AOS PROTOCOL AND PROCEDURE: DSC – STREAM DISCHARGE

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See configuration management system for approval history.

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	02/06/2014	ECO-01092	Initial release
B	01/26/2015	ECO-02636	Migration to new protocol template
C	02/29/2016	ECO-03662	Baseline of protocol following FOPs review
D	02/03/2017	ECO-04480	Updated to new template; changes to sampling frequency, point of zero flow, removal of 3 depth sampling
E	09/28/2017	ECO-05292	Baseline update of protocol sent to FOPS for review. Made slight revisions to Sections 1.1, 4.1, 4.2, 4.4, 4.5. Added definitions to Section 2.4. Included language on continuous discharge calculation to Section 3. Section 7: re-organized content throughout; added instrument-specific steps to flowmeter setup and measurement procedures; refined calibration procedures (did not change); added list of common data entry errors to post-measurement review section based on NEON-9064; replaced Figure 7 with one that shows equations and natural control segments; revised PZF procedure based on NEON-8821; added additional language on natural control types and how they affect ratings; added additional steps to data entry and verification based on NEON-9064. Added Appendix A which introduces plan for measuring river discharge. Added additional citations into References section. Made slight revisions to Appendix B. Removed Appendix C.

F	09/19/2018	ECO-05687	Section A.2: removed the requirement that >30% of velocity measurement stations within a discharge transect must contain velocity values >0.01 m/s in order for a discharge measurement to be conducted. Parser validation code now flags measurements that contain such low-velocity values; Section A.3: increased minimum filer parameter settings to 40 seconds based on standards set forth by the USGS; Section A.5: clarified station spacing requirements given wetted widths of channel; Section A6: updated equipment list for wadable discharge measurements; Section A7: provided instructions on how to setup first and last measurement stations given undercut left and right banks within the discharge transect; clarified the example that illustrate one and two-point velocity measurement techniques; Removed point of zero flow calculation requirement and instructions- this offset is now calculated within the stage-discharge rating curve code for each aquatic site; Point of zero flow calculations are no longer required to be measured by field ecologists. Added Appendix B: measuring discharge at NEON large river sites using acoustic Doppler current profilers from a piloted boat; cross-referenced all Tables and Figures; Moved Appendix B to Appendix D (Measuring Discharge with Acoustic Doppler Current Profiles via a Piloted Boat Deployments); added a new Appendix B (Measuring Discharge with Acoustic Doppler Current Profilers via Tethered Float Deployments) and Appendix C (Measuring Discharge with Acoustic Doppler Current Profilers via Remote Controlled ARC-Boat Deployments).
G	06/19/2020	ECO-06449	Protocol now includes all discharge measurement collection methods to date; updated Section 4.2 and 4.4 – added stipulations for ADCP methods at wadable streams and rivers; added SOP overview figures; made minor edits to SOP A station spacing and 10% discharge per station text; added SOP's E-H in Appendix A – measuring discharge at wadable stream sites using the ADCP method; added SOP's I-L – measuring discharge at river sites using the Remote Controlled Boat Method; added SOP's M-P – measuring discharge at river sites using the Piloted Boat Method; added reminders for ARC-Boat repair, viewing laptops in direct sun, and rating curve supplementary information in Appendix D; added site-specific information regarding the required number of annual bouts per site and site-specific sampling

			documentation references in Appendix E; revised and added new equipment tables in Appendix F.
H	03/16/2022	ECO-06781	• Update to reflect change in terminology from relocatable to gradient sites. • Revised logo.
J	05/14/2024	ECO-07084	• Information regarding flowmeter setup and setting configurations, flowmeter calibration, measuring discharge using the Flowmeter method (including setting up the discharge transect, collecting velocity, depth, and distance measurements, and evaluating the discharge measurement in the field) were removed from the protocol and placed into a separate SOP that contains technical information related to the Flowmeter method (RD[07]). • Information regarding establishing and testing Bluetooth connections for ADCP and GPS sensors (including Parani dongle configuration, and connection testing), measuring discharge using the ADCP method (including starting new measurements in WinRiver II software, completing pre-measurement QAQC, establishing transect start and end points, and collecting transect discharge measurements), and evaluating discharge measurements in the field using WinRiver II and Q-Rev software were removed from the protocol and placed into a separate SOP that contains technical information related to the ADCP method (RD[08]). • Updated applicable documents. • Slight updates to Methods section. • Updated total number of annual bouts and stream sites. • Added sampling impractical requirements. • Added references to Discharge Fulcrum app, ADCP post-processing and discharge visualization app throughout. • Updated minimum depth requirements for StreamPro ADCP. • Re-formatting occurred throughout document. • Updated NEON logo.

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1 OVERVIEW

1.1 Background

The degree to which streamflow, or discharge, affects the structure of stream and river ecosystems cannot be overstated. Stream ecologists consider discharge a master variable, as varying rates of discharge directly affect the physical, chemical, and thermal attributes of the stream ecosystems. High flow events have the ability to entirely reshape the physical habitat of streams by repositioning large woody debris, sediment, and boulders within the active channel, or the active channel itself. Flow rates often directly affect water temperatures, particularly during flood and low-flow events (Poole and Berman 2001). Surface water discharge rates directly affect flow through the hyporheic zone (space between sediments in the benthic zones of streams) as well, where microbial activity is concentrated. Consequently, discharge can directly affect nutrient cycling in streams (Grimm and Fisher 1984). Because of these and other interactions between discharge and the physicochemical attributes of streams, flow regime characteristics have been found to be significantly correlated with life history attributes of stream-dwelling organisms such as fishes (Mims and Olden 2012).

Flow regimes in stream and rivers worldwide are rapidly changing due to environmental stressors, consequentially affecting the ecological services these systems support. Climate change impacts the timing, magnitude, and severity of flood and drought events with profound consequences for lotic ecosystems. For example, peak flows in western North American rivers are consistently occurring earlier in the spring (Clow 2010) and these changes may significantly alter the habitat suitability for species such as cutthroat trout (Zeiglar et al. 2012). Land use change from natural cover to human-dominated landscapes can also affect discharge. Impervious surfaces (such as roads and rooftops) in urban landscapes transfer water directly to stream channels, resulting in elevated flood frequencies and magnitudes (Schoonover et al. 2006). Agricultural lands may also impact flow regimes either by reducing flows directly through withdrawals or elevating flow when soils become compacted (Dodds et al. 2004). All flow regime changes associated with land use substantially impact the biological communities that reside in the receiving waters (Cuffney et al. 2010, Dodds et al. 2004).

Because discharge is fundamentally important to stream ecosystems, NEON will calculate discharge in all rivers and stream sites within the Observatory. The discharge data product will be a crucial input to a number of additional high-level NEON data products, such as stream metabolism and nutrient fluxes. Consequently, discharge represents a critical component in the NEON Aquatic Observation System.

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 Data Products Catalog (RD[03]).

1.3 Acknowledgments

NEON acknowledges the current definitive works on this topic, "Discharge Measurements at Gaging Stations, U.S. Geological Survey Techniques and Methods Book 3, Chapter A8" by D. Phil Turnipseed and Vernon B. Sauer (2010) and "Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0): U.S. Geological Survey Techniques and Methods" by D.S. Mueller, C.R. Wagner, M.S. Rehmel, K.A. Oberg, and F. Rainville (2013).

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	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Data Quality Plan

2.2 Reference Documents

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

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Data Products Catalog
RD[04]	NEON.DOC.001271	OS Protocol and Procedure: DMP – Data Management
RD[05]	NEON.DOC.003282	NEON Protocol and Procedure: SIM – Site Management and Disturbance Data Collection
RD[06]	NEON.DOC.005247	AOS/TOS Standard Operating Procedure: NEON Aquatic and Terrestrial Site Navigation
RD[07]	NEON.DOC.005388	AOS Standard Operating Procedure: DSC – Configurations, Settings, and Collection Methods for Stream Discharge Measurements using the Flowmeter Method
RD[08]	NEON.DOC.005389	AOS Standard Operating Procedure: DSC – Configurations, Settings, and Collection Methods for Stream Discharge Measurements using the ADCP method
RD[09]	NEON.DOC.005390	Datasheets for AOS Protocol and Procedure: DSC – Stream Discharge

2.3 Acronyms

Acronym	Definition
ADCP	Acoustic Doppler Current Profiler
GPS	Global Positioning System
LEW	Left edge of water
MBT	Moving Bed Test
P&P	Procedure and Protocol
REW	Right edge of water
USGS	United States Geological Survey

2.4 Definitions

Acoustic Doppler Current Profiler (ADCP): a hydroacoustic current meter used to measure water velocity and depth over a depth range using the Doppler effect of sound waves scattered back from particles within the water column.

Area (A): The cross-sectional area of a stream or a subsection of a stream. For a rectangular subsection, area equals width times the depth. For an irregular cross-section, it is the summation of a series of subsection areas, or the width times the average depth.

Control: A specific section of a stream channel, located downstream from the staff gauge that controls the relation between gauge height and discharge at the staff gauge.

Depth (D): The depth of the water column at a particular point, measured from the water surface to the streambed.

Discharge (Q): (streamflow) The volume of water flowing through a cross-section during a given period of time, measured in units of volume per unit time, such as cubic feet per second, cubic meters per second, liters per second, gallons per minute, or acre-feet per year. Discharge is computed as velocity times area.

Fulcrum: Software tool used to create NEON electronic data entry applications.

Left edge of water (LEW): The edge of the stream that is on the observer's left when looking downstream.

Right edge of water (REW): The edge of the stream that is on the observer's right when looking downstream.

ServiceNow: Software tool used for problem/incident tracking and resolution.

Stage: Height of a stream or river relative to a fixed point. Stage can be measured at a single point in time by reading the water level on a calibrated staff gauge mounted in the stream channel. Stage can also be calculated continuously using models that regress surface water pressure data against observed staff gauge heights.

Station: A location along the stream discharge measurement transect where velocity and depth are measured, and area and streamflow are calculated. Station, or vertical, spacing is dependent on the wetted width of the channel and velocity distribution throughout the transect.

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

Transect: The stream cross-section across the channel along which velocity measurements are made to compute discharge.

Velocity (V): The speed of water flowing past a point along the transect, measured in units of rate, such as meters per second.

Wetted Width: Width of a stream channel that contains water.

3 METHOD

Discharge is a calculated metric obtained from a series of velocity and area measurements collected along a fixed cross-section in the stream or river (**Figure 1**) by NEON field ecologists. Each discharge sampling event is known as a discharge survey. Velocity and area measurements are integrated into a single value of stream discharge during each discharge survey. At each NEON stream and river site, stage-discharge rating curves are constructed that regresses discharge measurements against the staff gauge height recorded at the time of collection. To produce a rigorous rating curve with minimal uncertainty, discharge surveys must occur across the widest possible range of stage levels at each site. A continuous record of stream discharge is derived by applying rating curve coefficients to a continuous record of stage, which is derived by regressing observed gauge heights against surface water pressure data (collected by *in-situ* pressure transducers installed each site). Once the rating curve is established, and barring significant changes in channel morphology, a single measurement of water column depth in the stream channel is sufficient to estimate streamflow. The pressure transducer is located at a fixed location (near the discharge cross-section and a staff gauge) and yields a continuous estimate of stream discharge by measuring surface water pressure.

The purpose of this protocol is to provide guidance on how to successfully implement discharge surveys at NEON wadable streams and river sites. In conjunction with RD[07] and RD[08] (which supplement the protocol), the document details pre-deployment and post-measurement review, step-by-step field methods, data entry procedures, troubleshooting, instrument quality assurance plans, and safety guidelines specific to NEON sites and personnel. Two methods are presented for discharge surveys at NEON sites: the Flowmeter method and the ADCP method.

The Flowmeter method involves the operation of a handheld flowmeter to measure discharge while wading in the stream. A velocity flowmeter is attached to a wading rod to measure water velocity and depth across the channel. To obtain an estimate of total stream discharge within the cross-section, the stream is divided laterally into sub-sections. Within each sub-section, an instantaneous velocity magnitude is obtained and transformed to a volumetric discharge magnitude by applying the velocity across the full sub-section area. Total stream discharge is calculated by summing up the discrete volumetric discharges for each sub-section. The Flowmeter method is only applied at NEON wadable stream sites.

The ADCP method involves the operation of an acoustic Doppler current profiler (ADCP) that uses sound to measure water velocity based on the Doppler Effect. The ADCP is mounted to a trimaran float (at wadable stream sites), a remoted controlled boat (at river sites), or a piloted boat (at river sites), and is navigated across the channel as the sensor calculates discharge by continuously measuring velocity and area. At wadable stream sites, discharge can be measured using either the ADCP or the Flowmeter method, depending on stream conditions at the time of the measurement (conditions of use are described later in the protocol). At river sites, only the ADCP method is applied.

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 to resolve any field issues associated with implementing 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 NEON's problem tracking system.

Quality assurance is performed on data collected via these procedures according to the NEON Science Data Quality Plan (AD[05]).

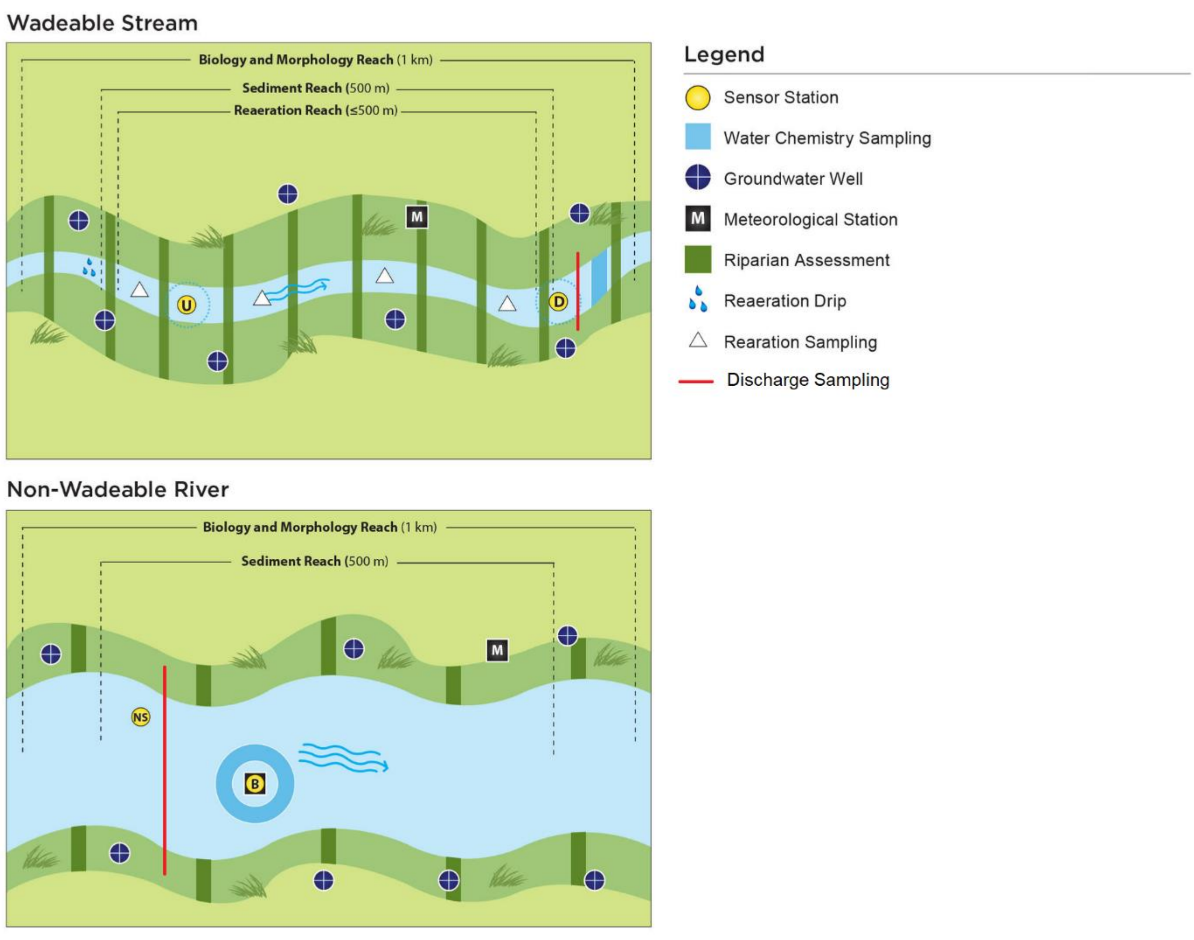

Figure 1. Sampling locations at NEON wadable stream and non-wadable river aquatic sites.

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Developing rigorous stage-discharge rating curves requires frequent discharge surveys to accurately characterize how stage-discharge relationships change over time. At wadable stream sites NEON's goal is to conduct twenty-two (22) discharge surveys annually over a wide range of stage levels while maintaining two (2) annual surveys to target measurements during high-flow events (when water levels are near bankfull stage). Flows at bankfull stage historically occur on 1.5 year intervals, though this frequency is expected to change as extreme weather events (e.g. heat waves and large storms) become more frequent and more intense. Collecting high-flow discharge measurements reduces the uncertainty in the stage-discharge rating curve, and thus estimates of continuous discharge. At river sites, twelve (12) discharge surveys are to be completed annually (**Table 1**). If necessary, the discharge sampling schedule may deviate in order to conduct measurements at certain flow levels. In these cases Field Science staff will work with Science staff to address scheduling changes. Gauge heights at which to target high-flow measurements at stream sites, site-specific stage-discharge rating curves and other hydrology data (such as continuous stage, discharge, and precipitation data) can be accessed using the openFlow Shiny app. Sampling impractical records must be created if targeted high-flow measurements were not completed within the year (**Section 4.3**).

Following initial development, the stage-discharge relationship expressed in rating curves must be verified over time, as ratings may shift due to bed scour, aggradation, or other changes in channel geometry. If Science staff determines that a rating shift is present, discharge sampling frequency at aa given site may need to change for purposes of validation, and, if necessary, the creation of a new rating curve. Channel morphology in streams with unconsolidated bed materials are expected to fluctuate to varying degrees on an annual and storm-event basis. As a result, rating curves for these channel types may require more frequent measurements than those for bedrock channels, which are more stable. Sampling frequency details for each site will be provided in Domain Specific Sampling Design documentation (**Appendix B**).

Table 1. Required sampling frequency for discharge surveys at NEON wadable stream and river sites.

Aquatic Site Types	Sampling Dates	Sampling Bouts per Year
Wadable Streams	Year-round (as feasible)	22 + 2 high flow target bouts
Rivers	Year-round (as feasible)	12

4.2 Criteria for Determining Onset and Cessation of Sampling

Criteria for determining the onset and cessation of sampling is dependent on the discharge method. These details are presented in the sub-sections below.

4.2.1 Sampling Cessation – Discharge Measurements at Wadable Stream Sites Using the Flowmeter Method

At wadable stream sites, discharge sampling should be conducted according to the site-specific interval (22 times per year + 2 target bouts during high-flow events) using the Flowmeter method under the following conditions:

1. Water is present in the stream channel.
    a. If water is not present in the channel then a discharge measurement cannot be conducted using any available method. Create a sampling impractical record in the Discharge Fulcrum app and submit a ServiceNow incident ticket documenting that the reach is dry.
2. It is safe to enter the stream channel.
    a. Reference AD[02] and any other Domain-specific safety plans that detail thresholds for working safely in the stream.
    b. If it is not safe to enter the channel but the floodplain can be safely accessed, use the ADCP method for discharge measurement.
3. The staff gauge is present and un-disrupted.
    a. If the staff gauge is not present, or has been disrupted or damaged, do not collect a discharge measurement using any available method unless the discharge survey is associated with a reaeration sampling event. Discharge should still be measured regardless of staff gauge presence during reaeration.
    b. Create a sampling impractical record in the Discharge Fulcrum app and submit a ServiceNow incident ticket documenting this occurrence.
4. Surface water to bed depth is between 0.04 and ~0.25 m in > 90% of the channel wetted width.
    a. The ADCP is the preferred method to measure discharge at wadable stream sites due to the high level of data quality the instrument provides. However, the handheld flowmeter can measure velocity at lower depths than the ADCP, making the Flowmeter method a suitable option to measure discharge during the low flow regime at many sites.
    b. The minimum depth for the ADCP will be determined on a site-by-site basis as environmental conditions affect the instrument's measurement ability. At sites with rough streambeds (i.e. large boulders or cobble) the minimum ADCP depth will likely be greater than at sites with smooth beds (i.e. sand or small gravel). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.
    c. There is no requirement for a minimum wetted channel width.

d. Discharge measurement quality is dependent on the continuous profile of water that maintains a minimum depth and is laminar throughout the majority of the discharge transect (this should not include the shallow edge sections).

i. If needed, move any substrate and/or cobbles within the discharge transect to (1) maintain hydrologic connection within the channel, (2) maintain the minimum depth requirements of the flowmeter, and (3) decrease the roughness of the streambed to improve data quality (reduce uncertainty in depth measurements).

ii. If larger debris is located in the discharge transect and cannot be moved, an alternative discharge measurement location should be considered. Submit a ServiceNow incident ticket to Science to document this occurrence and discuss a path forward.

e. If water depth is below this threshold and the discharge transect is dry, very nearly dry, or hydrologically disconnected, create a sampling impractical record in the app and submit a ServiceNow incident ticket to Science to document this occurrence.

f. At higher stage levels (water depth is ≥ ~0.25m in ≥ 90% of the channel wetted width), the ADCP method should be used. Environmental conditions specific to the site will likely dictate when the transition from the flowmeter to the ADCP method can occur (see above). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.

5. Minimal ice cover is present.

a. If the water surface is "lightly iced" over (< 1" of ice) and it can be safely broken up to clear/open up a 1m width along the entire discharge transect, collect a discharge measurement.

b. Record ice presence and temporary hydrologic conditions in the app and indicate that surface ice was broken in order to collect the measurement.

c. If the surface ice thickness is > 1", do not collect a stream discharge measurement. Record ice presence and temporary hydrologic conditions and create a sampling impractical record in the app.

4.2.2 Sampling Cessation – Discharge Measurements at Wadable Stream Sites Using the ADCP Method

At wadable stream sites, discharge sampling should be conducted according to the site-specific interval (22 times per year + 2 target bouts during high-flow events) using the ADCP method under the following conditions:

1. Water is present in the stream channel.

a. If water is not present in the stream channel then a discharge measurement cannot be conducted using any available method.

b. Create a sampling impractical record in the app and submit a ServiceNow incident ticket documenting that the reach is dry.

2. The staff gauge is present and un-disrupted.

a. If the staff gauge is not present, or has been disrupted or damaged, do not collect a discharge measurement using any available method unless the discharge survey is associated with a reaeration sampling event. Discharge should still be measured regardless of staff gauge presence during reaeration.

b. Create a sampling impractical record in the Discharge Fulcrum app and submit a ServiceNow incident ticket documenting this occurrence.

c. If the staff gauge is overtopped during high flows and a discharge measurement can be safely collected, install a physical marker that references the elevation of the edge of water (only do so if this can be accomplished in a safe manner). A total station survey can later be conducted to establish the gauge height at this elevation.

3. Surface water to bed depth is ≥ ~0.25m in ≥ 90% of the channel wetted width.

a. The minimum depth for the ADCP will be determined on a site-by-site basis as environmental conditions affect the instrument's measurement ability. At sites with rough streambeds (i.e. large boulders or cobble) the minimum ADCP depth will likely be greater than at sites with smooth beds (i.e. sand or small gravel). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.

b. There is no requirement for a minimum wetted channel width.

c. Discharge measurement quality is dependent on the continuous and laminar profile of water that maintains a minimum depth throughout the majority of the discharge transect (this should not include the shallow edge sections).

i. If needed (and it is safe to enter the channel), move smaller substrate and/or cobbles within the discharge transect to (1) maintain hydrologic connection within the channel, (2) maintain the minimum depth requirements specific to the ADCP at a given location, (3) decrease the roughness of the streambed to improve data quality (improve bottom tracking), and (4) minimize the unmeasured area at the bottom of the velocity profile.

ii. If larger debris is located in the discharge transect and cannot be moved, an alternative discharge measurement location should be considered. Document the alternative discharge location in the Discharge Fulcrum app and submit a ServiceNow incident ticket to Science to document this occurrence.

   d. At lower stage levels (water depth is ≤ ~0.25m in ≥ 90% of the channel wetted width), the Flowmeter method should be used. Environmental conditions specific to the site will likely dictate when the transition from the Flowmeter to the ADCP method can occur (see above). Consult with Science with questions as to when to utilize the Flowmeter vs. ADCP method.

4. Minimal ice cover is present.
   a. If the water surface is "lightly iced" over (< 1" of ice) and it can be safely broken up to clear/open up a 1m width along the entire discharge transect, collect a discharge measurement.
   b. Record ice presence and temporary hydrologic conditions in the app and indicate that surface ice was broken in order to collect the measurement.
   c. If the surface ice thickness is > 1", do not collect a stream discharge measurement. Record ice presence and temporary hydrologic conditions and create a sampling impractical record in the app.
5. See **Appendix C** for site-specific details on maximum depth thresholds, which are dependent on ADCP model type and individual instrumentation configurations.

4.3 Missed or Incomplete Sampling

Sampling according to the schedule is not always possible, and multiple factors may impede work in the field at one or more plots or sampling locations for a given bout. For example:

- Logistics – e.g., insufficient staff or equipment.
- Environment – e.g., deep snow/ice cover, excessive flooding, dangerous weather.
- Management activities – e.g., controlled burns, pesticide application.
- Targeted bouts for high-flow measurements were not completed within the year.

Instances such as those listed above must be documented for scheduling, tracking long-term site suitability, and informing end users of NEON data availability. Some types of missed sampling are due to events that should be recorded in the Site Management App; refer to the Site Management and Event Reporting Protocol for more detail (RD[05]).

Missed or Incomplete Sampling Terms

Terms that inform Missed or Incomplete Sampling include:

- **Protocol Sampling Dates**: Bout-specific sampling dates.
- **Scheduled Sampling Dates**: Bout-specific sampling dates scheduled by Field Science and approved by Science. These dates coincide with or are a subset of the Protocol Sampling Dates.

- **Missed Sampling**: Incidence of *scheduled sampling* that did not occur. Missed Sampling is recorded at the same resolution as data that are ordinarily recorded.
- **Sampling Impractical**: The field name associated with a controlled list of values that is included in the data product to explain a Missed Sampling event – i.e., why sampling did not occur.
- **Rescheduled**: Missed Sampling is rescheduled for another time within the *protocol sampling dates*, resulting in no change to the total number of sampling events per year.

The documentation that must accompany missed sampling depends on the timing, subsequent action, and the audience appropriate for numerous scenarios (**Figure 2**).

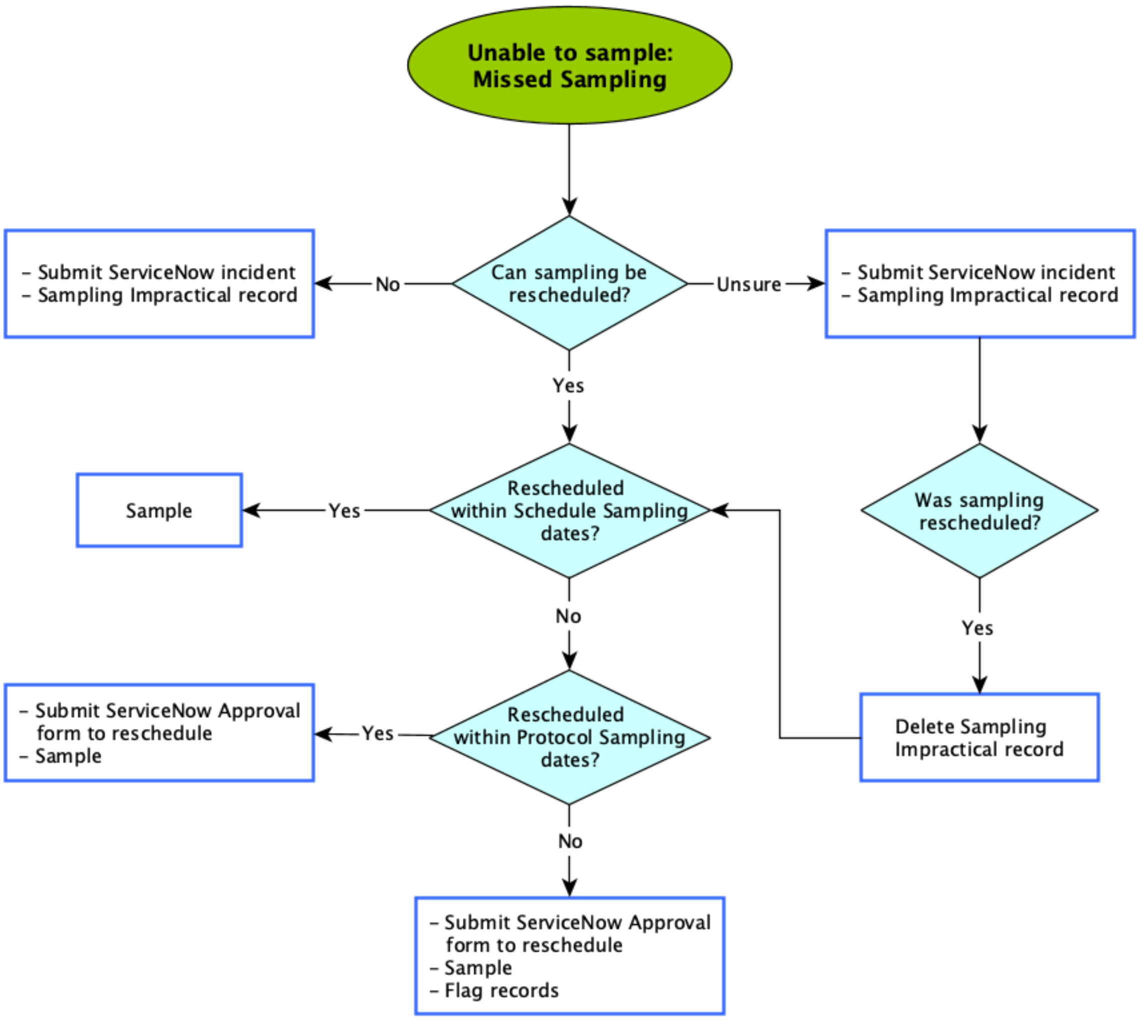

Figure 2. The documentation to account for a Missed Sampling event depends on the situation for each sampling unit not sampled per bout that is not sampled. Diamonds represent decision points and boxes describe the required action. Required actions may include: a) Submitting a ServiceNow incident, b) creating a Sampling Impractical record, c) creating a data Flag, d) creating a Site Management record, or e) some combination of (a) – (d).

To Report Missed or Incomplete Sampling:

1. Missed or Incomplete Sampling must be communicated to Science by a ServiceNow incident ticket.
   a. For Missed Sampling that is Rescheduled, there are some cases that require approval by Science and Operations (**Figure 2**).
   b. Consult **Table 2** to determine required actions if scheduled activities are delayed or canceled. The lead Field Ecologist can also consult the Delayed or Cancelled Activities table to best determine when reporting is required. However, this protocol is the ultimate source of information should any discrepancy exist.
2. Create a Fulcrum record for each Missed Sampling event in the field that cannot be rescheduled.
3. For each Missed Sampling record, the Sampling Impractical field must be populated in the mobile collection device (**Table 3**).

Table 2. Guidance for responding to delays and cancellations encountered during implementation of the Stream Discharge protocol.

Activity Name	Days Delayed from Schedule	Delay Action	Cancellation Action
Stream Discharge	> 28 days	IS/OS Schedule Change Request	Submit ServiceNow incident ticket

Table 3. Protocol-specific Sampling Impractical reasons entered in the Fulcrum application. In the event that more than one is applicable, choose the dominant reason sampling was missed.

Sampling Impractical Reason	Description
Location dry	Discharge cross-section is dry
Location frozen	Discharge cross-section is frozen
Location snow covered	Discharge cross-section is snow covered.
Staff gauge disturbed	Staff gauge is damaged, and an accurate measurement cannot be made
Staff gauge not installed	Staff gauge is not installed
Logistical	Discharge measurement cannot be made due to logistical reasons
Other	Discharge measurement cannot be made due to reasons not listed above

4.4 Estimated Time

Estimated time to complete the protocol is dependent on the type of discharge survey method. Estimates for each method are presented below.

4.4.1 Estimated Time – Discharge Measurements at Wadable Stream Sites Using the Flowmeter Method

The time required to implement the protocol using the Flowmeter method at wadable stream sites will vary depending on a variety of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below (**Table 4**) is an estimate based on completion of a task by a single skilled Field Scientist (i.e., not the time it takes at the beginning of the field season). Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a ServiceNow incident ticket should be submitted to Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 4. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the Flowmeter method at wadable stream sites.

SOP	Estimated time	Suggested staff	Total person hours
SOP A: Preparing for Sampling: Wadable Stream Sites Using the Flowmeter Method	10 minutes	1	0.2 h
SOP B: Field Sampling: Wadable Stream Sites Using the Flowmeter Method	30 minutes	1	0.5 h
SOP E: Post-Field Sampling Tasks	10 minutes	1	0.2 h
SOP F: Data Entry and Verification	10 minutes	1	0.2 h

4.4.2 Estimated Time – Discharge Measurements at Wadable Stream and River Sites Using the ADCP Method

The time required to implement the protocol using the ADCP method at wadable stream and river sites will vary depending on a variety of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below (**Table 5**) is an estimate based on completion of a task by a skilled 2-3 person team (i.e., not the time it takes at the beginning of the field season). Note that many of the pre-measurement tasks listed can be completed in parallel with one another. Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a ServiceNow incident ticket should be submitted to Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 5. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the ADCP method at wadable stream and river sites.

SOP	Estimated time	Suggested staff	Total person hours
SOP C: Preparing for Sampling: Wadable Stream and River Sites Using the ADCP Method	10-30 minutes	2	0.2 – 0.5 h
SOP D: Field Sampling: Wadable Stream and River Sites Using the ADCP Method	30-60 minutes	2	0.5 – 1.5 h
SOP E: Post-Field Sampling Tasks	10 minutes	1	0.2 h
SOP F: Data Entry and Verification	10 minutes	1	0.2 h

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.

- Activities in and around streams should only be performed when flow conditions are safe.
- Never enter the channel when it is unsafe to do so.
- Be aware of the potential for downstream debris transport as stage and flow levels increase.
- Logs, debris, cobble, and boulders can be very slippery and unsafe to walk on.

6 PERSONNEL

6.1 Training Requirements

All technicians must complete protocol-specific training as required in the Field Operations Job Instruction Training Plan (AD[04]). Additional protocol-specific required skills and safety training are described here.

Personnel should be:

- Trained in Water Safety Awareness.
- Trained in conducting discharge measurements using the Flowmeter and ADCP method.
- Adept at wading in streams.

7 STANDARD OPERATING PROCEDURES

SOP Overview

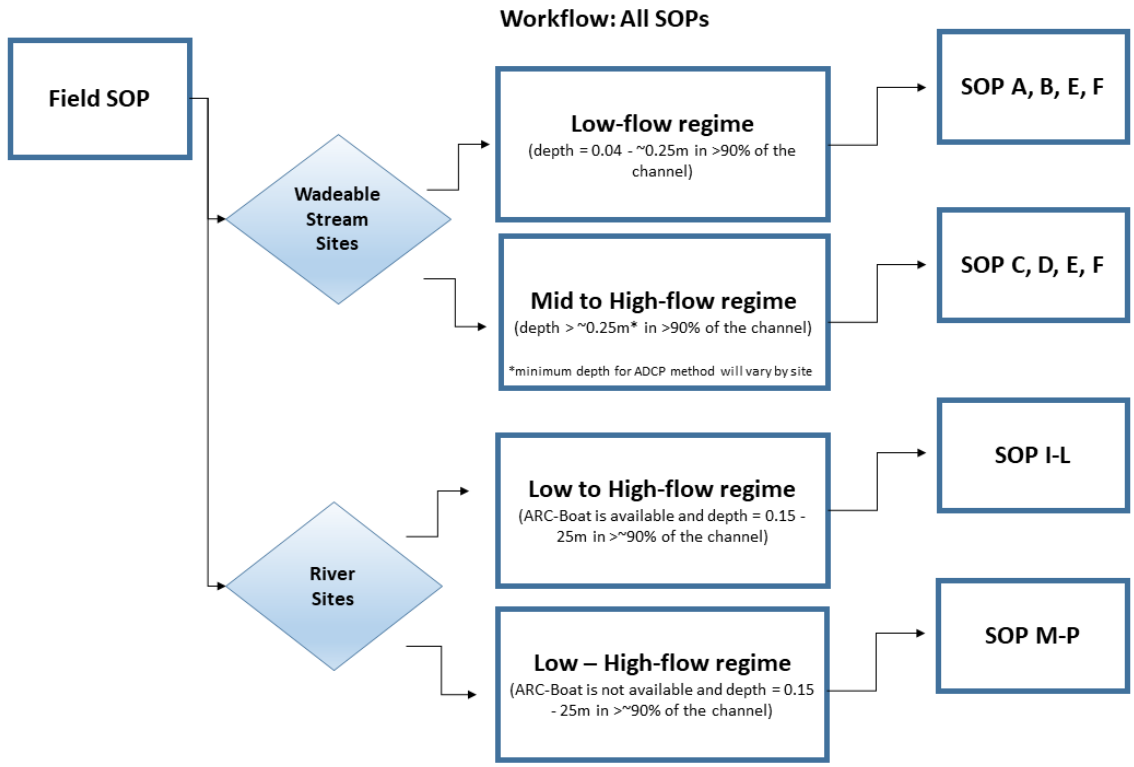

Figure 3. A high-level workflow diagram that visually shows how the separate SOPs are sequentially connected.

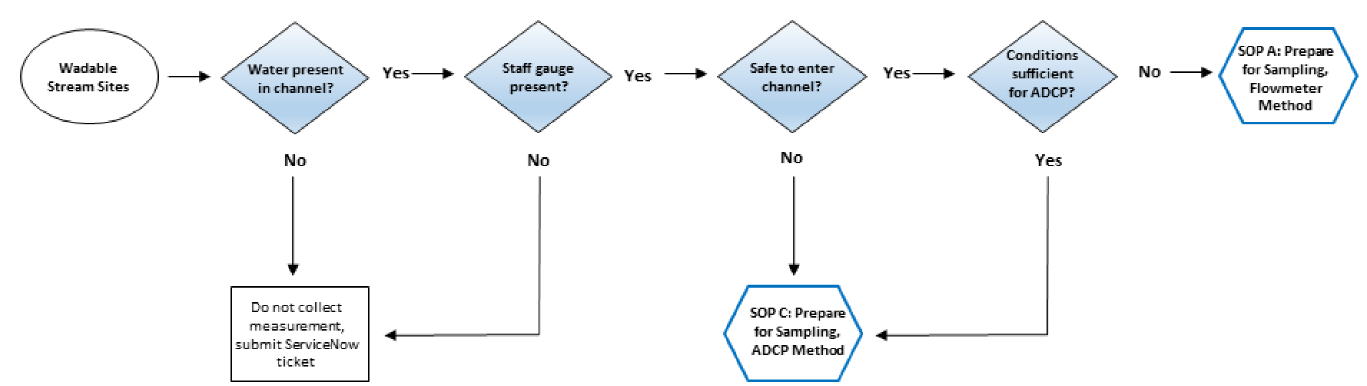

Figure 4. A high-level workflow diagram that visually shows the workflow for wadable stream sites.

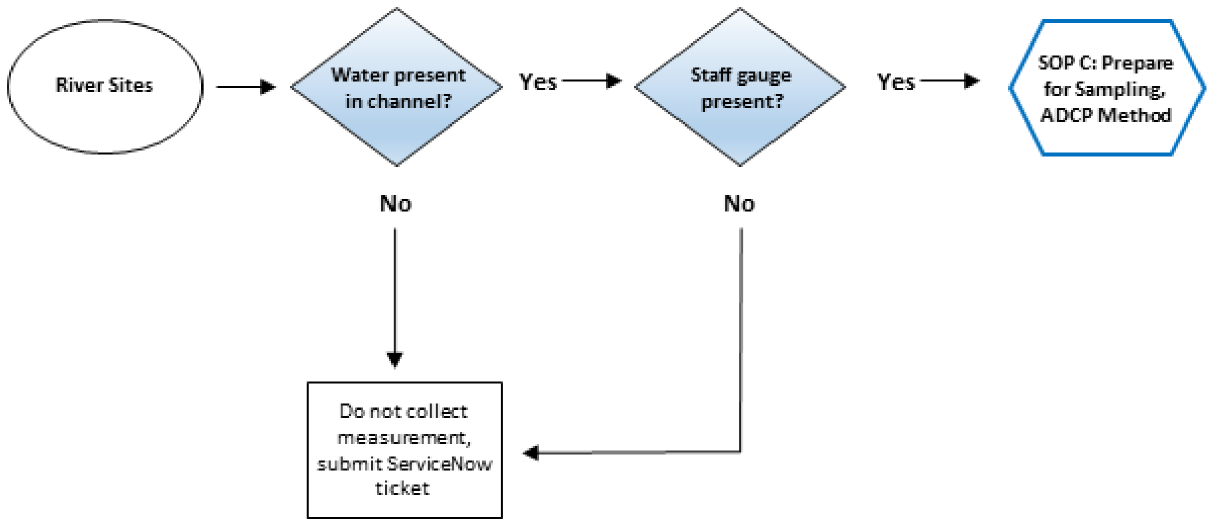

Figure 5. A high-level workflow diagram that visually shows the workflow for river sites.

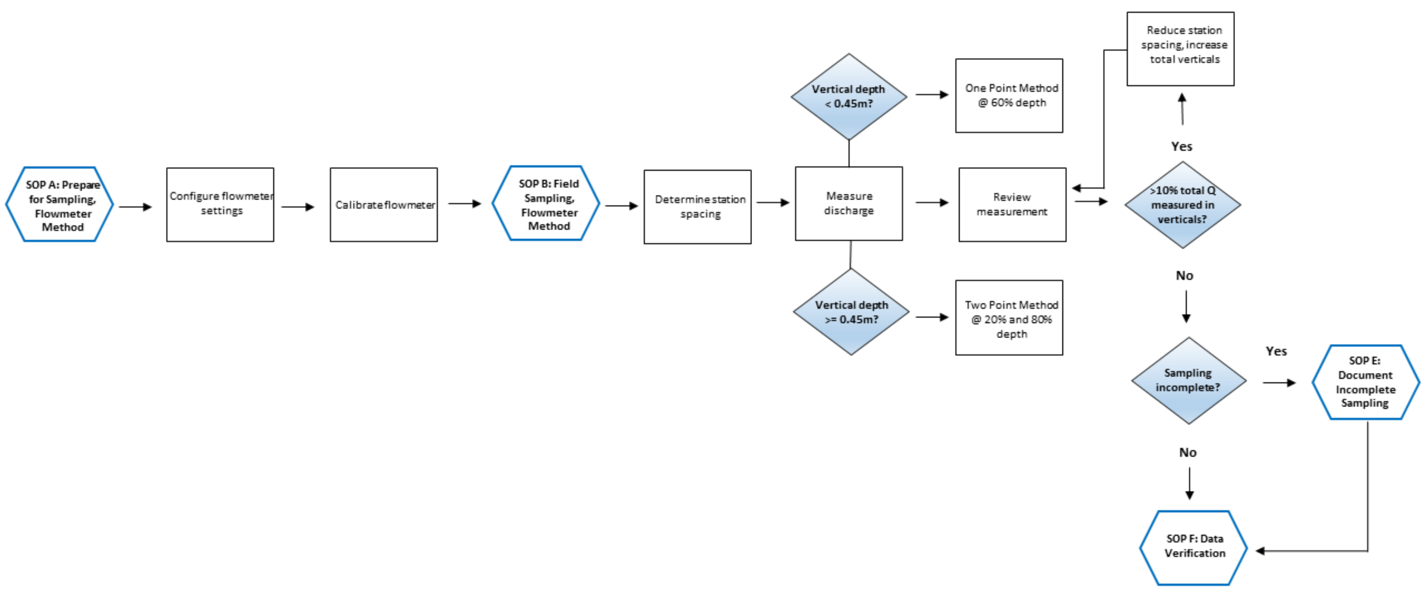

Figure 6. A detailed workflow diagram that visually shows the workflow for wadable stream sites using the Flowmeter method.

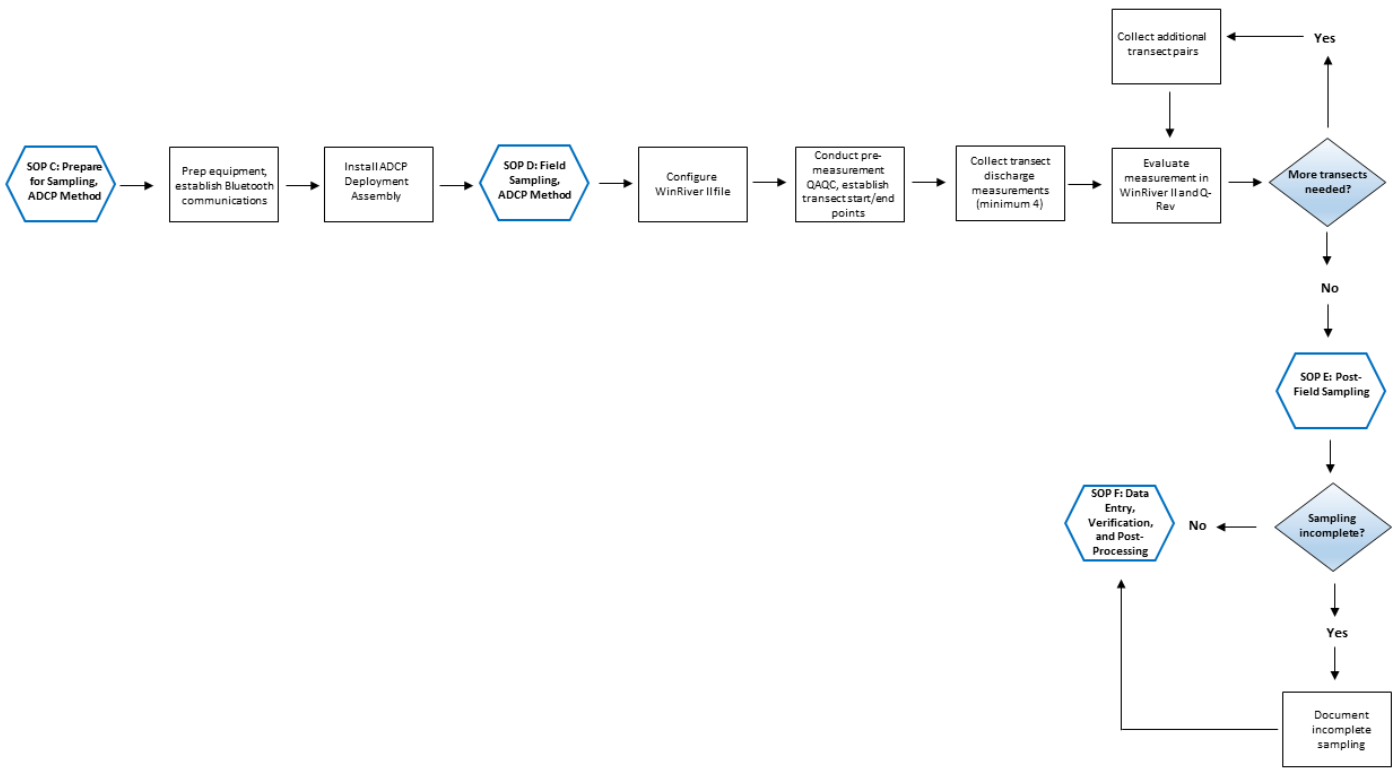

Figure 7. A detailed workflow diagram that visually shows the workflow for wadable stream and river sites using the ADCP method.

SOP A Preparing for Sampling: Wadable Stream Sites Using the Flowmeter Method

A.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged at the beginning of each field day, whenever possible.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets (RD[09]) should be carried along with the mobile devices to sampling locations at all times.

A.2 Preparing for Field Sampling

Prior to leaving the office ensure that the following criteria are met:

1. The flowmeter is fully charged.
2. All necessary equipment is gathered and prepared (**Appendix D**).
3. Sampling routes have been planned and saved for field teams using standard site navigation procedures (RD[06]). Route planning enhances sampling efficiency and helps avoid accidental foot traffic within NEON plots.

A.3 Navigate to the Discharge Transect

If a discharge transect, or cross-section, has already been established, the bounds should be permanently marked using stakes or plot markers (one on each side of the stream is ideal). Navigate to this location and proceed to **Section A.4.**

If a discharge transect has not been established at the site, proceed with the following steps:

1. Determine an appropriate location to establish a discharge transect.
    a. The transect location must be located in the riffle habitat unit in the same hydrologic unit as the staff gauge and pressure transducer.
    b. An ideal discharge transect will:
        i. Be located in a reasonably straight channel with velocity lines that are more or less parallel to each other.
        ii. Contain velocities that are > ~0.15 m/s, and depths that are > ~0.15m.
        iii. Contain a stable streambed free of obstructions that would create eddies, slack water, and turbulence.
        iv. Contain measurement sections that are roughly parabolic, trapezoidal, or rectangular.
        v. Contain a feature that provides a stable hydrologic control.

2. Take pictures of the transect location that best meets these criteria (including the control feature) and send to Science for consultation.
3. Proceed with the discharge measurement and document in the Discharge Fulcrum app that a new transect is being used.

A.4 Assess the Discharge Transect

Prior to collecting the discharge measurement, identify any environmental or instrumentation-based issues that would negatively affect data quality. Document any temporary hydrologic conditions in the Discharge app in Fulcrum. If conditions are unfavorable to discharge measurement collection, document in the app and submit a ServiceNow incident ticket.

Unfavorable conditions include, but are not limited to:

1. The staff gauge is either not present or has been displaced in some way (see **Section 4.2.1**).
2. The pressure transducer is either not present or has been displaced in some way.
   a. A discharge measurement should still be collected in the event that the pressure transducer is missing or has been displaced. The absence of this instrument does however prevent continuous discharge from being calculated. Submit a ServiceNow incident ticket to Science immediately if the pressure transducer is missing or has become displaced.
3. Too much water is present in the channel to safely conduct the wading survey.
   a. Refer to NEON Operations Field Safety and Security Plan (AD[02]) for details.
   b. Consider using the ADCP method (see **Section 4.2.1**).
4. There is an insufficient amount of water in the channel to conduct velocity measurements (see **Section 4.2.1**).
5. Refer to EHS Safety Policy and Program Manual (AD[01]) and Operations Field Safety and Security Plan (AD[02]) for further details.

A.5 Configure Settings and Calibrate the Flowmeter

It is critical that the flowmeter is calibrated, firmware is up to date, and the settings are configured correctly to ensure high data quality. Reference RD[07] for flowmeter setup, setting configuration, and calibration procedures.

This section of the SOP provides details on:

- Flowmeter firmware requirements
- Physical setup of the wading rod and flowmeter
- Required flowmeter settings
- Flowmeter calibration procedures

SOP B Field Sampling: Wadeable Stream Sites Using the Flowmeter Method

B.1 Setting up the Discharge Transect and Delineating Station Spacing for Depth and Velocity Measurements

Reference RD[07] for procedures on how to setup the discharge transect and delineate station spacing for velocity and area measurements.

This section of the SOP provides details on:

- Discharge survey orientation
- Station spacing relative to wetted width

B.2 Collecting Velocity, Depth, and Distance Measurements

Reference RD[07] for procedures on how to collect velocity, depth, and distance measurements.

This section of the SOP provides details on:

- Data entry using the Discharge Fulcrum application
- Measurement workflow and best practices, including one-point and two-point velocity methods

B.3 Evaluating the Discharge Measurement in the Field

Reference RD[07] for procedures on how to evaluate the discharge measurement in the field.

This section of the SOP provides details on:

- Evaluating individual station entries and individual station discharge calculations
- Evaluating the total measured discharge calculated for the discharge survey
- Evaluating metadata

SOP C Preparing for Sampling: Wadable Stream and River Sites Using the ADCP Method

C.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged at the beginning of each field day, whenever possible.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets (RD[09]) should be carried along with the mobile devices to sampling locations at all times.

C.2 Preparing for Field Sampling

Prior to leaving the office ensure that the following criteria are met:

1. All batteries are fully charged.
    a. Including the ADCP laptop, ADCP and GPS batteries and, if deploying the ADCP using the remote controlled boat method, all batteries associated with the ARC-Boat.
2. All necessary equipment is gathered and prepared (**Appendix D**).
3. Sampling routes have been planned and saved for field teams using standard site navigation procedures (RD[06]). Route planning enhances sampling efficiency and helps avoid accidental foot traffic within NEON plots.
4. All relevant software is available on the ADCP laptop to configure Bluetooth connections and collect and review ADCP data (RD[08]).
5. ADCP and GPS Bluetooth communication has been configured and tested (RD[08], with more information below).

ADCP and GPS Bluetooth connections must be established between the sensors and the ADCP laptop in order for the ADCP discharge method to be conducted. Initially establishing these connections should be done in the office prior to the field deployment. If the same ADCP laptop, ADCP, GPS antenna, Parani dongle (a USB interface adapter that is plugged into the laptop COM port) are used, the sensors should automatically connect to the ADCP laptop following the initial configuration.

Reference RD[08] for procedures on how to establish and test Bluetooth connections for the ADCP and GPS antennas. This section of the SOP provides details on:

- Parani Dongle Configuration
- Testing the GPS and ADCP connections in WinRiver II

C.3 Navigate to the Discharge Transect

If a discharge transect has already been established, the bounds should be permanently marked using stakes or plot markers (one on each side of the stream is ideal). Navigate to this location and proceed to **Section A.4.**

If a discharge transect has not been established at the site, proceed with the following steps:

1. Determine an appropriate location to establish a discharge transect.
    a. The transect location must be located in the same habitat unit in the same hydrologic unit as the staff gauge and pressure transducer.
    b. An ideal discharge transect will:
        i. Be located in a reasonably straight channel with velocity lines that are more or less parallel to each other.
        ii. Contain velocities that are > ~0.15 m/s, and depths that are > ~0.25m.
        iii. Contain a stable streambed free of obstructions that would create eddies, slack water, and turbulence.
        iv. Contain measurement sections that are roughly parabolic, trapezoidal, or rectangular.
        v. Contain a feature that provides a stable hydrologic control.
2. Take pictures of the transect location that best meets these criteria (including the control feature) and send to Science for consultation.
3. Proceed with the discharge measurement and document in the Discharge Fulcrum app that a new transect is being used.

C.4 Assess the Discharge Transect

Prior to collecting the discharge measurement, identify any environmental or instrumentation-based issues that would negatively affect data quality. Document any temporary hydrologic conditions in the Discharge Fulcrum app. If conditions are unfavorable to discharge measurement collection, document in the app and submit a ServiceNow incident ticket.

Unfavorable conditions include, but are not limited to:

1. The staff gauge is either not present or has been displaced in some way (see **Section 4.2.1).**
2. The pressure transducer is either not present or has been displaced in some way.
    a. A discharge measurement should still be collected in the event that the pressure transducer is missing or has been displaced. The absence of this instrument does however prevent continuous discharge from being calculated. Submit a ServiceNow

incident ticket to Science immediately if the pressure transducer is missing or has become displaced.

3. There is an insufficient depth within the channel to conduct velocity measurements with the ADCP (see **Section 4.2.1**).
    a. At wadable stream sites, consider using the Flowmeter method.
4. Refer to EHS Safety Policy and Program Manual (AD[01]) and Operations Field Safety and Security Plan (AD[02]) for further details.

C.5 Install the ADCP Deployment Assembly

Three ADCP deployment types can be used for discharge measurements based on the NEON site type (**Table 6**). At wadable steam sites, only trimaran float deployments are used. At river sites, remote-controlled deployments are the primary option and piloted boat deployments are the secondary option if the remote-controlled boat is not available. Configure the appropriate assembly and practice operation based on the site types listed in **Table 6**.

Table 6. ADCP deployment types at NEON wadeable stream and river sites. Installation and operation procedures are available in the Appendix sections listed.

Site type	ADCP deployment type	Installation and operation instructions
Wadable Streams	Trimaran float	Appendix E
Non-wadeable rivers	Remote-controlled boat (primary option)	Appendix F
Non-wadeable rivers	Piloted boat (secondary option)	Appendix G

SOP D Field Sampling: Wadeable Stream and River Sites Using the ADCP Method

D.1 Collecting an ADCP Discharge Measurement Using WinRiver II

Reference RD[08] for procedures on how to setup a new measurement file in WinRiver II and use the software to complete pre-measurement QAQC and collect ADCP discharge measurements.

This section of the SOP provides details on:

- Starting a new measurement file in WinRiver II
- Conducting pre-measurement QAQC procedures, including:
  - Setting the ADCP clock
  - Configuring ADCP reference navigation
  - Calibrating the ADCP internal compass
  - Executing the ADCP diagnostic test
  - Collecting an independent water temperature measurement
  - Performing Loop and Stationary Moving Bed tests
- Establishing Transect Start and End Points
- Collecting Transect Discharge Measurements

D.2 Evaluating the Discharge Measurement in the Field

Reference RD[08] for procedures on how to evaluate ADCP discharge measurements using WinRiver II and Q-Rev software.

This section of the SOP provides details on:

- Reviewing, finalizing, and saving data in WinRiver II.
- Reviewing, finalizing, and saving data in Q-Rev.

SOP E Post-Field Sampling Tasks

Once field verification of the measurement is complete, all materials shall be cleaned following standard operating procedures for cleaning field equipment used in aquatic systems. Batteries for the velocity meter, ADCP, GPS antenna, and/or ARC-Boat shall be charged or replaced as applicable.

E.1 Document Incomplete Sampling Within a Site

Discharge sampling is scheduled to occur at the prescribed sampling location according to the frequency and timing described in **Section 4** and **Appendix D** Ideally, sampling will occur at this sampling location for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (gradient sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced.

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions – e.g., stream morphology changes in such a way that the discharge measurement quality is reduced. Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that is biologically meaningful.

A discharge transect must be sampled during 100% of the bouts expected for the site (see **Appendix D** for the number of expected bouts and associated site sampling documentation) over a one-year period. Transects that cannot be sampled on this schedule should be considered compromised.

If sampling at a given transect is not possible during a given bout and an alternative location is available, document this occurrence in the app and submit a ServiceNow incident ticket to discuss with Science.

SOP F Data Entry, Verification, and Post-Processing

F.1 Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible. Alternatively, devices should be synced immediately upon return to the Domain Support Facility. Reference the **QC Checklist for Discharge** in the Sampling Support Library for information regarding data QAQC for this protocol.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets (RD[09]) should be carried along with the mobile devices to sampling locations at all times. Data collected on paper data sheets must be transcribed within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

F.2 Post-Processing

ADCP discharge measurement files are post-processed by Field Science staff using a Shiny app that runs validation procedures on the data (checks for required fields and term names), plots the stage/discharge data associated with the bout against the most current stage-discharge rating curve, and loads the measurement files into the NEON data pipeline.

The following data files must be available to complete final QAQC and post-processing:

- A single .mmt file (produced by WinRiver II)
- Multiple .PDO files (for each transect created in WinRiver II)
- A single .xml file (produced by Q-Rev)
- A single .mat file (produced by Q-Rev)
- Fulcrum stage data associated with the discharge bout (produced using the Discharge Fulcrum app during the measurement; the Shiny post-processing app will pull this data from the Portal so it must be available in L0 prior to post-processing)

The app pulls data from WinRiver II, Q-Rev, and Fulcrum to produce a table that contains metrics that are loaded to the NEON Data Portal. If data are missing, outside of an expected range, or do not meet naming convention standards, the user will be asked to go back and review and/or edit data in the applicable program and re-run the post-processing app. Reference the preceding sections for WinRiver II and Q-Rev data entry requirements while post-processing along with instructions contained in the Shiny application documentation. The discharge measurement that is being post-processed must also be checked against the most recently published stage-discharge rating curve (the app provides this visualization automatically). If the measurement being evaluated falls outside of the rating curve uncertainty, submit a ServiceNow incident ticket to discuss with Science. Field Science staff must maintain a local copy of all files relevant to the ADCP measurement for up to 2 years following initial upload to the Portal.

There are no post-processing requirements for discharge measurements collected using the Flowmeter method other than data entry QAQC described in **SOP F.1.**

8 REFERENCES

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APPENDIX A REMINDERS

ARC-Boat Tiller Repair:

The ARC-Boat tiller may become disconnected from the rudder shaft during transport or use, resulting in the inability to steer the ARC-Boat. A disconnected tiller can be easily repaired in the field with the proper tools. Repairing a broken tiller may involve a third party, such as the manufacturer or a machine shop.

Symptoms of ARC-Boat tiller failure:

- Clicking noise emanates from the ARC-Boat at higher speeds.
- Loss of rudder control.
- Inability to accurately steer boat in a given direction.
- ARC-Boat moves in circles when the throttle is applied.

To repair a disconnected ARC-Boat tiller (**Figure 8**):

- Remove the rear hatch plate on the ARC-Boat (**A**).
- Locate the tiller arm.
  - Note whether it is broken or disconnected from the rudder shaft (**B**).
  - If the tiller is broken the discharge measurement cannot be conducted and a more extensive repair is likely needed. Contact Science immediately.
  - If the tiller is disconnected from the rudder shaft use the following steps to re-connect the tiller to the rudder shaft.
- Remove the stainless steel connecting piece using a 5/32 Allen wrench (**C**).
- Reconnect the tiller arm to the stainless steel connecting piece.
- Carefully reconnect tiller arm to rudder shaft.
  - Ensure that the rudders are at exactly 90 degrees to the rear hull and the rudder shafts are at a 45 degree angle (**D, E**).
- Contact Science and/or the manufacturer (HR Wallingford) with any ARC-Boat repair questions.

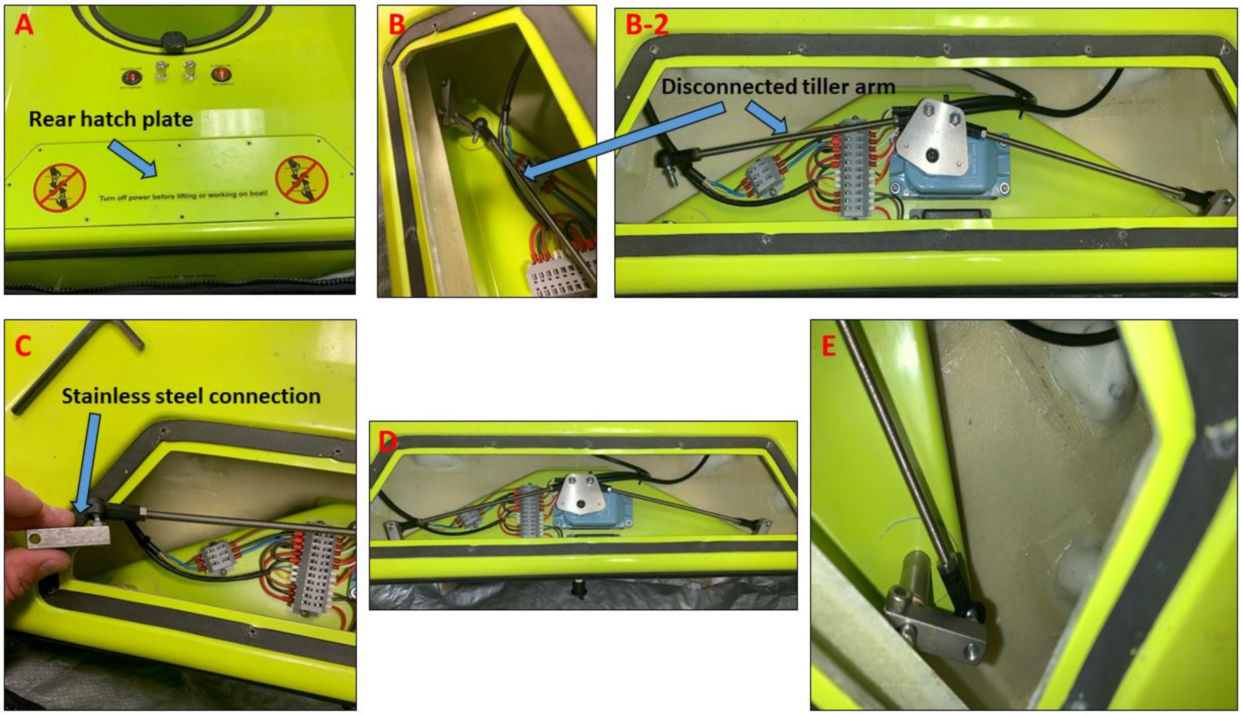

Figure 8. Repairing a disconnected tiller on the ARC-Boat.

Viewing the laptop screen in bright and direct sunlight:

Computer screens can be difficult to read in direct sunlight. Mouse cursor and screen contrast settings can be configured in Windows settings that make the laptop screen easier to read/navigate, increase the size of the mouse cursor, and provide a high contrast display.

To increase visibility on the laptop screen:

1. Configure mouse cursor size.
    a. Hit the "Windows" key on the laptop keyboard, located on the bottom left of the keyboard between "Ctrl" and "Alt" keys.
    b. Type "Mouse settings" and click the first result "Mouse settings".
    c. Click "Adjust Mouse & cursor size" to increase the size of the cursor.
    d. Adjust the cursor size to something reasonable for easy viewing in the field.
2. Increasing Screen Contrast
    a. Hit the "Windows" key on the laptop keyboard, located on the bottom left of the keyboard between "Ctrl" and "Alt" keys.
    b. Type "Contrast".

   c. Select "Turn high contrast on or off" to turn on high contrast and choose screen color themes that are easier to read.

3. Hotkey option: Left Alt + Left Shift + Print Screen (PrtSC).

APPENDIX B ESTIMATED DATES FOR THE ONSET AND CESSATION OF SAMPLING

Each domain has site-specific guidelines for timing of sample collection, which can be found in Domain Specific Sampling Designs (**Table 7**). The dates in the Sampling Design documents are estimated from historical hydrologic data. Dates presented are only a guide and are derived according to the logic presented in **Section 4.2**. Because individual years may vary widely from the average dates provided below, it is essential that domain staff monitor real-time conditions to determine when to start (and stop) sampling per environmental conditions, as described in **Section 4** of this protocol.

Table 7. Site-specific bout number, start dates, end dates and additional site-specific sampling guidance.

Domain Number	Req. # of Annual Bouts per Site	Document Number	Document Name
01	22 + 2 high flow targets	NEON.DOC.003600	Aquatic Site Sampling Design – NEON Domain 01
02	22 + 2 high flow targets	NEON.DOC.003601	Aquatic Site Sampling Design – NEON Domain 02
03	12	NEON.DOC.003602	Aquatic Site Sampling Design – NEON Domain 03
04	22 + 2 high flow targets	NEON.DOC.003603	Aquatic Site Sampling Design – NEON Domain 04
05	NA	NEON.DOC.003604	Aquatic Site Sampling Design – NEON Domain 05
06	22 + 2 high flow targets	NEON.DOC.003605	Aquatic Site Sampling Design – NEON Domain 06
07	22 + 2 high flow targets	NEON.DOC.003606	Aquatic Site Sampling Design – NEON Domain 07
08	12 (TOMB, BLWA) 22 + 2 high flow targets (MAYF)	NEON.DOC.003607	Aquatic Site Sampling Design – NEON Domain 08
09	NA	NEON.DOC.003608	Aquatic Site Sampling Design – NEON Domain 09
10	22 + 2 high flow targets	NEON.DOC.003609	Aquatic Site Sampling Design – NEON Domain 10
11	22 + 2 high flow targets	NEON.DOC.003610	Aquatic Site Sampling Design – NEON Domain 11
12	22 + 2 high flow targets	NEON.DOC.003611	Aquatic Site Sampling Design – NEON Domain 12
13	22 + 2 high flow targets	NEON.DOC.003612	Aquatic Site Sampling Design – NEON Domain 13
14	22 + 2 high flow targets	NEON.DOC.003613	Aquatic Site Sampling Design – NEON Domain 14
15	22 + 2 high flow targets	NEON.DOC.003614	Aquatic Site Sampling Design – NEON Domain 15
16	22 + 2 high flow targets	NEON.DOC.003615	Aquatic Site Sampling Design – NEON Domain 16

Domain Number	Req. # of Annual Bouts per Site	Document Number	Document Name
17	22 + 2 high flow targets	NEON.DOC.003616	Aquatic Site Sampling Design – NEON Domain 17
18	22 + 2 high flow targets	NEON.DOC.003617	Aquatic Site Sampling Design – NEON Domain 18
19	22 + 2 high flow targets	NEON.DOC.003618	Aquatic Site Sampling Design – NEON Domain 19

APPENDIX C SITE-SPECIFIC INFORMATION

ADCP Maximum Depth Measurement Thresholds per Site

The maximum measurement depth of StreamPro (used at wadable stream sites) and RiverPro (used at river sites) ADCP's is 2m and 25m, respectively. Additionally, certain StreamPro ADCPs have been upgraded to increase the maximum depth profiling to 6m at select sites (**Table 8**).

Table 8. Maximum measurement depths per StreamPro and RiverPro ADCP per site.

Domain Number	Site Name(s)	ADCP Model	Maximum Depth Measurement (m)
01	HOPB	StreamPro	2.00
02	POSE, LEWI	StreamPro	2.00
03	FLNT	RiverPro	25.00
04	CUPE, GUIL	StreamPro	6.00
06	KING, MCDI	StreamPro	6.00
07	LECO, WALK	StreamPro	2.00
08	MAYF, TOMB, BLWA	RiverPro	25.00
10/13	COMO, WLOU, ARIK	StreamPro	2.00
11	PRIN, BLUE	StreamPro	6.00
12	BLDE	StreamPro	2.00
14	SYCA	StreamPro	6.00
15	REDB	StreamPro	2.00
16	MART, MCRA	StreamPro	2.00
17	TECR, BIGC	StreamPro	2.00
18/19	CARI, OKSR, TOOK (TKIN, TKOT)	StreamPro	2.00

APPENDIX D EQUIPMENT

Reference tables in RD[07] and RD[08] for details on the equipment required to perform discharge measurement using the Flowmeter method and ADCP method, respectively. Additional material lists for various ADCP deployments can be found in **Appendix E**, **Appendix F**, and **Appendix G.**

APPENDIX E INSTALLATION AND OPERATION PRODCEDURES FOR ADCP TRIMARAN FLOAT DEPLOYMENTS AT WADEABLE STREAM SITES

This Appendix outlines procedures for:

- Assembling the StreamPro ADCP and SX Blue II GPS antenna models for trimaran float deployments
- Assembling the RiverPro ADCP and Hemisphere V102 GPS antenna models for trimaran float deployments
- Configuring the Pulley Assembly for trimaran float deployments
- Configuring the High Line Assembly for trimaran float deployments
- Operating the Pulley and High line Assemblies for trimaran float deployments

Multiple factors must be considered before installing non-temporary assemblies to deploy the trimaran float. Consult with Science to determine the ideal deployment infrastructure at your site given safety, permitting, access, and environmental conditions.

E.1 Assembling the StreamPro ADCP and SX Blue II GPS Antenna for Trimaran Float Deployments

The StreamPro ADCP and SX Blue II GPS antenna are used for ADCP discharge measurements at most NEON wadeable stream sites (**Appendix C**). Both units must be securely connected to the trimaran float (**Figure 9**) prior to beginning the discharge survey. An Allen wrench and the hand tool that is provided with the GPS are required for installation. This is a one-time installation that must be conducted upon receiving the instrumentation. Following this installation, the full configured unit (trimaran float with ADCP and GPS instrumentation) can be transported and stored as is, with batteries replaced as needed. The GPS can be removed later at the office to charge.

To assemble the StreamPro ADCP and SX Blue II GPS antenna to the trimaran float:

1. Attach the ADCP arm to the bow of the trimaran float using thumbscrews.
2. Pull the StreamPro ADCP through the bottom of the hole of the ADCP arm.
    a. Line up the arrow on the ADCP to the front of the ADCP arm (facing towards the bow of the trimaran float).
    b. Line up the grooves in the side of the StreamPro ADCP with those in the ADCP arm.
    c. Pull through all the way but do not tighten the adjacent thumbscrew.
3. Plug the ADCP cable into the electronics housing.
    a. Line up the prongs and twist the outer ring to secure the cable.
4. Connect the GPS arm to the GPS antennae using an Allen or adjustable wrench.
    a. Hand tightening will cause the antennae to come loose from the arm.
5. Remove the thumbscrew on the side of the ADCP arm in front of the ADCP.

6. Place the GPS arm over the ADCP arm.
    a. Make sure that the thinner side of the GPS arm rests on the front left side of the ADCP arm.
7. Slide the thumbscrew through the hole in the GPS arm and tighten to connect it to the ADCP arm. Ensure this is tight as this screw and arm secure the sensor in place by tightening the clamp/opening.
8. Remove the front plate of the ADCP electronics housing by disconnecting the three thumbscrews.
9. Remove the battery pack and insert 8 charged AA batteries.
10. Insert battery pack and replace front plate of the ADCP electronics housing.
    a. Make sure the thin rubber lining is still in place around the top of the battery pack enclosure.
    b. Remove batteries following Bluetooth configuration and testing so that they do not drain.
11. Remove the two corner screws that connect the GPS battery pack to the GPS electronics housing.
    a. These are the screws that line up to the holes in the GPS sun shield.
    b. These screws are no longer used in the assembly.
12. Using the two sets of GPS hardware provided (screws, spacers, washers) connect the GPS sunshield to the base of the GPS electronics housing (at the battery pack).
13. Connect the GPS sun shield to the top of the ADCP electronics housing using the four thumbscrews.
14. Connect the GPS antennae to the GPS electronics housing using the thin copper cable.
    a. The straight end of the cable connects to the GPS antenna, the angled end connects to the GPS electronics housing.
15. Installation is now complete. The unit can remain installed as is during times of transport, measurement use, and storage.

Figure 9. Above: Trimaran float, StreamPro ADCP, and SX Blue II GPS antenna components; Below: Illustrated workflow (top left to bottom right) detailing how to assemble the StreamPro ADCP unit and SX Blue II GPS antenna onto the trimaran float.

E.2 Assembling the RiverPro ADCP and Hemisphere V102 GPS Antenna for Trimaran Float Deployments

The RiverPro ADCP and Hemisphere V102 GPS antenna + electronics housing are used for ADCP discharge measurements at select NEON wadable stream sites (**Appendix C**). Both units must be securely connected to the trimaran float prior to beginning the discharge survey. Note that the trimaran float used to house the RiverPro ADCP is a larger model than the one used to house the StreamPro ADCP.

To assemble the RiverPro ADCP and Hemisphere V102 GPS antenna to the trimaran float (**Figure 10**):

1. Unfold the outrigger hulls from main hull by removing the pin in the bridle.
2. Connect the RiverPro ADCP to the GPS mount using M6 socket head cap screws (5mm Hex) and flat washers.
3. Insert the ADCP mounting plate into the moon pool lid.
4. Connect the ADCP cable from the trimaran float.
    a. Ensure that the Teledyne logo (flower) lines up when it the cable is plugged into the ADCP. The instrument will not work if the cable is plugged in upside down.
5. Connect the GPS cable to the Hemisphere V102 GPS and attach the GPS antenna to the GPS mount using 4 M8x16mm screws with lock and flat washers.
6. Attach the support braces, ADCP mounting plate and the GPS mount (with GPS antenna attached) to the main hull by aligning screw holes and tightening thumb screws.
7. Attach the GPS cable to the main hull by unscrewing the yellow cap and tightening the cable connecter to the port.
    a. These are the same type of cable connectors on the GPS antenna, ensure that the port is aligned, push in to connect, and rotate to tighten the connection.
8. Unscrew the cap to the electronics compartment.
9. Insert the 12V battery into the foam block to the secure battery.
10. Connect the two internal cables (GPS and ADCP/battery) within the compartment.
11. Connect the black spade lug connecter to the battery negative terminal.
12. Connect the red spade lug connector to the battery positive terminal.
13. Close and tighten the electronics compartment lid so that it is completely sealed.
14. Unfold the rear boat fins.
15. During operation and testing, turn on the main power switch located on the main hull to power the ADCP and GPS units.

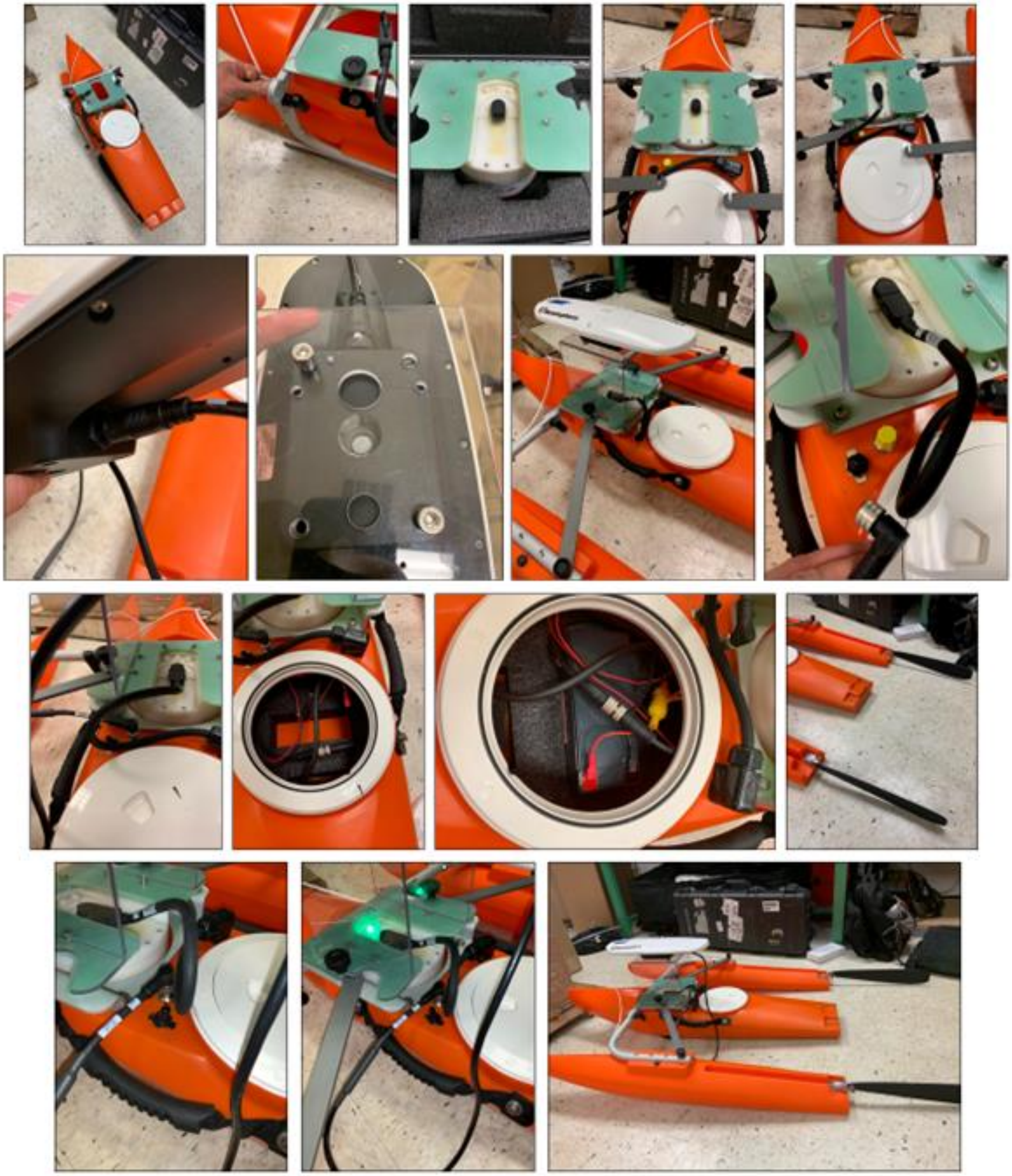

Figure 10. Illustrated workflow (top left to bottom right) detailing how to assemble the RiverPro ADCP unit and the Hemisphere GPS antenna onto the trimaran float.

E.3 Assembling the Pulley Assembly for ADCP Trimaran Float Deployments

The Pulley Assembly is the preferred mechanical assembly that can be used to deploy the ADCP during trimaran float deployments at wadable stream sites. The Pulley Assembly can be a temporary, seasonal, or permanent installation depending on safety requirements and site host/permitting requirements. The advantage of the Pulley Assembly is that, once installed, only a single operator is needed on the near bank to operate the ADCP across the channel.

The Pulley Assembly can be initially installed only when it is safe to access the opposite back to set the far post (never enter the channel when it is unsafe to do so). Materials used to construct the Pulley Assembly (**Table 9**) may vary. For example, PVC can be used as posts at some sites, while at others unistrut or snow stakes may be most effective. Components of the High Line Assembly (**Appendix E.4**) can also be used to construct the Pulley Assembly. Consult with Science and review safety and site host/permitting requirements before installing any type of non-temporary infrastructure for trimaran float deployments.

Table 9. Material list for deploying the trimaran float using the Pulley Assembly at wadeable stream sites.

Quantity	Item	Notes
2	Fixed Pulley (1 ¼“)	Eye bolt may require filing to fit through U-Bolt
2	U-Bolt (5/16” x 1 3/8” x 2 ½”)	Attaches to the Fixed Pulley and round post (U-Channel may be needed if unistrut is used)
1	#4 S-Biner Carabine	Attaches the Paracord loop and trimaran float O-ring
1	1/8” x 50’ Paracord	Tagline used to loop through Fixed Pullys; total length will vary based on channel width
2	PVC, unistrut, or snow stake posts (1” diameter minimum)	Anchors the tagline on each side of the channel
1	File	May be required to fit the eyebolt on the Fixed Pulley through the U-Bolt
1	Mallet	For driving posts into the floodplain (may require a more rigorous tool in some substrate)

To install the Pulley Assembly:

1. Start by installing a sturdy stake, PVC pipe, or unistrut post on each side of the channel, slightly upstream (~0.5m – 1m) of the discharge transect.
    a. If unistrut is used for the posts, an alternative material (like U-Channel) will be needed instead of U-Bolts (which best connect to rounded posts).
2. Ensure that the posts are nearly level across the channel and the line between them is perpendicular to the streamflow.
3. For non-temporary installations, ensure that the posts are installed at an elevation where the ADCP can be deployed at a wide range of stage levels.

4. Connect one of the Fixed Pulleys to one of the U-Bolts and repeat for the second set (**Figure 11**).
5. Slide the eye bolt of the Fixed Pully onto the "U" section of the U-Bolt and repeat this procedure for the second set.
    a. If the eye bolt is too small to slide over the U-Bolt, safely file the inside of the eye bolt down to the required diameter.
6. Slide and secure one of the U-Bolt/Fixed Pully assemblies over each of the posts (**Figure 11** and orient so that the Fixed Pulleys are facing out toward the stream and pointed at one another.
    a. Ensure that the Fixed Pulleys are at equidistant elevations across the channel so that the tagline will be level.

Figure 11. U-Bolt/Fixed Pully configuration used for the Pully Assembly trimaran float deployments. This example the U-Bolt is placed over a snow stake, rather than a post or unistrut.

7. Guide the Paracord through the Fixed Pulleys, creating a loop so that the ends of the Paracord meet.
    a. Neatly dress any extra Paracord so that it is out of the way of the ADCP deployment.
8. Where the ends of the Paracord meet, tie them to the S-biner Carabiner. A blunt line hitch knot is recommended to keep the cord snug (**Figure 12**).

Figure 12. Paracord/S-Biner Carabiner/float ringer connection used for the Pulley Assembly during trimaran float deployments.

9. Place the trimaran float in the stream and attach the O-ring at the end of the metal shaft that protrudes from the float to the S-biner Carabiner. If extra length between the float and the tagline is needed (e.g. during high flows), use Paracord between the metal ring and the S-biner Carabiner.
10. The trimaran float can now be navigated across the channel by pulling the Paracord tagline that is looped through the Fixed Pulleys.

E.4 Assembling the High Line Assembly for ADCP Trimaran Float Deployments

The Temporary High Line is a mechanical assembly that can be used as a temporary means to deploy the ADCP during trimaran float deployments at wadable stream sites. The High Line Assembly is limited in that it can only be used when it is safe to access the opposite back (to set the far post and operate the Control Rope). If both sides of the channel cannot be safely accessed during high flows (never enter the stream channel when it is unsafe to do so) consider the using the Pulley Assembly to deploy the trimaran float. Consult with Science and review safety and site host/permitting requirements before installing any type of non-temporary infrastructure.

The Highline Assembly involves a guideline that runs through a tripod system and across the channel to orient the trimaran float in the streamflow. An additional line runs through the guideline and is supported by crew members on each side of the stream that work together to pull the float steadily across the discharge cross-section. See **Table 10** for the complete material list and **Figure 13** for a labeled illustration of the materials included with the kit.

Table 10. Material list for deploying the trimaran float using the High Line Assembly at wadeable stream sites. *Materials included with the High Line Assembly kit.

Quantity	Item	Notes
1	Tripod*	Supports the winch and pulley posts on the near bank, levels the guideline
1	Winch post*	Connects to pulley post, tightens the guideline
1	Pulley post*	Connects to winch post, guides the guideline
1	Guideline rope*	Twine that is set between the tripod on the near shore and a fixed point on the opposite shore, orients the float as it is pulled across the channel by the Control Rope
1	Guideline support*	Metal tube that connects the Guideline rope to Trimaran rope
1	Guy wire + earth anchor*	Supports winch post/pulley post/tripod assembly on the near bank
1	Guy wire driving rod*	Supports guy wire
1	Control rope	Long length (twice the length of the channel + extra) of Paracord used to pull the float back and forth across the channel
1	Trimaran rope	A short section of Paracord that connects and orients the float off the Guideline rope (length should be shortened during high flows and lengthened during low flows)
2	Locking Carabiner	Connects the float to the Trimaran rope (1 required + 1 spare)
1	Mallet	Drive guy wire anchors into the substrate

Figure 13. Materials included with the High Line Assembly kit.

To assemble the High Line Assembly (see **Figure 14** for a visual aid):

1. Remove the wingnuts on the top of the Winch Post.
2. Slide the base of the Pulley Post into the top of the Winch Post.
3. Connect the Winch and Pulley at an angle into the Tripod.
4. Set the Winch handle so that is facing away from the Winch gears.
5. Loop the Guideline Rope through the two holes on the side of the Winch and knot them together.
6. Crank the Winch handle so that the guideline is looped through the Winch assembly.
7. Once a sufficient length of Guideline rope is looped through the Winch assembly, bring the end of the Guideline rope over the Pulley (at the top of the Pulley Post) and through the hook.
8. Securely attach the end of the Guideline Rope to a point on the opposite bank.
    a. A sturdy tree, post, or stake can be used to secure the Guideline Rope on the opposite bank.
    b. The Guideline rope should be slightly upstream (~ 0.5 – 1m) of the discharge transect, nearly level across the channel, and perpendicular to the streamflow.
9. Lock the Winch by setting the trigger tab at the top of the assembly to "ON".
10. Advance the Winch until there is no slack in the guideline between the Tripod and the opposite bank.
11. Attach the Guy wire to the base of the Winch Post using the Carabiner and thread this wire through the notch at the very bottom of the Winch Post.
12. Set the Driving rod into the Guy wire earth anchor and hammer the rod into the substrate to refusal.
13. On the Guideline support, line up the space between the white plastic lockers and the space that runs along the length of the bracket.
14. Attach the Guideline support to the Guideline rope between the tripod and the opposite bank.
    a. Place the Guideline rope through the Carabiner.
    b. Slide the Guideline rope through the space along the length of the Guideline support (so that the Guideline rope is inside the metal tube).
    c. Twist the white lockers to hold the Guideline in place within the Guideline support.
15. Connect the middle of the Control rope to the Carabiner on the Guideline support using a knot.
16. Bring the Guideline Rope with the Guideline support to the edge of water on the near bank.

17. Attach the section of Trimaran rope through the carabiner on the Guideline support.
    a. Adjust the length of the Trimaran rope based on the surface water velocity conditions.
    b. Set the length of the Trimaran rope so that the boat lies flat in the water and the surface velocity maintains the orientation of the bow pointed upstream.
    c. When stream velocity is high, the Trimaran rope should be shorter.
    d. When stream velocity is low, the Trimaran rope should be longer.
18. Gently place the trimaran float in the water to let sensors equilibrate. Secure both ends of the Control Rope to keep the float in position prior to the first measurement.
19. The trimaran float can now be navigated across the channel by an operator on the near bank pulling the Guideline rope while another operator on the far bank lets out slack.

Figure 14. Installing the High Line Assembly.

E.5 Operating the Pulley and High Line Assemblies during Trimaran Float Deployments

Practice pulling the trimaran float back and forth across the channel to (1) get comfortable with the ADCP deployment assembly, and (2) to assess data quality along the transect prior to measurement recording. The Pulley Assembly requires only one operator at the near bank while the High Line Assembly requires two operators working in conjunction on each bank.

- Install the ADCP in the trimaran float per instructions in **Appendices E.1** and **E.2**.

- Ensure that ADCP and GPS communications are established (**7C.2**) and all pre-measurement QAQC (RD[08]) is complete.
    - Remove the protective cap over the ADCP transducer before the float is set into the water.
- The trimaran float is navigated by an operator (or operators) pulling it across the channel via a tethered rope pulley system.
    - Using the Pulley Assembly, a single operator on the near bank pulls the Paracord through the pulleys, moving the float across the channel.
    - Using the High Line Assembly, and operator is on each bank pulling and releasing slack to move the float across the channel.
- Adjust the length of the rope attaching the trimaran float to the tagline based on velocity conditions.
- During high flows the length between the float and the tagline should be longer, during low flows this length can be extended. In both instances the length of rope should remain taught.
- Gloves are recommended to limit hand abrasion from the rope.
- The trimaran float must be moved at a slow and steady pace with the bow of the float pointed upstream. Sudden movements of the float will adversely affect data quality. The slow and steady speed of the float is paramount to data quality.
- Each transect measurement must last a minimum of 180 seconds. It is helpful for staff to call out the measurement duration during the measurement in order to adjust float speeds if needed.
- Ideally, the speed of the trimaran float should be below the water velocity, although this can be very difficult during low flow regimes.
- Practice bringing the trimaran float back and forth across the channel until boat staff members are accustomed to the operation.
    - During practice transects, also assess the data being measured (but not recorded) in WinRiver II. Evaluate the quality of the transect including total calculated depth, missing ensembles, bottom tracking, water vs. boat speed, etc.

APPENDIX F INSTALLATION AND OPERATION PRODCEDURES FOR REMOTE-CONTROLLED BOAT DEPLOYMENTS AT RIVER SITES

The RiverPro ADCP deployed in the ARC-Boat remote-controlled boat is the preferred means to measure discharge at NEON river sites. Hemisphere V102 antenna units are attached to the ARC-Boat and provide GPS heading and positioning data during each ADCP measurement. If the ARC-Boat is not available, the Piloted Boat method (**Appendix G**) should be used.

This Appendix outlines procedures for:

- Assembling the RiverPro ADCP into the ARC-Boat
- Assembling the Hemisphere GPS into the ARC-Boat
- Setting up the ARC-Boat
- Operating the ARC-Boat during remote-controlled float deployments

F.1 Attaching the ADCP to the ARC-Boat ADCP Adapter

The ARC-Boat ADCP adapter powers the RiverPro ADCP and holds it in place within the ADCP compartment of the boat. Prior to deploying the ARC-Boat into the water, always leave the protective cover on the base of the ADCP so that the beam lenses do not get scratched.

To attach the ADCP to the ARC-Boat ADCP Adapter (**Figure 15**):

1. Connect a fully charged 12V battery to the internal compartment of the ADCP adapter. The ADCP must be powered in order to communicate and collect measurements.
2. To access the inside of the ADCP adapter, remove the GPS mount plate by disconnecting the four nuts on the base.
3. Remove the ADCP adapter by loosening the four plastic screws at each of the corners.
4. Attach one end of the long set screws into the top of the ADCP.
5. Attach the other end of the long set screws to circular base plate of the ADCP adapter using the wingnuts.
6. Lubricate the connections of the ADCP and ADCP adapter cables with dielectric grease and connect the ADCP cable coming out of the ADCP adapter to the ADCP.
7. Flip the adapter switch to “Power ON”. The red light on the ADCP adapter should light up.
    a. One of the three LED lights on the ADCP will turn green when the instrument is powered.
    b. A red light on the ADCP indicates a system error. Contact Science if this light turns on.
8. Attach the circular base plate of the ADCP adapter to the hull of the ARC-Boat using the small set screws. Installation is now complete.

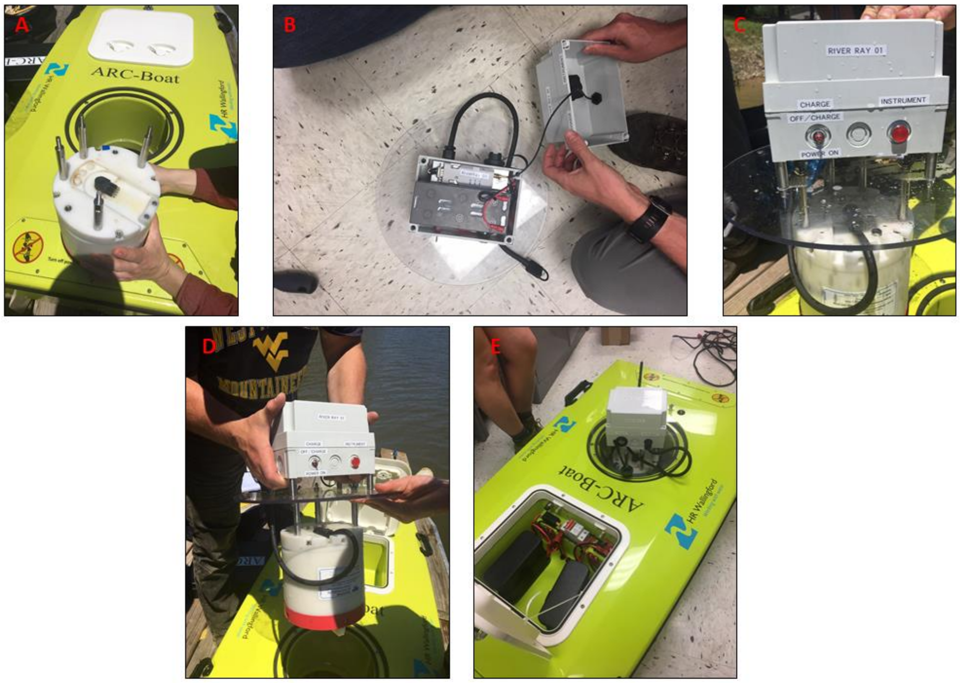

Figure 15. The ARC-Boat setup with the RiverPro ADCP adapter. A: connect the long set screws to the top of the ADCP; B: connect a fully charged 12V battery inside the ADCP adapter; C: connect the long set screws to the circular base plate of the adapter with the wingnuts, connect the ADCP cable coming out of the adapter to the ADCP, and flip the adapter switch to “Power On” (ADCP light should be green); D: the RiverPro ADCP and ARC-Boat ADCP adapter fully integrated; E: set the ADCP adapter with the ADCP into the ADCP compartment of the ARC-Boat and connect the circular base of the adapter to the boat using small set screws. Not shown: GPS mounting plate on top of the ADCP adapter.

F.2 Attaching the GPS Antenna to the ARC-Boat ADCP Adapter

A GPS mount plate is installed above the ARC-Boat ADCP adapter to hold the Hemisphere V102 GPS antenna in place. A 3/16” Allen wrench is required to install the GPS antenna onto the GPS mount. The GPS antenna must be located directly above the ADCP adapter and aligned with ADCP Beam 3.

To install the Hemisphere V102 GPS antenna onto the GPS mount (**Figure 16**):

1. Connect the ADCP Adapter to the ARC-Boat with the ADCP installed (**Appendix F.1**).
2. Disconnect the GPS cable at the back port of the GPS antenna.
    a. Loosen the cable connector by twisting it clockwise.
    b. Gently pull the cable so that it is released from the antenna.
3. Place the GPS antenna on top of the GPS mount, lining up the female threads in the antenna and the male threads on the mount.
4. Gently turn the GPS antenna clockwise until it is fully seated on the GPS mount.

5. Adjust the GPS antenna so that the front of the antenna is aligned with ADCP Beam 3 and the space between the two small holes in the back of the antenna is directly over the center of the ADCP adapter (**Figure 17**).
    a. The "front" of the GPS antenna is indicated by an arrow underneath the antenna.
    b. Placing a mark on top of the GPS antenna is a helpful way to ensure the front is always facing the correct direction.
    c. The area to be centered over the ADCP is indicated by the space between two small screws in the back of the unit.
6. Once the GPS is properly oriented, use a 3/16" Allen wrench to tighten each of the two set screws located on each side of the black base on the bottom of the GPS antenna so that it cannot move on the mount.
7. Connect the GPS cable into the back port of the GPS antenna.
    a. Make sure to line up the cable with the port properly. A small notch in the top of the cable indicates the correct orientation (the cable should be placed into the port so this notch is on the top).
    b. Once lined up, gently push the cable into the port.
    c. Tighten the cable connect so that it is securely connected to the GPS antenna.
8. Installation is now complete. When not in use, the GPS antenna should be disconnected from the GPS mount and stored in a protected location during transportation.
9. Reference RD[08] for information on applying External Heading offsets to GPS data if the GPS antenna is not aligned with Beam 3 of the ADCP.

Figure 16. Installing the Hemisphere V102 GPS antenna onto the ARC-Boat GPS mount.

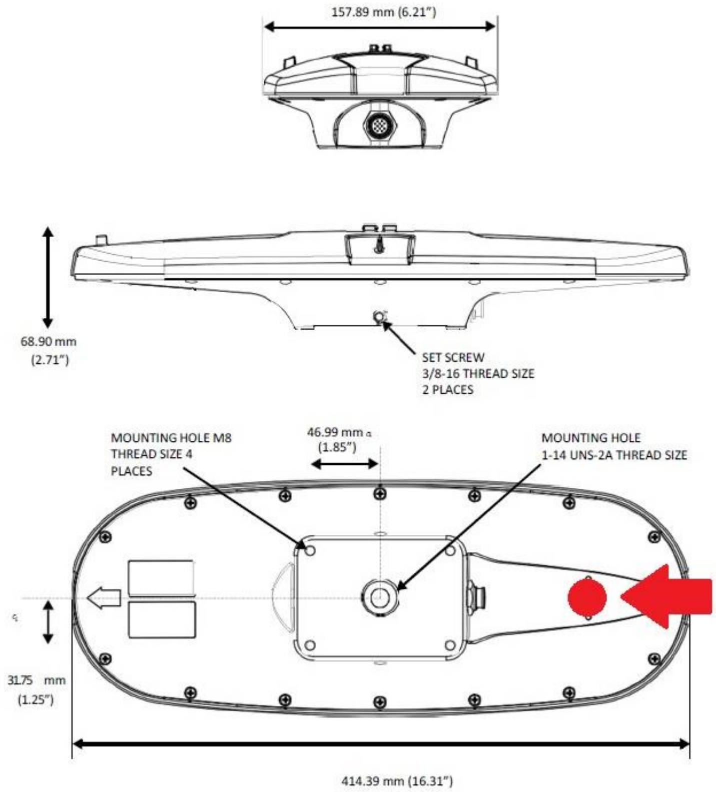

Figure 17. Hemisphere V102 GPS antenna schematics. Top: the back of the unit with cable port show; Middle: the side of the unit showing one of two set screw locations; Bottom: the base of the unit, the red circle to the right of the unit indicates the location that must be centered over the ADCP, the white arrow to the left of the unit indicates the direction the unit must face so that it is oriented toward Beam 3 of the ADCP.

F.3 Setting up the ARC-Boat

Prior to setting up the ARC-Boat (**Figure 18**), ensure that (1) the ADCP adapter is connected to the ADCP (**Appendix F.1)** and secured within the compartment of the boat, and (2) the GPS antenna is connected to the GPS mount (**Appendix F.2**).

To configure the remaining components of the ARC-Boat:

1. Ensure that the detachable bow is connected to main body.
2. Ensure the bilge plug is in place and tightened. It must form a secure seal with the hull to prevent the boat from filling with water and capsizing.
3. Set up the boat power supply.
    a. Unlock and open the battery compartment.
    b. Make sure all of the Control Switches are in OFF or neutral position.
        i. Isolator switch is in the OFF position.

   c. Radio Controller Power switch is in the OFF position.
   d. Both control sticks are centered in the neutral position.
   e. Main power switch on the deck (or the top) of the ARC-Boat bow near the front handles is in the OFF position.

4. Place two fully charged batteries in the battery compartment and connect them to the internal wiring connections within the compartment.
5. Turn ON the Isolator switch.
   a. The power LED will light up orange if power is connected.
6. Close the battery compartment and secure the latches, checking that the watertight seal is in place. Any water intrusion into this compartment will cause damage to the equipment.
7. Turn ON the Main Power switch.
   a. The ‘Props Live’ LED will turn red, indicating the ARC-Boat is powered ON and the props are capable of movement.
   b. Use extreme caution around the propellers and rudders when this switch is set to ON.
8. Ensure that the remote control battery is fully charged. Insert fresh batteries prior to the discharge measurement, if needed.
9. Center both sticks on the radio controller to put the ARC-Boat in neutral, so that the boat can be moved safely. The ARC-Boat is now powered, engaged, and ready for operation. Turn the Main Power and Isolator switches to OFF when not in use.

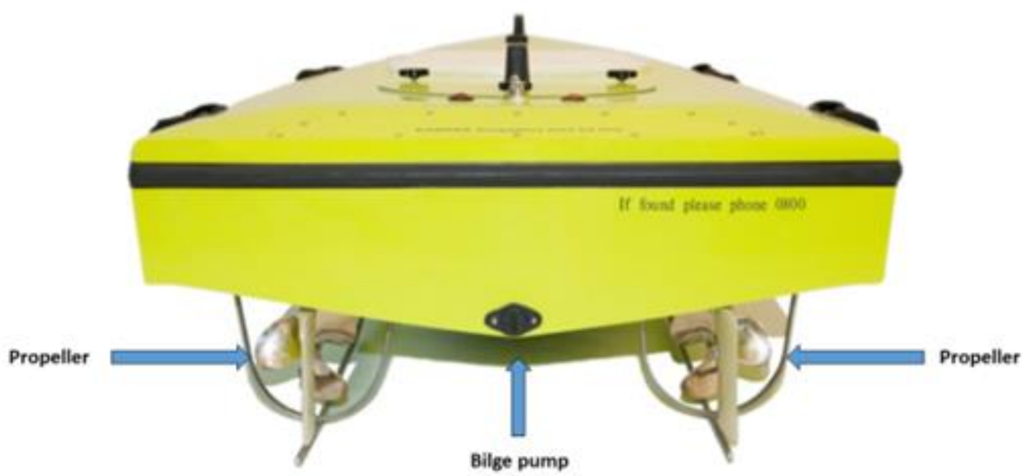

Figure 18. Above: Top of the ARC-Boat (not pictured: ADCP Adapter with GPS mount); Below: Stern of the ARC-Boat.

F.4 Operating the ARC-Boat during Remote-Controlled Boat Deployments

It is critical to become familiar with the ARC-Boat controller and comfortable with operating the instrument prior to discharge measurement collection. Consider the river conditions at the time of the measurement. ARC-Boats are designed to work in streamflow conditions from low flows to floods (surface water velocities of up to 5 m/s). Surface velocities outside of this range will cause the boat batteries to drain quickly and make controlling the boat very difficult. If velocities are such that the boat cannot be operated in a safe and efficient manner, do not proceed with the measurement.

Deploy the ARC-Boat in the water and practice using the remote control to drive and turn the boat. Keep the following considerations in mind:

- Always place the remote control strap around the neck of the operator to prevent it from accidently falling in the water.
- Ensure that all boat and remote control batteries are fully charged prior to the measurement and that spares are on hand if needed.
  - Low batteries in the boat can be observed by sluggish or lagging response to operation. Watch the voltage indicator on the remote control radio.
  - Charged batteries are critical for maintaining control of the boat during operation. As remote control and ARC-Boat batteries become low operational performance will decrease.
  - At a certain point, low voltage in either the remote or the boat batteries will result in signal loss and our motor failure, either of which results in the total loss of control of the boat.
  - The ARC-Boat is deliberately programmed to shut down in these situations for safety reasons and will drift with the current and have to be recovered.
  - Prior to deployment, it is best practice to always have a recovery plan in mind, contact information on the side of the boat, a beacon installed on the top of the boat for visibility, and a general idea of where the boat could end up if adrift.
- Operate the ARC-Boat so that the bow is pointed upstream and facing into the velocity path during the discharge measurement (**Figure 19**).
  - To obtain a sense of the velocity flow paths try letting the boat drift momentarily in the streamflow, this can allow the operator to gauge which way the velocity vectors are pointed within the discharge cross-section.
- Crabbing across the channel is not always possible during periods of low flow. Under these conditions it is allowable to have the bow of the boat pointed towards the opposite shore (**Figure 20**).
- The ARC-Boat rudders require motion in order to control the direction of the boat.
  - In cases where the boat is not in motion, the throttle will need to be activated to change the boat direction using the rudders.
- Standing slightly downstream of the ARC-Boat allows for easier orientation of how movements with the remote control relate to the ARC-Boat.

- If operating the remote control from a piloted boat, it is very important to remain far enough downstream so that the piloted boat motors and hull do not create velocity disturbances within the measurement transect.
- Operation of the remote controller will vary based on where the boat is in the channel and the desired path of the boat (**Table 11**).

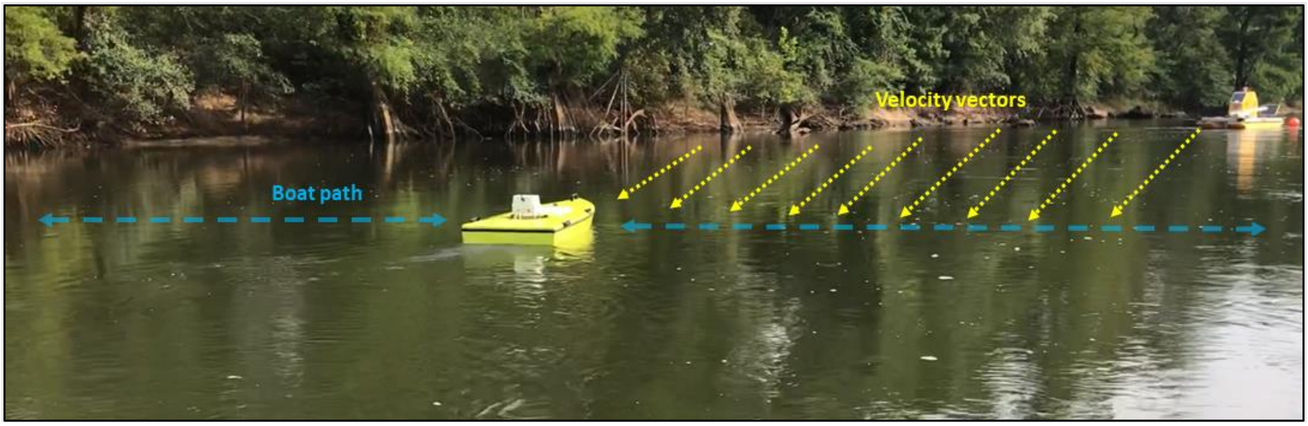

Figure 19. When surface water velocity is sufficiently high, operate the ARC-Boat in such a way that the bow is pointed into the velocity vectors and the boat is crabbed across the channel.

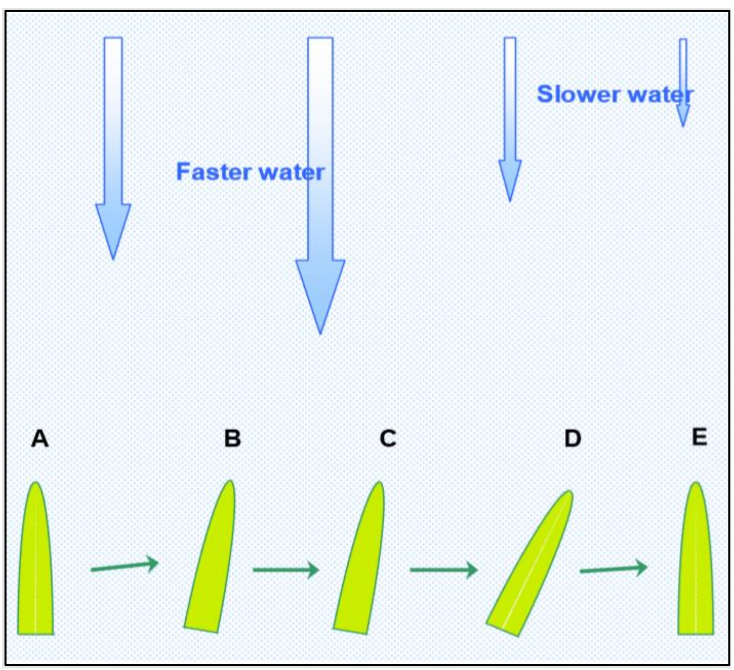

Figure 20. Illustration of different ways to control the ARC-Boat in a variety of streamflow regimes. See **Table 11** for corresponding controller tips.

Table 11. ARC-Boat controller tips while navigating in different streamflow regimes (see **Figure 20**) and performing various operations.

Operation	Controller Tips
Place the ARC-Boat in neutral (A)	Center the joy sticks on the radio controller.
Pulling away from shore (A)	Use low throttle and move the left joystick gently forward. Move the rudder in the intended direction using the right joystick.
Operating in slow water (D)	Lower the throttle and reduce the direction of the rudder. This allows the boat to remain steady.
Operating in fast water (B/C)	Increase the throttle to counter the increase in velocity and move the rudder further in the desired direction until the boat responds.
Approaching a bank (E)	Move the rudder strongly in the current direction and use very low throttle to make the stern come steadily towards the bank.
Making a smooth turn	Gently use the rudder and throttle controls at the same time. The ARC-Boat was designed to be capable of spinning on its own axis.
Maintaining a steady pace	Set the throttle to a constant pace. This minimizes battery consumption and overall wear on the boat.

APPENDIX G INSTALLATION PRODCEDURES FOR PILOTED BOAT DEPLOYMENTS AT RIVER SITES

The Piloted Boat method is the secondary preference to measure discharge at NEON river sites when the ARC-Boat is not available. Piloted boat deployments use a Kentucky II-type mount (originally developed by the USGS) to deploy the RiverPro ADCP off the side of a piloted boat (**Figure 21**). Materials to mount a GPS antenna to the piloted boat are currently not available. Bottom track must always be used as the reference navigation for this method and Loop or Stationary Moving Bed test results should be applied to correct for moving bed conditions, if present.

This Appendix outlines procedures for:

- Assembling the ADCP mount to the piloted boat

Figure 21. The ADCP mount deploys the ADCP off the side of a piloted boat.

G.1 Assembling the ADCP Mount to the Piloted Boat

To assemble the ADCP mount (**Figure 22**):

1. Ensure that the Boat Mount Base Plate is installed at the proper location of the boat where the ADCP can be securely deployed over the side and interference (proximity of magnetic materials, hull/motor effect) is minimized.
2. Install the Boat Mount Coupler into the Boat Mount Base Plate.
3. Insert the short vertical pipe into the Boat Mount Coupler.

4. Assemble the lower square section by attaching sections of pipe to the 90 degree elbows. Tighten each elbow with an Allen wrench. Place a vertical coupler at each end of the square.
5. Attach the Lower Square Section to the Short Pipe in the Boat Mount Base plate by sliding one of the vertical couplers on the Lower Square Section over the Short Pipe in the Boat Mount Base Plate.
6. Use an Allen wrench to tighten the vertical coupler to secure the Lower Square Section to the short pipe.
    a. One end of the Lower Square Section should now be sitting off the side of the boat.
7. Slide the Long Vertical Pipe through the opposite vertical coupler (the one that is off the side of the boat) and secure it in place by tightening the vertical coupler with an Allen wrench.
8. Attach the tether hook to the ADCP Coupler.
9. Attach the ADCP Coupler (with tether hook) to the circular ADCP Base Plate using an adjustable wrench to tighten the screws, nuts, and washers together.
10. Attach the ADCP Base Plate with ADCP Coupler to the base of the ADCP.
11. Attach the ADCP Coupler to the end of the Long Vertical Pipe so that the ADCP is securely deployed over the side of the boat.
12. Using a carabiner, attach a rope tether to the tether hook next to the ADCP Coupler.
13. Attach the tether rope to secure location on or inside the boat.
14. The ADCP depth can be adjusted by adjusting the ADCP Coupler and moving the Long Vertical Pipe up or down.
15. Remove the protective cover from the ADCP transducer lense and lower the sensor into the water.
16. Adjust the depth of the long vertical pipe so that the base of the ADCP is fully submerged.
    a. Do not lower the ADCP too far into the water column as this increases the unmeasured area at the top of the profile and creates a drag that negatively impacts velocity measurement.
    b. Measure and record the depth from the top of the water column to the ADCP beams. This is the transducer depth entered when starting a new measurement in WinRiver II (see RD[08]).
17. Installation is now complete. Allow the ADCP transducers to be submerged in the water for at least 5 minutes prior to discharge measurements in order to sufficiently equilibrate to the water temperature. Failure to do so will impact measurement accuracy.

Figure 22. Assembling the ADCP mount on a piloted boat.