so that when the station is moved to the new location it forms a near equilateral triangle with the COPs. **The angle between the total station and the two COPs should always be 90° or greater.**

        1) When possible, COP's for moving the station should be oriented in a triangular shape with the new station location. This triangle shall span the channel and extend outward into the floodplain. **Refer to SOP D for directions on how to enter the data into the POC and move the station to a new location.**

....   **Bankfull Edge**

- - -   **Toe Slope**

——   **Thalweg**

Figure 14. Examples of bankfull edge, toe slope, and thalweg at NEON wadeable stream sites.

SOP D   MOVING THE TOTAL STATION TO A NEW LOCATION

Moving the total station to a new location is necessary to continue the survey upstream. A majority of the time the station is moved because of obstructions by vegetation or to accommodate dramatic changes in the direction or elevation of the channel. Care should be taken when moving the station since there is the potential for error in combining the data between multiple station locations. When done correctly (i.e., thoughtful and tediously) a seamless continuation of measurements is ensured. Keep in mind that each time the station is moved any error is compounded as the survey continues. Be sure to double check and verify the total station is level, new COP's and BM's are shot correctly and the prism pole/prism is in perfect plumb position, **and most importantly the rod height (HR) is entered into the POC correctly**.

1. Identify two locations that can be used as control points (COP). The COPs selected for moving the station shall lie at two angles of an equilateral triangle. The third angle will be the "new" location of the total station. Be sure that the triangle is a large as possible, spans the channel, and can even exist outside of the FLP points.
2. Place orange survey cap on the ground, or locate a surface that can be marked for the point (i.e., use pin flag).
3. Survey the new COPs. **Each control point should be consecutively labeled beginning with COP01 as the first COP established.** Record the data for the COP on the data sheet.
4. Turn off the total station and remove it from the tripod.
    a. Place lens cap on and secure total station in the carrying case. **Be sure the case is locked before moving it.**
    b. Fold up the tripod legs
5. Move the total station to the new location. This location is the third corner of the triangle.
6. Set the station up **(See SOP A, A.7 for complete instructions on setting up the total station)**
7. Level the tripod
8. Attach the total station
9. Level the total station using the keypad and display
10. Turn on optic plummet laser
11. Reestablish communication between the POC and the total station. Follow the steps below using the POC. […] identifies what selection to make on the POC screen.
12. [HOME]
13. [MEAS REC]
14. [NEW STA]
15. Point System

  a. Heights [ON]
  b. [COORD/GRAPH]
  c. [ANYWHERE]
  d. D [OK]
16. Select a name for the point. Use default Sta1, Sta2, Sta3…
17. [TARGETS], NOTE: Make sure rod height is correctly entered.
18. [PT ID]
19. Use drop down menu to select the point you are on. Do not select the layout point. If you receive a warning notification on the POC that you have selected a design point, return to the list and select the other COP listed.
20. Select the first control point (COP). **One of the points surveyed in Step 3 and the point you are currently on.**
21. [OK]
22. Place the prism on the point [MEAS]
23. Move the prism to the second control point.
24. Select the second COP point from the table
25. [OK]
26. Measure distance to second COP.
27. [OK]
28. [CALC]
29. [SET]
30. [OK]
31. You may now measure and record points from the new station setup location.
32. Return to previous two control points from previous subsection and remeasure both COPs for backsights, then begin to collect points in the new subsection.

SOP E   SURVEY SET-UP DURING SITE REVISIT

Follow these steps for site revisits and QA/QC repeat surveys of sites.

One benchmark present

1. Set-up tripod and total station over the benchmark (See SOP A)
2. Start new job
3. Enter coordinates for benchmark location
4. Establish two new COP's
5. Determine GPS location of COP's.
6. Begin new site layout and shoot COP's

At least two benchmarks are inter-visible (e.g., both benchmarks are visible from the other)

1. Set up the total station over a benchmark point and visible from at least one other benchmark.
2. Open the survey template file on the total station.
3. Name the survey file following NEON convention. SITE ID-YYYY-MM-DAY (e.g., ARIK-2015-04-15).
4. Import the site control file which contain previously established benchmarks and control points. The site control file will have the naming format SiteID-Control-2015.
5. Navigate to the total station setup menu and initiate the setup routine. Choose to set up on a known point and select the appropriate point from the list (i.e., BEN0115)
6. Establish a backsight over a known point to orient the instrument
    a. Orientation of the total station is established by backsighting to a second benchmark that is in view of the current benchmark that the total station is set up on.
    b. Place the prism pole on the benchmark to be used as the backsight
    c. Aim and focus the telescope at the prism cross hairs.
    d. Shoot backsight and record the error in the notebook
        1) Error should not be greater than 0.050m horizontal and 0.030m vertical.
        2) If unable to establish backsight within the range of error see SOP A details for establishing backsight.
        3) If backsight errors are acceptable and three benchmarks are intervisible GO TO OPTION 3. If only two are intervisible go to OPTION 4

SOP F   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 site operations, this SOP will be performed annually to document channel changes and trigger more frequent occurrences of the stream morphology SOPs.

F.1   Habitat Survey

1. Navigate to the downstream permitted boundary of the site using reach boundary coordinates found in the Domain-specific Sampling Design.
2. Record the waypoint (latitude, longitude) and coordinate uncertainty (GPS accuracy) at the downstream boundary (Figure 16).
   a. A waypoint does not need to be recorded at the start of each habitat unit. Record the bottom and top of the reach, and every 10-15 habitat units in between.
3. Determine and record the habitat type of the habitat unit directly upstream of the boundary (Figure 15).
   a. Riffle
   b. Run
   c. Glide
   d. Pool
   e. Step pool
   f. Other (define)
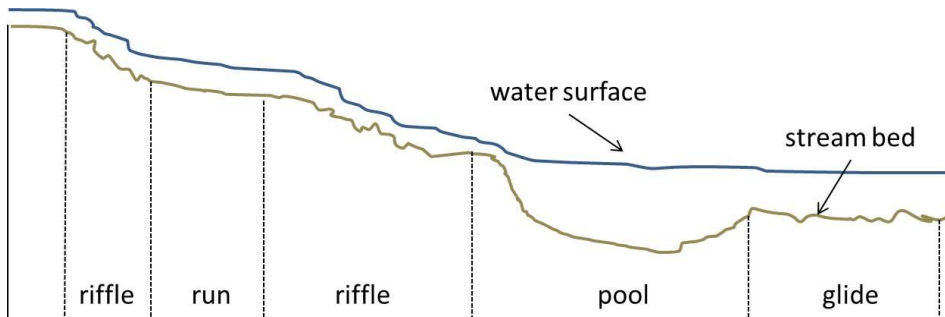
Figure 15. Example of habitat types in a wadeable stream.

4. Measure and record the length of the habitat unit along the thalweg.
   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.
5. Measure and record the maximum wetted width of the habitat unit.
6. Measure and record the depth of the habitat unit.
   a. Pools: measure depth at the deepest point
      i. If too deep to wade, measure the deepest location that you can and note '≥ [measured depth]' on the datasheet
   b. Riffles, runs, glides: measure depth in the thalweg

7. Estimate and record the percentage of submerged coarse woody debris (CWD%) for that habitat type to the nearest 5%. Think of this as debris that might be used as habitat for algae, macroinvertebrates, or fish.
   a. This is a relatively subjective rating, so the same technician should make the call for each habitat unit.
8. Estimate and record the size classes of the dominant substrata within the habitat unit. Substrata type classifications will be used to determine sampling location and sampler types for macroinvertebrate and periphyton sampling.
   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 brief visual estimate (no densiometer) of how much of the water's surface is shaded, affecting algal growth on the stream bed.
   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, make a note on the field datasheet.
   b. This is a relatively subjective rating, so the same technician should make the call 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 Steps 3-9.
11. Record a waypoint and coordinate uncertainty at the downstream end of every 10-15 habitat units. There is no need to record a waypoint at each habitat feature.
12. 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.
13. 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.
14. Continue until the entire permitted reach (up to 1 km) has been surveyed. Record a waypoint and coordinate uncertainty at the upstream end of the survey.

NEON Rapid Habitat Assessment
Wadeable Streams

Site (4-letter code): HOPB

Date (YYYY-MM-DD): 2015-09-15

Local time (HH:MM): 14:00

Recorded by: sparker@neoninc.org

Collected by: critz@neoninc.org

Sampling protocol: NEON.DOC.003162   Rev: A

Waypoint	Coordinate uncertainty (m)	Habitat unit type	Habitat unit Length (m)	Cumulative length from bottom of reach (m)	Wetted width (m)	Max depth (m)	CWD (%)	Substratum size class	Riparian cover (%)
42.468976, 72.321452 (downstream)	0.8	pool	5.5	5.5	6	0.52	10	cobble/sand/boulder	80
		step pool	7.5	13	7	0.18	2	boulder/cobble	95
		compound pool (3 pools)	7	20.5	3	0.22	1	sand/cobble/boulder	85
		riffle	10.5	28	3.6	0.13	2	boulder/cobble	75
		pool/run	13	35.5	3.6	0.20	1	gravel/cobble	50
		riffle	18.4	43	6.3	0.09	0	cobble	80
		pool	8.7	50.5	4	0.25	20	cobble	55
		riffle	11.4	58	3.3	0.14	0	cobble	90
		pool/run	13	65.5	4.3	0.27	10	cobble/sand/gravel	45
42.471340, 72.326925	0.4	step pool complex	20.6	73	3	0.22	0	cobble/boulder	50
		pool	5	80.5	4.7	0.17	2	cobble/sand	5
		riffle	6.4	88	4.6	0.12	0	cobble/boulder	5
		pool/run	7.4	95.5	4.7	0.14	0	peble/cobble	80
		step pool complex	11.5	103	4.5	0.12	1	cobble/pebble	80
		riffle	8.4	110.5	4.5	0.08	0	cobble/boulder	75
		pool/log jam	8.3	118	5.2	0.26	50	sand/cobble/CWD	20

Figure 16. Example of rapid habitat assessment datasheet.

F.2   Habitat Survey

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, **Figure 17**) using a metric ruler to the closest cm.
   a. Record B-axis length on datasheet (Figure 18).
   b. If the substratum is <2 mm, record as "sand", "silt", or "clay". With sand larger than silt and silt larger than clay. Clay particles will be so small that they are difficult to see individually.
   c. If the substratum is >25 cm, record as "boulder" or "bedrock". With boulders being large individual rocks while bedrock is a large mass of rock that may not have visible edges.
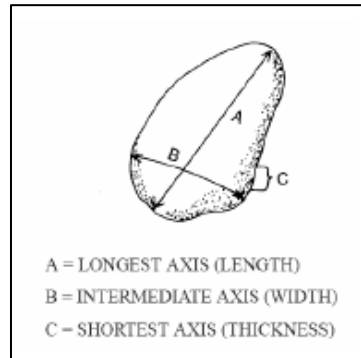
Figure 17. Measure the B-axis for pebble counts.

Site (4-letter code): *HOPB*					Recorded by: *sparker@neoninc.org*				
Date (YYYY-MM-DD): *2015-09-15*					Collected by: *critz@neoninc.org*				
Local time (HH:MM): *14:00*					Sampling protocol: *NEON.DOC.003162* **Rev:** *A*				

Habitat types: *riffle, run, pool*   *Record length of B-axis in cm*

	1	2	3	4	5	6	7	8	9	10
1-10	9.5	11	13	boulder	6	30	boulder	boulder	16	12
11 - 20	sand	sand	20	6	boulder	sand	boulder	14	22	36
21 - 30	boulder	4	3	18	boulder	boulder	15	boulder	boulder	sand
31 - 40	7	boulder	sand	boulder	10	10	boulder	boulder	8	21
41 - 50	sand	boulder	2	18	5	8	sand	sand	boulder	2
51 - 60	sand	sand	8	boulder	5	boulder	17	11	8	boulder
61 - 70	20	sand	2	10	13	3	sand	boulder	3	3
71 - 80	sand	21	11	boulder	30	sand	12	17	3	boulder
81 - 90	boulder	sand	4	22	16	28	32	boulder	20	sand
91 - 100	11	sand	boulder	23	boulder	boulder	20	13	17	16

Figure 18. Example pebble count datasheet.

5. Take another step into the stream channel and repeat Steps 3-4.
6. Move upstream step-by-step in a zig-zag pattern (from bank to bank) until 100 measurements have been recorded (Figure 19). Measurements are taken while passing through multiple habitat units as you move upstream, but at a minimum the most common habitat is captured.
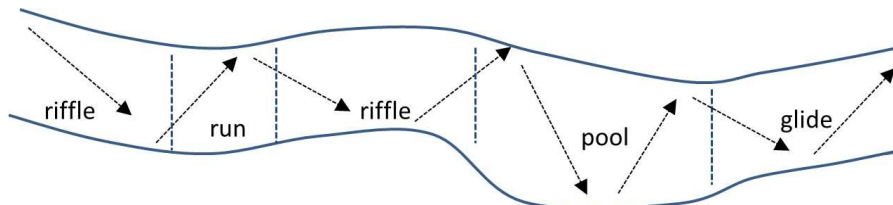
Figure 19. Zig-zag pattern through multiple habitats for pebble count measurements.

SOP G   Data Entry and Verification

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.

8   REFERENCES

River Stability Field Guide (Rosgen, D. 2008. River Stability Field Guide. Wildland Hydrology, Fort Collins.)

HILTI EN POS 150 180 series operator's manual (available online or CD copy in total station case)

APPENDIX A   DATASHEETS

The following datasheets are associated with this protocol:

Table 5. Datasheets associated with this protocol

NEON Doc. #	Title
NEON.DOC.003224	Datasheets for AOS Protocol and Procedure: Wadeable Stream Morphology
NEON.DOC.001646	General AQU Field Metadata Sheet

These datasheets can be found in Agile or the NEON Document Warehouse.

APPENDIX B   QUICK REFERENCES

The following information can be printed and taken to the field for reference

B.1   Keys to Success

1. Plan out new station locations carefully. Get the most out of each location. Each time the station is moved to a new location there is an opportunity for error.

2. When setting up a COPs for a new station setup be sure the angle between the new total station location and the two COPs is always 90° or greater. Take extra care to align the new station location in view of the two new control points. Be aware of obstructions such as large trees or banks. Once you move the station to the new location you MUST be able to shoot the two COPs

3. Check the level of the tripod and total station regularly.

4. Only change the rod height when standing at a point to survey. Make it a habit to change the rod height (HR) immediately after tightening the knob to lock the pole. This ensures you will enter the new rod height into the POC immediately. Forgetting to change the rod height prior to collecting data results in bogus measurements.

5. To reshoot a point due to an error. Place the rod back on the point, reshoot, and name with the same code and number and add the letter "R" to the end e.g., a reshoot of point "THA02" would be entered into the POC as "THA02R". **NEVER ATTEMPT TO DELETE DATA IN THE FIELD**

6. Be aware of changing data collection times by the POC. During rain or snow the signal time and quality between the POC and total station (Bluetooth^TM enabled) and most importantly the laser path from the total station to the prism and back may be reduced. This generally causes delays in data transmission. If data transmission is reduced consider halting the survey until conditions become more favorable.

7. Wetted edge points are a measurement of the location (x,y) and elevation (z) of the wetted edge/edge of water. Theoretically the wetted edge at a specific location on the left bank should be at the same elevation, equal z-dimension, as the coinciding point along the right bank. For this reason, be sure to capture the true elevation of the wetted edge. The wetted edge/edge of water is the point where the edge of the water contacts the bank (or other features of interest, such as wood or a log jam). In areas where there are "wetland" like edges (Arikaree River, D10) the wetted edge is not always obvious. For this reason, be consistent in the choice of location. If a wetted area exists such as a saturated soil or muddy bank, attempt to survey the actual stream channel wetted edge.

8. Be sure to hold the prism pole in the proper position when surveying wetted edges of channels with soft, muddy banks. Do not let the prism pole sink into the substrate giving a false reading of wetted edge elevation. If the total station and

POC lose connection, try returning to the location that you were at when the equipment lost communication. Place prism pole point on the ground, hold plumb, and wait for unit to reconnect. If unit does not reconnect with five seconds, line up with the red/green lights on the station and press the search button on the POC.

9. Take at least one backsight point every 100 shots. Use the same control point and verify each measurement is within the error tolerances for the protocol.

10. When setting up or moving the total station to a new location be sure to choose benchmark points or control points that form an equilateral triangle with the new station location. The three points (e.g. total station location, pt 1, and pt2) and the triangle they form should be as large as possible and span the stream with points on both banks and/or floodplains. The better the layout the easier it is to transform the total station data into a fixed geographic coordinate system.

11. If a feature is not present do not try to survey it. Bankfull indicators and other bank features fall into this category. The presence/absence of these features may change along the reach. You can only survey what is present.

12. The bank geometry points top and toe of bank provide the basic shape of the bank. However, when there are slope breaks present between these two points be sure to capture them using the code TOP for general topography. The TOP code can also be used in complex channels where there are numerous slope breaks in the wetted channel.

13. Remove the POC from the prism pole when taking thalweg measurements. One technician can work the POC from the bank while the other works as the rod person in the stream. This prevents the POC from being submersed in water. The POC can handle being dropped in water but should not be submerged for any period of time.

14. Set prism pole at the lowest possible height. This alleviates wiggle of the rod and deviation between the prism and the tip of the rod.

15. Walk with the prism pole perpendicular to the ground. This helps the prism and total station remain in contact, reducing the amount of time spent reestablishing communication between the two. Carrying the rod this way also alleviates the chances of injury if you fall with the prism pole in your hand. The rod is equipped with a sharp point on the end.

16. When moving the station to a new location carry the tripod and total station separately. Detach the station from the tripod and stow in the carrying case. This will avoid the likelihood of damage to the station or injury to the technician while carrying the equipment. The tripod with the total station attached is top heavy and not safe to carry as one unit.

17. Abide by sub-survey area flags to avoid repeat or missed data collection after changing stations.

18. If prism pole shifts during data acquisition reshoot the point.
19. **If an incorrect data entry is made into the POC (feature code, rod height, etc) correct it in the field by editing/deleting the data in the POC or re-shooting the points. Take careful notes of ANY change made in the field in the field data sheet.**

B.2   Survey Layout Using Total Station
1. Set up tripod over benchmark.
   a. Level tripod
2. Attach Total Station
   a. Level total station using display and keypad
3. Turn on the laser plummet, make sure laser is on center of benchmark, and measure the height of the instrument over the first benchmark point. If laser is not over center, realign tripod or station then re-level. Repeat until the laser pointer is on the center of the benchmark and both the tripod and total station are level.
4. Record the benchmark identification number, height of the instrument over benchmark, and the GPS coordinates of the benchmark into the field notebook.
5. Turn on POC
6. Establish communication with total station
7. Go to [MEAS REC]
8. [NEW JOB]
9. [NEW]
10. Enter Job Name using the format SITE ID-YYYY-MM-DD (e.g., ARIK-2015-04-10)
11. [OK] {OK}
12. [NEW STATION]
    a. HEIGHTS ON
    b. POINT SYSTEM- BLDG LINE-3pt
    c. Setup location [Over Pt]
13. [OK]
14. Enter the height of the prism under [HR]
15. Put prism over 1st benchmark (BEN001) and measure left bank
16. Put prism over 2nd benchmark (BEN002) and measure right bank
17. Press [OK] to skip Pt 3, it is not necessary
18. [NEXT]
19. [STAT H]
20. [MAN H]
21. Now measure the BEN height, Measure the BEN and enter Height as 1000m.
    a. 1000m is an arbitrary number that is used as a place holder for the z coordinate origin. When the data is transferred to ArcGIS the elevation will be adjusted to the actual value.
22. Put prism over elevation point and [OK]
23. [SET]
24. [OK]
    a. The station is location is set and can now measure and record.

25. Go to first point you want to record

B.3   Moving the Total Station: New Station Location

1. Identify two locations that can be used as control points (COP) and form an equilateral triangle with the new station location.
2. Mark the location with survey cap or other marker.
3. Name the points COP01, COP02 etc.
4. Survey both COPs
5. Record the data for the COP on the data sheet.
6. Turn off the total station and remove it from the tripod.
7. Move the tripod and total station to the new location
8. Set up the tripod
    a. Level the tripod
9. Attach the total station
    a. Level the total station
10. Turn on optic plummet laser
11. Turn on POC and re-establish communication between the POC and the total station.
12. On the POC select [HOME]
13. [MEAS REC]
14. [NEW STA]
15. Point System
    a. Heights [ON]
    b. [COORD/GRAPH]
    c. [ANYWHERE]
16. [OK]
17. Select a name for the point. Use default Sta1, Sta2, Sta3…
18. [TARGETS]
19. [Pt ID]
20. Use drop down menu to select the point you are on
21. Select the first control point (COP).
22. [OK]
23. Place the prism on the point [MEAS]
24. Move the prism to the second control point.
25. Select the point from the table
26. [OK]
27. Measure distance to control point, press [OK] to skip 3rd point
28. [OK]
29. [CALC]

30. [SET]
31. You may now measure and record points from the new station setup location

B.4   Surveying the Cross-section Profile
1. Find cross-section profile locations using a GPS
   a. Top of reach
   b. Bottom of reach
   c. Discharge transect
2. Stretch a measuring tape across the channel and pin at bankfull height
3. Record bankfull width in field notebook
4. Determine floodprone width (e.g. 2x thalweg depth)
5. Find floodprone width point. This point demarks the outer edge of the survey.
6. Collect data at floodprone width
7. Collect 4 additional data points between floodprone width and the (stream-side) edge of the floodplain.
8. Collect data working toward the midline of the stream at top of bank, along slope breaks, toe of bank. It is important to capture all slope breaks on the bank that lie on the transect.
9. Collect data along the bed of the stream at a frequency equal to bankfull width in cm /20). Use measuring tape to locate shots.
10. Collect data at thalweg
11. Collect data working away from the midline of the left wetted edge, toe of bank, slope breaks, top of bank. It is important to capture all slope breaks on the bank that lie on the transect.
12. Collect 4 additional data points between floodprone width and the (stream-side) edge of the floodplain.
13. Collect data at floodprone width

B.5   Surveying the Longitudinal Profile
1. Mark sub-survey area and features to be surveyed with pin flags.
   a. Woody Debris
   b. Pools and riffles
   c. Mid-channel islands
2. Begin the total station survey at the right bank floodprone width
3. Collect data at a point every 10m along the flood prone width location [code
4. : FLP] while walking upstream to end of the sub-survey area (pin flag)
5. Walk back downstream surveying floodplain points in a zig-zag pattern collecting data at a point every 5m.
6. Survey the location of all groundwater wells [code: GW#, with # being the number of the well from 1-8] and other NEON infrastructure on the floodplain.

7. Work upstream surveying points on the right bank [code: TOB, TOE, TOP], right bankfull indicators [code: BFI], if present, and right edge water [code: REW]. Survey points of inflection and points of maximum and minimum elevation for a given area [code: TOP]. Continue upstream to pin flags.

8. Work back downstream and collect data at thalweg points [code; THA], THA point measurements shall be taken along the entire path of the wetted channel and at a rate of ~1 data point per meter.

9. Survey other in-channel features.
    a. woody debris [code: WOD]
    b. woody snags [code: OWD]
    c. mid-channel features (e.g., large boulders [code:BLD], islands [code:TOP]
    d. point bars or dry areas that lie between the edge of water and the toe of the bank [code: TOP]).
    e. NEON aquatic sensors [code: SS1, SS2, MET]
    f. Pools, riffles, runs
    g. Topographic features [code: TOP] such as abandoned channels, bars, slope breaks on bank or in channel.

10. Work upstream collecting data points on the left bank [code: TOB, TOE, TOP], left bankfull indicators [code: BFI], if present, and left edge of water [code LEW]. Survey points of inflection and points of maximum and minimum elevation for a given area [code: TOP]. Continue upstream to pin flags.

11. Work back downstream and collect data at points along the left floodplain using codes [code: FLP].

12. Survey locations of all groundwater wells [GW1-GW8] and other NEON infrastructure on the left bank or left floodplain.

13. Survey left floodprone boundary and complete the sub-survey section at the left floodprone width point at the start of sub-survey section.

14. If necessary, fill in additional stream bed changes using the code TOP. **ADD ADDITIONAL TOP POINTS FOR THE CHANNEL BED IF THE STREAM IS WIDER THAN 2 METERS. This step should be done in streams with complex bed topography and incised beds.**

15. Shoot a backsight to a control point upon completion of the sub-survey section. Record the data for the COP backsight in the field data form.

B.6   Collecting Habitat Location and Woody Debris Data

1. Collect data points that demark the location and extent of all woody debris that is >10cm DBH and longer than 1m that lies within bankfull and touches the channel bed.

2. **For woody debris**:
    a. Survey the midpoint of the wood [code: WODXX]

      b. If a log jam is present survey the midpoint of the jam on the downstream side.

3. **For small woody debris**, e.g., beaver dams, small woody debris snags
      a. Survey one point in the middle of the feature [code: OWDXX)
      b. Choose the proper code to identify

4. **For Pools**:
      a. Survey a points at
            1) Pool Head (upstream extent) [code: POHXX)
            2) Pool Maximum Depth [code: POMXX)
            3) Pool Tail (downstream extent) [code: POTXX)
            4) Thalweg [code: THAXX)

5. **For Riffles**
      a. Survey a points at
            1) Riffle Head (upstream extent) [code: RIHXX)
            2) Riffle Tail (downstream extent) [code: RITXX)
            3) Thalweg [code: THAXX]

B.7   Total Station Codes for Data Input

Feature Description	Code
WATER CODES	
Left edge of water (looking downstream)	LEW
Right edge of water (looking downstream)	REW
Mid-channel edge of water	MEW
Wood/Log Jam edge of water	WEW
Side channel edge of water	SEW
CHANNEL FEATURE CODES	
Bankfull indicator	BFI
Thalweg	THA
Topographic point (e.g., change in elevation, slope or line of inflection along the channel bed)	TOP
Top of Bank	TOB
Toe of Bank	TOE
FLOODPLAIN CODES	
Flood Prone	FLP
Topographic point (e.g., slope breaks, abandoned channels)	TOP
CHANNEL HABITAT CODES	
Pool Head	POH
Pool tail	POT
Pool max depth	POM
Riffle Head	RIH
Riffle Tail	RIT
Large Boulders	BLD
Individual Woody Debris	WOD
Log Jam	JAM
Wood in Floodplain	WFP
Other small woody debris Jam (e.g., snag, beaver dam)	OWD
MISCELLANEOUS CODES	
NEON Sensor Sets (1 – upstream, 2- downstream)	SS1, SS2
NEON Met Station	MET
Groundwater Wells (GW)	GW1-GW8
Plant Transect Locations	P01-P10
Fish Reach Locations	F01-F11
Foresight	FOS
Backsight	BAS
Benchmark	BEN
Control Point	COP
Break Line	BRK

APPENDIX C   CHECKLIST FOR FIELD DEPLOYMENT

Preparation for field work

- ☐ Batteries are present and not damaged
    - ☐ Total Station (TS), POC
    - ☐ GPS
- ☐ Batteries are fully charged:
    - ☐ Total Station (TS)
    - ☐ POC
    - ☐ GPS
- ☐ Total station and carrying case are dry and free of dirt
- ☐ Total station turns on and is in working condition
- ☐ The following Items are in working order and packed:
    - ☐ POC Controller
    - ☐ POC metal stylus
    - ☐ POC to prism pole attachment clamp and screw
    - ☐ POC charging plug
    - ☐ Graduated and adjustable prism pole
        - ☐ Locking knob and clamp are present and in working condition
    - ☐ 360° mirrored prism
    - ☐ Prism pole bubble level
    - ☐ Total station unit
    - ☐ Total station battery charging unit
    - ☐ Total station battery charging unit cord
    - ☐ 2 total station batteries
    - ☐ 2 POC batteries
    - ☐ Tripod
    - ☐ 50 or 100m measuring tape
    - ☐ 25 pin flags
    - ☐ 1 roll of flagging
    - ☐ Field notebook
    - ☐ Morphology data sheet

APPENDIX D   ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

The dates in the table below are based on historic records and are estimates for the start and stop dates of sampling. It is essential that domain staff monitor real-time conditions to determine and plan survey bout dates that coincide with the guidelines in Section 4 of this protocol.

Table 6. Estimated dates for onset and cessation of data collection for NEON and NEON aquatic sites. Bars denote favorable conditions based on historic discharge data for streams in each domain.

Geomorphology Survey Schedule for Wadeable Aquatic Sites

Domain	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1							■	■	■			
2					■	■	■	■				
3												
4	■	■	■					■	■	■		■
5												
6	■	■	■			■	■	■	■	■	■	■
7					■	■	■	■				
8						■	■	■				
9												
10				■	■	■	■	■	■			
11						■	■	■	■			
12						■	■	■	■	■		
13							■	■	■	■		
14						■	■	■				
15						■	■	■	■			
16					■	■	■	■				
17	■	■	■	■			■	■	■	■	■	■
18							■	■	■	■		
19							■	■	■	■		

Bars denote favorable conditions based on historic discharge data for streams in each domain